The Houston Airport System

Design Criteria Manual

2015

HOUSTON AIRPORTS

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LIST OF ACRONYMS

AC	-	Advisory Circular
AGL	-	Above Ground Level
AIP	-	Airport Improvement Program
ALP	-	Airport Layout Plan
ALS	-	Approach Lighting System
ARSR	-	Air Route Surveillance Radar
ARTCC	-	Air Route Traffic Control Center
ASDE	-	Airport Surface Detection Equipment
ASR	-	Airport Surveillance Radar
ASTM	-	American Society for Testing and Materials
ATCT	-	Air Traffic Control Tower
AWOS	-	Automated Weather Observing System
CE	-	Code Enforcement – City of Houston
CFR	-	Code of Federal Regulations
COE	-	Corps of Engineers
COH	-	City of Houston
CBP	-	Customs and Border Protection
DEIS	-	Draft Environmental Impact Statement
DNL	-	Day Night Average Sound Level
FAA	-	Federal Aviation Administration
HAS	-	Houston Airport System
INFRA	-	Infrastructure Group – HAS Project Management, Asset Management, Environmental, Master Planning, Design, Construction and Maintenance
MALSR	-	Medium Intensity Approach Lighting System with Runway Alignment Light System
MSL	-	Mean Sea Level
NAAQS	-	National Ambient Air Quality Standard
NAS	-	National Airspace System
NAVAIDS		Air Navigation Facility
NCP	-	Noise Compatibility Program
NEPA	-	National Environmental Policy Act
NLR	-	Noise Level reduction
NOTAM	-	Notice to Airmen
ODALS	-	Omnidirectional Approach Lighting System
PWE	-	COH Public Works and Engineering Department
REIL	-	Runway End Identifier Lights
RVR	-	Runway Visual Range
TRACON	-	Terminal Radar Approach Control
TSA	-	Transportation Safety Administration
TxDOT	-	Texas Department of Transportation
VHF	-	Very High Frequency
VOR	-	VHF Omnidirectional Range
WAAS	-	Wide Area Augmentation System

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1 GENERAL INFORMATION

1.1 Scope and Purpose - This Manual establishes specific design criteria for all public infrastructure, terminal buildings and other public facilities owned, operated or maintained by the Houston Airport System (HAS). It also serves as a design guide for all other facilities constructed within the boundaries of the George Bush Intercontinental Airport (IAH), the William P. Hobby Airport (HOU) and Ellington Airports (EFD) hereinafter referred to as "Airport." The Design Criteria manual is not intended to limit or dismiss the experience, knowledge or talent of the Designer or Contractor. HAS encourages Designers and Contractors to recommend alternates when deviations from the guidelines would be beneficial. However, adherence to these guidelines should result in project development that conforms to the goals and objectives of HAS. Additional design criteria are contained in the following manuals for projects of specific scope and location on airport property:

1. "Tenant Improvement Program -TIP Guidelines " for concession spaces in terminal buildings.
2. "Surveyors Handbook" for each of the HAS airports, George Bush Intercontinental (IAH), William P.Hobby (HOU) and Ellington Airport (EFD), the latest editions.
3. CAD/Geospatial Data Standards & Procedures Manual, the latest editions.
4. I.T.-Infrastructure Technology Specifications
5. Landside Aesthetics Master Plan (LAMP), December, 1999.

1.2 HAS Standards – The following are standard with respect to all HAS projects, either civil or architectural.

1.2.1 Project Report – The Project Report is both the link between the budget concept requirements of the CIP definition phase and final design as well as a record of the project's progress through all design phases to final contract documents. A well developed and complete report is essential to:

- Provide a basic source on necessary data and cost estimates regarding proposed work required to support project goals and objectives.
- Describe a functional need.
- Provide a comprehensive justification of the need for the proposed project including, but not limited to, a life-cycle cost analysis.
- Provide the analysis of the reasonable alternatives to accommodate the need.
- Provide the criteria that are the basis for the preparation of contract documents, a preliminary project schedule, project scope, and associated budget.
- Define the design and construction elements, e.g. delivery method, number of design/construction packages, suggested or required project milestones, etc.

Throughout this Manual there will be references to elements that will be added to the Project Report, such as the Geotechnical Report or various calculations. These elements are added for the purpose of building up the history of the Project's development while maintaining focus on the functional need it is designed to address. In cases where industry, economic, or demand changes require a change in the goals and therefore a change in the objectives of the Project, those shall also be documented so that the management and design team can continue to focus on the need that the project is designed to address and the current objectives that need to be satisfied. It is very important that this Project Report be maintained as a living document, whether it is required for submission to FAA, as is required for Airport Improvement Program (AIP) projects, or whether the project is funded solely by the Houston Airport System's funds.

1.3 Request for Variances and/or Interpretation Statement - It is recognized that variances to the referenced standards and/or other design criteria in this Manual, may be necessary. A request for variance shall be submitted to the Project Manager along with any substantiating documentation. Approval of changes to the standards in this Manual may only be granted by the City Engineer for the Houston Airport System. Please note that request for variance from the code requirements enforced by the City of Houston Public Works Department cannot be granted by the Houston Airport System. All projects on the Houston Airport System campuses are subject to the City of Houston code requirements. These standards are to be considered in addition to the City of Houston code requirements and adherence to these requirements is necessary for Houston Airport System approval.

1.4 Procedures for Changes to this Manual - Proposed changes or additions to this manual should be submitted to the City Engineer for the Houston Airport System for consideration. Requests for such change or addition shall include a complete description of the change proposed and shall be accompanied by sufficient technical analyses to support the change or addition. A form for such requests can be obtained from any HAS Project Manager.

1.5 Project Type - Facilities constructed by HAS shall be referred to as "HAS Projects." All other construction projects shall be referred to as "Tenant Projects."

1.6 HAS Project Manager -Reference is made in this document to "HAS Project Manager". For the purposes of this manual, "HAS Project Manager" is defined as follows:

1. For HAS Projects, "HAS Project Manager" shall be the Project Manager assigned by the Infrastructure (INFRA) Group.
2. For Tenant Projects, "HAS Project Manager" shall be the Infrastructure (INFRA) Project Manager for Tenant Improvement Projects.

1.7 HAS Insurance Requirements -A current insurance certificate is required for every Contractor performing work on the premises of the Airport. The minimum coverage required is Comprehensive General Liability, Workers Compensation and Automobile and Truck Liability at such limits as defined in the Designer's or Contractor's contract with the City of Houston. For work in the Air Operations Area, an additional Umbrella or Excess Liability is required. Coverage levels are as stated in individual contracts. Consult with the Project Manager for specific Insurance requirements.

1.8 Manual for Design of Streets and Roadways - Texas Department of Transportation (TxDOT) Highway Design Section Operations and Procedures Manual, latest version, shall govern the design of streets and roadways that connect to or are otherwise governed by the standards of the State of Texas Department of Transportation. Construction Specifications shall be taken from "Standard Construction Specifications for Wastewater Collection Systems, Water Lines, Storm Drainage, Street Paving, and Traffic", latest edition, published by the City of Houston Department of Public Works and Engineering, except as modified herein.

1.9 Federal Aviation Administration (FAA) Standards - These standards may be obtained from the Federal Aviation Administration, Post Office Box 1689, Fort Worth, Texas 76101; U. S. Department of Transportation, Subsequent Distribution Section, M-4943, Washington, D.C. 20590; Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402; or other FAA regional offices. Most FAA standards and forms are available through the FAA website: http://www.faa.gov/airports/.

1.10 Survey Standards – Surveys conducted for design and for construction layout shall conform to the requirements of the Surveyor's Handbook for the subject airport. These handbooks indicate the datum and coordinate system that shall be used for the design and construction layout of all projects at the subject airport. Surveyor's Handbooks are available from the HAS Project Manager.

1.11 Glare and Noise in Buildings

1.11.1 Glare -It is imperative that all structures be glare controlled. Exterior finishes should meet the requirements of the Landside Aesthetics Master Plan (LAMP); however, finishes should be selected that will minimize glare. Light colored materials on roofs are acceptable. Designers should review FAA requirements prior to final design. In no case will materials or installations be allowed that will cause, or contribute to, pilot confusion.

1.11.2 Noise - All structures, whose primary function is to house people-oriented activities, shall be designed with a suitable combination of building materials and execution of construction details in accordance with established architectural and acoustical principles to reduce the noise between the outside and inside of the building to the following levels.

1.11.2.1 The methodology to be used shall be the Shell Isolation Rating (SIR) method set out by the U.S. Department of Commerce, National Bureau of Standards "Design Guide for Reducing Transportation Noise In and Around Buildings" - Publication: Building Science Series No. 84.

1.11.2.1.1 Schools, churches, hotels, meeting facilities and other spaces where noise intrusion is more sensitive than average and would disrupt the intended operation of the space - SIR 40 dB.

1.11.2.1.2 Offices, shops, Terminals, etc. where routine people-to-people and telephone communications occur frequently - SIR 30 dB.

1.11.2.1.3 Warehouses, freight facilities and other structures not involving significant communication between individuals - No Limit.

1.11.2.2 The design shall take into account all possible paths into the facility to include, but not be limited to walls, roofs, windows, doors and ventilation openings.

1.12 Regulation of Construction Overview

1.12.1 HAS Airport Construction and Fire Prevention Standards - The City of Houston regulates construction within the boundaries of George Bush Intercontinental Airport, William P. Hobby Airport, and Ellington Airport. These requirements are based on the adoption of, and amendments to, the Building Code, Fire Code, Electrical Code, Mechanical Code, Plumbing Code, Fuel Gas Code and Energy Code by the City of Houston.

1.12.2 Construction Permit Required – A Construction Permit must be obtained from the City of Houston, Department of Public Works in order to construct, enlarge, alter, repair, move, demolish, or change the occupancy of a building or structure, or to erect, install, enlarge, alter, repair, remove, convert or replace any electrical, gas, mechanical or plumbing system, the installation of which is regulated by the Construction and Fire Prevention Standards, or to perform any construction work on the Airports. The City of Houston Public Works Department shall be referred to as Building Standards and Building Official when referencing City of Houston Code requirements. With respect to the requirements of this Manual, requirements in excess of those contained in City Code are enforced by the City Engineer for the Houston Airport System who is represented on individual projects by his

designated Project Manager. Only the City Engineer for the Houston Airport System is authorized to grant variances or make changes to the standards contained in this Manual. Specifically, changes to this Manual may not be authorized by the Public Works Department of the City of Houston or any other City of Houston entity.

1.12.2.1 Submittals – The Applicant shall submit to the Building Official items A through D below with the Application for Construction Permit form. Refer to Commissioning Policy and Procedures for HAS construction projects. The Contractor shall pay the building permit fee (Item E) and submit the documents listed in item F after award of the contract and after the Construction Permit has been issued.

A. Complete and dated plans (including traffic control plans if applicable) of sufficient clarity to indicate the location, nature and extent of the work proposed and with sufficient detail to indicate that the proposed work conforms to the provisions of the Construction and Fire Prevention Standards, the Design Criteria Manual, and other applicable laws, statutes, orders, City of Houston Ordinances, and regulations. Typically, for HAS projects, the Designer will submit the application for permit at the 95% completion milestone. Note that the plans submitted should not indicate that they are 95% complete. Plans and specifications shall be prepared by an architect; engineer or other design professional licensed in the State of Texas to practice as such and shall bear the seal of the design professional responsible for preparation of the plans and specifications. Licensed professional means an individual who is licensed in the appropriate discipline for the plans and who has been in responsible charge of their preparation. Submit two (2) sets of construction documents. The Building Official shall accept only full-size prints for plan review. Detailed information regarding submissions is contained on Public Works and Engineering Form 1105, "Prerequisite Checklist Plan Review Procedures." Please note that for HAS projects each sheet shall be signed by an appropriately licensed HAS Assistant Director or the City Engineer as appropriate. Also, when applying for a Construction Permit, the City of Houston requires a survey for Asbestos Containing Materials (ACM) by persons licensed by the Texas Department of State Health Services (DSHS). If asbestos materials are present then specifications for abatement must be prepared by a licensed Environmental Consultant.

B. Completion of an Accessibility Compliance Checklist is required for all projects. The Designer must submit the Texas Department of Licensing and Regulation (TDLR) assigned EABPRJ# (TDLR's acronym identifying a project number assigned by that agency) with the application for permit. A construction permit cannot be issued until all required information has been received and approved.

C. If applicable, completion of Airspace Study Application form (FAA Form 7460-1) is required. Approval from the Federal Aviation Administration (FAA) is required for projects resulting in a change in the Airport Layout Plan or for the use of cranes and certain other construction equipment. Permits for construction will be limited until required FAA approvals are obtained.

D. Applicant is required to schedule a meeting with the Planning and Programming Section of the Planning, Design and Construction Division to discuss the project scope, typically at the 15% stage in a project's development. Based upon the scope, the Planning and Programming Section will provide the technical input for completing the Environmental Compliance Checklist (ECC). The purpose of this checklist is to identify the environmental

regulations that apply to the proposed construction or to the operation of the completed work, structure, or facility. The Applicant must submit to the Project Manager the Checklist and all applicable attachments prior to application for permit.

E. The construction contractor shall provide a check payable to the City of Houston for payment of Plan Review and Permit Fees which must be paid at the Building Official's office (City of Houston, Department of Public Works and Engineering, Code Enforcement, 3300 Main St. Houston, TX 77002, 713-535-7510). Furnish to the Building Official a Certification Letter (internal memorandum or e-mail for HAS Projects) stating the estimated cost of construction. This sum must be consistent with the amount indicated on the TDLR Project Registration form required in Item B above.

F. Prior to proceeding with the installation of fire protection or fire alarm systems, three (3) full-size sets of shop drawings, hydraulic calculations and related submittal data must be submitted to the Building Official.

1.12.2.2 Building Construction Projects – For building construction projects, provide the following information on the cover sheet of the drawings:

1. Construction Application Number (Note: This number shall be added to the plan set after it is assigned. It will not be available when submitted for review).
2. The street address of the structure for a remodel. If the structure is new the address will be assigned by the City of Houston Code Enforcement Office.
3. For tenant projects the name and address of the Owner
4. The edition of the codes under which the project is designed
5. Building Code Use and Occupancy Classification
6. Building Code Construction Type
7. Design Occupant Load and Exiting Analysis
8. If automatic sprinkler system is provided
9. U-factors of building envelope systems and a statement signed and sealed by the architect of record that the building envelope complies with the Energy Code
10. Tabulation of building components and systems and a statement signed and sealed by the engineer of record that all building components and systems comply with the Energy Code.

1.12.3 Construction Permit Issued -When it has been determined that the plans for the proposed project are in compliance with the Construction and Fire Prevention Standards, the Design Criteria Manual and that all other requirements have been met, the Building Official will approve the Construction Application and issue a Construction Permit. Typically the Designer will complete an Environmental Assessment Memorandum outlining the environmental conditions of the Project, and an Environmental Close-Out Checklist that will be completed and submitted to the HAS Project Manager at the close of construction, will be provided by the HAS Project Manager.

1.12.4 Project Construction and Inspection – Through the Notice to Proceed letter, the Applicant is given instructions to contact the HAS Project Manager for the purpose of scheduling a pre-construction conference. The conference should include the Applicant, the Applicant's Contractor and the Contractor's major Subcontractors. The Contractor will be briefed on rules, regulations and procedures to be followed for construction projects on the Airport. The Contractor must submit an emergency phone list, any required submittals and a construction schedule. After posting the Construction Permit and placing approved construction documents at the project site, and receiving a Notice to Proceed, the Contractor may begin construction. An inspection is required before

covering or concealing any electrical, plumbing, utility, mechanical, fire sprinkler, fire alarm or structural systems. Work may not progress beyond any point for which an inspection is required until the Contractor receives an approved inspection report for the inspected work. Further, the location of all new or replaced electrical, mechanical, plumbing, utility, fire sprinkler, fire alarm, communications, data, or structural systems shall be either confirmed to be in the location shown on the plans or its altered location identified on the contractor's set of red-line plans that form the basis of the as-built drawings. The HAS Project Manager or HAS Inspector may request that an HAS survey crew verify the locations on a random basis for use as a quality control measure in evaluating the contractor's red-line plan set.

1.12.5 Record Documents -Record documents (as-constructed) reflecting the final installation after all modification and changes shall be furnished to the HAS Project Manager at the end of each construction project. Record specifications shall be those used for the actual construction, marked with changes made by addendum, change order, or product substitution. Record drawings shall be made on reproducible vellum copies with the required Contractor's signature block attesting to the accuracy and completeness of the drawings. Submitted record drawings will include full sets of signed and sealed hard copy drawings with changes noted. **For HAS Capital Projects, also provide electronic media.** Electronic submittal shall be AutoCAD dwg 2014 version or later. All drawings shall have support files (XREFS) correctly "binded." Plot configuration files are also required with the AutoCAD submittals.

All file transfers shall be written to a CD, DVD, or external hard drive as appropriate for the amount of information submitted. It is the responsibility of the consultant to ensure that all electronic deliverables are provided in an accessible AutoCAD, Revit, BIM environment. The record drawings shall include the following information:

1. The final location, alignments, elevations, and material type of all underground utilities.
2. The final location of all structures, buildings, roads, parking areas, and other elements of the project.
3. The final locations of all heating and air conditioning equipment, ductwork, air devices, piping, or other devices necessary to the operation of the HVAC systems.
4. The final locations of all plumbing equipment, pumps, piping, necessary for the operation of the plumbing systems.
5. The final locations of all the electrical equipment, devices, wiring sequences, wiring methods and connections of component systems as installed. The drawings shall include color codes, panel identification, and any other information necessary to identify and locate the equipment.
6. All initiating devices such as flow switches/pressure switches for fire protection systems.
7. Initiating devices, wiring sequence, wiring method, and connections of the components of the protective signaling system as installed. The drawings shall include color codes and terminal identifications.
8. The final locations of all the communications equipment, devices, wiring sequences, wiring methods and connections of component systems as installed. The drawings shall include color codes.
9. The final locations of all the security equipment, wiring sequences, wiring methods and connections of component systems as installed. The drawings shall include color codes.
10. All abandoned piping (Note: No abandoned utility shall be left in place without the express written consent of the City Engineer. Abandoned in place utilities, when authorized by the City Engineer, will be noted on the record drawings).
11. Location of any identified, but undisturbed asbestos remaining encapsulated.

1.12.6 Certificates of Occupancy/Use – The Contractor must deliver to the HAS Project Manager the completed Environmental Close-Out Checklist at the close of construction. Upon acceptance of the Environmental Close-Out Checklist by the HAS Project Manager, other required submittals and acceptance of the work following all required final inspections, the Building Official will issue a Certificate of Occupancy/Use. After receipt of the required As-Built Documents and correction or completion of any outstanding items of work the HAS Project Manager will issue the notice of final completion.

THE FOLLOWING REQUIREMENTS PERTAIN ONLY TO HAS PROJECTS:

1.13 Project Process Overview -The following overview describes, in general, the process used for design and construction of HAS Projects. A key element throughout the progress of any HAS Project is the development and maintenance of the Project Report. The Project Report will be based upon the Project Development Brochure developed during the planning and programming phases of project development. It will be expanded throughout as described in this manual and is meant to establish a complete project history that provides a record of all important planning, design and construction phase decisions; calculations; understanding of the existing conditions; conditions that were unforeseen that were identified during construction and how those conditions were addressed; and any other major issues and actions that materially affected completion of the project.

1.13.1 Commissioning Policy and Procedures – Commissioning is required on all HAS construction projects, including development, maintenance and renovation, having a construction budget greater than $500,000 or HAS building construction projects, including new construction and modifications, having a construction budget greater than $50,000. For HAS construction projects subject to the commissioning requirement, the City Engineer or his designee shall not issue a Notice to Proceed until HAS has approved the Commissioning Plan. The City Engineer or his designee shall not issue a notice of substantial completion until all pre-occupancy commissioning activities identified in the Commissioning Plan have been successfully completed and appropriately documented.

Design Consultants – The following information pertains to design consultants for HAS Projects and their services.

1.13.2 Selection of Consultant(s) - Proposals are solicited for professional services through advertisements. A "short list" of candidates is selected after a careful review of the Statements of Qualifications that are submitted. These "short listed" firms are usually asked to make a presentation to a selection committee, which will make the recommendation for final selection.

1.13.3 Consultant Contract - After completion of the selection process, the first-rated consultant(s) enter into contract negotiations with HAS representatives. If negotiations with the first-rated firm(s) are unsuccessful, negotiations may be terminated, and HAS representatives may begin negotiations with the next highest rated firm(s). Once an agreement is successfully negotiated, the final contract is presented to the City of Houston City Council for approval. If Council approves the agreement, the contract will be executed by the Mayor, and a notice to proceed with design will be issued.

1.13.4 Project Initiation - At the beginning of every design project, a pre-design conference will be scheduled to be attended by the project manager, contract administrator, other HAS representatives and pertinent members of the design team. During this meeting, discussion will include the program for the design, the project budget and the project schedule as well as any other stakeholder issues and operational considerations that may impact the design, the project phasing, or special requirements to maintain service during construction.

1.13.5 Design Milestones - Design review submittals are required at 30%, 65%, 95% and 100% levels of completion. Specific information on the requirements and level of detail required for each of these submittals is described in the following sections.

1.13.6 Project Review - Normally, two weeks should be allowed for HAS staff review of each submittal. However, additional time may be required under certain circumstances, particularly if there are interfaces with other projects, or if outside agency approvals are necessary.

1.13.7 Review Comments – The consultant must respond to all review comments. Copies of these responses shall be turned in to the project manager with the next submittal or as directed otherwise. Review comments provided in writing or noted directly on the submitted drawings must be referenced in the Project Report that accompanies each submission and the response described in sufficient detail, i.e., as determined by the City Engineer, to determine that the issue has been adequately addressed. Submittals made without addressing the previous comments will be considered incomplete.

1.13.8 Consultant Participation During Bid Phase – In general the following process is usually followed in the selection of contractors. Construction bids are solicited through general advertisements. A pre-bid conference is conducted prior to the final submission and opening of the bids to discuss the scope of the work and answer questions from bidders. The pre-bid conference may include the Designer and HAS Project Manager hosting a tour of the project site. The design consultant is expected to conduct or participate in this conference to provide answers to pertinent questions and to assist in preparing any resulting contract addenda. At the advertised time, the bids that have been received will be opened and read in accordance with City of Houston procedures. The Designer typically will be asked to assist in analyzing the bids to determine the responsive low bidder. A notice to proceed with construction will be issued after City Council approval of the construction contract, appropriation of the funds necessary to complete the project, and execution of the construction contract by the Mayor. In the event that an alternative delivery method is selected for an individual project, the selection process will be qualification based and essentially follow that described for selection of the design consultant.

1.13.9 Consultant Participation During Construction Process - Prior to the start of construction, a pre-construction conference is held to review contract requirements, operational and site restrictions, notification procedures and required inspections. Depending upon contract scope requirements, the consultant may be responsible for assisting in the review of shop drawings, submittals, change orders and other documents and may be required to attend periodic or regular construction progress meetings. On some projects, partnering sessions may be conducted. HAS representatives, the consultant, the contractor and/or the construction manager, the major sub-contractors, and interested stakeholders will be included in the partnering sessions.

1.13.10 Consultant Participation at Completion of Construction – Depending upon contract requirements, the consultant generally participates in a final project "walk-through" at the completion of construction and is usually responsible for reviewing the contractor's certified as-built drawings and specifications submittal and for preparing the final record drawings.

1.14 Software Requirements and Project Design Delivery – Production and maintenance of project documentation shall comply with the HAS Airport CAD/Geospatial Data Standards and Procedures Manual. During the design and construction phases of the project the Designer shall supply information as required by the HAS Project Management software. HAS will provide appropriate forms and instructions for the Designer and contractor to utilize for submissions. Processes included in the automated processing may include, but are not limited to, project collaboration and communication, requests for information (RFI), requests for proposals (RFP), architect instructions (AI), work change directives (WCD), change orders (CO), invoices, final plan submissions, etc. The final deliverables shall consist of the construction Contract Documents which shall be complete and shall set forth in detail all work required for the architectural, civil, structural, mechanical, plumbing, electrical, fire protection and fire detection, communication, security and utility service systems, including transportation interfaces, site work, and all necessary bidding information.

1.15 Design Calculations - Most design projects require that various engineering calculations be performed and/or design criteria/material cut sheets be assembled that provide the basis for information on the construction plans and specifications. These values and calculations shall be assembled in the Project Report. These documentation requirements will vary for each specific design discipline.

1.16 Required Submittals - During the planning and design stages of project development, certain submittals are required in bound form for review and approval. The submittals described below should be considered as the minimum. Intermediate reviews may be required only if the scope of the project has been changed or if an earlier review found the plans and specifications unacceptable, either as a whole or in part. The required stage of completion of the plans and specifications shall be as hereinafter outlined. For each major element, at each stage of development, it is essential that the Designer address the existing systems and whether they intend to 1) install system extensions identical to the existing system; 2) install a system that is compatible with the existing system meaning that the project includes all programming or adjustment to the existing system necessary to ensure compatibility; or 3) propose a complete system change that includes not only installation associated with the current project but replacement of the entire system, including all ancillary systems that currently are interfaced. Replacement shall only be considered if accompanied by cost-benefit and life-cycle cost analyses that support the proposal. Likewise, for any change that requires reprogramming or other adjustments to the existing system a life-cycle cost analysis will be required to support the proposal.

Prior to any construction or design of grant funded projects, a detailed survey plan as required by FAA Advisory Circular 150/5300-16A or later must be submitted and approved by FAA and the National Geodetic Survey (NGS). All reports and approvals required by FAA shall be submitted as specified in Advisory Circulars 150/5300-16A, and -18B or later.

1.16.1 Schematic Design Phase (early-review) - For all HAS Projects the schematic plans, 30%, and specifications shall include:

1. A boundary survey and/or site topographic survey shall be made on the ground of the proposed building or construction site. All points shall be tied to the existing Airport Coordinate System using the appropriate Survey Handbook for the subject airport. Ground survey verification of existing utility alignments and flow lines is required unless specifically exempted by the City Engineer.
2. All existing buildings, facilities, contours, roadways, utilities, or signs in the immediate area of the project site or relevant to the proposed work should be shown on a preliminary site plan.
3. Layouts of the proposed roadways, access drives, parking areas, site utilities and building locations should be shown.
4. The Project Report, built upon the Project Development Brochure that indicates the objective of the project including articulated goals and objectives; the design standards applicable; any specific design conditions imposed by HAS or other regulatory agencies; any conditions imposed by a Record of Decision, mitigation measures articulated in a Finding of No Significant Impact, any proprietary specification or specifications written around a single manufacture's product or any specifications naming a manufacturer or manufacturers of acceptable products along with a justification for the non-competitive selection, with the exception of products that are on a preapproved listing published by the FAA or a listing of repurchased materials or products that were competitively selected by HAS with guaranteed prices for the project, so that prior approval of the City Engineer and/or the FAA can be obtained, etc. This Project Report shall be supplemented throughout the project and shall become the official complete record of the project.

1.16.2 Schematic plans and specifications for Airfield Projects shall include:

1. All existing terminals, runways, taxiways, taxilanes, aprons, vehicle service roads delineated on airfield elements, ground support equipment areas, emergency roads, buildings and structures, contours, underground utilities, or signs in the immediate area of the project site or relevant to the proposed work should be shown. Identify from the Airport Stormwater Drainage Master Plan the outfall number for drainage.
2. All existing FAA NAVAIDS, duct banks, guidance signs, lighting fixtures, electrical ducts, vaults, handholes, and circuit locations should be shown and identified.
3. Layouts of proposed paving, drainage, and electrical improvements, including stationing, coordinates and dimensions.
4. Limits and dimensions of all object free areas, safety areas, exclusion zones, NAVAIDS, critical areas, and FAR Part 77 airspace surfaces that affect project site.
5. Locations of proposed buildings, signs, NAVAIDS, AOA fences, and other site structures.

1.16.3 Schematic plans and specifications for Buildings shall include:

1. Building code summary on cap sheet showing governing codes and requirements for building and site.
2. Floor plans showing dimensions and square footage of usable areas.
3. Elevations showing heights and planned access for items that are important to future maintenance of the facility.
4. Location of chases, shut-off valves, clean outs and other facility elements that are important in the future maintenance of the facility.
5. Schedule of materials to be used.
6. Design Data - The building program and any special studies, life cycle cost analysis which will affect the project design.
7. Tower Line-of-Sight Studies (if required).
8. Service entrances, grease traps, trash locations, and recycling provisions.
9. Design live loads.

1.16.4 Schematic plans and specifications for HVAC shall include:

1. Mechanical rooms including dimensions demonstrating accessibility of equipment for future maintenance activities.
2. Location of all chases required for air conditioning systems.
3. Location of all air handling and refrigeration equipment.
4. Calculations indicating that the improvements can be accommodated by the existing supply system or equipment layout to provide the required additional capability.
5. Narrative description of the proposed systems including a schematic diagram of air flow through the various system components (the general scheme outlined in the narrative must be previously discussed with the HAS Project Manager and agreed to at the Pre-design Conference). This narrative to be part of the Project Report. The narrative shall also address the existing and proposed control systems and whether they are compatible, reprogramming of the existing system will be required, or whether replacement of the existing system is proposed. Any major changes to systems must be accompanied by a benefit cost and life-cycle cost analyses to support the proposed change.

1.16.5 Schematic plans and specifications for Plumbing shall include:

1. A brochure defining all plumbing fixtures.
2. Narrative description of plumbing systems proposed, including source of exterior services.
3. Location of janitorial closets, slop sinks and supply storage.

1.16.6 Schematic plans and specifications for Electrical shall include:

1. Electrical rooms.
2. Narrative description of the proposed systems including a schematic diagram of the distribution system (the general scheme outlined in the narrative must be previously discussed with the HAS Project Manager and agreed to at the Pre-design Conference).
3. Preliminary lighting layout showing general types of illumination to be used such as fluorescent, H.I.D., or others.
4. Tabulation of lighting levels to be used for the design of the lighting system.
5. A sample lighting calculation for a typical room or area (exterior lighting projects).
6. An analysis indicating that sufficient service is currently available or identification of a need for additional service.
7. Confirmation that the Designer understands that AC(BX) and MC cable shall not be permitted on any project in HAS owned and operated facilities.
8 Locations of permanent or temporary generators for emergency power (Note: If the policy decision is made to provide locations for temporary generators the layout plan shall provide a basic location for permanent transfer switches to facilitate such connections.)
9. Location and protection required for maintaining existing service and identification of FAA cables and tenant owned utilities. The designer shall demonstrate understanding of the FAA systems and requirements for maintenance and replacement of FAA facilities.

1.16.7 Schematic plans and specifications for Fire Protection shall include:

1. Fire vehicle access.
2. Narrative description of fire protection systems proposed, including source of exterior fire protection services such as water mains.
3. Schematic fire protection drawings with identification of all sprinkled areas and areas protected by other automatic suppression systems.
4. Drawings shall be drawn to a scale of 1/8”=1’-0”.

1.16.8 Schematic plans and Specifications for Communications shall include:

1. Communication rooms.
2. Confirmation that the Designer understands that no domestic water, sewer, or HVAC lines will be routed through or in the ceiling space above any communications room (MDF or IDF).
3. Narrative description of the proposed systems including a schematic diagram of the communication system (the general scheme outlined in the narrative must be previously discussed with the HAS Project Manager and agreed to at the Pre-design Conference).
4. Confirmation that additions or adjustments to the manned communication rooms will be made with ergonomically designed features to avoid muscular, skeletal or sensory damage to the communications staff.

1.16.9 Schematic plans and specifications for Security shall indicate:

1. Site security.
2. CCTV/monitor and equipment rooms.
3. Narrative description of the proposed systems including a schematic diagram of the security system (the general scheme outlined in the narrative must be previously discussed with the HAS Project Manager and agreed to at the Pre-design Conference). The narrative shall describe the compatibility of the proposed system with existing systems and what actions will be taken to ensure that all systems will work together at the completion of the project. If major changes are proposed in the existing system the submission shall include benefit-cost and life-cycle cost analyses in support of the proposal.
4. Confirmation that additions or adjustments to the manned CCTV monitor and equipment rooms will be made with ergonomically designed features to avoid muscular, skeletal, or sensory damage to the security staff.

1.16.10 Number of Submittals: Submit the number of sets of schematic plans required by the designer's contract to the HAS Project Manager for review and approval before proceeding to Design Development stage.

1.16.11 Design Development Phase (mid-review) -For all HAS Projects the Design Development, 65% plans and specifications shall include all information in previous submittals plus all annotated comments from previous submittals and shall indicate:

1. Proposed landscaping, exterior signing, exterior lighting, fencing and gates, or other site elements.
2. Preliminary horizontal and vertical alignments for all roadways, drainage systems, and applicable exterior utilities tied into Airport coordinate system.
3. Preliminary paving and parking layouts with horizontal and vertical ties to site survey and representative cross-sections.
4. Preliminary Cost Estimates and Construction Schedule.
5. Perspective Rendering - May be required if the project has visual impact on the Airport development as a whole.
6. Design data and analysis.
7. Soil tests data and analysis.
8. Outline Specifications are required at the 30% and 65% submittals.
9. Project Report that includes elements 4 through 8 as well as a discussion of each significant design decision and its rationale.
10. Quantity or schedule of value outline indicating the assets which are included in the project and will be tracked throughout. Agreement on the assets included will be between HAS PDC and HAS Finance and will be established by meeting with the Designer approximately one month prior to the 65% submittal date.

1.16.12 Design Development plans and specifications for Airfield Projects shall include:

1. Horizontal and vertical layouts for all proposed airfield paving, emergency roads, haul routes, laydown sites and drainage features.
2. Layouts for proposed airfield electrical circuits, NAVAIDS, and underground utilities.
3. Drainage calculations and preliminary hydraulic gradient profiles supporting the utility layout and potential underground conflicts with both existing and proposed utilities.
4. Typical sections for each type of paving, including surface and groundwater drainage features.

5. Site access points, lay-down areas, and haul routes with preliminary protection details to support the NPDES permit application.
6. Typical details for all paving, jointing, sealing, drainage, electrical, utilities, etc...
7. Preliminary safety and phasing plans and draft FAA Notification of Construction Form 7460-1.
8. A listing of any previously unreported proprietary specification or specifications written around a single manufacturer's product or any specification naming manufacturer or manufacturers of acceptable products along with a justification for the non-competitive selection, with the exception of products that are on a preapproved listing published by the FAA or a listing of pre-purchased materials or products that were competitively selected by HAS with guaranteed prices for the project, so that prior approval of the HAS Engineer and/or the FAA, as required, can be obtained.
9. PLB/PBB- Passenger Loading Bridges/Passenger Boarding Bridges must show operational equipment specifications for model type, tunnels, swing, lift, retraction and extension limits and proposed aircraft fits.
10. Indicate fuel pits, 400hz and PCAir equipment with proposed aircraft fits.
11. Indicate lines of all "Taxilane, Lead -In and Parking" positions of proposed Aircraft and movements onto active areas of the AOA.

1.16.13 Design Development plans and specifications for Buildings shall include:

1. Floor plans.
2. Framing plans.
3. Ceiling plans.
4. Roof plans.
5. Sections and elevations.
6. Details of typical conditions.

1.16.14 Design Development plans and specifications for HVAC shall include:

1. Mechanical rooms with all equipment and required connecting ductwork drawn to scale (this requirement is mandatory to establish the space needs for mechanical equipment).
2. Routing of major piping systems when space is a consideration; and ductwork for remainder of project in one line form to indicate the breakdown of proposed zones.
3. Report on design criteria and system loads (include in Project Report).
4. Specifications shall be in the form of an outline covering all Heating & Air Conditioning equipment and materials to be used in the project.
5. A listing of any previously unreported proprietary specification or specifications written around a single manufacturer's product or any specification naming manufacturer or manufacturers of acceptable products along with a justification for the non-competitive selection, with the exception of products that are on a preapproved listing published by the FAA or a listing of pre-purchased materials or products that were competitively selected by HAS with guaranteed prices for the project, so that prior approval of the HAS Engineer and/or the FAA, as required, can be obtained.

1.16.15 Design Development plans and specifications for Plumbing shall indicate:

1. All plumbing fixtures including those for disabled persons drawn to scale.
2. Roof drains and route of storm drains to storm sewer.
3. Sump pump and sewage ejector locations.

4. One typical riser diagram for each type of system.
5. Report on design criteria and system loads (include in Project Report).
6. Specifications shall be in the form of an outline covering all plumbing equipment and materials to be used in the project.
7. A listing of any previously unreported proprietary specification or specifications written around a single manufacturer's product or any specification naming manufacturer or manufacturers of acceptable products along with a justification for the non-competitive selection, with the exception of products that are on a preapproved listing published by the FAA or a listing of pre-purchased materials or products that were competitively selected by HAS with guaranteed prices for the project, so that prior approval of the HAS Engineer and/or the FAA, as required, can be obtained.

1.16.16 Design Development plans and specifications for Electrical shall include:

1. Electrical rooms with all equipment drawn to scale as well as door opening and space utilization beyond the doors, in order to determine the viability of pulling the machinery out for replacement when necessary (this requirement is mandatory to establish the space needs for electrical equipment).
2. Routing of feeder and service conduit systems when space is a consideration.
3. A one-line diagram of distribution system shall indicate approximate equipment and service size.
4. Lighting layout for projects, including exterior systems, with tabulated loads.
5. A brochure showing cut sheets on all lighting fixtures (and poles) proposed for project. Submit five (5) sets of D.D. electrical systems plans for review and approval before proceeding to final working drawings (Contract Bid Documents).
6. A calculation indicating that existing service is adequate or identifying additional service needs as well as estimates to provide additional service required (include in Project Report).
7. Description of the accommodation of emergency power requirements, including a detailed description of the items that will be connected to the emergency buss (include in Project Report). Note that this may require a policy decision on the part of HAS and needs to be identified early in the design process
8. Specifications shall be in the form of an outline covering all electrical equipment and materials to be used in the project.
9. A listing of any previously unreported proprietary specification or specifications written around a single manufacturer's product or any specification naming manufacturer or manufacturers of acceptable products along with a justification for the non-competitive selection, with the exception of products that are on a preapproved listing published by the FAA or a listing of pre-purchased materials or products that were competitively selected by HAS with guaranteed prices for the project, so that prior approval of the HAS Engineer and/or the FAA, as required, can be obtained

1.16.17 Design Development plans and specifications for Fire Protection shall include:

1. Fire protection plans shall indicate all underground water mains and their sizes.
2. Fire hydrant locations.
3. Proposed water supply connections to sprinkler systems.
4. Control valve locations.
5. Fire alarm panel locations.
6. Smoke control/removal systems layout.
7. Underground valve meter pit.

8. Standpipe locations.
9. Include a description of the design rationale for the system (include in Project Report).
10. Specifications shall be in the form of an outline covering all fire protection items, equipment and materials including manufacturers and model numbers to be used in the project (this shall include smoke/heat detectors and pressure, flow, and tamper switches). Note that the current standard system used by HAS is Notifier and all new installations or renovations must use equipment manufactured by Notifier and only Notifier certified technicians will be permitted work on or install the equipment.

1.16.18 Design Development plans and specifications for Communications shall include:

1. Communication rooms with all equipment drawn to scale (this requirement is mandatory to establish the space needs for equipment).
2. One-line diagram of communication system shall indicate intercom, speakers, equipment, terminal boards and cabinets.
3. Include a description of the design rationale for the system (include in Project Report).
4. Specifications shall be in the form of an outline covering all communication equipment and materials to be used in the project.
5. A listing of any previously unreported proprietary specification or specifications written around a single manufacturer's product or any specification naming manufacturer or manufacturers of acceptable products along with a justification for the non-competitive selection, with the exception of products that are on a preapproved listing published by the FAA or a listing of pre-purchased materials or products that were competitively selected by HAS with guaranteed prices for the project, so that prior approval of the HAS Engineer and/or the FAA, as required, can be obtained.

1.16.19 Design Development plans and specifications for Security shall indicate:

1. CCTV/monitor and equipment rooms with all equipment drawn to scale (this requirement is mandatory and is required to establish the space needs for equipment). Provide adequate working clearance for monitors and operator console.
2. One-line diagram of security system shall indicate control panels, sensors, cameras, monitors, telephone interface, and any other system devices critical to operation.
3. Include a description of the design rationale for the system (include in Project Report).
4. Specifications shall be in the form of an outline covering all security equipment and materials to be used in the project.
5. A listing of any previously unreported proprietary specification or specifications written around a single manufacturer's product or any specification naming manufacturer or manufacturers of acceptable products along with a justification for the non-competitive selection, with the exception of products that are on a preapproved listing published by the FAA or a listing of pre-purchased materials or products that were competitively selected by HAS with guaranteed prices for the project, so that prior approval of the HAS Engineer and/or the FAA, as required, can be obtained.

1.16.20 Number of Submittals: Submit the number of sets of Design Development plans required by the designer's contract, to the HAS Project Manager for review and approval before proceeding to Construction Documents stage.

1.16.21 Construction Document (CD) Phase (final-review) -For all HAS Projects the Construction Document, 95% and 100%, plans and specifications shall include all information in previous submittals plus all annotated comments from previous submittals and shall include:

1. Complete drawings with all plan, profile, detail, section, schedule, calculation and miscellaneous sheets included.
2. Specifications complete in final typed form.
3. Final Construction schedule.
4. Final cost estimate.
5. Storm water pollution prevention plan.
6. The CD Phase Project Report updated through the completion of Construction Documents to be further updated to include disposition of comments on the CD submission.

1.16.22 Construction Document plans and specifications for Airfield Projects shall include:

1. All proposed paving and facilities.
2. Proposed grading and surface contours.
3. Final profiles and flow lines for all drainage systems.
4. All required sections and details.
5. If federally funded project a limited Project Report meeting the requirements of FAA's required Engineer's Report.
6. Estimated quantities including paving PWL bonus.
7. Comply with all codes of regulatory agencies with jurisdiction for airfield projects

1.16.23 Architectural Construction Document plans and specifications shall include:

1. Index, Symbols, Abbreviations, Key Plan Notes.
2. Demolition, Site Plan, Temp Work.
3. Plans, Material Schedule, Door Schedule, Key Drawing.
4. Sections, Exterior Elevations.
5. Detailed Floor Plans.
6. Interior Elevations.
7. Reflected Ceiling Plans.
8. Vertical Circulation, Stairs, Elevators, Escalators.
9. Exterior Details.
10. Interior Details.
11. Include all information in previous submittals plus annotated comments from last submission review.
12. Prior to any renovation or demolition activity at a facility, no matter how small the activity or how new the facility, the City of Houston requires a survey for Asbestos Containing Materials (ACM) by persons licensed by the Texas Department of State Health Services (DSHS). If asbestos materials are present then specifications for abatement must be prepared by a licensed Environmental Consultant.
13. For any construction that will require existing floors or walls to be penetrated (typically by coring), the specifications shall require that the facility to be cored shall be x-rayed in order to prevent damage to existing structure and equipment.
14. A listing of any item that has been included in an established allowance and how the allowance will be allotted and released.

1.16.24 Structural Construction Document plans and specifications shall include:

1. Index, Symbols, Abbreviations, Key Plan, Notes, Loading Criteria.
2. Demolition Site Work.
3. Foundation Plans and Details, Foundation Design Criteria.
4. Framing Plans and Details.
5. Elevations.
6. Details.
7. Schedules.
8. Special Design.
9. Include all information in previous submittals plus annotated comments from last submission review.

1.16.25 Construction Document plans and specifications for HVAC shall include:

1. All air conditioning systems drawn to scale, including all ductwork in two lines with all fittings to scale.
2. Sections through mechanical rooms to adequately describe the construction requirements.
3. Schedule of all major items of equipment drawn on the plan sheets to indicate performance characteristics.
4. All piping systems complete with necessary sections to clarify routing.
5. Applicable details, including those included in the Design Criteria modified to suit project.
6. Flow diagrams and riser diagrams in isometric form for each piping and ventilation system except drains.
7. A copy of the heating and air conditioning load, ventilation, air pressurization calculations shall be furnished for future reference. Calculations shall clearly indicate all zoning requirements, etc.
8. The type and contents of the Test and Balance Reports to be furnished shall coincide with the work scope of the system being designed.
9. Include all information in previous submittals plus annotated comments from last submission review.
10. A listing of any item that has been included in an established allowance and how the allowance will be allotted and released.
11. Evidence that a constructability check for continuity and conflicts among all building systems was performed.

1.16.26 Construction Document plans and specifications for Plumbing shall indicate:

1. All plumbing fixtures shown and identified by a number.
2. Riser diagrams in isometric form for all plumbing risers in the building.
3. Flow diagrams for all pressure systems including hot and cold water, gas, oxygen, air vacuum, etc.
4. Details such as lavatory connection pump connection, hot water generator, water softener, sewer manholes, backflow prevention, water header, etc.
5. Schedule all major equipment on drawings.
6. Plumbing fixtures may be scheduled, but must also be described in detail in the specifications.

7. Include all information in previous submittals plus annotated comments from last submission review.
8. A listing of any item that has been included in an established allowance and how the allowance will be allotted and released.

1.16.27 Construction Document plans and specifications for Electrical shall include:

1. All electrical systems drawn to scale including light fixtures, distribution equipment and other miscellaneous system components.
2. Schedule of all light fixtures, switchboards and motor control centers.
3. Schedule of all panel boards which include connected loads and demand loads. All panel boards are to be door-in-door type.
4. One-line diagram of electrical distribution system including all equipment, feeder, service ratings and available symmetrical three phase fault current at each device.
5. Applicable standard details from these guidelines modified to suit project.
6. One-line diagrams for each system including the emergency buss and any permanent generator or transfer switch locations.
7. Include all information in previous submittals plus annotated comments from last submission review.
8. A listing of any item that has been included in an established allowance and how the allowance will be allotted and released.

1.16.28 Construction Document plans and specifications for Fire Protection shall include:

1. All fire risers shown and identified by a number.
2. Flow diagrams and riser diagrams for fire protection pressure systems.
3. Details such as fire hose cabinets, fire hydrants, fire pumps, fire department connections, backflow prevention, water header, connections, cathodic protection and riser insulation's, etc...
4. Schedule all major equipment on drawings; fire sprinkler drawings will include all piping sizes and locations, drawn to scale of no less than % inch equals one foot
5. Include all information in previous submittals plus annotated comments from last submission review.
6. A listing of any item that has been included in an established allowance and how the allowance will be allotted and released.

1.16.29 Construction Document plans and specifications for Communications shall include:

1. All communication system equipment, cabinets, boards drawn to scale, telephone outlets, intercom stations, repeater stations, etc.; one-line diagram of communication systems.
2. Applicable standard details from these guidelines modified to suit project.
3. Include all information in previous submittals plus annotated comments from last submission review.
4. A listing of any item that has been included in an established allowance and how the allowance will be allotted and released.

1.16.30 Construction Document plans and specifications for Security shall indicate:

1. All security system control and monitoring equipment drawn to scale, sensor locations and types.
2. Applicable standard details from these guidelines modified to suit project.
3. Security devices.
4. Security signage.
5. Individual zone location and designation, with all alarm device locations, including the security alarm and data panel, annunciators, and any other devices necessary for the operation of the system.
6. Include all information in previous submittals plus annotated comments from last submission review.
7. A listing of any item that has been included in an established allowance and how the allowance will be allotted and released.

1.16.31 Number of Submittals: Submit the number of sets of Contract Bid Documents required by the designer's contract, for review and approval before printing for distribution to bidders.

1.16.32 The documents at this point should be ready to be signed and sealed pending approval by the HAS Project Manager. Once these documents are approved, signed and sealed, they can be provided to contractors for bidding purposes.

1.17 Specification Format - For all non-AIP projects, specifications shall be in accordance with the Construction Specification Institute (CSI). For all airfield construction and other Airport Improvement Program (AIP) funded projects, contract documents shall be prepared in accordance with AC 150/5370-10F, or the latest edition. SECTION 1, including Notice to Bidders, Instructions to Bidders, Proposal Forms, Bid Schedule Forms, Bond Forms, General and Special Provisions of the contract documents shall be prepared based on guidance and direction from the HAS Project Manager and shall comply with City of Houston standard requirements.

1.18 Coordination of Design – The prime design firm is responsible for and shall ensure that the design is coordinated between disciplines. The following sections describe the minimum Quality Control reviews expected of the prime firm prior to the submission of Contract Documents.

1.18.1 HVAC -The final HVAC drawings shall, as a minimum, be checked for the following:

1. Electrical lighting fixtures shall be checked for conflict with air diffusers, ceiling grilles, sprinkler heads, ceiling type speakers, and other ceiling mounted devices.
2. Ductwork shall be checked for clearance between ceiling construction and underside of beams, recessed lighting fixtures and other interferences where space is limited.
3. Large mechanical system piping shall be coordinated with building structure to assure clearances and accessibility for maintenance. Piping and electrical switchgear locations are to be coordinated.
4. Coordinate requirements for louvers, equipment supports and other devices serving mechanical systems, but furnished under the general construction section of the project.
5. Coordinate special types of or HAS furnished equipment for correct rough-in requirements.
6. Plans and specifications shall be checked for conflicts.

7. Plans shall be coordinated for size and location of all chases or dedicated corridors (i.e. space dedicated for future baggage handling system).

1.18.2 Plumbing -The final Plumbing drawings shall, as a minimum, be checked for the following:

1. Piping shall be coordinated with building construction, beams, etc., to assure clearances and accessibility for maintenance. Piping and electrical switchgear locations are to be coordinated.
2. Piping shall be checked for clearance between ceiling construction and underside of beams, recessed lighting fixtures and other interferences where space is limited.
3. Piping, ductwork, electrical conduits, etc. shall be checked for interferences that would prevent proper installation of each system.
4. Coordinate special types of equipment for correct rough-in requirements.
5. Plans shall be coordinated for size and location of all chases.

1.18.3 Electrical - The final Electrical drawings shall, as a minimum, be checked for the following:

1. Electrical lighting fixtures shall be checked for conflict with air diffusers, ceiling grilles, sprinkler heads, ceiling type speakers, etc...
2. Large electrical system conduit and pull boxes shall be coordinated with building construction, beams, etc., to assure clearances and accessibility. Piping and electrical switchgear locations are to be coordinated.
3. Plans and specifications shall be checked for conflicts.
4. Plans shall be coordinated for size and location of all chases.

1.18.4 Fire Protection -The final Fire Protection drawings shall, as a minimum, be checked for the following:

1. Piping shall be coordinated with building construction, beams, etc., to assure clearances and accessibility for maintenance. Piping and electrical switchgear locations are to be coordinated.
2. Routing of sprinkler piping shall have minimum turns to avoid building construction, etc.
3. No areas are to be left without fire protection/detection, such as wedges in terminals and utility closets when one project is subdivided into several phases.

1.18.5 Communications -The final Communications drawings shall, as a minimum, be checked for the following:

1. Ceiling type speakers shall be checked for conflict with light fixtures, air diffusers, ceiling grilles, sprinkler heads, etc.
2. Large communication system conduit and pull boxes shall be coordinated with building construction, beams, etc., to assure clearances and accessibility.

1.18.6 Security - The final Security drawings shall, as a minimum, be checked for the following:

1. Security system components and types and locations shall be coordinated through the HAS Project Manager with the HAS Public Safety Section to properly interface with the existing system.
2. Coordinate design to allow for uninterrupted operation of existing security systems. Security must be maintained during construction.
3. Large security system conduit and pull boxes shall be coordinated with building construction, beams, etc., to assure clearances and accessibility.

1.18.7 Exterior Utilities -The final Exterior Utility drawings shall, as a minimum, be checked for the following:

1. Electrical lighting poles, manholes, handholds and underground conduit shall be coordinated with existing utility locations as well as installation of other new utilities.
2. Plans and specifications shall be checked for conflicts.

1.18.8 Phasing Plans – The building construction phasing drawings shall, as a minimum, be checked for the following:

1. Contractor movement is not adversely affected by pedestrian corridors. Contractor laydown area is not separated from the worksite by maintenance of traffic accommodations.
2. Safe fire exit routes are maintained through construction and exit on the AOA is minimized.
3. Construction is adequately screened from the public in maintained areas.
4. Construction shelters that will be in place for long phases are visually and acoustically designed to minimize interface and maintain security.
5. Seemingly innocent notations that can adversely affect the budget or schedule are thoroughly vetted and venues examined so that the schedule and budget are adequately compensated. (i.e. a temporary fire corridor that requires several "small" adjustments through construction but every adjustment requires substantial work to maintain the fire protection level.)
6. A listing of any item that has been included in an established allowance and how the allowance will be allotted and released.

1.19 Project Solicitation - Proposals shall be solicited in accordance with the City of Houston procedures and regulations. HAS will coordinate and be responsible for the contracting arrangements. Public Advertisement for Bids by HAS will be run for two (2) consecutive Fridays in the Houston Chronicle. Bid announcements will also be posted on the HAS web site, www.fly2Houston.com.

1.20 Sale and Issuance of Contract Documents to Contractors -Beginning on Monday after the first Friday advertisement, bid packages will be available to bidders from source indicated in the advertisement. The Designer should confirm this procedure with the HAS Project Manager.

1.21 Pre-Bid Conference -HAS will conduct a Pre-Bid conference for the prospective bidders. The Designer will brief the bidders on the overall scope of the project, assist HAS in answering questions from bidders and help conduct a site tour.

1.22 Addenda - If questions come up during the Pre-Bid Conference or if there are clarifications required, the Designer will provide answers to the project Manager. HAS is responsible for issuing all Addenda.

1.23 Bid Opening – Bid opening will be conducted in accordance with current City of Houston procedures. After the bid opening the Designer will perform a bid analysis. Upon completion of the bid analysis a recommendation to award the contract to the lowest responsible bidder will be issued to HAS for approval.

1.24 Pre-Construction -Upon approval of the project, the applicant, his design agents, and his contractor shall meet with HAS Representatives for a pre-construction conference. At such time, principal aspects of coordination will be established: project schedule, coordination, inspections, as well as any other items of a timely nature to the project.

1.25 Site Clean-up - The Designer should specify that the Contractor will be responsible for maintaining an orderly and accommodative environment of the construction area, lay-down areas, parking areas, areas used for debris disposal, and any area used by the contractor for any purpose and shall, prior to conclusion of the work, remove all rubble, debris, and surplus material occasioned from the immediate site. In addition, Contractor shall similarly render and restore all off-site areas disturbed during the construction of the facility. Each project shall contain such signage alerting the public to the temporary nature of the visual or operational impacts of the project and advising when the work will be completed as required by HAS.

1.26 Operational Procedures -The Airports are in operation twenty-four (24) hours a day and construction procedures must provide safe operation during the entire period. In order to provide operating safety, a system of tags shall be provided by the HAS and shall be specified in the construction documents for turning central chilled water systems, central hot water systems, steam, plumbing or utility systems on and off to facilitate construction. The Designer shall identify all interface valves on the plans or provide for new valves to use for sectionalization. Prior to sectionalizing or turning off systems, the Contractor shall tag the valve and his representative shall sign. At the same time, the HAS Project Manager and the respective operating and maintenance organizations shall all sign at the same time. Prior to turning the system back on, all representatives shall again sign off on the operation.

1.27 Operational Safety - In order to provide operational safety, the Contractor is to notify the appropriate Airport Operations Center 48-hours prior to any proposed activity that will shut down or otherwise affect the operation of any utility, system or operation so that a work area notice (WAN) can be issued. Also, notification must be made to the AOC two (2) hours prior to commencement of work and prior to turning fire protection/detection systems, or any other system, on or off. The contractor is expected to give the following information when submitting the 48-hour notice and again once in contact with the Operations Center:

1. Name and phone number of contractor.
2. System identification (i.e. sprinkler valve number, fire alarm zoning identification).
3. Time the system will be deactivated.
4. Time the system will be reactivated.
5. Total time the system will be out of service.
6. The areas, activities, or zones that will be affected.

1.28 Testing -Prior to the time the system is connected in the main system, detailed testing requirements shall be completed as specified by the Design Engineer.

END OF SECTION 1

2.1 LAND PLANNING AND SITE WORK

2.2 GENERAL

2.2.1 Airport Layout Plan: The Airport Layout Plan (ALP) is a scaled graphic presentation of existing and ultimate airport facilities, as approved by the Federal Aviation Administration (FAA). Reference is made to FAA Advisory Circular (AC) 150/5070-6B (or latest edition) guidance on developing Airport Master Plans (AMP) and for ALP requirements. The ALP is a public document, which serves as a record of land and facility requirements, both present and future, as well as a source document for land use proposals. All proposed capital improvements must comply with the ALP. Any such project must be submitted through the Planning and Programming Section of HAS to the FAA to determine if the project is in compliance with the ALP or if the ALP can be changed to accommodate the proposed project. Refer to SECTION 1 for airspace application. For detailed information concerning the most current ALP, consult the HAS Project Manager. One of the greatest dangers to the schedule for projects not currently shown on the ALP is environmental clearance which must be resolved before a program can move forward.

2.2.2 Site Plans: A site plan shall be prepared for all relevant projects referencing FAA Advisory Circular (AC) 150/5300-13 CHG 11 or latest edition for Airport Design. The site plan shall delineate all existing and proposed facilities and features. The site plan shall provide a clear schematic of the intended land use, project or building layout, site and project dimensions, access points, proximity to existing structures, proximity to the security fence, and underground utilities, etc. This plan will be used to initiate coordination among the HAS departments, the FAA and tenants adjacent to the site. The site plan is also used to initiate changes to the ALP and to address potential line-of-sight and security access issues. The maximum building or equipment heights shall be indicated on the site plan prior to determining line-of-sight acceptability. A traffic impact analysis will be required for all landside development projects that will change the vehicular traffic on any landside roadways. A landscape plan for each site shall also be submitted with the site plan.

2.2.3 Site Work: Site work includes clearing, grubbing, grading, drainage, paving, and special site development structures. All site work shall be designed and conducted to improve the overall aesthetics of the Airport and to promote future development.

2.2.4 Site Preparation: The site shall be prepared meeting minimum requirements of FAA Advisory Circular AC 150/5300-13A or latest edition while preserving the natural character of the terrain by minimum disturbance of existing ground forms, with the objective to develop an attractive, suitable and economical project site. Surface and subsurface flow from storm water shall be diverted away from buildings and pavements to prevent undue saturation of the subgrade that could damage structures and weaken pavements. However, the designer shall carefully select the building location because redirecting subsurface water must be constantly monitored since water will choose to follow the path of least resistance.

2.3 ENVIRONMENTAL

2.3.1 Storm Water Pollution Prevention Plan: For projects disturbing greater than one acre, a Storm Water Pollution Prevention Plan, including an erosion control plan, must be submitted to the HAS Project Manager along with a signed Notice of Intent before a Notice to Proceed will be issued. Erosion control measures shall be designed and implemented to effectively prevent discharge of sediments to the storm drain system and receiving waters. Care shall be taken in the design and implementation of such measures to ensure that a safety hazard, such as ponding water on a roadway, does not occur. Further, it is important to recognize that water retention causes a bird attractant and a

hazard to navigation so NO retention can be developed on airport property and that any detention areas must discharge water to a dry bottom condition within 24-hours.

2.3.2 Storm Water Quality: All new or renovated facilities must be designed to minimize the impact of storm water discharges on the environment and assure that the facility can be operated in compliance with environmental laws and regulations. The facility Operator is the company, agency, or entity that will have operational control of daily activities at the facility following the issuance of a Certificate of Occupancy/Use.

As one example, all new or renovated facilities must be designed so as to eliminate contamination of storm water, or at a minimum, reduce contamination of storm water runoff below the federal discharge benchmarks defined by federal law (65 FR 64767) and any subsequent applicable federal regulation, as well as those in the Texas Pollutant Discharge Elimination System (TPDES) storm water permit and any subsequent applicable state regulation. In addition, the City of Houston Public Works and Engineering Department issues storm water permits, which are issued by the City Engineer for Public Works and Engineering rather than Code Enforcement.

2.3.2.1 Preliminary Actions: In order to ensure compliance with the above-described objectives, the Operator shall submit the following documents to HAS prior to making any application for a construction permit to construct or renovate a facility from which there will be a change in storm water discharge:

1. Documents, prepared by the Operator, describing the type and nature of all activities to occur at the site that could potentially impact storm water quality, runoff velocity, runoff volume or watershed characteristics.
2. Documents, prepared by the Operator, detailing the operational controls that will be implemented at the facility. This could possibly be in the form of an operational storm water pollution prevention plan (SWPPP), or the format could be less structured. In any case, the operational measures/restrictions to be employed at the facility must be clearly stated.
3. A certification, sealed by the design engineer, stating that "Based upon the above representations made by the Operator, the proposed structural controls will impel storm water discharged from the facility to meet EPA benchmark standards."

2.3.2.2 Construction Permit: Upon submittal of the three requested documents and approval by HAS, the Operator shall satisfy the requirements of these procedures to such extent that HAS will recommend approval of a construction permit to City of Houston, Department of Public Works and Engineering.

2.3.2.3 Post-Construction Procedures: After at least 3 months of regular operation at the facility, HAS's Planning and Programming Section (P&P) of the Planning, Design and Construction Division (PDC) may elect to conduct testing to verify the efficacy of the operational and structural controls. If P&P determines that testing is not necessary, P&P will notify the HAS Project Manager of this decision, so that a final determination of substantial completion can be made. If P&P elects to conduct testing, P&P personnel will select appropriate pollutant parameters, select a collection event, collect storm water samples, send the samples out for analysis and provide the results in the form of a Storm Water Quality Report. P&P is committed to ensuring that initial testing and reporting will be completed in less than 9 months after the start of regular operations at the facility.

2.3.2.3.1 Acceptable Test Results: If the testing indicates adherence with all EPA benchmark parameters, P&P will send a notification to the HAS Project Manager that no further action is required, and if all other requirements have been satisfied, the HAS Project Manager will issue a final notice of substantial completion.

2.3.2.3.2 Unacceptable Test Results: If the testing indicates that any EPA benchmark parameter has been exceeded, the project may not be closed out until the Operator has remedied the problem to the satisfaction of P&P. P&P will send correspondence to the HAS Project Manager when satisfied with the remedies proposed by the Operator. If the Operator has failed to remedy the problem to the satisfaction of P&P within 6 months after notification thereof, then the facility will be subject to continued monitoring by P&P at the Operator's expense.

2.3.2.3.3 Continued Monitoring at Operator's Expense: Monitoring will continue until the problem has been remedied to the satisfaction of P&P. Monitoring costs may include labor, supplies, equipment, laboratory charges, and analysis associated with the collection of grab and composite samples from all discharges from the facility. The samples may be analyzed for any pollutants identified in the benchmark standards.

2.3.2.4 Spill Prevention Control and Countermeasures Plan: Facilities may be subject to Spill Prevention Control and Countermeasures Plan (SPCC) regulations at 40 CFR 112. The design of any new or renovated facility must include a submittal by the Operator with a formal determination as to whether SPCC is required; and if so, the design must incorporate the measures specified at 40 CFR 112 or any subsequent applicable federal or state regulation.

2.3.3 Excavated Soil Materials: Excavated materials must be managed and disposed of in accordance with applicable environmental regulations. Projects that involve subsurface drilling or the excavation, stock piling or movement of soils require a soil management plan that details procedures to be employed to ensure proper handling and disposal. No excavated material or concrete rubble may be removed from any of the Airports without approval P&P. Submit requests through the HAS Project Manager.

2.3.4 Sanitary Sewer Discharges - Discharges to the Airport Sanitary Sewer System (SSS) shall be in accordance with the current legal standards of the Texas Commission on Environmental Quality (TCEQ) or of any governmental body having legal authority to set such standards. Construction Specifications shall be taken from "Standard Construction Specifications for Wastewater Collection Systems, Water Lines, Storm Drainage, Street Paving, and Traffic", latest edition, published by the City of Houston Department of Public Works and Engineering, except as modified herein. No variance from these specifications or the modifications herein may be made without the approval of the City Engineer for the Houston Airport System (referred to throughout as the City Engineer).

2.3.4.1 On Site Disposal - Any proposed on-site disposal method such as a septic tank and drain field shall be subject to Airport approval as well as any and all required county or state health department permit procedures. Any system so approved and permitted shall be designed, installed and operated in accordance with "Construction Standards for Private Sewage Facilities" of the TCEQ.

2.3.4.2 Sanitary Sewage Discharge Standard - Admissible wastes discharge into the SSS is defined herein as admissible discharges. Waste discharges into the SSS that are prohibitive, are defined herein as prohibitive discharges.

2.3.4.3 Admissible Discharges - Wastes discharged into the SSS shall consist only of wastewater, properly shredded garbage and other wastes which the system is capable of handling, so that:

2.3.4.3.1 Effluent from the SSS meets the current legal standards of the TCEQ or of any governmental body having legal authority to set standards for such effluents.

2.3.4.3.2 The SSS is not damaged to the extent to cause unnecessary repairs or replacements resulting in increased operation and maintenance expenses.

2.3.4.4 Prohibitive Discharges - To enable the highest degree of treatment in the most economical manner possible, and to comply with Federal and State regulations, certain solids, liquids and gases are hereby prohibited from entering the SSS in excess of standards as set by Federal and State regulations. The prohibitive discharges listed below shall apply at the points of entry.

2.3.4.4.1 Federal and state regulatory agencies periodically modify standards on prohibitive discharges. Therefore, revisions to, additions to, or deletions from the items listed in this section will become necessary to comply with these latest standards.

2.3.4.4.2 No discharge of any of the following shall be allowed into the SSS at a point of entry: Storm water, ground water, roof runoff, sub-surface drainage or water originating from downspouts, yard drains, yard fountain and ponds, or lawn sprays. If the character of the wastewater from any manufacturer or industrial plant, building or other premises is such that it will damage the SSS, or cannot be treated satisfactorily in the SSS, the wastewater shall be prevented from entering the SSS.

2.3.4.4.3 No discharge of any of the following substances, materials, waters or wastes into the SSS shall be allowed:

1 Any liquid having a temperature higher than 150 degrees Fahrenheit;
2 Any water or wastes which contain wax, grease, oil, plastic or other substance that will solidify, or become discernibly viscous at temperatures between 32 to 150 degrees Fahrenheit;
3 Any solids, slurries or viscous substances of such character as to be capable of causing obstruction to the flow in sewers, or other interference with the proper operation of the SSS, such as ashes, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, plastics, wood, whole blood, paunch manure, hair and fleshlings, entrails, lime residues, slops, chemical residues, paint residues or bulk solids.
4 The maximum allowable suspended solids is 250 mg/l and the BOD shall be less than 250 mg/l;
5. Any solids, liquids, or gases which by themselves or by interaction with other substances may cause fire or explosion hazards, or in any other way be injurious to persons, property, or the operators of the SSS;
6. Any garbage that has not been properly comminuted or shredded;
7. Any noxious or malodorous substance which, either singly or by interaction with other substances, is capable of causing objectionable odors, or hazard to life, or forms solids that will cause obstructions to flow, or creates any other condition deleterious to structures or treatment processes, or requires unusual provisions, alteration, or expense to handle such substance. The maximum allowable hydrogen sulfide is 0.1 mg/l;

8. Any waters or wastes having a pH less than 6.0 or greater than 10.0 or having any corrosive property capable of causing damage or hazards to structures, equipment, or personnel. of the SSS;
9. Any wastes or waters containing suspended or dissolved solids of such character and quantity that unusual attention or expense is required to handle such materials in the SSS;
10. Any waters or wastes containing a toxic or poisonous substance, such as plating or heat-treating wastes, in sufficient quantity to injure or interfere with any wastewater treatment process, to constitute a hazard to humans or animals, or to create any hazard in the receiving waters of the Wastewater Treatment Plant;
11. Any wastes or waters exceeding the concentrations listed below:

a. Antimony greater than 0.01 mg/l
b. Arsenic greater than 0.05 mg/l
c. Barium greater than 5.0 mg/l
d. Beryllium greater than 0.01 mg/l
e. Bismuth greater than 0.5 mg/l
f. Boron greater than 1.0 mg/l
g. Cadmium greater than 0.01 mg/l
h. Chromium (hexavalent) greater than 0.05 mg/l
i. Chromium (trivalent) greater than 5.0 mg/l
j. Cobalt greater than 1.0 mg/l
k. Copper greater than 1.0 mg/l
l. Cyanides greater than 1.0 mg/l
m. Fluorides greater than 1.5 mg/l
n. Hydrogen Sulfide greater than 0.1 mg/l
o. Iron greater than 0.3 mg/l
p. Lead greater than 0.1 mg/l
q. Manganese greater than 1.0 mg/l
r. Mercury greater than 0.005 mg/l
s. Molybdenum greater than 1.0 mg/l
t. Nickel greater than 1.0 mg/l
u. Phenol greater than 0.005 mg/l v.
v. Selenium greater than 0.02 mg/l
w. Silver greater than 0.1 mg/l
x. Tin greater than 1.0 mg/l
y. Uranylion greater than 5.0 mg/l
z. Zinc greater than 5.0 mg/l

12. Any free or emulsified oil and grease exceeding, on analysis, an average of 100 mg/l (834 pounds per million gallons) of either, or both, or combinations of free or emulsified oil and grease if it appears probable that such wastes:
a. can deposit grease or oil in the sewer lines in such manner to clog the sewers;
b. can overload skimming and grease handling equipment;
c. are not amenable to bacterial action or other treatment processes then being employed by Airport and will, therefore, pass to the receiving waters without being affected by normal wastewater treatment processes;
d. can have deleterious effects on the treatment process due to excessive quantities.

13. Any radioactive wastes greater than the allowable releases as specified by current National Institute of Standards & Technology handbooks dealing with the handling of and release of radioactivity.

14. Significant industrial users, as defined by the United States Environmental Protection Agency, shall be subject to additional restrictions such as may be promulgated by the Houston Airport System, the City of Houston or any of its regulatory Departments.

2.4 STORM DRAINAGE Construction Specifications shall be taken from "Standard Construction Specifications for Wastewater Collection Systems, Water Lines, Storm Drainage, Street Paving, and Traffic", latest edition, published by the City of Houston Department of Public Works and Engineering, except as modified herein. No variance from these specifications or the modifications herein may be made without the approval of the City Engineer for the Houston Airport System (referred to throughout as the City Engineer). Designers are advised that soil testing at both Bush Intercontinental and Hobby Airports indicate the presence of corrosive to extremely corrosive soils as well as both a high concentration of free chloride ions and very acidic subsurface conditions. Care should be exercised in specifying pipe and drainage structure materials that are adequately protected from such environmental conditions. For drainage on the airside, FAA Advisory Circular 150/5320-5C or the latest published edition shall be followed.

2.4.1 Drainage of Unpaved Areas Adjacent to Buildings - Unpaved areas adjacent to buildings shall be sloped to direct surface water and roof drainage away from buildings at a minimum slope of five (5%) percent in the first ten (10) feet of horizontal distance. Unpaved areas shall be permanently stabilized with vegetative cover to prevent erosion and soil loss. Surfaces paved with concrete or bituminous pavement shall have a slope of not less than 0.5 percent in the direction of drainage, to prevent ponding.

2.4.2 Drainage of Unpaved Areas not Occupied by Buildings - Portions of the site not occupied by buildings or pavement shall have adequate continuous slopes to drain toward watercourses, drainage swales, roadways, and storm drainage inlets. Drainage swales or channels shall be sized and sloped to accommodate the design runoff. Sheet flow across sidewalks is allowable when necessary due to site conditions but is discouraged. The concentrated runoff shall be carried under walkways in pipes or by suitable sidewalk drains. Swales shall be used to intercept water at the top and bottom of banks where large areas are drained. To provide positive drainage, a slope of not less than two (2%) percent for turfed areas is desirable. Slopes shall be designed to ensure non-erosive runoff velocities. Turf banks, where required, shall be graded to permit the use of gang mowers, providing a maximum slope of four (4) horizontal to one (1) vertical. The tops and bottoms of all slopes shall be gently rounded in a transition curve for optimum appearance and ease of maintenance.

2.4.3 Landside Storm Drainage - Storm drainage design in those areas referred to as the "Landside" shall be governed by the latest edition of the Texas Department of Transportation (TxDOT) Hydraulic Manual. Minor head losses in storm drain systems as well as other coefficients presented in this Design Criteria Manual shall supersede those presented in the TxDOT Hydraulic Manual where they differ. In instances where a conflict arises between the Landside Design and the Air Operations Area (AOA) Design, the more conservative criteria shall govern.

2.4.4 Determination of Design Discharge - In order to properly determine the design storm runoff for a given installation, consideration must be given to the design storm rainfall, the runoff coefficient as affected by the surface condition and by the geometry of the watershed, plus the influence of the time of concentration. The runoff coefficients and minimum inlet times (time of concentration) to be used in

determining runoff shall be documented for review and approval. Adjustments to the runoff coefficients may be required to account for future build out conditions. The rational formula shall be used for drainage areas up to approximately two hundred (200) acres. Other methods presented in the TxDOT Hydraulic Manual are to be used for runoff from drainage areas greater than two hundred (200) acres.

2.4.5 Drainage Report -All drainage designs shall be contained in a Drainage Report and shall be submitted to the HAS Project Manager for review and approval. The Drainage Report shall be in such form as to provide the basis for timely and consistent review and will be made a part of the permanent record for future evaluation as a chapter in the Project Report. The drainage report shall contain the following:

1. Description and plan of existing drainage facilities.
2. Description and plan of proposed drainage facilities (which may be half size reduction of preliminary or final design plans).
3. Drainage area map.
4. Description of analysis.
5. All calculations associated with the determination of runoff coefficients, volume of runoff, time of concentration, inlet size, culvert or pipe size and elevation of hydraulic gradient, discharge flow and velocity and any other items pertinent to the drainage design.
6. Consideration of drainage alternatives and recommended facilities.
7. A certification signed and sealed by a professional engineer registered in the State of Texas that the design procedure is in full compliance with the requirements of these criteria.
8. Description of measures taken for velocity dissipation to ensure non-erosive velocities at points of discharge.
9. All calculations associated with the drainage design shall be included in tabular form in the final design plans.
10. The drainage area map shall be no smaller than a one (1) inch equals two hundred (200) feet scale, and show all streets, building pads and other existing and proposed features. The drainage area map shall show the boundary of the drainage area contributing runoff into the proposed system. The area shall be further divided into numbered sub-areas to determine flow concentration points or inlet location(s). Drainage area maps shall show streets, land-use and land-use boundaries, existing ground elevations on two (2) foot contours, and a summary table of peak design flows for sub-areas with acreage, runoff coefficient, and inlet time shown.
11. Quantity and direction of design flow within streets, alleys, natural and manmade drainage ways and at all system intersections shall be clearly shown on the drainage area map. Existing and proposed drainage inlets, storm drainage systems and drainage channels shall be clearly shown and differentiated on the drainage area map.

2.4.6 Flow in Gutters - The permissible spread of water into the street or thoroughfare shall in all cases govern the hydraulic capacity of a given street. On multiple lane roadways, the permissible spread of water will not close more than one (1) travel lane in each direction. For two (2) lane roadways, the water shall be limited to 1/2 of each lane width.

2.4.7 Storm Drain Inlets - Various charts are available in the Drainage Manual that shall be used to determine the capacity and efficiency of the particular type of inlet chosen. When designing inlets, freedom from clogging or from interference with traffic shall take precedence over hydraulic considerations. Precast units may be used for load bearing applications only with the approval of the HAS Project Manager.

2.4.8 Placement of Manholes and Inlets -Manholes or combination manholes and inlets shall be placed wherever necessary for clean-out and inspection purposes. Place manholes at changes in direction, junctions of pipe runs, and at intervals of three hundred (300) to five hundred (500) feet in long pipe runs where the size or direction is not changed. The invert of the manhole section shall be rounded to match the inverts of the pipes entering the manhole in order to reduce eddying and resultant head losses. For manholes that are larger than the incoming or outgoing pipes, expansion losses can sometimes be significant. The use of aircraft rated manholes may be required in some cases depending on location and shall be coordinated with the HAS Project Manager. In all cases aircraft rated inlets and manholes shall be used within runway or taxiway safety areas as depicted on the Airport Layout Plan.

2.4.9 Flow in Storm Drains and Their Appurtenances -Storm drains shall be designed to have a minimum mean velocity of 3 feet per second flowing full. Velocities greater than thirteen (13) feet per second shall be avoided.

2.4.10 Design of Closed Storm Drainage System - In the preparation of hydraulic designs, a thorough investigation shall be made of all existing structures and their performance on the waterway in question. The design frequency for all new closed drainage systems shall be 10 years with a combined 100-year emergency overflow as required herein. The total capacity of the drainage facility, including surface flow within limits of available right-of-way or easements, shall be equal to or greater than the runoff of a storm of 100-year design frequency. Shall the 100-year storm runoff exceed the capacity of the above design, then the closed storm system shall be designed based on a minimum 25-year frequency, or larger, to develop a 100-year emergency overflow system. The hydraulic gradient shall be calculated for all storm drain lines and culverts and shall not be designed above the entrance flowline of any inlet. The permissible difference between the hydraulic gradient and top-of-curb is normally two (2) feet.

2.4.11 Design and Analysis of Open Channels - Backwater analysis is to be developed for major channels to establish water surface elevation and to avoid adverse impacts on adjacent properties. All new channels shall be designed using the one hundred (100) Year Design Frequency HEC-2 Water Surface Profiles Method as presented in the U.S. Army Corps of Engineers, Water Resources Support Center or alternate methodology as approved by the HAS Project Manager. Channels shall be concrete lined for velocities over 7.5 feet per second. A 2'-0" freeboard will be incorporated into the design calculations.

2.4.12 Design of Culverts - Drainage culverts shall pass storm flow from the upstream side of highway, road or railroad to the downstream side without causing excessive backwater head and without creating excessive downstream velocities. The designer shall keep the discharge velocities within safe limits (usually 6 feet per second) while selecting the most economical structure that will provide satisfactory service. Methods presented in the TxDOT Hydraulic Manual shall be used with the 100-Year design frequency.

2.4.13 Manholes, Catch Basins, Inlets and Inspection Holes

2.4.13.1 Mortar: Mortar shall consist of one part Portland Cement and two parts sand. The Portland Cement shall conform to the requirements of ASTM C 150, Type I. The sand shall conform to the requirements of ASTM C 144.

2.4.13.2 Concrete: Plain and reinforced concrete used in structures, connections of pipes with structures, and the support of structures or frames shall conform to the requirements of ACI 301.

2.4.13.3 Precast Concrete Pipe Manhole Rings: Precast concrete pipe manhole rings shall conform to the requirements of ASTM C 478. Unless otherwise specified, the risers and offset cone sections shall have an inside diameter of not less than 36 inches nor more than 48 inches.

2.4.13.4 Frames, Covers and Grates: The castings shall conform to one of the following requirements:

1. Gray iron castings: ASTM A 48, Class 30B and 35B.
2. Malleable iron castings: ASTM A 47.
3. Steel castings: ASTM A 27.
4. Structural steel for grates and frames: ASTM A 283, Grade D.
5. Ductile iron castings: ASTM A 536.
6. All castings or structural steel units shall conform to the dimensions shown on the plans and shall be designed to support the loadings specified.
7. Each frame and cover or grate unit shall be provided with fastening members to prevent it from being dislodged by traffic but which will allow easy removal for access to the structure.
8. All castings shall be thoroughly cleaned and given two coats of approved bituminous paint. After fabrication, structural steel units shall be galvanized to meet the requirements of ASTM A 123. Bituminous paint shall be black.

2.4.13.5 Placement and Treatment of Castings, Frames, and Fittings: All castings, frames, and fittings shall be placed in the positions indicated on the plans or as directed by the Engineer, and shall be set true to line and to correct elevation. If frames or fittings are to be set in concrete or cement mortar, all anchors or bolts shall be in place and position before the concrete or mortar is placed. The unit shall not be disturbed until the mortar or concrete has set.

2.4.13.6 Placement and Treatment of Casting, Frames and Fittings on Previously Constructed Masonry - When frames or fittings are to be placed upon previously constructed masonry, the bearing surface or masonry shall be brought true to line and grade and shall present an even bearing surface in order that the entire face or back of the unit will come in contact with the masonry. The unit shall be set in mortar beds and anchored to the masonry as indicated on the plans or as directed and approved by the Engineer. All units shall set firm and secure.

2.4.13.6.1 After the frames or fittings have been set in final position and the concrete or mortar has been allowed to harden for 7 days, then the grates or covers shall be placed and fastened down.

2.4.13.7 Steps: The steps or ladder bars shall be gray or malleable cast iron or galvanized steel or wedge locking, steel reinforced rubber encased. The steps shall be the size, length, and shape shown on the plans and those steps that are not galvanized or plastic encased shall be given a coat of bituminous paint, when directed.

2.4.13.7.1 The steps shall be installed as indicated on the plans or as directed by the Engineer. When the steps are to be set in concrete, they shall be placed and secured in position before the concrete is poured. When the steps are installed in brick masonry, they shall be placed as the masonry is being built. The steps shall not be disturbed or used until the concrete or mortar has hardened for at least 7 days. After this period has elapsed, the steps shall be cleaned and painted, unless they are galvanized or plastic encased.

2.4.13.7.2 When steps are required with precast concrete pipe structures, they shall be cast into the sides of the pipe at the time the pipe sections are manufactured or set in place after the structure is erected by drilling holes in the concrete and cementing the steps in place.

2.4.13.7.3 When steps are required with corrugated metal structures, they shall be welded into aligned position at a vertical spacing of 12 inches.

2.4.13.7.4 In lieu of steps, prefabricated ladders may be installed. In the case of concrete structures, the ladder shall be held in place by grouting the supports in drilled holes. In the case of metal structures, the ladder shall be secured by welding the top support and grouting the bottom support into drilled holes in the foundation or as directed.

2.4.13.8 Concrete Structures: Concrete structures shall be built on prepared foundations, conforming to the dimensions and form indicated on the plans. The construction shall conform to the requirements specified in ACI-301. Any reinforcement required shall be placed as indicated on the plans and shall be approved by the Engineer before the concrete is poured. All invert channels shall be constructed and shaped accurately so as to be smooth, uniform, and cause minimum resistance to flowing water. The interior bottom shall be sloped downward toward the outlet. Designers are reminded of the presence of free Chloride Ions in the soil at the HAS Airports and should take appropriate measures in design to protect any reinforcing in the structure.

2.4.13.9 Precast Concrete Pipe Structures: Precast concrete pipe structures shall conform to the requirements of ASTM C 478 and shall be constructed on prepared or previously placed slab foundations and shall conform to the dimensions and locations shown on the plans. All precast concrete pipe sections necessary to build a completed structure shall be furnished. The different sections shall fit together readily, and all jointing and connections shall be cemented with mortar. The top of the upper precast concrete pipe member shall be suitably formed and dimensioned to receive the metal frame and cover or grate, or other cap, as required. Provision shall be made for any connections for lateral pipe, including drops and leads that may be installed in the structure. The flow lines shall be smooth, uniform, and cause minimum resistance to flow. The metal steps which are embedded or built into the side walls shall be aligned and placed at vertical intervals of 12 inches. Metal steps which are embedded or built into side walls shall be aligned and placed as shown on the plans, and, as required by Federal Law, conform to OSHA requirements. When a metal ladder replaces the steps, it shall be securely fastened into position.

2.4.13.10 Inlet and Outlet Pipes: Inlet and outlet pipes shall extend through the walls of the structures for a sufficient distance beyond the outside surface to allow for connections but shall be cut off flush with the wall on the inside surface, unless otherwise directed. For concrete or brick structures, the mortar shall be placed around these pipes so as to form a tight, neat connection.

2.4.14 Pipe Materials for Storm Drains, Trench Drains, and Culverts

1. Reinforced Concrete Pipe: ASTM C 76.
    a. Class V required for active AOA airfield areas.
2. Reinforced Concrete D-Load Pipe: ASTM C 655.
3. Reinforced Concrete Arch Pipe: ASTM C 506.
4. Reinforced Concrete Elliptical Pipe: ASTM C 507.
5. Precast Reinforced Concrete Box Sections: ASTM C 789 and C 850.
6. Bituminous-Coated Structural Plate Pipe, Pipe Arch, and Arches: AASHTO M 167 & 243.
7. Aluminum Alloy Structural Plate for Pipe, Pipe Arch, and Arches: AASHTO M 219.
8. Polyvinyl Chloride (PVC) Pipe: ASTM D 3034.

9. Corrugated Polyethylene Drainage Tubing: AASHTO M 252.
10. Corrugated Polyethylene Pipe 12 to 24 Inches in Diameter: AASHTO M 294.

2.4.15 Concrete Pipe Cradles -Concrete for pipe cradles shall have a minimum compressive strength of 2000 psi at 28 days and conform to the requirements of ASTM C 94.

2.4.16 Rubber Gaskets -Rubber gaskets for rigid pipe shall conform to the requirements of ASTM C 1232. Rubber gaskets for PVC shall conform to the requirements of ASTM F 477. Rubber gaskets for zinc-coated steel pipe and precoated galvanized pipe shall conform to the requirements of ASTM D 1056, for the "E "closed cell grades.

2.4.17 Pipe Joint Mortar -Pipe joint mortar shall consist of one part Portland cement and two parts sand. The Portland cement shall conform to the requirements of ASTM C 150, Type I. The sand shall conform to the requirements of ASTM C 144.

2.4.18 Oakum -Oakum for joints in bell and spigot pipe shall be made from hemp (Cannabis Sativa) line, or Benares Sunn fiber, or from a combination of these fibers. The oakum shall be thoroughly corded and finished.

2.4.19 Poured Filler -Poured filler for joints shall conform to the requirements of ASTM D 1190.

2.4.20 Plastic Gaskets -Plastic gaskets shall conform to the requirements of AASHTO M 198 (Type B).

2.4.21 Pipe Bedding – Bedding for rigid pipe shall conform to one of the following classes:

Class A: Class A bedding shall consist of a continuous concrete cradle.

Class B: Class B bedding shall consist of a bed of granular materials having a thickness of at least 6 inches below the bottom of the pipe and extending up around the pipe for a depth of not less than 30 percent of the pipe's vertical outside diameter. The layer of bedding material shall be shaped to fit the pipe for at least 10 percent of the pipe's vertical diameter and shall have recesses shaped to receive the bell of bell-and-spigot pipe. The bedding material shall be sand or selected sandy soil conforming to the following:

Sieve	% Passing
2 inch	100
1 inch	90-100
½ Inch	50-80
No. 4	30-60
No. 100	0-5

Class C: Class C bedding shall consist of bedding the pipe in its natural foundation to a depth of not less than 10 percent of the pipe's vertical outside diameter. The bed shall be shaped to fit the pipe and shall have recesses shaped to receive the bell of bell-and-spigot pipe.

2.4.22 Bedding, Flexible Pipe: Pipe bedding for flexible pipe, the bed shall be roughly shaped to fit the pipe, and a bedding blanket of sand or fine granular material shall be provided as follows:

Pipe Corrugation Depth	Minimum Bedding Depth
1/2 inch	100
1 inch	90-100
2 inches	50-80
2-1/2 inches	30-60

2.4.23 Bedding, PVC and Polyethylene Pipe: For PVC and polyethylene pipe, the bedding material shall consist of coarse sands with a maximum particle size of ¾-inch. For pipe installed under paved areas, no more than 12 percent of the material shall pass the No. 200 sieve. For all other areas, no more than 50 percent of the material shall pass the No. 200 sieve. The bedding shall have a thickness of at least 6 inches below the bottom of the pipe and extend up around the pipe for a depth of not less than 12 inches.

2.4.24 Deflection - Longitudinal deflection at each pipe joint shall not exceed one degree in any direction

2.5 PIPE UNDERDRAINS

2.5.1 Pipe Design -The pipe shall be designed for the application, including appropriate clean outs, and shall meet at least one of the following appropriate requirements.

1. Perforated Vitrified Clay Pipe ASTM C 700
2. Perforated Concrete Pipe ASTM C 44
3. Porous Concrete Pipe ASTM C 54
4. Polymer Precoated Perforated Corrugated Steel Pipe ASTM A 762
5. Perforated, Laminated Wall Bituminized Fiber Pipe ASTM D 2418
6. Smooth-Wall Perforated PVC Pipe ASTM F 758
7. Poly (Vinyl Chloride)(PVC) Corrugated Sewer Pipe ASTM F 949 With a Smooth Interior and Fittings

2.5.2 Mortar -Pipe joint mortar shall consist of one part Portland Cement and two parts sand. The Portland Cement shall conform to the requirements of ASTM C 150, Type I. The sand shall conform to the requirements of ASTM C 144.

2.5.3 Seals -Elastomeric seals shall conform to the requirements of ASTM F 477.

2.5.4 Porous Backfill - Porous backfill shall be free of clay, humus, or other objectionable matter, and shall conform to the gradation in Table 1 when tested in accordance with ASTM C 136.

TABLE 1. GRADATION OF POROUS BACKFILL		
Sieve Designation (square openings)	**Percentage by Weight Passing Sieves**	
	Porous Material No. 1	**Porous Material No. 2**
1-1/2 inch	--	100
1 inch	--	90-100
3/8 inch	100	25-60
No. 4	95-100	5-40
No. 8	--	0-20
No. 16	45-80	--
No. 50	10-30	--
No. 100	0-10	--

2.5.4.1 When two courses of porous backfill are specified in the plans, the finer of the materials shall conform to particle size tabulated herein for porous material No. 1. The coarser granular material shall meet the gradation given in the tabulation for porous material No. 2.

2.5.5 Prefabricated Underdrains: Prefabricated underdrains shall consist of a nonwoven, needle-punched, polyolefin geotextile, tightly encapsulating an internal polyolefin core. The product shall allow the entry of water from all sides of the core and shall be designed to minimize fabric intrusion into the core. When a one-sided core is used, the core shall have at least 5% of its area in unobstructed inflow through the back or shoulder side and at least 65% on the front or pavement side. The prefabricated underdrains shall conform to the following requirements:

2.5.5.1 Core material shall have a water absorption of 0.05% at 24 hours when tested in accordance with ASTM D 570; and shall show no fungus growth when tested in accordance with ASTM G 21.

2.5.5.2 Filter fabric shall have a tensile strength of 90 lbs. minimum and an elongation of 50% when tested in accordance with ASTM D 4632; a burst strength of 150 psi minimum when tested in accordance with ASTM D 3786; a puncture strength of 45 psi minimum when tested in accordance with ASTM D 3787; permeability of 0.20 cm/sec when tested in accordance with ASTM D 4491; and shall retain 70% of its strength when subjected to UV Radiation in accordance with ASTM D 4355. The filter fabric shall show no fungus growth when tested in accordance with ASTM G 21.

2.5.5.3 Geocomposite underdrains shall have a compressive strength of 55 psi minimum with a 12% maximum deformation when tested in accordance with ASTM D 1621. Geocomposite Underdrains shall also be able to carry a flow rate of 15 GPM/ft-width in soil environment when tested in accordance to ASTM D 4716.

2.5.5.4 The underdrain system shall include fittings and materials needed to make splices and outlets compatible with SDR 35 and Schedule 40 PVC pipe.

2.5.6 Slotted Drains: The slotted drain shall consist of a corrugated metal conforming to the requirements of ASTM A 760. The corrugated metal drain shall be 14 gage. The spacers in the slot shall be 3/16" steel.

2.5.6.1 The slotted drain system shall include fittings, materials and appurtenances needed to make splices and outlets compatible with RCP Pipe and shown on the plans.

2.5.6.2 Cleanouts for slotted drains shall have no-hub connections. Access frame shall be round, coated cast iron with heavy-duty scoriated secured cover, Josam Series 58850, or approved equal. The PVC pipe shall have a threaded end and a threaded plug.

2.5.7 Excavation for Pipe Underdrains: The width of the pipe trench shall be sufficient to permit satisfactory jointing of the pipe and thorough tamping of the bedding material under and around the pipe, but shall not be less than the external diameter of the pipe plus 6 inches on each side. The trench walls shall be approximately vertical.

2.5.7.1 Where rock, hardpan, or other unyielding material is encountered, it shall be removed below the foundation grade for a depth of at least 4 inches. The excavation below grade shall be backfilled with selected fine compressible material, such as silty clay or loam, and lightly compacted in layers not over 6 inches in uncompacted depth to form a uniform but yielding foundation.

2.5.7.2 Where a firm foundation is not encountered at the grade established, due to soft, spongy, or other unstable soil, the unstable soil shall be removed and replaced with approved granular material for the full trench width. The engineer shall determine the depth of removal necessary. The granular material shall be compacted to provide adequate support for the pipe.

2.5.7.3 Excavated material not required or acceptable for backfill shall be disposed of by the Contractor as directed by the Engineer. The excavation shall not be carried below the required depth; when this is done, the trench shall be backfilled with material approved by the Engineer and compacted to the density of the surrounding earth material.

2.5.7.4 The bed for the pipe shall be so shaped that at least the lower quarter of the pipe shall be in continuous contact with the bottom of the trench. Spaces for the pipe bell shall be excavated accurately to size to clear the bell so that the barrel supports the entire weight of the pipe.

2.5.7.5 The Contractor shall do such trench bracing, sheathing, or shoring necessary to perform and protect the excavation as required for safety and conformance to governing laws. Unless otherwise provided, the bracing, sheathing, or shoring shall be removed by the Contractor after the completion of the backfill to at least 12 inches over the top of the pipe. The sheathing or shoring shall be pulled as the granular backfill is placed and compacted to avoid any unfilled spaces between the trench wall and the backfill material.

2.5.8 Installing Pipe Underdrains

2.5.8.1 Clay or Concrete Pipe. The laying of the pipe in the finished trench shall be started at the lowest point and laid upgrade. When bell and spigot pipe is used, the bells shall be laid upgrade. If tongue and groove pipe is used, the groove end shall be laid upgrade. Holes in perforated pipe shall be placed down, unless otherwise shown on the plans. Set pipe firmly and accurately to line and grade so that the invert will be smooth and uniform. Pipe shall not be laid on frozen ground.

2.5.8.2 Metal and Fiber Pipe. The metal pipe shall be laid with the separate sections joined firmly together with bands, with outside laps of circumferential joints pointing upgrade, and with longitudinal laps on the sides. Any metal in the pipe or bands not protected thoroughly by galvanizing shall be coated with suitable asphaltum paint.

2.5.8.2.1 The sections of bituminized-fiber pipe shall be securely fastened together with suitable fittings. When the fiber couplings are tapered, they shall provide a tight, driven fit.

2.5.8.2.2 During installation, the asphalt-protected pipe shall be handled without damaging the asphalt coating. Any breaks in the bitumen or treatment of the pipe shall be refilled with the type and kind of bitumen used in coating the pipe originally.

2.5.8.3 PVC Pipe. PVC pipe shall be installed in accordance with the requirements of ASTM D 2321.

2.5.8.4 All Types of Pipe. The upgrade end of pipelines, not terminating in a structure, shall be plugged or capped as approved by the Engineer.

2.5.8.4.1 Unless otherwise shown on the plans, a 4-inch bed of granular backfill material shall be spread in the bottom of the trench throughout the entire length under all perforated pipe underdrains.

2.5.8.4.2 Pipe outlets for the underdrains shall be constructed when required or shown on the plans. The pipe shall be laid with tight-fitting joints. Porous backfill is not required around or over pipe outlets for underdrains. All connections to other drainage pipes or structures shall be made as required and in a satisfactory manner. If connections are not made to other pipes or structures, the outlets shall be protected and constructed as shown on the plans.

2.5.8.5 Manufacturer's Representative: For prefabricated underdrains and slotted drains, the manufacturer's representative shall be present at the beginning of the installation as required by the Construction Manager or Contractor and shall remain on site until released by the Engineer.

2.6 ROADS

2.6.1 Design Reference -The latest edition of the Texas Department of Transportation (TxDOT) Highway Design Section Operations and Procedures Manual contains the basic design criteria standards and guidelines that will be the reference document for the future roadway projects at the Airports unless otherwise specified. Deviation from these criteria will not be allowed without written approval from the City Engineer. Construction Specifications shall be taken from "Standard Construction Specifications for Wastewater Collection Systems, Water Lines, Storm Drainage, Street Paving, and Traffic", latest edition, published by the City of Houston Department of Public Works and Engineering, except as modified herein. No variance from these specifications or the modifications herein may be made without the approval of the City Engineer for the Houston Airport System (referred to throughout as the City Engineer).

2.5.1.1 The following minimum criteria applies to all non-airfield roadways within the HAS Airport Campuses. Deviations from these requirements require approval from the City Engineer.

Classification	Roadway ROW Width
Freeway	400 Feet
Primary Arterial	150 Feet
Secondary Arterial	120 Feet
Local Road	80 Feet

2.5.2 Roadway Pavement Section – Follow TxDOT design standards. As a guideline, the typical roadway pavement section consists of eight (8) inch thick continuously reinforced concrete pavement, five (5) inches of cement treated base and nine (9) inches of lime/fly ash or cement/fly ash treated subgrade, depending on whether the soils are sandy or clay (see addendum for sample specifications). All curbs shall be poured monolithic with the roadway pavement. An alternate roadway pavement section consists of eight (8) inch thick continuously reinforced concrete pavement, five (5) inches of asphalt base and nine (9) inches of lime/fly ash or cement/fly ash treated subgrade.

2.5.3 Design Speeds -The Design Speed represents the maximum safe speed that can be maintained over a section of roadway and is influenced by the required posted speed limit, terrain, functional road classification and economic considerations. All design criteria shall be commensurate with selected design speeds. All selected design speeds shall be presented to the HAS Project Manager for review and approval prior to final design.

2.5.3.1 Freeway - Currently, JFK Boulevard and Will Clayton are the only designated major arterials on the Airports. The posted speed limit on JFK Boulevard and Will Clayton are fifty (50) mph except where the speed limit is reduced for safety reasons. The posted speed limit on the various City roadways is regulated by the City of Houston Department of Public Works and Engineering and may be subject to change.

2.5.3.2 Primary Arterial System – The JFK frontage roads are considered a primary arterial and are currently posted at forty-five (45) mph throughout.

2.5.3.3 Secondary Arterial System -Posted speed limits of 30-35 mph with through routes linking major roadways and providing access to major facilities.

2.5.3.4 Collector System - The posted speed limit for the terminal roadways shall be thirty (30) mph.

2.5.3.5 Local Road System -This type of local access road provides a direct access to abutting property (parking lots, Terminals, lease sites, etc.) for local traffic circulation movements and shall have posted speed limits of thirty (30) mph.

2.5.3.6 Ramps -The design speed for on and off ramps shall be determined in accordance with TxDOT criteria. Under conditions of restricted geometrics on certain ramp connections, the design speed shall not be less than twenty-five (25) mph.

2.5.4 Design Vehicles

2.5.4.1 Size and Weight - The physical and operating characteristics of an authorized vehicle of designated type establishes roadway design controls to accommodate the vehicle of that type. All new and major reconstruction of roadways shall be designed to meet minimum requirements set forth for WB-50 design vehicles, unless waived by the City Engineer, in which case the design vehicle shall be single-unit (SU) truck as an absolute minimum. TxDOT has established minimum turning paths for these design vehicles to be used as controls in geometric design. It is vitally important that fire-fighting and other emergency equipment be capable of maneuvering on all circulation roads.

2.5.4.1.1 Load limits shall conform to the minimum requirements set forth for Federal and State highways.

2.5.4.2 Turning Radii -All turning radii shall be designed to accommodate the wheel path of the critical design vehicles without encroachment of curbs. The minimum design radius at intersections is 30 feet. Minimum design radius at driveways shall be fifteen (15) feet.

2.5.5 Alignment

2.5.5.1 Stopping Sight Distance -Safe stopping sight distance shall be established using wet pavement conditions and, as the controlling design vehicle, the passenger car with eye height at 3.5 feet and object height of 0.5 feet. Design values shall be in accordance with the requirements listed in the TxDOT Manual.

2.5.5.2 Horizontal Curvature -The maximum degree of curvature shall conform to the design values listed in the TxDOT Manual for a particular design speed.

2.5.5.3 Superelevation -The maximum rate of superelevation is 0.06 feet per foot.

2.5.5.4 Vertical Curvature - Length of vertical curves is determined by the algebraic sum of gradients and the design speed. The K-values listed in the TxDOT Manual for crest curves and sag curves shall be used in calculating the minimum required lengths of vertical curves.

2.5.5.5 Ramp Geometry -All on and off ramps and direct connections to arterials shall be designed for a minimum of one (1) lane of traffic operation with provisions for emergency parking unless otherwise directed.

2.5.5.6 Maximum Grades -The maximum grade of ramps is six (6) percent.

2.5.5.7 Minimum Grades -The minimum grade of ramps is 0.5 percent.

2.5.6 Obstruction Clearances

2.5.6.1 Clear Zones - A clear, unobstructed, relatively wide and flat (4:1 or flatter slope) area beyond the edge of the travel lane is required for all new and major reconstruction projects.

2.5.6.2 Horizontal Clearances - Horizontal clearances shall be measured from edge of the travel lane to the face of obstruction such as column, bent cap or wall. Horizontal clearance shall be in accordance with the Texas Department of Transportation, Highway Design Section, Operations and Procedures Manual.

2.5.6.3 Safety Treatment of Drainage Structures - Culvert headwalls and other drainage systems shall have appropriate safety treatments.

2.5.6.4 Vertical Clearances -The minimum effective vertical clearance for arterial and collector roads shall be sixteen (16) feet six (6) inches over the usable roadway including shoulders. Minimum effective vertical clearance for all other roadways shall be fourteen (14) feet six (6) inches. These clearances provide provision for future resurfacing. Please note that effective vertical clearances over roadways with sag curves shall take into account the length of the longest design vehicle and wheel locations as they affect the height of the top of the vehicle.

2.5.7 Cross Section Elements

2.5.7.1 Pavement Width -The minimum standard lane width of twelve (12) feet shall apply to all roadway systems under this section, including Aircraft Rescue and Fire Fighting (ARFF) roads except ramps where a minimum standard lane width of fourteen (14) feet shall be used. Bi-directional two- lane roads without usable shoulders require a total pavement width of not less than thirty-four (34) feet except for perimeter roads within the Air Operations Area (AOA) where the total pavement width may be twenty-four (24) feet.

2.5.7.2 Shoulders - On major, high design speed (equal to or greater than 50 mph), uncurbed facilities, a minimum traversable shoulder width of ten (10) feet is required.

2.5.7.2.1 On one-lane ramps, shoulders shall be placed on each side of the travel lane for a combined effective width to allow a stalled or stopped vehicle to be passed. Outside shoulders shall be a minimum of six (6) feet, and inside shoulders a minimum of two (2) feet.

2.5.7.2.2 Six (6) inch curbs shall be used primarily on collector, service roads, and other low speed (less than 50 mph) type facilities. They shall not be used in connection with high speed facilities, expressways, and ramp areas. Where needed for drainage purposes at ramps, curbs shall be mountable type. On two-lane, two-way roads, a minimum of two (2) feet on each side for curb and gutter shall be included in the total width of the roadway.

2.5.7.3 Speed Change Lanes - This section shall apply to auxiliary lanes with respect to median openings and at-grade intersections supplementary to through traffic movements.

2.5.7.3.1 The required length of the auxiliary lanes and size of median opening for turning vehicles shall be in accordance with applicable standards as outlined in the TxDOT Manual.

2.5.7.4 Cross Slope -The standard cross slope on all new paving projects and major reconstruction paving projects is ¼ inch per foot of pavement width.

2.5.7.5. Special Features - It is recognized that certain conditions will require the use of features not described in this Manual. The design of these features shall be based on good engineering practice for the specific feature and based on similar designs used by the City of Houston. The design shall consider the functional characteristics of the installation as well as the familiarity of the driver with the installation.

2.5.8 Roadway Signs -The design of signs for roadways shall be in accordance with the Texas Manual for Uniform Traffic Control Devices, latest edition. The signs, posts, breakaway features and foundations shall conform to TxDOT Standards. The erection of signs on bridge structures will require prior written approval from the HAS Project Manager.

2.6 EXCAVATION FOR STRUCTURES

2.6.1 All excavation for structures and structure footings shall be made to the lines and grades or elevations shown on the plans. The excavation shall be of sufficient size to permit the placing of the full width and length of the structure or structure footings shown. The elevations of the bottoms of footings, as shown on the plans, shall be considered as approximate only; and the Engineer may order, in writing, changes in dimensions or elevations of footings necessary to secure a satisfactory foundation.

2.6.2 Boulders, logs, or any other objectionable material encountered in excavation shall be removed. All rock or other hard foundation material shall be cleaned of all loose material and cut to a firm surface either level, stepped, or serrated, as directed by the Engineer. All seams or crevices shall be cleaned out and grouted. All loose and disintegrated rock and thin strata shall be removed. When concrete is to rest on a surface other than rock, special care shall be taken not to disturb the bottom of the excavation, and excavation to final grade shall not be made until just before the concrete or reinforcing is to be placed. Questions as to the meaning of "just before" are resolved through a determination by the Project Manager, or at his discretion the Project Inspector.

2.6.3 All bracing, sheathing, or shoring shall be performed as necessary to implement and protect the excavation and the structure as required for safety or conformance to governing laws.

2.6.4 Unless otherwise provided, bracing, sheathing, or shoring involved in the construction of this item shall be removed after the completion of the structure. Removal shall be effected in a manner which will not disturb or mar finished masonry.

2.6.5 After each excavation is completed, the Contractor shall notify the Engineer to that effect; and concrete or reinforcing steel shall be placed after the Engineer has approved the depth of the excavation and the character of the foundation material.

2.7 ACKFILL FOR STRUCTURES

2.7.1 After a structure has been completed, the area around it shall be filled with approved material, in horizontal layers not to exceed 8 inches in loose depth. For areas under pavement and safety areas, compact to 95% to 100% of the Standard Proctor Density, in accordance with ASTM D 698. For all other areas, compact to 93% of the Standard Proctor Density. Moisture content shall be held to a range of from 1% below to 3% above optimum. Each layer shall be deposited all around the structure to approximately the same elevation. The top of the compacted fill shall meet the elevation shown on the plans or as directed by the Engineer.

2.7.2 Backfilling shall not be placed against any structure until permission is given by the Engineer. In the case of concrete, such permission shall not be given until the concrete has been in place 7 days, or until tests made by the laboratory under supervision of the Engineer establish that the concrete has attained sufficient strength to provide a factor of safety against damage or strain in withstanding any pressure created by the backfill or the methods used in placing or compacting it. Sufficient strength shall be interpreted as being 75% of the design strength, or the strength expected to be obtained in 7 days, whichever is greater.

2.8 SITE ELEMENTS

2.8.1 Retaining Walls - Wherever slopes must be steeper than a slope of 4:1 (four horizontal units to one vertical unit), the use of retaining walls will usually be required. Either vertical or battered wall faces are acceptable. Exposed concrete may be required to be buff color with surface texture matching that of adjacent buildings. Trenching or sprinkler systems shall not be allowed in the passive soil area.

2.8.2 Fencing

2.8.2.1 Leased Property Fencing - All fencing on leased property is the responsibility of the Tenant and shall be aesthetically pleasing. This can be accomplished by use of material matching or similar to adjacent structures. Chain link fencing shall be screened with plantings where appropriate. Planting materials must be approved by HAS and no fruit bearing ornamental trees will be permitted.

2.8.2.2 AOA Fencing – Security fencing shall be constructed at locations adjacent to the Air Operations Areas (AOA) with no openings or gaps in excess of 4 inches, preferably less than 2”(may be 4 to 6 inches below gates) and shall consist of the following components:

Use and Section	Nominal Outside Diameter (Inches)	Normal Weight per Foot (+/10% Tolerance)	
		Type I	Type II
End corner and pull posts			
Fabric height of 6’-0”, round	2.375	3.65	3.12
square	2.00	2.60	
Over 6’0”, round	2.875	5.79	4.64
, square	2.50	5.10	
Rails and post braces	1.66	2.27	1.83

Intermediate Posts For Fabric Heights	Nominal Outside Diameter (Inches)	Normal Weight per Foot (+/- 10% Tolerance)	Normal Weight per Foot (+/- 10% Tolerance)
6’-0” and less, round	1.90	2.72	2.28
‘C’ Section	1.875	2.28	2.28
Over 6’-0”, round	2.375	3.65	3.12
C Section	2.25	2.64	2.664

Note that existing fence at Ellington International Airport (EFD) is galvanized rather than coated and there are no mow strips at any of the three airports. It is the intent of HAS to bring all AOA fencing up to these standards as new fence locations are constructed or existing fencing is replaced.

2.8.2.2.1 Fence and Gates – Eight (8) feet in height of number 10 gauge , 2-inch Black PVC coated steel chain link mesh with three (3) strands of number 12 gage, four point barbed wire mounted above the fence with an outward extension of forty five (45) degrees. Any water crossings or outfalls shall have coverage equal in strength and durability to the actual fence. Fence posts shall be installed on ten (10) feet centers maximum. Post, rails and braces shall be Black PVC coated steel sized in accordance with the table below. Hinges and latches shall be zinc-coated. Vertical concrete retaining walls with no ledges, handholds or other means of scaling that are six feet or higher will only require the barbed wire extensions. No structure, barrier or other facility which will provide a platform of any kind shall be located within 10’ horizontally of any AOA fence.

2.8.3 AOA Signs -HAS will furnish sign graphics in the form of a master suitable for photographic enlargement. Signs shall be constructed of screen-printed reflective vinyl film on a .080 inch anodized aluminum panel. Anchor signs to fence fabric with #6 galvanized wire ties.

2.8.3.1 Fence Signs - Warning signs shall be affixed to the fence on centers of 200 feet maximum and at each turn of the fence of 45 degrees or greater. Signs shall be 24 inches in height by 30 inches in width. Fence sign graphics will include the Airport brand and the following copy: "Air Operations Area – No Trespassing" Sign specifications can be obtained from the HAS Sign Shop.

2.8.3.2 Gate Signs – All AOA gates will be assigned a gate number by HAS Operations. Sign specifications can be obtained from the HAS Sign Shop.

2.8.4 Concrete Mow Strip – A concrete mow strip 36 inches in width centered on the fence shall be installed at all permanent fencing. The concrete strip shall be four (4) inches in thickness and reinforced with flat 6-inch by 6-inch, W2.9 X W2.9, welded wire fabric. Place on two-inch sand cushion. Provide contraction joints spaced four (4) feet on center and pre-molded one half (1/2) inch expansion joint material spaced at thirty-two (32) feet on center.

2.8.5 Post and Cable System – A post and cable system shall be installed in all areas where vehicles have unobstructed access to fences and gates adjacent to runways and taxiways. Acceptable systems shall be CASS ^{tm} system by Trinity Industries, Inc., Brifen Wire Rope Safety Fence by Brifen USA or an approved equal.

2.8.6 Concrete Traffic Barriers – Concrete traffic barriers (CTB) shall be installed on the AOA side of AOA gates parallel to and three feet from the gate.

2.8.7 Gate Locks – All new unmanned AOA gates shall be equipped with an electronic card reader system and shall comply with CFR 49, Section 1542.207. Regulations are available at http://www.access.gpo.gov/cgi-bin/cfrassemble.cqi?title=201049. Designer needs to check with the HAS Project Manager to determine the currently approved equipment. Currently there are manually operated AOA gates. If the Designer is directed by the HAS Project Manager to install a new manually operated gate without an electronic card reader a key/padlock system will be installed using STANLEY/BEST padlocks.

2.8.8 AOA Fence Screening and Equipment – Screenings shall not be attached to AOA fencing. A separation dimension of 10 feet shall be maintained between the AOA fence and any movable objects such as equipment or any other object that may provide a platform.

2.8.9 AOA Gate Barriers – At manned AOA gates, when barriers are required by the HAS Airport General Manager, provide a surface mounted barricade system equal to Delta Scientific Corporation (TW2015) or Natsatka Barrier, Inc. as follows:

1. Hydraulic or pneumatic controlled barricade system with one-inch thick, eighteen-inch high metal plate in specified length to act as a physical barrier to entry or exit when in the raised position.
2. Provide surface-mounted, above grade installation.
3. The system shall be crash rated based on US Corps of Engineers acceptance criteria of at least 5,000 pounds at 30 miles per hour.
4. The barricade shall be automatically lowered to allow passage of authorized vehicles by card swipe through the Airport Board's Automatic Access Control System (AACS), and the barricades shall be capable of being operated by authorized personnel pushing a button inside the guard station. The barricade shall have a minimum height in the up position of 21 inches, and when lowered shall be less than 2" in height.

2.8.10 AOA Guard Stations – Guard houses are required at manned AOA gates equal to Model DA75Sw as manufactured by Port-A-King Building Systems, Earth City, Mo.

2.8.11 Flagpoles -Flagpoles shall be cone tapered aluminum, dark bronze anodized finish, with all standard fittings. Flagpoles shall be adequately supported and provided with lightning protection. No lighting shall be provided that points upward to illuminate the flags or flagpoles.

2.8.12 Trash Handling -Space shall be provided for trash handling devices and containers depending on the size, location and type of trash which is to be disposed. Design plans shall indicate the proposed method(s) for trash disposal. All equipment used for handling, storage, or compaction of trash which may be in the public view shall be screened. Equipment shall be finished in a color to match other painted building equipment. Also, the dumpster type containers shall be oriented for ease of approach by truck. All trash containers shall be covered or otherwise enclosed to prevent access by wildlife and high winds. No open topped trash containers are permitted within the Air Operations Areas.

2.8.13 Fire Lane Markings: Fire lanes shall be marked with a six (6) inch painted red stripe. The words "FIRE LANE NO PARKING" shall be stenciled in white paint, four (4) inch high letters with a ¾- inch stroke. The interval between stenciled signs shall be adequate to inform the public of the existence of the fire lane but in no event shall the interval be greater than twenty (20) feet. Markings shall be on each side of the designated fire lane. The shade and type of paint shall comply with State of Texas specifications for traffic paint.

2.8.14 Security Gates and Other Security Devices Across Fire Apparatus Access Roads: All automatic gates and devices across required fire apparatus access roads shall open upon activation of building fire alarm system and remain open until such time that the fire alarm is reset, or; shall open with a signal from a 3M Opticom system. The gate shall also open from a signal received from a HAS Signal Receiving Device (SRD), or; HAS Selected Vehicle Device (genie). All automatic gates and devices shall incorporate a fail-safe manual backup or release. All gates and devices shall permit the safe exit of emergency vehicles at all times.

2.8.15 Walks - Pedestrian concrete walks shall be constructed between buildings and other essential locations where such a need may occur. The minimum standard width for sidewalk pavement shall be four (4) feet with proper cross slope for adequate drainage. The minimum standard walkway pavement shall be of four (4) inch thick concrete reinforced with flat 6-inch X 6- inch, W2.9 x W2.9, welded wire fabric on a minimum two (2) inch sand cushion. Rolled wire fabric will not be permissible as walkway or other reinforcing. Provide contraction joints spaced every four (4) feet (approximate). Premolded one-half (½) inch expansion joint material spaced at thirty-two (32) feet is required. Curb cuts and ramps shall meet the accessibility requirements of the Americans with Disabilities Act.

2.9 SANITARY SEWER SYSTEM

2.9.1 General Information - This chapter defines general design criteria that applies to the design of exterior utilities at all HAS airports.

2.9.1.1 It is highly recommended that a cementitious fill material be considered as a back fill material for all trenches occurring under any roadway, runway, taxiway, shoulders or parking lot. Good engineering practice, scheduling, construction demands (material set time) and any future excavation requirement shall be considered in selecting the proper material. All pipes under any roadway, runway safety zone, taxiway safety zone, shoulders or parking lot shall be placed using Class A bedding.

2.9.1.2 Existing utility information is available through the various HAS Departments and the most current as-built information is available from the Planning, Design and Construction Division, Planning & Programming Section. However, it shall be expressly understood that HAS cannot accept responsibility for the locations shown on "as-built" drawings. It shall be the designer's responsibility to verify locations or the adequacy of file information prior to design and construction of utility extensions, duct banks, conduits or connections to such facilities.

2.9.1.3 Wherever possible, disposal of sewage shall be by gravity to the Sanitary Sewer System (SSS). Airport mains shall be extended as required to establish gravity flow disposal. Ejector type pumps will only be allowed when gravity connection to the SSS is not possible. On-site disposal will only be allowed in remote Airport areas where mains do not exist or cannot be extended for gravity or ejector disposal.

2.9.1.4 Wastewater mains shall have slopes that allow the flows to achieve velocities of 3.0 fps, if possible. The minimum velocity shall not fall below 2.0 fps. Should slopes not permit achievement of a velocity of 2.0 fps pump stations shall be employed. Slopes that will create a flow velocity in excess of 10.0 fps shall be avoided.

2.9.2 Sanitary Sewer System - All proposed connections to the SSS shall be described by plans and specifications from the user end of the lateral to actual connection to the Airport main(s). Manholes shall be cast-in-place reinforced concrete and installed every three hundred (300) feet, at connections to mains and at 45 degree and 90 degree changes in main runs. Manhole covers shall have "Sanitary Sewer" imprinted on them. Aircraft rated manholes and covers are required within all runway and taxiway safety areas as shown on the approved Airport Layout Plan.

2.9.2.1 No permanent Airport facility requiring sanitary sewage disposal shall be opened, occupied, or operated without an approved permanent lateral connection to an Airport main or a specifically approved alternative.

2.9.2.2 Approved materials for gravity flow sanitary sewer pipe are: ASTM D2241 SDR 26, AWWA C900, C905 PVC pipe, or ASTM D 2680 PVC pipe. ASTM D 2680 PVC pipe shall not be used for pressurized mains. The minimum lateral size shall be six (6) inches in diameter. All lateral to main connections shall be made at a manhole. SDR-35 PVC shall not be used. Elastomeric gaskets shall also meet ASTM F477.

2.9.2.3 Testing: Prior to testing, all sanitary sewer lines must be inspected with a video system and a copy of the DVD submitted to the HAS Project Manager for approval. After approval of the DVD, all installed SSS pipe must be tested so that the completed system will have a zero (0) exfiltration loss per two (2) hours, where the hydrostatic head at the design hydraulic grade line is no less than four (4) feet of test stack with the height of the test stack matching the highest elevation of the SSS. A pneumatic test at 3 psi may be substituted for the hydrostatic test to substantiate the exfiltration criteria. The air pressure shall be equivalent to the comparable hydrostatic test pressures. Certified copies of all tests shall be provided to the HAS Project Manager.

2.9.2.4 Manholes must be vacuum-tested with a negative pressure of 3 psi, maintaining a zero (0) pressure drop for five minutes.

2.9.2.5 Lift Stations shall include a minimum of two (2) submersible electrically operated sewage pumps (redundant) with low level shutoff, high level alarm and intermediate level sensors required for pump cycling. Pumps shall be manufactured to grind and safely pump wastewater.

2.9.2.6 Wet-pits shall be concrete, cast-in-place with access for inspection and pump maintenance.

2.9.2.7 Lift Stations shall be located with due consideration for screening, maintenance access and emergency access.

2.9.2.8 The AWWA C900, C905, or C303 reinforced concrete cylinder pipe (RCCP) is required for all pressurized applications. All pressurized pipe shall be installed within casings under roadways, taxiways, and runways. Casing pipe shall be RCCP or PVC (schedule 80 or AWWA C900). Steel casings can be used with proper cathodic protection as described in Section 11 – Corrosion Control. Corrugated steel pipe shall not be used as casing pipe. All pipe installed within sleeve will require RACI North America or approved equal – spacers on four (4) feet center.

2.9.2.9 Longitudinal deflection at each pipe joint shall not exceed one degree in any direction.

2.9.2.10 Bedding for Sanitary Sewer System: After trench has been cut to a depth below the barrel of the pipe a distance of three inches, the bedding shall be brought to a point 1/8 pipe diameter above grade with cement stabilized sand. Bell holes shall be formed, if required, a trough scooped out to grade and the pipe laid and jointed as specified. The cement stabilized sand shall then be brought up in uniform layers of either side of the pipe and over the pipe to a point 6 inches above the top and 6 inches below bottom of the pipe. Density shall be at least 90 percent of maximum density as determined by ASTM D 698. Moisture content shall be within minus 2 to plus 4 of optimum.

2.10 DEICING RUNOFF COLLECTION SYSTEM

2.10.1 Pipe: High Density Polyethylene Pipe (HDPE) shall conform to AWWA C901 and AWWA C906. Force mains shall be minimum DR 11 and gravity lines shall be minimum DR 17. Pipe shall be of the type and size designated on the plans or in the proposal. Pipe shall be manufactured from a PE 3408 resin listed with the Plastic Pipe Institute (PPI) as TR-4. The resin material shall meet the specifications of ASTM D3350 with a minimum cell classification of PE345464C. Pipe shall have a manufacturing standard of ASTM D3035 and be manufactured by an ISO 9001 certified manufacturer. The pipe shall contain no recycled compounds except that generated in the manufacturer's own plant from resin of the same specification from the same raw material. The pipe shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, voids, or other injurious defects.

2.10.2 Butt Fusion Fittings: Butt fusion fittings shall be in accordance with ASTM D3261 and shall be manufactured by injection molding a combination of extrusion and machining, or fabricated from HDPE pipe conforming to this specification. All fittings shall be pressure rated to provide a working pressure rating no less than that of the pipe. Fabricated fittings shall be manufactured using a McElroy Datalogger to record fusion pressure and temperature. A graphic representation of the temperature and pressure data for all fusion joints made producing fittings shall be maintained as part of the quality

control. The fitting shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, voids, or other injurious defects.

2.10.3 Electrofusion Fittings: Electrofusion Fittings shall be PE3408 HDPE, Cell Classification of 345464C as determined by ASTM D3350-99 and be the same base resin as the pipe. Electrofusion Fittings shall have a manufacturing standard of ASTM F1055

2.10.4 Flanged and Mechanical Joint Adapters: Flanged and Mechanical Joint Adapters shall be PE 3408 HDPE, Cell Classification of 345464C as determined by ASTM D3350-99 and be the same base resin as the pipe. Flanged and mechanical joint adapters shall have a manufacturing standard of ASTM D3261. All adapters shall be pressure rated to provide a working pressure rating no less than xxxxx.

2.10.5 Mechanical Restraint: Mechanical restraint for HDPE may be provided by mechanical means separate from the mechanical joint gasket-sealing gland. The restrainer shall provide wide, supportive contact around the full circumference of the pipe and be equal to the listed widths. Means of restraint shall be machined serrations on the inside surface of the restrainer equal to or greater than the listed serrations per inch and width. Loading of the restrainer shall be by ductile iron follower that provides even circumferential loading over the entire restrainer. Design shall be such that restraint shall be increased with increases in line pressure.

2.10.5.1 Serrated restrainer shall be ductile iron ASTM A536 with a ductile iron follower; bolts and nuts shall be corrosive resistant, high strength alloy steel

2.10.5.2 The restrainer shall have a pressure rating of, or equal to that of the pipe on which it is used or 150 psi whichever is lesser. Restrainers shall be JCM Industries, Sur-Grip or pre-approved equal.

2.10.5.3 Pipe stiffeners shall be used in conjunction with restrainers. The pipe stiffeners shall be designed to support the interior wall of the HDPE. The stiffeners shall support the pipe's end and control -the "necking down" reaction to the pressure applied during normal installation. The pipe stiffeners shall be formed of 304 or 316 stainless steel to the HDPE manufacturers published average inside diameter of the specific size and DR of the HDPE. Stiffeners shall be by JCM Industries or pre-approved equal.

Nominal Size	Restraint Width	Serrations per Inch
4", 6"	1-1/2"	8
8", 10" & 12"	1-3/4"	8

2.10.6 Manholes - Manholes for deicing runoff collection system waste lines shall be constructed in accordance with the details shown on the plans and in accordance with the requirements of paragraph 2.3.13 Manholes, Catch Basins, Inlets and Inspection Holes.

2.11 POTABLE WATER SUPPLY -All proposed connections to or extensions of the Potable Water Systems (PWS) shall be described by plans, specifications and contract requirements, including details of connections at the user side of the meter and the actual connections to the Airport main.

2.11.1 General - Material and construction for potable water main additions or extensions shall be accomplished in accordance with the "Standard Construction Specifications for Wastewater Collection Systems, Water Lines, Storm Drainage, Street Paving and Traffic", City of Houston Department of Public Works and Engineering, latest edition (hereafter referred to as the "COH Specs") unless otherwise revised or altered by requirements of this Manual or specifically approved by the City Engineer.

2.11.2 Water Flow Tests - Tests must be conducted to verify residual pressures and water flow in coordination with HAS Airport Physical Plant Maintenance personnel.

2.11.3 Plans and Specifications -Plans and specifications for all facilities requiring potable water service shall contain complete contract requirements for the furnishing and installation of a metered water service including the actual connection to HAS's distribution system. Dual water services, connected to separate isolable sections of the PWS, shall be provided where water usage requirements are such that forty-eight (48) hour maintenance or emergency repair interruptions cannot be tolerated or required for fire protection.

2.11.4 Emergency Water Supply - All buildings shall have an emergency water supply connection for supplying potable water to the facility whenever the domestic water service line is drained for repairs.

2.11.5 Service Lines - All service lines shall be adequately sized to provide a minimum of twenty (20) psig residual pressure at a 1200 gpm flow rate. Normal main static pressures may be verified with HAS Airport Physical Plant Maintenance.

2.11.6 Pipe Casing Required - All pressurized pipe shall be installed within casings under roadways, taxiways and runways. Casing pipe shall be reinforced concrete cylinder pipe RCCP or PVC (Schedule 80 or AWWA C900). Steel casing pipe can be used except that steel has to be cathodically protected. Corrugated steel pipe shall not be used as casing pipe.

2.11.7 Separation of Water Lines from Wastewater Lines - Water line shall be spaced and separated from wastewater lines by nine (9) feet as required by TCEQ regulations. If this separation is unattainable, the replacement of the existing main must be considered on the basis of age, the existence of non-pressure joints and the overall condition of the main.

2.11.8 Friction Loss in Mains - Mains are to be sized to ensure less than one (1) foot of head loss per thousand (1,000) feet of main, at a Hazen Williams coefficient of C=110.

2.11.9 Bends - All bends shall be restrained both horizontally and vertically by the placement of concrete thrust blocks and meta-lug restraint joint.

2.11.10 Longitudinal Deflection - Longitudinal deflection at each pipe joint shall not exceed one degree in any direction.

2.11.11 Pipe Material -Potable water lines shall conform to EPA, NSF standards and to the following material requirements:

1. Polyvinyl Chloride (PVC) Pressure Pipe one (1) to three (3) inches in diameter shall conform to ASTM D 1785, or type (K) copper.

2. Polyvinyl Chloride (PVC) Pressure Pipe greater than four (4) inches and up to twelve (12) inches in diameter shall conform to AWWA C900 Class 235, DR 18. Pipe shall be furnished in ductile iron equivalents (CIOD).
3. Polyvinyl Chloride (PVC Pressure Pipe greater than or equal to fourteen (14) inches and up to twenty-four (24) inches in diameter shall conform to AWWA C905, Class 235, DR 18 for and shall be furnished in cast iron equivalents.
4. Ductile Iron Pipe (DIP) shall be Class 51 DIP conforming to AWWA C150, AWWA C151 and having a cement mortar lining conforming to AWWA C104.
5. Fittings for PVC and DIP pipe shall conform to C-153 Class 350 compact ductile iron.

2.11.12 Water Meters – Water meters shall comply with City of Houston Engineering and Public Works standards for equipment specifications ad well as testing and approval. Water meters shall be sized in accordance with good design practice for the service intended. Meters specified shall be compatible with electronic data collection equipment to enable on-site electronic collection of meter readings. Water usage shall be recorded on both a visual odometer and in an electronic memory.

1. Meters up to two (2) inches in size shall be multi-jet type with magnetic drive andsealed registers. These water meters shall meet or exceed the requirements of AWWA C708 for Cold Water Meters - Multi-jet Type.
2. Meters greater than two (2) inches shall be turbine type. These water meters shall meet or exceed the requirements of AWWA Class II Turbines standard.
3. Registers for all meters shall read in straight U.S. Gallons.
4. Water meters shall be Badger or approved equal.
5. Meters shall be constructed of compatible metals throughout to prevent any corrosive reaction between component metals.

2.11.12.1 Positive Displacement Meters with Electronics Pit or Vault Application:

5/8” x ¾ M-25 Badger Meter with RTR and Pit Electronics with 3’ lead (Specify wire length if more than 3’ needed)

1” M-70 Badger Meter with RTR and Pit Electronics with 3’ lead (Specify wire length if more than 3’ needed)

1-1/2” M-120 Badger Meter with Test Plug and RTR and Pit Electronics with 3’ lead (Specify wire length if more than 3’ needed)

2” M-170 Badger Meter with Test Plug and RTR and Pit Electronics with 3’ lead (Specify wire length if more than 3’ needed)

Mechanical room or Interior Room Application

5/8” x ¾ M-25 Badger Meter with RTR and Outdoor Remote NOT PREWIRED (Specify lead wire length if more than 25’ needed)

1” M-70 Badger Meter with RTR and Outdoor Remote NOT PREWIRED (Specify lead wire length if more than 25’ needed)

1-1/2” M-120 Badger Meter with Test Plug RTR and Outdoor Remote NOT PREWIRED (Specify lead wire length if more than 25’ needed)

2” M-170 Badger Meter with Test Plug RTR and Outdoor Remote NOT PREWIRED (Specify lead wire length if more than 25’ needed)

2.11.12.2 Turbine Meters with Electronics Pit or Vault Application
1-1/2” T160 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

2” T200 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

3” T450 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

4” T1000 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

6” T2000 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

8” T3500 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

10” T5500 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

12” T6200 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

16” T6600 Badger Turbo Meter with Strainer RTR and Pit Electronics (Specify lead wire length if more than 3’ needed)

Mechanical Room or Interior Application
1-1/2” T160 Badger Turbo Meter with Strainer RTR and Outdoor Remote NOT PREWIRED (Specify lead wire length if more than 25’ needed)

2.11.13 Meter Boxes -Meter boxes or vaults shall be specified for each meter. Meter locations shall be identified on the plans and shall be outside the facility served and at a location that is at all times accessible to utility personnel and service equipment. Construction details shall be shown on the plans including the details of all internal piping. Piping details shall include a minimum requirement of two (2) isolating valves, the meter, and any necessary additional fittings required to remove or service the water meter without closing valves at any location other than at the meter box. All installations requiring three (3) inch or larger meters shall be provided with a bypass line with gate valve and arranged such that the bypass can provide unmetered service to the facility during periods of time when the meter is being serviced or replaced. All meter boxes or vaults containing three (3) inch or larger meters shall be free draining or be provided with a sump pump which discharges into the nearest storm drain. All drainage design for meter vaults shall be coordinated and approved by HAS. Meter boxes and vaults shall have cast iron or steel deck plate covers as required to provide adequate service access to the meter location. Where the weight of the cover or cover sections exceeds twenty-five (25) pounds, the meters shall be provided with sensor extension cable for mounting the sensor on the side of the box or vault which shall be easily readable through a small access door in the cover.

2.11.14 Backflow Preventers - Where the service line provides potable water for a domestic service and also connects with other closed or chemically treated systems that could foreseeably contaminate the potable water line, a backflow preventer shall be installed. Drains off the backflow preventer assembly shall be drained to the sanitary sewer. Taps to mains, to provide water for fire protection or other closed pipe systems, shall have a double check valve assembly at the fire line tap. An alternate method of backflow prevention consisting of a twelve (12) inch air gap between an unrestricted overflow of an atmospheric makeup tank and the source of water is also acceptable. All double check and reduced pressure backflow preventers must be certified for operation after installation by a TCEQ certified tester.

2.11.15 Reduced Pressure Backflow Preventers – All pressure reducing backflow preventers that are installed to protect high-hazard services from back flowing must be tested annually from the date they are installed and certified. Examples of high-hazard services are:

1. Aspirators
2. Autoclaves
3. Sterilizers
4. Lab bench equipment
5. Sewage pumps
6. Sewage ejectors
7. Firefighting systems (with toxic liquid foam concentrates)
8. Connections to sewer pipe
9. Irrigation systems with chemical additives
10. Trap primers

2.11.16 Wall or Floor Penetrations - In meter vaults or mechanical rooms where a potable water or fire line penetrates wall or slab, install "Link-Seals" to prevent moisture infiltration.

2.11.17 Tapping Water Mains - Where services require the tapping of any existing reinforced concrete cylinder water distribution main, the Designer shall specify that the Contractor employ a qualified specialty contractor to perform this service. Tapping of all water mains shall be done in accordance with AWWA standards and coordinated with HAS. The tap shall be performed only at the horizontal tangent of the main in conjunction with either a tapping gate valve with a dielectric insulating gasketed flange or a corporation stops. Gate valves shall be in accordance with Section 2.11.20 Purging and Sterilization of Water Mains. Standard corporation stops shall be Mueller H-15000 or approved equal.

2.11.17.1 Tapping sleeves with tapping valves shall be used whenever possible for connections to existing mains in order to avoid water service interruptions. Size on size taps are allowed up to twelve (12) inches, e.g. 12" x 12", 8" x 8", etc. Sizes less than one standard pipe size taps are the largest allowed on 16 inch and larger connections, e.g. 16" x 12", 16" x 8", 16" x 6".

2.11.17.2 Type "D" connections for mains that are designed to cross each other shall be utilized.

2.11.17.3 A new valve shall be installed at the point of connection for water main extensions to facilitate testing and chlorination of the new main prior to its placement into service.

2.11.18 Exposed Pipe - All ferrous piping exposed in meter vaults or boxes shall be equipped at both entrances and exits to the vault or boxes with a dielectric insulating coupling. All ferrous piping exposed in meter vaults or boxes shall be coated with Mobilzine 7 or approved equal with a dry film thickness of two (2) to three (3) mils., applied to clean dry surfaces and as recommended by the manufacturer of the paint. Link seals shall be specified for all penetrations in meter vaults.

2.11.19 Temporary Water Service (Backflow Preventer) - All temporary construction water services shall be provided with a line sized backflow preventer double check valve assembly. Services shall not be initiated until backflow prevention devices have been approved by the HAS Project Manager.

2.11.20 Purging and Sterilization of Water Mains - Before any newly constructed water main will be permitted to be placed into service in the potable water supply, it shall be flushed or purged, sterilized and tested to assure compliance with TCEQ standards.

2.11.20.1 Water pipe disinfection shall be in accordance with the following:

2.11.20.2 Flushing -Provisions shall be made to flush the pipe with potable water until all dirt, sludge, and debris are removed. If flushing is unsuccessful, the pipe must be purged.

2.11.20.3 Purging -Purging shall be accomplished by passing an appropriate sized "Polly-Pig(s)" through the pipe.

2.11.20.4 The design shall make provisions for preparing the pipe for the installation and removal of "Polly-Pig(s)" as required.

2.11.20.5 Sterilization - Sterilization of the main shall be accomplished by injecting calcium hypochlorite into one end of the line until water released from the other end indicates a chlorine residual of fifty (50) PPM. All valves shall then be closed and the solution shall be allowed to disinfect the pipe for at least twenty-four (24) hours. Provisions shall be made for disposing all chlorinated water into the sanitary sewer system directly after the completion of the sterilization process.

2.11.20.6 Disinfection and sterilization shall be performed in accordance with AWWA C651, latest edition.

2.11.21 Valves and Hydrants -This section covers the materials and installation of all valves and hydrants of various types, and their appurtenances.

2.11.21.1 Gate Valves: Gate valves shall be non-rising stem, solid-wedge gates with cast iron body and bronze mountings. Unless otherwise specified, valves three (3) to twelve (12) inches in size with working pressures of 200 psi or less shall be in strict accordance with American Water Works Association Standard Specification for "Gate Valves for Ordinary Water Works Service," designation C509, latest revision. Gate valves with resilient seated gates in accordance with AWWA C509, latest edition, are preferred.

2.11.21.1.1 Flanges for valves shall be drilled to match connecting flanges. All flanges shall conform to the standard specification of the American National Standards Institute. Flanges shall be Class 125 for all pipes, fittings, and valves three (3) to twelve (12) inches in diameter with a working pressure of 200 psi or less and flange bolts shall be coated for corrosion control.

2.11.21.1.2 Buried valves shall be mechanical joint or push-on rubber gasket joint bell for pipe 2-26 spigots, unless otherwise specified.

2.11.21.1.3 All gate valves shall be non-rising stem unless otherwise indicated, and shall turn counterclockwise to open. Valves shall be provided with a hand wheel operator unless otherwise designated. Valves or corporation stops for buried service shall be provided with two (2) inch square nut operator and shall be installed with extension stems where required to extend operating nut to within twelve (12) inches of the finished grade.

2.11.21.2 Valve Stacks and Vaults - Valves or corporation stops buried in the ground shall be provided with cast iron valve stacks of proper dimensions to fit over the valve bonnets, and to extend to the finished ground line in paved areas or slightly above finished grade in other areas. Tops shall be complete with covers and shall be adjustable. Valve stacks shall be set vertical and concentric with the valve stem. A concrete pad shall be poured around all valve stacks when not in paved areas. Valves sixteen (16) inches and larger shall be installed in a vault.

2.11.21.3 Blocking Under Valves - All gate valves twelve (12) inches and larger which are buried shall rest on a concrete pad. Pad shall extend for the full width of the trench to the back of the bell (or flange). Concrete shall be 2000 psi for blocking valves.

2.11.21.4 Bronze Gate Valves - Gate valves two (2) inches and smaller shall be all bronze, non-rising stem, with wedge disc and screwed ends. Unless otherwise indicated, they shall be for 300 psi working pressure, Crane No. 437 or equal.

2.11.21.5 Outlet Valves - Blind flanges or plugs, as applicable, shall be furnished and installed on all valves located at outlet points or terminal points where the water main does not continue. Dead end main structures shall be avoided whenever possible. If unavoidable, dead end mains shall be designed to accommodate periodic flushing. The following two (2) design alternatives shall be considered:

1. Locate a fire hydrant less than fifty (50) feet from the main's end;
2. Install a flush point at the main's end.

2.11.21.6 Air Release Valves - Manual air release valves shall be located on each side of main line valves and at other applicable locations and shall be comprised of a main line corporation stop, Mueller H-15025, brass service fittings as required, a curb stop, Mueller H-15275 and soft copper pipe with flared fittings. A nylon isolation bushing shall be installed between the main and corporation stop. Automatic air release (and vacuum release) valves shall be installed at high points on mains.

2.11.21.7 Surface Boxes - Surface box for manual air release where required shall be cast iron box and lid, twelve (12) inches deep and twelve (12) inches in diameter Trinity Valley Iron and Steel No. 4465 or approved equal. Raised letters on the cover shall read "WATER". If locks are installed they shall be STANLEY/BEST brand.

2.11.21.8 Fire Hydrants - Fire hydrants shall be 5-¼ inch Waterous "Pacer" or approved equal. Hydrants shall be a breakaway traffic model with six (6) inch mechanical joint shoe to be buried at five (5) feet except where different depth is shown in the hydrant schedule.

1. Subsurface hydrants are not allowed for use on the airport except when approved by the Houston Fire Department. Subsurface (or flush-mount) fire hydrants shall be Mueller Dresser flush type models or approved equal with box and cover.
2. Hydrants shall have one four (4) inch pumper nozzle and two 2-½ inch hose nozzles with National Standard Threading. All hydrants will be fitted with (supplied and installed by the contractor) a four (4) inch "Quick Coupler Adapter" as manufactured by Hydra-Storz, part number Hyst-4040ST-CAP. Operation shall be by National Standard Pentagon nut, 1-½ inch flat to point, open to left, by not more than eight (8) or nine (9) full turns of the operating nut. Hydrants shall meet the requirements of AWWA C502.
3. Blocking and Drainage - Concrete blocking shall be poured behind hydrants against undisturbed earth. Washed gravel shall be placed appropriately around the shoe of the hydrant to effectively drain the hydrant barrel.
4. Quantity and Spacing Adequate fire hydrants shall be provided for each structure such that any point on the perimeter of the structure can be reached by a hose laid outside the structure of a length not to exceed three-hundred (300) feet. The maximum spacing for fire hydrants along roadways is two hundred and fifty (250) feet.
5. Isolation for Maintenance - All fire hydrants shall be isolated from the main waterline and from other water services by installation of a gate valve between the main waterline and the fire hydrant in order to facilitate repair of the fire hydrant without having to shut off the main waterline.
6. Fire Hydrant Service Lines - Service lines shall be adequately sized to provide a minimum fire flow and duration in accordance with the Fire Code and in areas where no buildings are located shall be capable of sustaining 2500 GPM with a twenty (20) psig residual pressure.
7. Cathodic Protection - All fire hydrants shall be cathodically protected.

2.11.21.9 Thrust Blocks -Concrete with a minimum strength of two thousand (2,000) pounds per square inch in twenty-eight (28) days shall be placed for blocking at each change in direction of the pipe line, in such manner as will substantially brace the pipe against undisturbed trench walls. All fittings shall be wrapped in poly prior to thrust block placement to allow future removal of concrete without damage to fittings. Concrete blocking shall have been in place four (4) days prior to testing the pipe line. Thrust blocks shall be used at:

1. Changes in direction, as at tees and bends.
2. Changes in size, as at reducers.
3. Changes in elevation, as at tees and bends (concrete block anchors preferred).
4. Stops, as at a dead end.
5. Valves, where thrusts may be expected.

2.11.21.9.1 At all points where wet connections are made to existing lines, the tapping connection fittings shall be supported by blocking up to the spring line with two thousand (2,000) psi concrete.

2.12 LANDSCAPE IRRIGATION SYSTEM

2.12.1 General - Installation of automatic watering systems is required for the entire area along major entrance roadways, the infield areas and any designated landscape areas with the exception of areas previously noted under the section on Retaining Walls. Outlying areas such as the secondary service roads in support areas, perimeter planting areas, and airfield grass areas do not require sprinkler systems. However, truck watering of trees in these areas will be necessary for the first two (2) years after initial planting.

2.12.2 Sleeving - It is important that all irrigation related sleeving be installed for newly-developed areas so that sprinkler systems can be incorporated without the disruption of transportation systems. It is required that PVC (polyvinyl chloride) piping be used in general planting areas.

2.12.3 Approved Manufacturers - All irrigation materials and equipment are to be manufactured by "Rainbird" or approved equivalent. This provides common equipment throughout the Airports, allowing maintenance personnel to make necessary repairs while maintaining a quality system. All pipe and fittings shall be schedule 40 PVC.

2.12.4 Irrigation Controllers - All irrigation controllers shall be "Rainbird" stainless steel cabinet models, such as the ESP-SAT-TW-SS controllers or an approved equivalent. All irrigation satellite controllers must be connected to a Cluster Control Unit (CCU) by a two-wire path (Maxicable or PE-39 "telephone type" wire). All new sites must have a CCU with stainless steel cabinet with two-wire path to each satellite controller. Each CCU must have a Maxicom compatible freeze sensor and rain sensor.

2.12.5 Freeze Sensors - Freeze sensors shall be Hunter Industries "Freeze-Clik" or approved equivalent (temperature set point at 3°C +/- 2°C (37°F), 24 VAC 6 amp rating, closed above 3°C and open below 3°C). Freeze sensor shall be mounted at a height and location that is out of direct sunlight and where free outdoor air circulation is possible. Each freeze sensor must be attached by a two-wire path (of no lighter gauge than 20 AWG) to a Rainbird M51300 Sensor Decoder. Sensor decoders must be housed in the base of a stainless steel controller cabinet (within an existing satellite controller cabinet, a CCU cabinet, or a separately installed cabinet). The sensor decoder shall be also connected to the Maxicom two-wire path.

2.12.6 Rain Sensors - Rain sensors shall be Rainbird Rain Counter model number S-300 or approved equivalent (tipping bucket / magnetic reed switch style; rainfall per tip: 0.01"). Each rain sensor must be attached by a two-wire path (of no lighter gauge than 20 AWG) to a Rainbird M51200 Pulse Decoder. Pulse decoders must be housed in the base of a stainless steel controller cabinet (within an existing satellite controller cabinet, a CCU cabinet, or a separately installed cabinet). The pulse decoder shall be also connected to the Maxicom two-wire path.

2.12.7 Wiring - Wiring shall be 12 gauge-UF irrigation wire using 3M brand "DBY" or "DBR" connectors.

2.12.8 Maintenance Equipment - Maintenance equipment shall consist of Rainbird manufactured equipment. "Rainbird Maxicom" type or approved equivalent shall be used for computer-controlled systems.

2.12.9 Gate Valves - All gate valves of four (4) inch or three (3) inch size shall be Mueller or equivalent with standard cube head on stem. Valve stack shall be standard cast iron or equivalent with appropriate cast iron lid. Electric remote control valves shall be "Rainbird" GB-Series valves or an approved equivalent. All electric valves shall be enclosed in a standard 10-inch valve box.

2.12.10 Large Grass Areas - The large open grass areas along primary access roads for each airport shall be irrigated with rotor type heads distributing water from forty (40) to ninety (90) feet in diameter, depending on the available pressure. Sprinklers of substantial construction, such as "Rainbird" 900 or 950 Eagle or Falcon heads or approved equivalent, shall be used to withstand the abuse normally associated with heavy maintenance equipment. These rotor heads shall be on KBI Schedule 80 swing joints or equivalent.

2.12.11 Small Grass Areas - Small grassed areas, which occur adjacent to roadway paving, shall be sprinkled with smaller diameter pop-up heads so that close control can be maintained on windblown mist. All pop-up spray heads shall be "Rainbird" 1800 Series, or approved equivalent, with appropriate nozzles and nozzle screens.

2.12.12 Groundcover Irrigation – Groundcover areas along all access roadways and in the fields shall be irrigated according to the size of the planting areas and obstructions within these areas. The groundcover underplanting for tree dominated areas will require "Rainbird" 1812 Series with appropriate spacing and proper nozzles, to provide adequate coverage. Large open plantings of groundcover shall incorporate rotor type heads such as "Rainbird" 5000 Series rotors, model 5004, or approved equivalent with proper nozzles for proper coverage.

2.12.13 Quick Coupler Valves - Flush lawn quick coupler valves, "Rainbird" 33D or approved equivalent, shall be provided in all landscape planted areas. They shall be located so that all trees and planting areas can be reached by a one hundred (100) foot length of hose.

2.12.14 Irrigation Piping - Irrigation piping shall not be installed on top of roadway slopes or along retaining wall toes, unless cut-off valves are positioned at lower levels and away from structure.

2.12.15 Deflection - Longitudinal deflection at each pipe joint shall not exceed one degree in any direction.

2.12.16 Pipe Bedding: After the trench has been cut to a depth below the barrel of the pipe a distance of three inches, the bedding shall be brought to a point slightly above grade with compacted sand. Bell holes shall be formed, if required, a trough scooped out to grade and the pipe laid and jointed as specified. The sand shall then be brought up in uniform layers of either side of the pipe and over the pipe to a point level with the top of the pipe. Density shall be at least 90 percent of maximum density as determined by ASTM D 698. Moisture content shall be within minus 2 to plus 4 of optimum.

2.12.17 Temporary Irrigation - Temporary irrigation systems used to establish the growth of turf in airfield areas require special considerations. Approval by both the City Engineer and the Airport General Manager or his designee is necessary prior to final design.

2.12.18 Backflow Preventors - All landscape irrigation systems connected to the main City supply shall have backflow preventors installed and certified.

2.13 NATURAL GAS -Plans for proposed buildings or additions to facilities requiring natural gas service shall be submitted to the local gas company for review of demand requirements and available service limits.

2.13.1 Any necessary main extensions or alterations shall be installed in accordance with the recommendations of the local natural gas company, other applicable sections of this Design Criteria Manual and the appropriate plumbing code requirements.

2.13.2 The use of LP gas is prohibited on any HAS airport.

2.14 FUELING SYSTEMS

2.14.1 Design of the Fuel System shall meet or exceed the applicable City of Houston Fire Code.

2.15 LICENSE AGREEMENTS - All proposed additions or extensions to existing Airport mains, natural gas mains, telephone, FAA, or electric ducts, conduits or direct bury cables shall be installed within existing licensed or easement areas, where possible. If existing licensed or easement areas are not adequate, additional licenses or easements will be required.

2.15.1 Minimum licensed area for one (1) utility when licensed area is adjacent to existing licensed area is five (5) feet. Minimum licensed area for one utility when licensed area is not adjacent to existing licensed area is fifteen (15) feet. Minimum licensed area for one (1) utility and drainage pipeline is twenty (20) feet.

2.15.2 Sharing of existing and proposed licensed areas is encouraged. Minimum licensed area widths for more than one facility will be determined by the utilities involved.

2.15.3 The Lessee shall be responsible for furnishing a land survey describing any requested or required License Agreement. Survey data will be submitted to HAS in appropriate electronic format for incorporation in the Airport Master Utility Plan and Property Map.

2.16 SPECIAL AIRFIELD DESIGN STANDARDS

2.16.1 General Information - This section covers all applicable facilities within the Air Operations Area (AOA) that shall be planned, designed and constructed in accordance with current Federal Aviation Administration (FAA) standards and criteria. These consist of Federal Aviation Regulations (FAR's) and Advisory Circulars (AC's) current editions. Copies may be obtained from the FAA Southwest Regional Office and U.S. Department of Transportation.

2.16.2 Design Criteria - In some cases, the AC's offer the Designer a range of criteria, in which case this Design Criteria Manual will establish minimum standards to be used at the HAS airports. If there are design criteria decisions to be made which are not covered in the respective AC or this Manual, the project Designer will make recommendations to the City Engineer on a case-by-case basis.

2.16.3 Critical Design Aircraft – The Critical Design Aircraft (CDA) shall be a composite aircraft representing a collection of aircraft identified for each project for geometric and structural design of airfield pavement; however the standard for IAH is Airplane Design Group VI (ADG) & Taxiway Design Group -7 per AC 150/5300-13A or latest edition, except when dealing with existing facilities that are designed to a lesser standard and confirmed by the Assistant Director, Planning & Programming that the lesser standard should be maintained. Use of the existing standard must be approved on a case by case basis. The standard for HOU is ADG Group IV. For Ellington Airport the CDA will depend on the facility being addressed. The final decision on the applicable CDA rests with the Assistant Director, Planning & Programming. Changes from this standard may be made pertaining to any of the following elements:

1. Runway Length - The CDA will be furnished by the HAS Project Manager.
2. Width, Clearances and Separations of Runways, Taxiways and Parking Aprons - The CDA, or its associated Airplane Design Group per AC 150/5300-13A or latest edition, will be recommended by the Designer based on traffic forecasts furnished by the HAS Project Manager or Tenant Airline.
3. Pavement Design - The CDA will be furnished by the HAS Project Manager.

2.16.4 HAS Approval of Design Criteria - Review by the Assistant Director, Planning and Programming in conjunction with the General Manager of the subject airport of all AOA ADG standards shall be accomplished prior to final design.

2.16.5 Geometrics – All airfield geometry shall conform to the current Airport Layout Plan (ALP). Detailed geometry not included or referenced on the ALP shall conform to the requirements in AC 150/5300-13A or latest edition and other relevant AC's. All filets for "Cockpit-over Centerline steering will be designed in accordance with AC 150/5300-13A or latest edition.

2.16.6 Line of Sight: All runways and runway safety areas shall conform to the line-of-sight criteria of AC 150/5300-13A or latest edition. Taxiways under the control of the Air Traffic Control (ATC) Towers shall be in full view of the tower cab full length and width. An ATC Tower Line-of-Sight (Shadow) Study shall be prepared to determine the line-of-sight acceptability. Ramp control towers, where applicable, may require line-of-sight studies for aircraft parking areas and taxilane intersections.

2.16.6.1 - Line-of-sight considerations may also be required when facilities are planned and designed near, or in the vicinity of, FAA NAVAIDS. Prior to commencement of airfield construction, a FAA Form 7460 shall be completed with appropriate information and exhibits required by the FAA on which FAA can conduct an Aeronautical Study of the proposal – (reference AC 70/7460-2 and FAR Part 77). Non-AOA projects will require an Airspace Form for staging areas, batch plants, construction cranes and other related items. Construction activities (temporary stationary objects) shall be reviewed through the Airports Local Airspace Review Program administered by HAS.

2.16.6.2 No construction activity shall commence until the Airspace Study is completed and comments have been incorporated into the project plans and specifications.

2.16.7 Gradients and Slopes – All paved and turfed areas on the airfield AOA shall conform to the requirements of AC 150/5300-13A or latest edition, and as supplemented by the following criteria:

2.16.7.1 Side slopes on excavation (cut) and embankment (fill) areas outside of runway and taxiway safety areas shall have a slope no steeper than four (4) horizontal to one (1) vertical.

2.16.7.2 All topography and above ground objects, except those required by function for navigation, shall be clear of the imaginary surfaces of FAR Part 77 and shaped or designed to avoid line-of-sight problems and interferences with Airport navigational instruments and facilities. Objects that are within safety areas shall comply with FAR Part 139.

2.16.7.3 The standard crowns (transverse slope) on runways and taxiways shall be one percent, except where flatter grades are necessary due to intersection transitions, in which case they shall be a minimum of 0.5 percent.

2.16.7.4 All paved runway shoulders and taxiway shoulders shall be paved with a minimum of one percent to a maximum of five (5) percent surface gradient. The desirable slope is two (2) percent. The maximum slope shall not be used without approval of the HAS Project Manager. The edge of pavement to edge of shoulder conform joint shall be at the same elevation (no pavement lip).

2.16.7.5 Pavement gradients on aircraft parking aprons shall be 0.5 percent min., except where conforming or transitioning to existing facilities, and except for fifty (50) feet from Terminal buildings at the gate and parking positions which shall be one (1) percent to conform to NFPA Standard 415 on "Aircraft Fueling Ramp Drainage."

2.16.7.5.1 Gradients, slopes, and object clearing criteria for "Obstacle Free Zones", "Runway and Taxiway Safety Areas," and "Runway Protection Zones" shall conform to the standards of AC 150/5300-13A or latest edition for the respective critical aircraft or mix of aircraft.

2.16.8 Air Operations Area (AOA) Storm Drainage - Storm drainage design of the Airport in those areas referred to as the AOA shall be governed by AC 150/5320-5C or the latest published edition. Additional HAS storm drainage design criteria and requirements are located in Section 2.3.3 - Storm Drainage. In those instances where a conflict shall arise between the landside design and the AOA design, the more conservative criteria shall govern.

2.16.8.1 Hydrology - For drainage areas less than two hundred (200) acres the Rational Method is acceptable for determining the amounts of rainfall and runoff in the AOA to be used as a basis for drainage system designs. The Rainfall Intensity Curves presented in the Weather Bureau Technical Paper No. 40 shall be used. The storm interval as presented in AC 150/5320-5 or latest edition shall be used.

2.16.8.2 Computation, Collection and Disposition of Runoff - For projects inside the AOA, the rational method shall be used in the determination of runoff for a drainage area of two hundred (200) acres or less. The Designer shall contact the HAS Project Manager for the method to be used in determining runoff from drainage areas larger than two hundred (200) acres. The coefficients that are utilized in the rational formula, as well as charts for surface flow time calculations, are presented in AC 150/5320-5C or the latest published edition. A topographical map shall be prepared of existing conditions, preferable with a two (2) foot contour intervals as well as a detailed plan showing proposed and ultimate layout of the runways, taxiways, aprons, and building areas with the finished contours drawn to a one (1) foot interval or less. With the addition of various basins, storm pipelines and drainage sketched upon the detailed plane, it will become a working drawing for drainage considerations at the site. Open channel calculations will be in accordance with the FAA Manual procedures utilizing various nomographic solutions presented in AC 150/5320-5C or the latest published edition. The conveyance analysis and design of culverts in the AOA shall be in accordance with the Texas Department of Transportation Hydraulic Manual. Minor losses shall be calculated by methods presented in Section 2.3.3.9 – Design of Closed Storm Drainage System.

2.16.8.3 The Drainage System – Some of the considerations to be used in the design of the drainage system are: construction, pollution control (e.g. oils, greases, first flush pollutants, glycol, etc.), erosion controls, maintenance of the system, and provision for apron waste. The above ground detention or retention of water on the AOA shall not be allowed except as such detention areas currently exist and are not scheduled to be demolished. Where practical, drainage systems within the AOA shall be enclosed systems since open channels may create a hazard to ARFF response equipment and attract wildlife. Due to existing conditions at all three airports and the topography of the Houston area completely enclosing the storm drainage system is not practical; however, to the extent practical designers are encouraged to find ways to enclose as much of the system as possible. In areas where apron waste, deicing fluids, lavatory truck spills, or fuel spills may be an issue, provisions shall be made in the storm drain systems design for the interception of environmental pollutants during both wet and dry weather. Contaminated runoff with pollutant concentrations greater than EPA's benchmarks shall be directed through appropriate pollution abatement equipment or retained for enhanced treatment. The system must ensure that a reasonably foreseeable spill of an environmental contaminant, during both wet and dry weather, is passively contained such that no contaminant is discharged to waters of the state.

2.16.9 Runway Exits

2.16.9.1 High Speed Exit Taxiway – Locations shall be as shown on the Airport Layout Plans. The geometric layout shall either match existing high speed exit taxiways on the Airport or conform to AC 150/5300-13A or latest edition. Larger-than-standard fillet radii shall be investigated where traffic "back turns" are anticipated.

2.16.9.2 Right Angle Connector Taxiway – Right angle intersections shall meet the requirements of cockpit-over-centerline steering and shall conform to the requirements of AC 150/5300-13A or latest edition.

2.16.10 Runway and High Speed Exit Taxiway Grooving – All runway and taxiway grooving shall conform to AC 150/5320-12C or latest edition. Slurry from sawing must be vacuumed as part of the sawing operation and disposed of off the Airport property. Final cleanup shall include flushing by water.

2.16.11 Aprons – Where holding aprons are included in the project scope, the overall location and geometric layout will be furnished by the HAS Project Manager. Widths, clearances, fillet radii and other details not furnished shall conform to AC 150/5300-13, or as recommended by the Designer and approved by the HAS Project Manager.

2.16.11.1 Aircraft parking aprons shall be based on an "Apron Utilization Plan". Apron utilization criteria, including wingtip clearance, shall be approved by the HAS Project Manager and must be within the maneuvering limits of the Aircraft Characteristics Manual of the Critical Design Aircraft. Aircraft service pits shall be located to minimize impact on Portland Cement Concrete (PCC) pavement joint performance.

2.16.12 Pavement Design – Pavement design for all aircraft rated pavements shall be based on FAA methodology and requirements in AC 150/5320-6E or the latest published edition. Standard sections exist for the various aircraft pavements encountered at the HAS Airports. Deviation from these standard sections requires the submittal of a pavement report prepared by a qualified geotechnical and materials engineering firm and a pavement section design sealed by a professional engineer registered in the State of Texas and the approval of the City Engineer. Some sample specifications are included as an Appendix to this Section. All emergency (ARFF) roads, tenant (tug) roads and other service roads shall conform to the design criteria in Section 2.5 - Roads.

2.16.12.1 Pavement Type - All airfield pavements shall be rigid Portland Cement Concrete (PCC) pavement, except blast protective pavement shoulders and blast pads unless otherwise approved by the City Engineer. Blast protective pavement type shall be recommended by the Designer and approved by the City Engineer based on an occasional pass by the critical maintenance or Aircraft Rescue and Fire Fighting (ARFF) equipment.

2.16.12.2 Subgrade, Soils and Pavement Testing Investigation Program – Each project Designer shall prepare a recommended soils program for the HAS Project Manager's review and approval. A final soils report shall be submitted with the final construction documents and included as an appendix to the Project Report.

2.16.12.3 Subgrade Treatment – All subgrades shall be either lime/fly ash-treated or cement/fly ash-treated depending on whether the underlying soil is sand or clay. The thickness of the treated subgrade and quantity of lime, cement, and fly ash shall be specified in the soils report submitted by the Designer.

2.16.12.4 Underdrains – An underdrain/edge drain system is required on all pavement sections unless recommended otherwise by the Designer and approved by the City Engineer. If underdrains are not recommended, the Designer shall present the basis on which they are not recommended and submit to the City Engineer for approval. System layout, elements, and design shall be designed based on soils investigation results, pavement function, and other relevant factors and parameters.

2.16.12.5 Subbase and Base Course – All full strength airfield pavements shall include a nine (9) inch Cement Treated Base course as a minimum.

2.16.12.6 Portland Cement Concrete Pavement (PCC) – PCC shall be designed based on 650 psi flexural strength at twenty-eight (28) days. All pavements shall be reinforced with steel and contain steel reinforcing designed to accommodate the effects of temperature. Keyways will not be allowed. Surface texture may be burlap drag, broom, or other approved micro-texture, except that all runways and high speed exits shall be grooved by sawing.

2.16.12.7 Asphalt Pavement – Asphalt pavement shall not be used except as blast protective pavement on shoulders and blast pads and certain pavements at HOU and EFD as recommended by the Designer and approved by the City Engineer. Mix design proportions and criteria may be either FAA P-401 (AC 150/5370-10) or Texas Department of Transportation Specification No. 340 with specific approval of the City Engineer. All joints between concrete and asphalt shall be sawed and sealed to retard moisture intrusion and vegetation growth.

2.16.13 Pavement Marking – Pavement marking of runways, taxiways, taxilanes and other paved areas within aircraft operations areas shall conform to AC 150/5340- 1J or the currently applicable Advisory Circular and be approved by the HAS Project Manager. Pavement marking on taxiways and aprons may be thermoplastic marking as per the requirements of Advisory Circular 150/5370-10F or latest edition. The use of thermoplastic marking must be justified through a life-cycle cost analysis. Provide Type III Glass Beads.

2.16.14 Turfing – Composition and application of seed fertilizer and sod shall be coordinated with the HAS Project Manager. The placement of all turfing adjacent to paved shoulders and blast pavement shall be 1-1/2 inches below the pavement surface and "pinned down" to avoid lifting by aircraft engine blast

2.16.15 Site Preparation for NAVAIDS – Design criteria for NAVAID critical areas shall conform to AC 150/5300-13A or latest edition. FAA NAVAIDS access roads shall be a minimum of ten (10) feet wide. Airport facilities will be checked for compliance with FAA electromagnetic standards. See FAA Advisory Circular AC 70/7460-2.

2.16.16 Safety and Security During Construction – The Designer shall coordinate with HAS Airport Operations through the Project Manager, regarding all safety and security provisions of the project. Other considerations, depending on the project scope, include interim or temporary pavement marking and lighting, and required Special Provisions to fit the project. Provisions must be made for and included in all contract documents pertaining to safety during construction, construction sequencing, access to the site, Contractor's staging area, haul routes, concrete wash out area, project scales, barricades, fencing, traffic control, etc. AC 150/5370-2E, or latest edition, FAA Southwest Regional Order 5200.5b, and HAS Operational Instructions for Maintenance and Construction on the AOA contains the means by which construction may be accomplished within the AOA.

2.16.17 Construction Specifications – All airfield construction contract documents shall be prepared in accordance with AC 150/5370-10F or the latest published edition. The non-technical (front end "boiler plate") portion (including Notice to Bidders, Instructions to Bidders, Proposal Forms, Bid Schedule Forms, Bond Forms, General and Special Provisions, etc.) of the contract documents shall be prepared based on guidance and direction from the Planning Design and Construction Division and as coordinated with the HAS Project Manager.

2.16.18 Aircraft Rescue and Fire Fighting (ARFF) Roads -This pavement section is typically seven (7) inches of continuously reinforced concrete pavement on nine (9) inches of lime/fly ash or cement/fly ash treated subgrade as appropriate for the subgrade soil type.

2.16.18.1 Load Limits: The minimum vehicle load limit for Fire Apparatus Access Roads is 53,000 lbs. The minimum vehicle load limit for A.O.A. fire apparatus access roads is 113,000 pounds. All bridges and elevated roads shall conform to this requirement.

2.16.18.2 Turning Radius: The external turning radius (wall to wall) shall not be less than fifty-seven (57) feet. The internal radius shall be no less than thirty-five (35) feet. The turn at no time will be less than twenty-two (22) feet wide.

2.16.18.3 Grade: The maximum grade change of any portion of a fire apparatus access road shall not exceed ten (10) feet of rise per hundred (100) feet of run.

END OF SECTION 2

Appendix to Section 2 – Guide Specifications

Please note that many references to "Engineer" are changed to City Engineer, meaning the City Engineer for the Houston Airport System throughout these guide specifications. This is intentional. If there is any question whether to use "engineer" or "City Engineer" please consult the HAS Project Manager.

Sample Specification

CEMENT FLY-ASH STABILIZED SUBGRADE

GENERAL

1.01 DESCRIPTION

A. Consists of spreading Portland Cement and fly ash upon subgrade, mixing, and compacting to required density, lines, grades, and cross-sections when required by soil conditions and approved by the City Engineer.

PRODUCTS

2.01 MATERIALS

A. Portland Cement to be Type I, standard brand, conforming to the requirements of ASTM C150, one sack (cubic foot) to weigh 94 pounds, one barrel to weigh 376 pounds. Bulk cement may be used provided weighing and handling is approved. Subgrade soils are to be free or organics or other deleterious materials. Total soluble sulfates shall not exceed 0.3%. All cement shall be placed in slurry form.

B. Fly ash shall meet the requirements of ASTM C-593, Section 3.2, when sampled and tested in accordance with Section 4, 6, and 8. The loss on ignition shall not exceed 3%. The fly ash shall be Class C fly ash. Lignite fly ash will not be permitted. All fly ash shall be placed in slurry form.

EXECUTION

3.01 PROPORTIONING

A. The ratio of cement to soil will be based on dry material weight and will be established by the City Engineer in the field to provide desired stability. The percentage of moisture in the soil at time of cement and fly ash application is not to exceed the quantity that will permit uniform and intimate mixture of soil, cement, and fly ash during a dry mixing operation, and is not to exceed the specified optimum moisture content for the soil-cement mixture, as determined from ASTM 0558. The percentage of cement and fly ash will be selected so as to achieve a target compressive strength of 150 psi at 28 days and 300 psi at 90 days. The estimated percentages are 4% cement and 10% fly ash.

B. Spreading and Mixing. The cement and fly ash in slurry form will be mixed in a concrete batch plant and transported and spread in ready-mix concrete trucks with some auxiliary equipment if necessary. Do not mix or place this cement/fly ash slurry if the air temperature is below 40°F.

C. Compaction. Compact stabilized subgrade to 95 percent of the maximum density obtained from ASTM 0558 with suitable self-propelled or towed rollers. The top surface of compacted subgrade is to be smooth, dense, and free of compaction ridges, cracks, or loose material, and is to conform to

elevations, grades, and lines shown on the Plans. Moisture content at the time of compaction shall range from ±2 percent dry to 10 percent wet of the optimum moisture content.

A test section of 100 square yards will be installed prior to actual production. The Contractor will be paid for successful completion of this test section.

D. Curing. After compaction and finishing, wet cure the surface for a period of at least 72 hours by sprinkling or prevent moisture loss by placing an approved asphaltic membrane. Adequate wet or membrane curing shall be maintained until placement of next lift of material. During curing, the Contractor is to protect the subgrade from construction and/or other traffic. If required, maintain moisture content during curing by sprinkling or other approved method.

4.01 METHODS OF MEASUREMENT

A. Manipulation of cement and fly ash for stabilized roadway *pavement* subgrade will be measured by the square yard of subgrade actually stabilized and compacted to a 6inch and 8-inch depth and as shown on Plans.

B.Cement for stabilized roadway pavement subgrade, when approved by City Engineer, will be measured by the ton of 2,000 pounds dryweight.

C. Fly ash will be measured by the ton of 2,000 pounds dry weight.

5.01 BASIS OF PAYMENT

A. Payment for manipulation of cement and fly ash for stabilized subgrade to be at the Contract unit price bid per square yard. The price is to include payment for cost of labor and equipment used for manipulating, pulverizing and compaction.

B.Payment for cement for stabilized subgrade will be paid for at Contract unit price per ton complete in place. The payment will be for the dry weight of cement.

C.Fly ash will be paid for at the contract unit price per ton complete in place. The payment will be for the dry weight of fly ash. Payment will be made under: 02730-1 6" Cement Fly ash Stabilized Subgrade-per square yard 02730-2 8" Cement Fly ash Stabilized Subbase -per square yard 02730-3 Cement -per Ton 02730-4 Fly Ash -per ton (TN.

END OF DOCUMENT APPENDIX SECTION 2

Sample Specification

LIME FLY ASH STABILIZED SUBGRADE

SECTION 02730 LIME FLY ASH STABILIZED

SUBGRADE DESCRIPTION

155-1.1 This item shall consist of constructing one or more courses of a mixture of soil, lime, and water in accordance with this specification, and in conformity with the lines, grades, thicknesses, and typical cross sections shown on the plans.

MATERIALS

155-2.1 HYDRATED LIME. All lime shall be manufactured high-calcium quicklime, low calcium quicklime, or hydrated lime, as defined by ASTM C 51, and conform to the requirements of ASTM C 977. By product lime or any form of calcium oxide (CaO), calcium hydroxide (Ca(OH)2), magnesium oxide (MgO) or magnesium hydroxide (Mg(OH)2), alone or in combination, that are not directly produced from quicklime produced from calcining limestone, shall not be permitted.

155-2.2 COMMERCIAL LIME SLURRY. Commercial lime slurry shall be a pumpable suspension of solids in water. The water or liquid portion of the slurry shall not contain dissolved material in sufficient quantity to be naturally injurious or objectionable for the purpose intended. The solids portion of the mixture, when considered on the basis of "solids content," shall consist principally of hydrated lime of a quality and fineness sufficient to meet the following requirements as to chemical composition and residue.

a. Chemical Composition. The "solids content" of the lime slurry shall consist of a minimum of 70%, by weight, of calcium and magnesium oxides.

b. Residue. The percent by weight of residue retained in the "solids content" of lime slurry shall conform to the following requirements:

Residue retained on a No.6 (3360 micron) sieve --Max. 0.0% Residue retained on a No. 10 (2000 micron) sieve -Max. 1.0% Residue retained on a No. 30 (590 micron) sieve --Max. 2.5%

c. Grade. Commercial lime slurry shall conform to one of the following two grades:

Grade 1. The" dry solids content" shall be at least 31 % by weight, of the slurry. Grade
2. The "dry solids content" shall be at least 35%, by weight, of the slurry.

155-2.3 QUICKLIME. ASTM C 618, Class C and the applicable testing procedures modified as follows:

a. Loss by ignition shall not be more than 3.0 percent

b. Combined content of silica oxide (Si02), ferric oxide (Fe203), and aluminum oxide (AI20 3) shall be not less than 50 percent.

c. Lime pozzolan strength, minimum compressive strength shall be 600 psi at 7 days, 130+3 degrees F. d. Fly Ash produced from sub-bituminous coal shall be used. Fly ash from lignite will not be permitted.

155-2.4 PROHIBITED. Lime containing magnesium hydroxide is prohibited.

155-2.5 WATER. Water used for mixing or curing shall be reasonably clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product. Water shall be tested in accordance with and shall meet the suggested requirements of AASHTO T 26. Water known to be of potable quality may be used without test.

155-2.6 SOIL. The soil for this work shall consist of materials on the site or selected materials from other sources and shall be uniform in quality and gradation, and shall be approved by the Engineer. The soil shall be free of roots, sod, weeds, and stones larger than 2-1/2 inches (60 mm).

COMPOSITION

155-3.1 LIME. Lime shall be applied at the rate specified on the plans (7% Lime -Dry Weight) for the depth of subgrade treatment shown.

155-3.2 FLY ASH. Fly ash shall be applied at rate of 8 percent by weight for the depth of Subgrade treatment shown on drawings.

155-3.3 TOLERANCES. At final compaction, the lime and water content for each course of subgrade treatment shall conform to the following tolerances:

Material Tolerance

Lime +0.5% Fly Ash +0.5% Water + 2%, -0%

WEATHER LIMITATIONS

155-4.1 WEATHER LIMITATION. The lime/fly ash-treated subgrade shall not be mixed while the atmospheric temperature is below 40 F (4 C) or when conditions indicate that temperatures may fall below 40 F (4 C) within 24 hours, when it is foggy or rainy, or when soil or subgrade is frozen.

EQUIPMENT

155-5.1 EQUIPMENT. The equipment required shall include all equipment necessary to complete this item such as: grading and scarifying equipment, a spreader for the f1yash flurry or lime slurry, mixing or pulverizing equipment, sheepsfoot and pneumatic or vibrating rollers, sprinkling equipment, and trucks. The equipment for lime slurry and f1yash slurry is to be capable of producing a homogenous and uniform mixture of water and lime or fly ash as applicable.

CONSTRUCTION METHODS

155-6.1 GENERAL. It is the primary requirement of this specification to secure a completed subgrade containing a uniform lime mixture, free from loose or segregated areas, of uniform density and moisture content, well bound for its full depth, and with a smooth surface suitable for placing subsequent courses.

It shall be the responsibility of the Contractor to regulate the sequence of his/her work, to use the proper amount of lime, maintain the work, and rework the courses as necessary to meet the above requirements.

Prior to beginning any lime treatment, the subgrade shall be constructed and brought to grade as specified in Item P-152 "Excavation and Embankment" and shall be shaped to conform to the typical sections, lines, and grades as shown on the plans. The material to be treated shall then be excavated to the secondary grade (proposed bottom of lime treatment) and removed or windrowed to expose the secondary grade. Any wet or unstable materials below the secondary grade shall be corrected, as directed by the Engineer, by scarifying, adding lime, and compacting until it is of uniform stability. The excavated material shall then be spread to the desired cross section.

If the Contractor elects to use a cutting and pulverizing machine that will remove the subgrade material accurately to the secondary grade and pulverize the material at the same time, he will not be required to expose the secondary grade nor windrow the material. However, the Contractor shall be required to roll the subgrade, as directed by the Engineer, and correct any soft areas that this rolling may reveal before using the pulverizing machine. This method will be permitted only where a machine is provided which will ensure that the material is cut uniformly to the proper depth and which has cutters that will plane the secondary grade to a smooth surface over the entire width of the cut. The machine must give visible indication at all times that it is cutting to the proper depth.

155-6.2 APPLICATION. Lime and Fly ash shall be spread only on that area where the first mixing operations can be completed during the same working day. The application and mixing of lime and fly ash with the soil shall be accomplished by the methods hereinafter described as "Slurry Placing." Dry placing of lime and fly ash will not be permitted.

a. Slurry Placing. The lime or fly ash shall be mixed with water in trucks with approved distributors and applied as a thin water suspension or slurry. Commercial lime slurry shall be applied with a lime and fly ash percentage not less than that applicable for the grade used. The distribution of lime shall be attained by successive passes over a measured section of subgrade until the proper amount of lime has been spread. The amount of lime spread shall be the amount required for mixing to the specified depth that will result in the percentage determined in the job mix formula. The distributor truck shall continually agitate the slurry to keep the mixture uniform.

Lime slurry shall be placed first following by mixing. Fly ash slurry shall be placed following the first mixing.

155-6.3 MIXING. The mixing procedure shall be the same for "Dry Placing" or "Slurry Placing" as hereinafter described:

a. First Mixing. The full depth of the treated subgrade shall be mixed with an approved mixing machine. Lime shall not be left exposed for more than 6 hours. The mixing machine shall make two coverages. Water shall be added to the subgrade during mixing to provide a moisture content above the optimum moisture of the material and to ensure chemical action of the lime and subgrade. After mixing, the subgrade shall be lightly rolled to seal the surface and help prevent evaporation of moisture. The water content of the subgrade mixture shall be maintained at a moisture content above the optimum moisture content for a minimum of 48 hours or until the material becomes friable. During the curing period, the material shall be sprinkled as directed. During the interval of time between application and mixing, lime that has been exposed to the open air for 6 hours or more, or to excessive loss due to washing or blowing will not be accepted for payment.

b. Second Mixing. The fly ash slurry shall be applied prior to the second mixing. The full depth of the treated Subgrade shall be mixed with an approved mixing machine. Fly ash shall not be left exposed for more than 6 hours. The mixing machine shall make two coverages. Water shall be added to the Subgrade during mixing to provide moisture content above the optimum moisture of the material. During the interval of time between application and mixing, fly ash that has been exposed to the open air for 6 hours or more, or to excessive loss due to washing or blowing will not be accepted for payment.

c. Final Mixing. If the mixture contains clods after the second mixing, they shall be reduced in size by blading, discing, harrowing, scarifying, or the use of other approved pulverization methods so that the remainder of the clods shall meet the following requirements when tested dry by laboratory sieves:

	Percent
Minimum of clods passing 1 inch sieve	x **[Engineer Specify]**
Minimum of clods passing No.4 sieve	y **[Engineer Specify]**

155-6.4 COMPACTION. Compaction of the mixture shall begin immediately after final mixing. The material shall be aerated or sprinkled as necessary to provide optimum moisture. The field density of the compacted mixture shall be at least 93 percent of the maximum density of laboratory specimens prepared from samples taken from the material in place. The specimens shall be compacted and tested in accordance with ASTM D 1557. The in-place field density shall be determined in accordance with ASTM D 1557 or ASTM D 2922. Any mixture that has not been compacted shall not be left undisturbed for more than 30 minutes. The moisture content of the mixture at the start of compaction shall not be below nor more than 2 percentage points above the optimum moisture content. The optimum moisture content shall be determined in accordance with ASTM D 1557 and shall be less than that amount which will cause the mixture to become unstable during compaction and finishing.

The material shall be sprinkled and rolled as directed by the Engineer. All irregularities, depressions, or weak spots that develop shall be corrected immediately by scarifying the areas affected, adding or removing material as required, and reshaping and recompacting by sprinkling and rolling. The surface of the course shall be maintained in a smooth condition, free from undulations and ruts, until other work is placed thereon or the work is accepted.

In addition to the requirements specified for density, the full depth of the material shown on the plans shall be compacted to the extent necessary to remain firm and stable under construction equipment. After each section is completed, tests will be made by the Engineer. If the material fails to meet the density requirements, it shall be reworked to meet these requirements. Throughout this entire operation, the shape of the course shall be maintained by blading, and the surface upon completion shall be smooth and shall conform with the typical section shown on the plans and to the established lines and grades. Should the material, due to any reason or cause, lose the required stability, density, and finish before the next course is placed or the work is accepted, it shall be recompacted and refinished at the sole expense of the Contractor.

155-6.5 FINISHING AND CURING. After the final layer or course of lime/fly ash treated subgrade has been compacted, it shall be brought to the required lines and grades in accordance with the typical sections. The completed section shall then be finished by rolling, as directed, with a pneumatic or other suitable roller sufficiently light to prevent hair cracking. The finished surface shall not vary more than 3/8 inch (9 mm) when tested with a 16- foot (4.8 meter) straightedge applied parallel with and at right angles to the pavement centerline. Any variations in excess of this tolerance shall be corrected by the Contractor, at his/her own expense, in a manner satisfactory to the Engineer.

The completed section shall be moist-cured for a minimum of 7 days before further courses are added or any traffic is permitted, unless otherwise directed by the Engineer. Subsequent courses shall be applied within 14 days after the lime/fly ash-treated subgrade is cured.

If, for any approved reason, any portion of the lime-fly ash stabilized Subbase top layer cannot be overlaid in 7 days, the Lime-fly ash-stabilized Subbase will be sealed with an approved bituminous material at a rate between 0.10 and 0.15 gallons per square yard.

155-6.6 THICKNESS. The thickness of the lime/fly ash-treated subgrade shall be determined by depth tests or cores taken at intervals so that each test shall represent no more than 300 square yards (250 square meters). When the base deficiency is more than 1/2 inch (12 mm), the Contractor shall correct such areas in a manner satisfactory to the Engineer. The Contractor shall replace, at his/her expense, the base material where borings are taken for test purposes.

155-6.7 MAINTENANCE. The Contractor shall maintain, at his/her own expense, the entire lime/fly ash-treated subgrade in good condition from the start of work until all the work has been completed, cured, and accepted by the Engineer.

METHOD OF MEASUREMENT

155-7.1 The yardage of Lime-fly ash treated subgrade to be paid for shall be the number of square yards (square meters) completed and accepted.

155-7.2 The amount of lime to be paid for shall be the number of tons of dry-lime contained in the lime slurry used as authorized.

155-7.3 The amount of fly ash to be paid for shall be the number of tons of dry fly ash contained in the fly ash slurry used as authorized.

BASIS OF PAYMENT

155-8.1 Payment shall be made at the contract unit price per square yard (square meter) for the lime/fly ash-treated subgrade of the thickness specified. The price shall be full compensation for furnishing all material, except the lime, and for all preparation, delivering, placing and mixing these materials, and all labor, equipment, tools and incidentals necessary to complete this item.

155-8.2 Lime will be paid for under section 02715.

155-8.3 Payment shall be made at the contract unit price per ton of fly ash. This price shall be full compensation for furnishing this material; for all delivery, placing and incorporation of this material; and for all labor, equipment, tool, and incidentals necessary to complete this item.

Payment will be made under:

Item 02730-1	Fly Ash – Per Ton
Item 02730-2	8 inch Thick Lime Fly Ash Stabilized Subbase – per square yard
Item 02730-4	12 inch Thick Lime Fly Ash Stabilized Subbase – per square yard

TESTING REQUIREMENTS

ASTM D 698 Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5 lb (2.49 kg) Rammer and 12-in. (305 mm) Drop

ASTM D 1556 Density of Soil in Place by the Sand-Cone

Method ASTM D 2922 Density of Soil in Place by the Nuclear

Density Method AASHTO T 26 Quality of Water to be used in

Concrete

MATERIAL REQUIREMENTS

ASTM C 977 Quicklime and Hydrated lime for Soil Stabilization

END OF DOCUMENT

Sample Specification

Item P-401 PLANT MIX BITUMINOUS PAVEMENTS

DESCRIPTION

401-1.1 This item shall consist of pavement courses composed of mineral aggregate, polyethylene (if required), and bituminous material mixed in a central mixing plant and placed on a prepared course in accordance with these specifications and shall conform to the lines, grades, thicknesses, and typical cross sections shown on the plans. The surface course composition or type is to be polymer-modified asphalt concrete (PMAC) for runway pavements, and standard asphalt concrete (AC) for runway and taxiway pavements. Each course shall be constructed to the depth, typical section, and elevation required by the plans and shall be rolled, finished, and approved before the placement of the next course.

MATERIALS

401-2.1 AGGREGATE. Aggregates shall consist of crushed stone, *or* crushed gravel, or crushed slag with or without natural sand or other inert finely divided mineral aggregate. The portion of materials retained on the No.4 (4.75 mm) sieve is coarse aggregate. The portion passing the No.4 (4.75 mm) sieve and retained on the No. 200 (0.075 mm) sieve is fine aggregate, and the portion passing the No. 200 (0.075 mm) sieve is mineral filler.

a. Coarse Aggregate. Coarse aggregate shall consist of sound, tough, durable particles, free from adherent films of matter that would prevent thorough coating and bonding with the bituminous material and be free from organic matter and other deleterious substances. The percentage of wear shall not be greater than 35 percent when tested in accordance with ASTM C 131. The sodium sulfate soundness loss shall not exceed 10 percent, or the magnesium sulfate soundness loss shall not exceed 13 percent, after five cycles, when tested in accordance with ASTM C 88.

Aggregate shall contain at least 75 percent by weight of individual pieces having two or more fractured faces and 90 percent by weight having at least one fractured face. The area of each face shall be equal to at least 75 percent of the smallest midsectional area of the piece. When two fractured faces are contiguous, the angle between the planes of fractures shall be at least 30 degrees to count as two fractured faces. Fractured faces shall be obtained by crushing.

The aggregate shall not contain more than a total of 8 percent, by weight, of flat particles, elongated particles, and flat and elongated particles, when tested in accordance with ASTM D 4791 with a value of 5: 1.

b. Fine Aggregate. Fine aggregate shall consist of clean, sound, durable, angular shaped particles produced by crushing stone, slag, or gravel that meets the requirements for wear and soundness specified for coarse aggregate. The aggregate particles shall be free from coatings of clay, silt, or other objectionable matter and shall contain no clay balls. The fine aggregate, including any blended material for the fine aggregate, shall have a plasticity index of not more than 6 and a liquid limit of not more than 25 when tested in accordance with ASTM D 4318.

Natural (nonmanufactured) sand may be used to obtain the gradation of the aggregate blend or to improve the workability of the mix. The amount of sand to be added will be adjusted to produce mixtures conforming to requirements of this specification. The fine aggregate shall not contain more than 10 percent natural sand by weight of total aggregates. If used, the natural sand shall meet the

requirements of ASTM D 1073 and shall have a plasticity index of not more than 6 and a liquid limit of not more than 25 when tested in accordance with ASTM D 4318.

The aggregate shall have sand equivalent values of 45 or greater when tested in accordance with ASTM D 2419.

c. Sampling. ASTM D 75 shall be used in sampling coarse and fine aggregate, and ASTM C 183 shall be used in sampling mineral filler.

401-2.2 MINERAL FILLER. If filler, in addition to that naturally present in the aggregate, is necessary, it shall meet the requirements of ASTM D 242.

401-2.3 BITUMINOUS MATERIAL. Bituminous material shall conform to the following requirements: AASHTO M320 Performance Grade (PG) 64-16.

The Contractor shall furnish vendors' certified test reports for each lot of bituminous material shipped to the project The vendors' certified test report for the bituminous material can be used for acceptance or tested independently by the City Engineer.

401-2.4 ASPHALT MODIFIER. In cases where a polymer-modified asphalt is specified, a polymer additive is to be incorporated into the mix. The polymer additive is to be polyolefinic, primarily low density polyethylene, and is to meet the following requirements:

Test Property	*Specification*	*Limit*
Melt Index	*ASTMD1238*	*1.0-15.0*
Density	*ASTMD 792*	*0.910-*
Melting Point		*230°-275°*

*The type and grade of asphalt cement used for modification is to conform to the requirements of401-*2.3.

The modified asphalt cement is to have the properties indicated in the Table below, for Grade PMHMF:

Property	***PM FL X Grade***	***PM STD Grade***	***PM HMF Grade***	***Specification***
Viscosity @ 140°F Maximum (poises)[1] Minimum	*2,500 1,000*	*5,000 2,500*	*15,000 5,000*	*ASTM D 2171*
Penetration @ 77°F Maximum (mm)[1] Minimum	*120 60*	*90 40*	*60 30*	*ASTM D 5*
Retained Penetration Percent after TFOT Aging	*50+*	*55+*	*60+*	*ASTM D 1754*
Softening Point ^{o}F	*115*	*120*	*125*	*ASTM D 2398*

[1] *Viscosity or penetration value should be used as a basis for specifications.*

The Advanced Asphalt Technologies, LLC process or an approved equal is to be used. Advanced Asphalt Technologies can be reached at 703-444-4200. The additive product to be one which has previously been used in an asphaltic concrete mixture for the purpose of reducing pavement cracking and plastic deformation on airport pavements. Contractor is to submit data which indicates that the product has a proven record of performance regarding compatibility with asphaltic concrete mixtures, blending of the product with asphalt cement, and placing and compacting the mixture. Data submitted to include evaluation of two controlled field applications after a minimum of ten (10) years performance time on airfield pavement under heavy commercial traffic and pre-approval of the product from the Federal Aviation Administration for use on airport pavements. The polyethylene is to be blended with bituminous material in a high-speed, high-shear mixer.

401-2.5 PRELIMINARY MATERIAL ACCEPTANCE. Prior to delivery of materials to the job site, the Contractor shall submit certified test reports to the City Engineer for the following materials:

a. Coarse Aggregate.
   (1) Percent of wear.
   (2) Soundness.
   (3) Unit weight of slag.

b. Fine Aggregate.
   (1) Liquid limit.
   (2) Plasticity index.
   (3) Sand equivalent.

c. Mineral Filler.

d. Bituminous Material *and Polymer Additives.* Test results for bituminous material shall include temperature/viscosity charts for mixing and compaction temperatures.

The certification(s) shall show the appropriate ASTM test(s) for each material, the test results, and a statement that the material meets the specification requirement.

The City Engineer may request samples for testing, prior to and during production, to verify the quality of the materials and to ensure conformance with the applicable specifications.

401-2.6 ANTI-STRIPPING AGENT. Any anti-stripping agent or additive if required shall be heat stable, shall not change the asphalt cement viscosity beyond specifications, shall contain no harmful ingredients, shall be added in recommended proportion by approved method, and shall be a material approved by the Texas Department of Transportation.

COMPOSITION

401-3.1 COMPOSITION OF MIXTURE. The bituminous plant mix shall be composed of a mixture of well- graded aggregate, filler and anti-strip agent if required, *polyethylene additive (if required),* and bituminous material. The several aggregate fractions shall be sized, handled in separate size groups, and combined in such proportions that the resulting mixture meets the grading requirements of the job mix formula (JMF).

401-3.2 JOB MIX FORMULA. No bituminous mixture for payment shall be produced until a job mix formula has been approved in writing by the City Engineer. The bituminous mixture shall be designed using procedures contained in Chapter 5, MARSHALL METHOD OF MIX DESIGN, of the Asphalt Institute's Manual Series No.2 (MS-2), Mix Design Methods for Asphalt Concrete sixth edition.

The design criteria in Table 1 are target values necessary to meet the acceptance requirements contained in paragraph 401-5.2b. The criteria are based on a production process which has a material variability with the following standard deviations:

Stability (lbs.) =270
Flow (0.01 inch) = 1.5
Air Voids (%) = 0.65

If material variability exceeds the standard deviations indicated, the job mix formula and subsequent production targets shall be based on stability greater than shown in Table 1, and the flow and air voids shall be targeted close to the mid-range of the criteria in order to meet the acceptance requirements.

Tensile Strength Ratio (TSR) of the composite mixture, as determined by ASTM D 4867, shall not be less than 75, nor shall the dry strength be less than 200 psi as determined by ASTM D 1074. Anti-stripping agent shall be added to the asphalt, as necessary, to produce a TSR of not less than 75 while maintaining a minimum dry strength of200 psi. If an antistrip agent is required, it will be provided by the Contractor at no additional cost to the Owner. The job mix formula shall be submitted in writing by the Contractor to the City Engineer at least 30 days prior to the start of paving operations and shall include as a minimum:

a. Percent passing each sieve size for total combined gradation, individual gradation of all aggregate stockpiles and percent by weight of each stockpile used in the job mix formula.

b. Percent of asphalt cement.

c. Asphalt performance, viscosity or penetration grade.

d. Number of blows of hammer compaction per side of molded specimen.

e. Mixing temperature.

f. Compaction temperature.

g. Temperature of mix when discharged from the mixer.

h. Temperature-viscosity relationship of the asphalt cement.

i. Plot of the combined gradation on the Federal Highway Administration (FHWA) 45 power gradation curve.

j. Graphical plots of stability, flow, air voids, voids in the mineral aggregate, and unit weight versus asphalt content.

k. Percent natural sand.

l. Percent fractured faces.

m. Percent by weight of flat particles, elongated particles, and flat and elongated particles (and criteria).

n. Tensile Strength Ratio (TSR).

o. Dry strength

p. Antistrip agent (if required).

The Contractor shall submit to the City Engineer the results of verification testing of three (3) asphalt samples prepared at the optimum asphalt content. The average of the results of this testing shall indicate conformance with the job mix formula requirements specified in Tables 1, 2 and 3.

When the project requires asphalt mixtures of differing aggregate gradations, a separate job mix formula and the results of job mix formula verification testing must be submitted for each mix.

The job mix formula for each mixture shall be in effect until a modification is approved in writing by the City Engineer. Should a change in sources of materials be made, a new job mix formula must be submitted within 3 days and approved by the City Engineer in writing before the new material is used. After the initial production job mix formula(s) has/have been approved by the City Engineer and a new or modified job mix formula is required for whatever reason, the subsequent cost of the City Engineer's approval of the new or modified job mix formula will be borne by the Contractor. There will be no time extension given or considerations for extra costs associated with the stoppage of production paving or restart of production paving due to the time needed for the City Engineer to approve the initial, new or modified job mix formula.

Where polymer-modified asphalt is specified, the amount of polymer additive to be used in the mixture is to be based on previous laboratory studies and recommendations of the manufacturer/supplier. The additive shall be used in the laboratory mix design that is submitted to the City Engineer for approval. The polyethylene content is to be a minimum of 5.5 *percent by weight of the total polymer-modified asphalt cement content. The job mix formula will be developed by the polyethylene supplier using aggregate and asphalt cement furnished by the Contractor. The formula is to be submitted in writing to the City Engineer at least 30 days prior to the planned start of paving operations and is to indicate the definite percentage of each sieve fraction of aggregate, the percentage of asphalt cement, the percentage of polyethylene, and the temperature of the completed mixture when discharged from the mixer. For Advanced Asphalt Technologies asphalt, the bitumen content is expected to be toward the lower end of the range shown on Table 3.*

TABLE 1 – MARSHALL DESIGN CRITERIA	
TEST PROPERTY	Pavements Designed for Aircraft Gross Weights of 60,000 Lbs. or More of Tire Pressures of 100 psi or More
Number of Blows	75
Stability, pounds (newtons) minimum	a. 2,500 for PMAC b. 2,150 for AC
Flow, 0.01 in (0.25 mm)	10 – 14
Air Voids (percent)	22.8 – 4.2
Percent voids in mineral aggregate, minimum	See Table 2

TABLE 2 – MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE		
Maximum Particle Size		Minimum Voids in Mineral Aggregate
in.	Mm	Percent
½	12.5	14
¾	19.0	13
1	25	12
1-1/2	37.5	11

The mineral aggregate shall be of such size that the percentage composition by weight, as determined by laboratory sieves, will conform to the gradation or gradations specified in Table 3 when tested in accordance with ASTM C 136 and C 117.

The gradations in Table 3 represent the limits that shall determine the suitability of aggregate for use from the sources of supply. The aggregate, as selected (and used in the JMF), shall have a gradation within the limits designated in Table 3 and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve, or vice versa, but shall be well graded from coarse to fine.

Deviations from the final approved mix design for bitumen content and gradation of aggregates shall be within the action limits for individual measurements as specified in paragraph 401-6.5a. *For polymer-modified asphalt, the bitumen content is to be determined using the Ignition Test Method, ASTM D* I *6307.* The limits still will apply if they fall outside the master grading band in Table 3.

The maximum size aggregate used shall not be more than one-half of the thickness of the course being constructed except where otherwise shown on the plans or ordered by the City Engineer.

TABLE 3 – AGGREGATE – BITUMINOUS PAVEMENTS	
Sieve Size	Percentage by Weight Passing Sieve
1 ½ in. (37.50 mm)	-
1 in. (25.0 mm)	-
¾ in. (19.0 mm)	100
½ in. (12.5 mm)	79-99
3/8 in. (9.5 mm)	68-88
No. 4 (4.74 mm)	48-68
No. 8 (2.36 mm)	33-53

No. 16 (1.18 mm)	20-40
No. 30 (0.60 mm)	14-30
No. 50 (0.30 mm)	9-21
No. 100 (0.15 mm)	6-16
No. 200 (0.075 mm)	3-6
Asphalt percent* Stone or Gravel	5.0-7.5

**For polymer-modified asphalt, the values shown are for total binder content.*

The aggregate gradations shown are based on aggregates of uniform specific gravity. The percentages passing the various sieves shall be corrected when aggregates of varying specific gravities are used, as indicated in the Asphalt Institute Manual Series No.2 (MS-2), Chapter 3.

401-3.4 TEST SECTION. Prior to full production, the Contractor shall prepare and place a quantity of bituminous mixture according to the job mix formula(s). The amount of mixture shall be sufficient to construct a test section 300 ft long and 20-30 ft wide, placed in two lanes, with a longitudinal cold joint, and shall be of the same depth specified for the construction of the course which it represents. A cold joint is an exposed construction joint at least 4 hours old or whose mat has cooled to less than 160°F.

The test section may be located in an area to be paved in the project, as approved by the ***City*** *Engineer, provided that whenever possible, the test section is to be placed in an area where it will receive little traffic.* The underlying grade or pavement structure upon which the test section is to be constructed shall be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section shall be the same type and weight to be used on the remainder of the course represented by the test section.

The *test* section shall be evaluated for acceptance as a single lot in accordance with the acceptance criteria in paragraph 401-5.1 and 401-6.3. The *test* section shall be divided into equal sublots. As a minimum the test section shall consist of 3 sublots.

The test section shall be considered acceptable if; 1) stability, flow, mat density, air voids, and joint density are 90 percent or more within limits; 2) gradation and asphalt content are within the action limits specified in paragraphs 401-6.5a and 5b; and 3) the voids in the mineral aggregate are within the limits of Table 2.

If the initial test section should prove to be unacceptable, the necessary adjustments to the job mix formula, plant operation, placing procedures, and/or rolling procedures shall be made. A second test section shall then be placed. If the second test section also does not meet specification requirements, both sections shall be removed at the Contractor's expense. Additional test sections, as required, shall be constructed and evaluated for conformance to the specifications. Any additional sections that are not acceptable shall be removed at the Contractor's expense.

Full production shall not begin until an acceptable section has been constructed and accepted in writing by the City Engineer. Once an acceptable test section has been placed, payment for the initial test section and the section that meets specification requirements shall be made in accordance with paragraph 401-8.1. *Each accepted test section is to be defined as one lot of pavement.*

Job mix control testing shall be performed by the Contractor at the start of plant production and in conjunction with the calibration of the plant for the job mix formula. If aggregates produced by the plant do not satisfy the gradation requirements or produce a mix that meets the JMF it will be necessary to reevaluate and redesign the mix using plant-produced aggregates. Specimens shall be prepared and the optimum bitumen content determined in the same manner as for the original design tests.

Contractor will not be allowed to place the test section until the Contractor Quality Control Program, showing conformance with the requirements of Paragraph 401-6.1, has been approved, in writing, by the City Engineer.

401-3.5 TESTING LABORATORY. The Contractor's laboratory used to develop the job mix formula shall meet the requirements of ASTM D 3666 including the requirement to be accredited by a national authority such as the National Voluntary Laboratory Accreditation Program (NVLAP), the American Association for Laboratory Accreditation (AALA), or AASHTO Accreditation Program (AAP). Laboratory personnel shall meet the requirements of Section 100 of the General Provisions. A certification signed by the manager of the laboratory stating that it meets these requirements shall be submitted to the City Engineer prior to the start of construction. The certification shall contain as a minimum:

a. Qualifications of personnel; laboratory manager, supervising technician, and testing technicians.

b. A listing of equipment to be used in developing the job mix.

c. A copy of the laboratory's quality control system.

d. Evidence of participation in the AASHTO Materials Reference Laboratory (AMRL) program. e. ASTM D 3666 certification of accreditation by a nationally recognized accreditation program.

CONSTRUCTION METHODS

401-4.1 WEATHER LIMITATIONS. The bituminous mixture shall not be placed upon a wet surface or when the surface temperature of the underlying course is less than specified in Table 4. The temperature requirements may be waived by the City Engineer, if requested; however, all other requirements including compaction shall be met.

TABLE 4 BASE TEMPERATURE LIMITATIONS		
Mat Thickness	Base Temperature (Minimum)	
	Deg. F	Deg. C
3 in (7.5 cm) or greater	40	4
Greater than 1 in. (2.5 cm) but less than 3 in. (7.5 cm)	45	7
1 in. (2.5 cm) or less	50	10

401-4.2 BITUMINOUS MIXING PLANT. Plants used for the preparation of bituminous mixtures shall conform to the requirements of ASTM D 995 with the following changes:

a. Requirements for All Plants.

(1) Truck Scales. The bituminous mixture shall be weighed on approved scales furnished by the Contractor, or on certified public scales at the Contractor's expense. Scales shall be inspected and sealed as often as the City Engineer deems necessary to assure their accuracy. Scales shall conform to the requirements of the General Provisions, Section 90-01.

In lieu of scales, and as approved by the City Engineer, asphalt mixture weights may be determined by the use of an electronic weighing system equipped with an automatic printer that weighs the total paving mixture. Contractor must furnish calibration certification of the weighing system prior to mix production and as often thereafter as requested by the City Engineer.

(2) Testing Facilities. The Contractor shall provide laboratory facilities at the plant for the use of the City Engineer's acceptance testing and the Contractor's quality control testing. The City Engineer will always have priority in the use of the laboratory. The lab shall have sufficient space and equipment so that both testing representatives (City Engineer's and Contractor's) can operate efficiently. The lab shall also meet the requirements of ASTM D 3666.

The plant testing laboratory shall have a floor space area of not less than 150 square feet, with a ceiling height of not less than *7-1/2* feet. The laboratory shall be weather tight, sufficiently heated in cold weather, air-conditioned in hot weather to maintain temperatures for testing purposes of 70 degrees F +/- 5 degrees F. The plant testing laboratory shall be located on the plant site to provide an unobstructed view, from one of its windows, of the trucks being loaded with the plant mix materials.

Laboratory facilities shall be kept clean, and all equipment shall be maintained in proper working condition. The City Engineer shall be permitted unrestricted access to inspect the Contractor's laboratory facility and witness quality control activities. The City Engineer will advise the Contractor in writing of any noted deficiencies concerning the laboratory facility, equipment, supplies, or testing personnel and procedures. When the deficiencies are serious enough to be adversely affecting the test results, the incorporation of the materials into the work shall be suspended immediately and will not be permitted to resume until the deficiencies are satisfactorily corrected.

As a minimum, the plant testing laboratory shall have:

(a) Adequate artificial lighting
(b) Electrical outlets sufficient in number and capacity for operating the required testing equipment and drying samples.
(c) Fire extinguishers (2), Underwriters Laboratories approved
(d) Work benches for testing, minimum 2-12 feet by 10 feet.
(e) Desk with 2 chairs
(f) Sanitary facilities convenient to testing laboratory
(g) Exhaust fan to outside air, minimum 12 inch blade diameter
(h) A direct telephone line and telephone including a FAX machine operating 24 hours per day, seven days per week
(i) File cabinet with lock for City Engineer
(j) Sink with running water, attached drain board and drain capable of handling separate material
(k) Metal stand for holding washing sieves
(l) Two element hot plate or other comparable heating device, with dial type thermostatic controls for drying aggregates
(m) Mechanical shaker and appropriate sieves (listed in JMF, Table 3) meeting the requirements of ASTM E-II
for determining the gradation of coarse and fine aggregates in accordance with ASTM C 136
(n) Marshall testing equipment meeting ASTM D 6926, ASTM D 6927, automatic compaction equipment capable of compacting three specimens at once and other apparatus as specified in ASTM C 127, D 2172, D 2726, and D 2041
(o) Oven, thermostatically controlled, inside minimum 1 cubic foot
(p) Two volumetric specific gravity flasks, 500 cc
(q) Other necessary hand tools required for sampling and testing
(r) Library containing contract specifications, latest ASTM volumes 4.01, 4.02, 4.03 and 4.09, AASHTO standard specification parts I and II, and Asphalt Institute Publication MS-2.
(s) Equipment for Theoretical Specific Gravity testing including a 4,000 cc pycnometer, vacuum pump capable of maintaining 30 ml mercury pressure and a balance, 16-20 kilograms with accuracy of 0.5 grams
(t) Extraction equipment, centrifuge and reflux types and ROTOflex equipment
(u) A masonry saw with diamond blade for trimming pavement cores and samples
(v) Telephone

Approval of the plant and testing laboratory by the City Engineer requires all facilities and equipment to be in good working order during production, sampling and testing. Failure to provide the specified facilities shall be sufficient cause for disapproving bituminous plant operations.

The Owner shall have access to the lab and the plant whenever Contractor is in production.

(3) Inspection of Plant. The City Engineer, or City Engineer's authorized representative, shall have access, at all times, to all areas of the plant for checking adequacy of equipment; inspecting operation of the plant: verifying weights, proportions, and material properties; and checking the temperatures maintained in the preparation of the mixtures.

(4) Storage Bins and Surge Bins. Use of surge and storage bins for temporary storage of hot bituminous mixtures will be permitted as follows:

(a) The bituminous mixture may be stored in surge bins for *a* period of time not to exceed 3 hours.

(b) The bituminous mixture may be stored in insulated storage bins for a period of time not to exceed 24 hours. The bins shall be such that mix drawn from them meets the same requirements as mix loaded directly into trucks.

If the City Engineer determines that there is an excessive amount of heat loss, segregation, or oxidation of the mixture due to temporary storage, no temporary storage will be allowed.

(5) Blending of Asphalt Cement and Polyethylene. Off-site blending of the asphalt cement and the polyethylene will not be permitted. Blending of the asphalt cement and polyethylene will be accomplished by the supplier of the modifier in a mobile plant located at the asphalt plant. The plant shall provide a level and stable site for the mobile plant with dimensions of at least 65feet by 12feet. A clear height of at least 20 feet is required for production. The site is to be situated adjacent to both the base asphalt cement storage tank and asphalt proportioning pump. The blending unit will be connected to the existing pipelines of the asphalt plant by the supplier.

The supplier will also provide fittings and lines for the connection. The Contractor is to make available valves and gates to access the storage tank, the line to the proportioning pump, and, when needed, to install a return line.

(6) Production Limitations. The capacity of one mobile mixing unit is 12 tons of modified asphalt per hour.

More than one unit can be set up at the plant to support a large operation. No additional compensation will be considered or allowed by reason of the effects of the above limitations on mix production or placement.

401-4.3 HAULING EQUIPMENT. Trucks used for hauling bituminous mixtures shall have tight, clean, and smooth metal beds. To prevent the mixture from adhering to them, the truck beds shall be lightly coated with a minimum amount of paraffin oil, lime solution, or other approved material. Petroleum products shall not be used for coating truck beds. Each truck shall have a suitable cover to protect the mixture from adverse weather. When necessary, to ensure that the mixture will be delivered to the site at the specified temperature, truck beds shall be insulated or heated and covers shall be securely fastened.

401-4.4 BITUMINOUS PAVERS. Bituminous pavers shall be self-propelled with an activated heated screed, capable of spreading and finishing courses of bituminous plant mix material that will meet the specified thickness, smoothness, and grade. The paver shall have sufficient power to propel itself and the hauling equipment without adversely affecting the finished surface.

The paver shall have a receiving hopper of sufficient capacity to permit a uniform spreading operation. The hopper shall be equipped with a distribution system to place the mixture uniformly in front of the screed without segregation. The screed shall effectively produce a finished surface of the required evenness and texture without tearing, shoving, or gouging the mixture.

The paver shall be equipped with a control system capable of automatically maintaining the specified screed elevation. The control system shall be automatically actuated from either a reference line and/or through a system of mechanical sensors or sensor-directed mechanisms or devices that will maintain the paver screed at a predetermined transverse slope and at the proper elevation to obtain the required surface. The transverse slope controller shall be capable of maintaining the screed at the desired slope within plus or minus 0.1 percent.

The controls shall be capable of working in conjunction with any of the following attachments:

a. Ski-type device of not less than 30 feet (9.14 m) in length.
b. Taut stringline (wire) set to grade.
c. Laser control.
d. ***An automatic grade control system is to be used/or the runway/taxiway overlay courser(s).***

If, during construction, it is found that the spreading and finishing equipment in use leaves tracks or indented areas, or other blemishes in the pavement that are not satisfactorily corrected by the scheduled operations, the use of such equipment shall be discontinued and satisfactory equipment shall be provided by the Contractor.

401-4.5 ROLLERS. Rollers of the vibratory, steel wheel and pneumatic-tired type shall be used. They shall be in good condition, capable of operating at slow speeds to avoid displacement of the bituminous mixture. The number, type, and weight of rollers shall be sufficient to compact the mixture to the required density while it is still in a workable condition.

All rollers shall be specifically designed and suitable for compacting hot mix bituminous concrete and shall be properly used. Rollers that impair the stability of any layer of a pavement structure or underlying soils shall not be used. Depressions in pavement surfaces caused by rollers shall be repaired by the Contractor at its own expense.

The use of equipment that causes crushing of the aggregate will not be permitted. ***Additionally, "three wheel" (three-drum) steel rollers will not be permitted***

a. Nuclear Densometer. The Contractor shall have on site a nuclear densometer during all paving operations in order to assist in the determination of the optimum rolling pattern, type of roller and frequencies, as well as to monitor the effect of the rolling operations during production paving. The Contractor shall also supply a qualified technician during all paving operations to calibrate the nuclear densometer and obtain accurate density readings for all new bituminous concrete. These densities shall be supplied to the City Engineer upon request at any time during construction. No separate payment will be made for supplying the density gauge and technician.

401-4.6 PREPARATION OF BITUMINOUS MATERIAL. The bituminous material shall be heated in a manner that will avoid local overheating and provide a continuous supply of the bituminous material to the mixer at a uniform temperature. The temperature of the bituminous material delivered to the mixer shall be sufficient to provide a suitable viscosity for adequate coating of the aggregate

particles, but shall not exceed 325 degrees F (160 degrees C), unless otherwise required by the manufacturer.

When polymer modified asphalt is specified, the temperature of the modified bituminous material delivered to the mix shall be sufficient to produce a suitable viscosity for adequate coating of the aggregate particles, but is not to be less than 300°F nor greater than 330°F.

401-4.7 PREPARATION OF MINERAL AGGREGATE. The aggregate for the mixture shall be heated and dried prior to introduction into the mixer. The maximum temperature and rate of heating shall be such that no damage occurs to the aggregates. The temperature of the aggregate and mineral filler shall not exceed 350 degrees F (175 degrees C) when the asphalt is added. Particular care shall be taken that aggregates high in calcium or magnesium content are not damaged by overheating. The temperature shall not be lower than is required to obtain complete coating and uniform distribution on the aggregate particles and to provide a mixture of satisfactory workability.

401-4.8 PREPARATION OF BITUMINOUS MIXTURE. The aggregates and the bituminous material shall be weighed or metered and introduced into the mixer in the amount specified by the job mix formula. The combined materials shall be mixed until the aggregate obtains a uniform coating of bitumen and is thoroughly distributed throughout the mixture. Wet mixing time shall be the shortest time that will produce a satisfactory mixture, but not less than 25 seconds for batch plants. The wet mixing time for all plants shall be established by the Contractor, based on the procedure for determining the percentage of coated particles described in ASTM D 2489, for each individual plant and for each type of aggregate used. The wet mixing time will be set to achieve 95 percent of coated particles. For continuous mix plants, the minimum mixing time shall be determined by dividing the weight of its contents at operating level by the weight of the mixture delivered per second by the mixer. The moisture content of all bituminous mixtures upon discharge shall not exceed 0.5 percent.

401-4.9 PREPARATION OF THE UNDERLYING SURFACE. Immediately before placing the bituminous mixture, the underlying course shall be cleaned of all dust and debris. A tack coat, as applicable, is to be applied in accordance with Section 02748, as required by the Contract Drawings, or as directed by the City Engineer.

401-4.10 LAYDOWN PLAN, TRANSPORTING, PLACING, AND FINISHING. Prior to the placement of the bituminous mixture, the Contractor shall prepare a laydown plan for approval by the City Engineer. This is to minimize the number of cold joints in the pavement. The laydown planshall include the sequence of paving laydown by stations, width of lanes, temporary ramp location(s),and laydown temperature. The laydown plan shall also include estimated time of completion for each portion of the work (i.e. milling, paving, rolling, cooling, etc.). Modifications to the laydown plan shall be approved by the City Engineer.

The bituminous mixture shall be transported from the mixing plant to the site in vehicles conforming to the requirements of paragraph 401-4.3. Deliveries shall be scheduled so that placing and compacting of mixture is uniform with minimum stopping and starting of the paver. Hauling over freshly placed material shall not be permitted until the material has been compacted, as specified, and allowed to cool to atmospheric temperature.

For all runway, taxiway and apron pavements, Contractor shall use a stringline to place each lane of each lift of bituminous surface course. However, at the Contractor's option, Contractor shall use stringline for first lift of bituminous surface course and then survey the grade of that lift. Provided grades of that lift of

bituminous surface course meet the tolerances of paragraphs 401-5.2b (6), then Contractor may place successive lifts of bituminous surface course using a long ski, or laser control per paragraph 401-4.4. However, Contractor shall survey each lift of bituminous surface course and certify to City Engineer that every lot of each lift meets the grade tolerances of paragraph 4015.2b (6) before the next lift can be placed without a stringline. If the grades of a single lot do not meet the tolerances of 401-5.2b (6), then the Contractor shall use a stringline for each entire lift. Corrective action in paragraph 401-5.2b(6) applies to the final lift of surface course; however, for multiple lift construction, the Contractor shall correct to ensure the final lift of surface course is a minimum of 1.5 inches and a maximum of 3 inches.

The Contractor may elect to use a material transfer vehicle to deliver mix to the paver.

Where polymer modified asphalt is specified, the modified asphalt mix is to be delivered to the paver at $305^{o} \pm 10^{o}$ F. Breakdown rolling must be completed at a temperature greater than 270°F.

Paving during nighttime construction shall require the following:

a. All paving machines, rollers, distribution trucks and other vehicles required by the Contractor for his operations shall be equipped with artificial illumination sufficient to safely complete the work.

b. Minimum illumination level shall be twenty (20) horizontal foot candles and maintained in the following areas:

(1) An area of 30 feet wide by 30 feet long immediately behind the paving machines during the operations of the machines.

(2) An area 15 feet wide by 30 feet long immediately in front and back of all rolling equipment, during operation of the equipment.

(3) An area 15 feet wide by 15 feet long at any point where an area is being tack coated prior to the placement of pavement.

c. As partial fulfillment of the above requirements, the Contractor shall furnish and use complete artificial lighting units with a minimum capacity of 3,000 watt electric beam lights, affixed to all equipment in such a way to direct illumination on the area under construction.

d. In addition, the Contractor shall furnish *a minimum of* 4 portable floodlight units or *as directed by the City Engineer.*

If the Contractor places any out of specification mix in the project work area, the Contractor is required to remove it at its own expense, to the satisfaction of the City Engineer. If the Contractor has to continue placing non-payment bituminous concrete, as directed by the City Engineer, to make the surfaces safe for aircraft operations, the Contractor shall do so to the satisfaction of the City Engineer. It is the Contractor's responsibility to leave the facilities to be paved in a safe condition ready for aircraft operations. No consideration for extended closure time of the area being paved will be given. As a first order of work for the next paving shift, the Contractor shall remove all out of specification material and replace with approved material to the satisfaction of the City Engineer. When the above situations occur, there will be no consideration given for additional construction time or payment for extra costs.

The initial placement and compaction of the mixture shall occur at a temperature suitable for obtaining density, surface smoothness, and other specified requirements but not less than 250 degrees F (121 degrees C).

Edges of existing bituminous pavement abutting the new work shall be saw cut and carefully removed as shown on the drawings and painted with bituminous tack coat before new material is placed against it.

Upon arrival, the mixture shall be placed to the full width by a bituminous paver. It shall be struck off in a uniform layer of such depth that, when the work is completed, it shall have the required thickness and conform to the grade and contour indicated. The speed of the paver shall be regulated to eliminate pulling and tearing of the bituminous

Unless otherwise permitted, placement of the mixture shall begin along the centerline of a crowned section or on the high side of areas with a one-way slope. The mixture shall be placed in consecutive adjacent strips having a minimum width of 15 ft except where edge lanes require less width to complete the area. Additional screed sections shall not be attached to widen paver to meet the minimum lane width requirements specified above unless additional auger sections are added to match. The longitudinal joint in one course shall offset the longitudinal joint in the course immediately below by at least I foot (30 cm); however, the joint in the surface top course shall be at the centerline of crowned pavements. Transverse joints in one course shall be offset by at least 10 feet (3 m) from transverse joints in the previous course.

Transverse joints in adjacent lanes shall be offset a minimum of 10 feet (3 m).

On areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture may be spread and luted by hand tools. Areas of segregation in the surface course, as determined by the City Engineer, shall be removed and replaced at the Contractor's expense. The area shall be removed by saw cutting and milling a minimum of 2 inches deep. The area to be removed and replaced shall be a minimum width of the paver and a minimum of 10 feet long.

401-4.11 COMPACTION OF MIXTURE. After placing, the mixture shall be thoroughly and uniformly compacted by power rollers. The surface shall be compacted as soon as possible when the mixture has attained sufficient stability so that the rolling does not cause undue displacement, cracking or shoving. The sequence of rolling operations and the type of rollers used shall be at the discretion of the Contractor, *except that 3-Hlheel steel drum rollers are not to be used.* The speed of the roller shall, at all times, be sufficiently slow to avoid displacement of the hot mixture and be effective in compaction. Any displacement occurring as a result of reversing the direction of the roller, or from any other cause, shall be corrected at once.

Sufficient rollers shall be furnished to handle the output of the plant. Rolling shall continue until the surface is of uniform texture, true to grade and cross section, and the required field density is obtained.

To prevent adhesion of the mixture to the roller, the wheels shall be equipped with a scraper and kept properly moistened but excessive water will not be permitted.

In areas not accessible to the roller, the mixture shall be thoroughly compacted with approved power driven tampers. Tampers shall weigh not less than 275 pounds have a tamping plate width not less than 15 inches, be rated at not less than 4,200 vibrations per minute, and be suitably equipped with a standard tamping plate wetting device.

Any mixture that becomes loose and broken, mixed with dirt, contains check-cracking, or in any way defective shall be removed and replaced with fresh hot mixture and immediately compacted to conform to the surrounding area. This work shall be done at the Contractor's expense. Skin patching shall not be allowed.

401-4.12 JOINTS. The formation of all joints shall be made in such a manner as to ensure a continuous bond between the courses and obtain the required density. All joints shall have the same texture as other sections of the course and meet the requirements for smoothness and grade.

The roller shall not pass over the unprotected end of the freshly laid mixture except when necessary to form a transverse joint. When necessary to form a transverse joint, it shall be made by means of placing a bulkhead or by tapering the course. The tapered edge shall be cut back to its full depth and width on a straight line to expose a vertical face prior to placing the adjacent lane. In both methods, all contact surfaces shall be given a tack coat of bituminous material before placing any fresh mixture against the joint. '

Longitudinal joints which are irregular, damaged, uncompacted, or otherwise defective or which have been left exposed for more than 4 hours, or whose surface temperature has cooled to less than 160 F shall be cut back to expose a clean, sound surface for the full depth of the course. All contact surfaces shall be given a tack coat of bituminous material prior to placing any fresh mixture against the joint. The cost of this work and tack coat shall be considered incidental to the cost of the bituminous course.

401-4.13 SKID RESISTANT SURFACES/SAW-CUT GROOVING. If shown on the plans, skid resistant surfaces for asphalt pavements shall be provided by construction of saw-cut grooves. Pavement shall be sufficiently cooled prior to grooving.

Transverse grooves shall be saw-cut in the pavement forming a *1/4* inch wide by *1/4* inch deep by 1-1/2 inches center to center configuration. The grooves shall be continuous for the entire length of the pavement. They shall be saw-cut transversely in the pavement to within 10 feet of the pavement edge to allow adequate space for equipment operation. The tolerance for saw-cut grooves shall meet the following:

a. Alignment tolerance -Plus or minus *1-1/2* inches in alignment for 75 feet.

b. Groove tolerance -Minimum depth 3/16 inch, except that not more than 60 percent of the grooves shall be less than 1/4 inch. Maximum depth 5/16 inch. Minimum width 1/4 inch. Maximum width *5/16* inch.

c. Center-to-center spacing -Minimum spacing *1-3/8* inches. Maximum spacing *1-5/8* inches.

Grooves shall not be less than 6 inches and not more than 18 inches from in-pavement light fixtures. Cleanup of waste material shall be continuous during the grooving operation. Waste material shall be disposed of off-site in accordance with governing laws and regulations. All arrangements for disposal of waste material shall be made prior to the start of grooving. Waste material shall not be allowed to enter the airport storm or sanitary sewer system.

MATERIAL ACCEPTANCE

401-5.1 ACCEPTANCE SAMPLING AND TESTING. Unless otherwise specified, all acceptance sampling and testing necessary to determine conformance with the requirements specified in this section will be performed by the City Engineer at no cost to the Contractor except that coring and as required in this section shall be completed and paid for by the Contractor. Testing organizations performing these tests, shall meet the requirements of ASTM D 3666. All equipment in Contractor furnished laboratories shall be calibrated by an independent testing organization prior to the start of operations at the Contractor's expense.

a. Plant-Produced Material. Plant-produced material shall be tested for stability, flow, and air voids on a lot basis. Sampling shall be from material deposited into trucks at the plant or from trucks at the job site. Samples shall be taken in accordance with ASTM D 979. A lot will consist of:

- one day or shift's production not to exceed 2,000 tons (I 814 000 kg), or
- a half day or shift's production where a day's production is expected to consist of between 2,000 and 4,000 tons (1 814000 and 3 628 000 kg), or
- similar subdivisions for tonnages over 4,000 tons (3 628000 kg).

Where more than one plant is simultaneously producing material for the job, the lot sizes shall apply separately for each plant.

(1) Sampling. Each lot will consist of four equal sublots. Sufficient material for preparation of test specimens for all testing will be sampled by the City Engineer on a random basis, in accordance with the procedures contained in ASTM D 3665. One set of laboratory compacted specimens will be prepared for each sublot in accordance with ASTM D 6926, at the number of blows required by paragraph 401-3.2, Table J. Each set of laboratory compacted specimens will consist of three test portions prepared from the same sample increment.

The sample of bituminous mixture may be put in a covered metal tin and placed in an oven for not less than 30 minutes or more than 60 minutes to stabilize to compaction temperature. The compaction temperature of the specimens shall be as specified in the job mix formula.

(2) Testing. Sample specimens shall be tested for stability and flow in accordance with ASTM D 6927. Air voids will be determined by the City Engineer in accordance with ASTM D 3203.

Prior to testing, the bulk specific gravity of each test specimen shall be measured by the City Engineer in accordance with ASTM D 2726 using the procedure for laboratory-prepared thoroughly dry specimens, or ASTM D 1188, whichever is applicable, for use in computing air voids and pavement density.

For air voids determination, the theoretical maximum specific gravity of the mixture shall be measured twice for each sublot in accordance with ASTM D 2041, Type C, D or E container. The value used in the air voids computation for each sublot shall be based on the average of the two maximum specific gravity measurements for the sub lot.

The stability and flow for each sublot shall be computed by averaging the results of all test specimens representing that sublot.

(3) Acceptance. Acceptance of plant produced material for stability, flow, and air voids shall be determined by the City Engineer in accordance with the requirements of paragraph 401-5 .2b.

b. Field Placed Material. Material placed in the field shall be tested for mat and joint density on a lot basis.

(1) Mat Density. The lot size shall be the same as that indicated in paragraph 401-5.la and shall be divided into four equal sub lots. One core of finished, compacted materials shall be taken by the Contractor from each sub lot. Core locations will be determined by the City Engineer on a random basis in accordance with procedures contained in ASTM D 3665. Cores shall not be taken closer than one foot from a transverse or longitudinal joint.

(2) Joint Density. The lot size shall be the total length of longitudinal joints constructed by a lot of material as defined in paragraph 401-5.la. The lot shall be divided into four equal sublots. One core of finished, compacted materials shall be taken by the Contractor from each sub lot. Core locations will be determined by the City Engineer on a random basis in accordance with procedures contained in ASTM D 3665. ALL CORING SHALL BE CENTERED ON THE JOINT. THE MINIMUM CORE DIAMETER FOR JOINT DENSITY DETERMINATION SHALL BE 5 INCHES.

(3) Sampling. Samples shall be neatly cut with a core drill. The cutting edge of the core drill bit shall be of hardened steel or other suitable material with diamond chips embedded in the metal cutting edge. The minimum diameter of the sample shall be five inches. Samples that are clearly defective, as a result of sampling, shall be discarded and another sample taken. The Contractor shall furnish all tools, labor, and materials for cutting samples and filling the cored pavement. Cored holes shall be filled in a manner acceptable to the City Engineer and within one day after sampling.

(4) Testing. The bulk specific gravity of each cored sample will be measured by the City Engineer in accordance with ASTM D 2726 or ASTM D 1188, whichever is applicable. The percent compaction (density) of each sample will be determined by dividing the bulk specific gravity of each sublot sample by the average bulk specific gravity of all laboratory prepared specimens for the lot, as determined in paragraph 401-5.la(2). The bulk specific gravity used to determine the joint density at joints formed between different lots shall be the lowest of the bulk specific gravity values from the two different lots.

(5) Acceptance. Acceptance of field placed material for mat density will be determined by the City Engineer in accordance with the requirements of paragraph 40 1-5.2b (I). Acceptance for joint density will be determined in accordance with the requirements of paragraph 401-5 .2b (J).

c. Partial Lots -Plant-Produced Material. When operational conditions cause a lot to be terminated before the specified number of tests have been made for the lot, or when the Contractor and City Engineer agree in writing to allow overages or other minor tonnage placements to be considered as partial lots, the following procedure will be used to adjust the lot size and the number of tests for the lot.

The last batch produced where production is halted will be sampled, and its properties shall be considered as representative of the particular sublot from which it was taken. In addition, an agreed to minor placement will be sampled, and its properties shall be considered as representative of the particular sublot from which it was taken. Where three sub lots are produced, they shall constitute a lot. Where one or two sublots are produced, they shall be incorporated into the next lot, and the total number of sub lots shall be used in the acceptance plan calculation, i.e., n =S or n =6, for example. Partial lots at the end of asphalt production on the project shall be included with the previous lot.

Partial Lots -Field Placed Material. The lot size for field placed material shall correspond to that of the plant material, except that, in no cases, shall less than three (3) cored samples be obtained, i.e., n = 3.

401-5.2 **ACCEPTANCE CRITERIA.**

a. General. Acceptance will be based on the following characteristics of the bituminous mixture and completed pavement as well as the implementation of the Contractor Quality Control Program and test results:

(1) Stability
(2) Flow
(3) Air voids
(4) Mat density
(5) Joint density
(6) Thickness
(7) Smoothness
(8) Grade

Mat density and air voids will be evaluated for acceptance in accordance with paragraph 401-5.2b (1). Stability and flow will be evaluated for acceptance in accordance with paragraph 40l-5.2b (2). Joint density will be evaluated for acceptance in accordance with paragraph 401-5.2b (3).

Thickness will be evaluated by the City Engineer for compliance in accordance with paragraph 401-5.2b (4). Acceptance for smoothness will be based on the criteria contained in paragraph 401-5.2b(S). Acceptance for grade will be based on the criteria contained in paragraph 401-5.2b (6).

The City Engineer may at any time, notwithstanding previous plant acceptance, reject and require the Contractor to dispose of any batch of bituminous mixture which is rendered unfit for use due to contamination, segregation, incomplete coating of aggregate, or improper mix temperature. Such rejection may be based on only visual inspection or temperature measurements. In the event of such rejection, the Contractor may take a representative sample of the rejected material in the presence of the City Engineer, and if it can be demonstrated in the laboratory, in the presence of the City Engineer, that such material was erroneously rejected, payment will be made for the material at the contract unit price.

b. **Acceptance Criteria.**

(1) Mat Density and Air Voids. Acceptance of each lot of plant produced material for mat density and air voids shall be based on the percentage of material within specification limits (PWL). If the PWL of the lot equals or exceeds 90 percent, the lot shall be acceptable. Acceptance and payment shall be determined in accordance with paragraph 401-8.1.

(2) Stability and Flow. Acceptance of each lot of plant produced material for stability and flow shall be based on the percentage of material within specification limits (PWL). If the PWL of the lot equals or exceeds 90 percent, the lot shall be acceptable. If the PWL is less than 90 percent, the Contractor shall determine the reason and take corrective action. If the PWL is below 80 percent, the Contractor must stop production and make adjustments to the mix. Lots with PWL below 80 percent for stability or flow values shall be removed and replaced at the expense of the Contractor.

(3) Joint Density. Acceptance of each lot of plant produced material for joint density shall be based on the percentage of material within specification limits (PWL). If the PWL of the lot is equal to or exceeds 90 percent, the lot shall be considered acceptable. If the PWL is less than 90 percent, the Contractor shall evaluate the reason and act accordingly. If the PWL is less than 80 percent, the Contractor shall cease operations and until the reason for poor compaction has been determined. IF THE PWL IS LESS THAN 71 PERCENT, THE PAY FACTOR FOR THE LOT USED TO COMPLETE THE JOINT SHALL BE REDUCED BY 5 PERCENTAGE POINTS. This lot pay factor reduction shall be incorporated and evaluated in accordance with paragraph 401-5 .1

(4) Thickness. Thickness of each lift of surface course shall be evaluated by the City Engineer for compliance to the requirements shown on the plans. Measurements of thickness shall be made by the City Engineer using the cores extracted for each sublot for density measurement. The maximum allowable deficiency at any point shall not be more than ¼ inch less than the thickness indicated for the lift. Average thickness of lift, or combined lifts, shall not be less than the indicated thickness. Where the thickness tolerances are not met, the lot or sub lot shall be corrected by the Contractor at his expense by removing the deficient area and replacing with new pavement. The Contractor, at his expense, may take additional cores as approved by the City Engineer to circumscribe the deficient area.

(5) Smoothness. The final surface shall be free from roller marks. The finished surfaces of each course of the pavement, except the finished surface of the final course, shall not vary more than % inch when evaluated with a 16 foot straightedge. The finished surface of the final course of pavement shall not vary more than ¼ inch when evaluated with a 16 foot straightedge. The lot size shall be 2,000 (1,650) square yards (square meters). Smoothness measurements shall be made at 50 foot intervals and as determined by the City Engineer.

In the longitudinal direction, a smoothness reading shall be made at the center of each paving lane. In the transverse direction, smoothness readings shall be made continuously across the full width of the pavement. However, transverse smoothness readings shall not be made across designed grade changes.

At warped transition areas, straightedge position shall be adjusted to measure surface smoothness and not design grade transitions. When more than 15 percent of all measurements within a lot exceed the specified tolerance, the Contractor shall remove the deficient area to the depth of the final course of pavement and replace with new material. Skin patching shall not be permitted. Isolated high points may be ground off providing the course thickness complies with the thickness specified on the plans. High point grinding will be limited to 15 square yards. Areas in excess of 15 square yards will require removal and replacement of the pavement in accordance with the limitations noted above.

(6) Grade. The finished surface of the pavement shall not vary from the gradeline elevations and cross sections shown on the plans by more than ½ inch (12.70 mm). The finished grade of each lot will be determined by running levels at intervals of 50 feet (15.2 m) or less longitudinally and all breaks in grade transversely (not to exceed 50 feet) to determine the elevation of the completed pavement. The Contractor shall pay the cost of surveying of the level runs that shall be performed by a

licensed surveyor. The documentation, stamped and signed by a licensed surveyor, shall be provided by the Contractor to the City Engineer. The lot size shall be 2,000 (1,650) square yards (square meters). When more than 15 percent of all the measurements within a lot are outside the specified tolerance, or if anyone shot within the lot deviates Y. inch or more from planned grade, the Contractor shall remove the deficient area to the depth of the final course of pavement and replace with new material. Skin patching shall not be permitted. Isolated high points may be ground off provided the course thickness complies with the thickness specified on the plans. High point grinding will be limited to 15 square yards. Areas in excess of 15 square yards will require removal and replacement of the pavement in accordance with the limitations noted above.

c. Percentage of Material within Specification Limits (PWL). The percentage of material within specification limits (PWL) shall be determined in accordance with procedures specified in *Section 01457*. The specification tolerance limits (L) for lower and (U) for upper are contained in Table 5.

d. Outliers. All individual tests for mat density and air voids shall be checked for outliers (test criterion) in accordance with ASTM E 178, at a significance level of 5 percent. Outliers shall be discarded, and the PWL shall be determined using the remaining test values.

TABLE 5. MARSHALL ACCEPTANCE LIMITS FOR STABILITY, FLOW, AIR VOIDS, DENSITY

TEST PROPERTY	Pavements Designed for Aircraft Gross Weights of 60,000 Lbs. or More or Tire Pressures of 100 Psi or More	
Number of Blows	75	
	Specification Tolerance	
	L	U
Stability, minimum, pounds	a. 2,150 for PMAC b. 1,800 for AC	-
Flow, 0.0 I-inch	8	16
Air Voids Total Mix, percent	2	5
Mat Density, percent	96.3	-
Joint density, percent	93.3	-

The criteria in Table 5 are based on production processes which have variability with the following standard deviations:

Surface Course Mat Density (%), 1.30
Base Course Mat Density (%), 1.55
Joint Density (%), 2.1

The Contractor should note that (1) 90 PWL is achieved when consistently producing a surface course with an average mat density of at least 98 percent with 1.30% or less variability, (2) 90 PWL is achieved when consistently producing a base course with an average mat density of at least 97.5 percent with 1.55% or less variability, and (3) 90 PWL is achieved when consistently producing joints with an average joint density of at least 96 percent with 2.1 % or less variability.

401-5.3 RESAMPLING PAVEMENT FOR MAT DENSITY.

a. **General**. Resampling of a lot of pavement will only be allowed for mat density, and then, only if the Contractor requests same, in writing, within 48 hours after receiving the written test results from the City Engineer. A retest will consist of all the sampling and testing procedures contained in paragraphs 401-5.1b and 401-5.2b (1). Only one resampling per lot will be permitted.

   (1) A redefined PWL shall be calculated for the resampled lot. The number of tests used to calculate the redefined PWL shall include the initial tests made for that lot plus the retests.

   (2) The cost for resampling and retesting shall be borne by the Contractor, *unless the results of the retesting indicate that work in place does comply with the specifications. In that case, the Contractor will be reimbursed for the cost of retesting.*

b. Payment for Resampled Lots. The redefined PWL for a resampled lot shall be used to calculate the payment for that lot in accordance with Table 6.

c. Outliers. If the tests within a lot include a very large or a very small value that appears to be outside the normal limits of variation, check for an outlier in accordance with ASTM E 178 at a significance level of 5 percent, to determine if this value should be discarded when computing the PWL.

CONTRACTOR QUALITY CONTROL

401-6.1 GENERAL. The Contractor shall develop a Quality Control Program in accordance with Section 100 of the General Provisions. The program shall address all elements that affect the quality of the pavement including, but not limited to:

a. Mix Design
b. Aggregate Grading
c. Quality of Materials
d. Stockpile Management e. Proportioning
f. Mixing and Transportation g. Placing and Finishing
h. Joints
i. Compaction
j. Surface Smoothness
k. Personnel
l. Laydown Plan

The Contractor shall perform quality control sampling, testing, and inspection during all phases of the work and shall perform them at a rate sufficient to ensure that the work conforms to the contract requirements, and at minimum test frequencies required by paragraph 401-6.3 and Section 100 of the General Provisions. As a part of the process for approving the Contractor's plan, the City Engineer may require the Contractor's technician to perform testing of samples to demonstrate an acceptable level of performance. '

No partial payment will be made for materials that are subject to specific quality control requirements without an approved plan.

401-6.2 TESTING LABORATORY. The Contractor shall provide a fully equipped asphalt laboratory meeting the requirements of paragraph 401-3.5 and 401-4.2a (2) located at the plant or job site. The Contractor shall provide the City Engineer with certification stating that all of the testing equipment to be used is properly calibrated and will meet the specifications applicable for the specified test procedures.

401-6.3 QUALITY CONTROL TESTING. The Contractor shall perform all quality control tests necessary to control the production and construction processes applicable to these specifications and as set forth in the approved Quality Control Program. The testing program shall include, but not necessarily be limited to, tests for the control of asphalt content, aggregate gradation, temperatures, aggregate moisture, field compaction, and surface smoothness. A Quality Control Testing Plan shall be developed as part of the Quality Control Program.

a. Asphalt Content. A minimum of two extraction tests shall be performed per lot in accordance with ASTM D 6307 or ASTM D 2172 for determination of asphalt content. The weight of ash portion of the extraction test, as described in ASTM D 2172, shall be determined as part of the first extraction test performed at the beginning of plant production; and as part of every tenth extraction test performed thereafter, for the duration of plan production. The last weight of ash value obtained shall be used in the calculation of the asphalt content for the mixture. The asphalt content for the lot will be determined by averaging the test results.

For polymer-modified asphalt concrete, the bitumen content is to be determined using the Ignition Test Method, ASTMD 6307.

The use of the nuclear method for determining asphalt content in accordance with ASTM D 4125 is permitted *wizen polymer-modified asphalt concrete is not specified,* provided that it is calibrated for the specific mix being used.

b. Gradation. Aggregate gradations shall be determined a minimum of twice per lot from mechanical analysis of extracted aggregate in accordance with ASTM D 5444 and ASTM C 136 (Dry Sieve). When asphalt content is determined by the nuclear method, aggregate gradation shall be determined from hot bin samples on batch plants, or from the cold feed on drum mix or continuous mix plants, and tested in accordance with ASTM C 136 (dry sieve) using actual batch weights to determine the combined aggregate gradation of the mixture.

c. Moisture Content of Aggregate. The moisture content of aggregate used for production shall be determined a minimum of once per lot in accordance with ASTM C 566.

d. Moisture Content of Mixture. The moisture content of the mixture shall be determined once per lot in accordance with ASTM D 1461 or AASHTO T11O.

e. Temperatures. Temperatures shall be checked, at least four times per lot, at necessary locations to determine the temperatures of the dryer, the bitumen in the storage tank, the mixture at the plant, and the mixture at the job site.in-Place Density Monitoring. The Contractor shall conduct any necessary testing to ensure that the specified density is being achieved. A nuclear gauge may be used to monitor the pavement density in accordance with ASTM D 2950.

f. Additional Testing. Any additional testing that the Contractor deems necessary to control the process may be performed at the Contractor's option.

g. Monitoring. The City Engineer reserves the right to monitor any or all of the above testing.

401-6.4 SAMPLING. When directed by the City Engineer, the Contractor shall sample and test any material that appears inconsistent with similar material being sampled, unless such material is voluntarily removed and replaced or deficiencies corrected by the Contractor. All sampling shall be in accordance with standard procedures specified.

401-6.5 CONTROL CHARTS. The Contractor shall maintain linear control charts both for individual measurements and range (i.e., difference between highest and lowest measurements) for aggregate gradation and asphalt content. Control charts shall be posted in a location satisfactory to the City Engineer and shall be kept current. As a minimum, the control charts shall identify the project number, the contract item number, the test number, each test parameter, the Action and Suspension Limits applicable to each test parameter, and the Contractors test results. The Contractor shall use the control charts as part of a process control system for identifying potential problems and assignable causes before they occur. If the Contractor's projected data during production indicates a problem and the Contractor is not taking satisfactory corrective action, the City Engineer may suspend production or acceptance of the material.

CONTROL CHART LIMITS BASED ON RANGE (Based on n = 2)	
Sieve	Suspension Limit
½ inch (12.5 mm)	11 percent
⅜ inch (9.5 mm)	11 percent
No. 4 (4.75 mm)	11 percent
No. 16 (1.18 mm)	9 percent
No. 50 (0.30 mm)	6 percent
No. 200 (0.075 mm)	3.5 percent
Asphalt Content	0.8 percent
Temperature of Mix	***30° F***

a. Individual Measurements. Control charts for individual measurements shall be established to maintain process control within tolerance for aggregate gradation and asphalt content. The control charts shall use the job mix formula target values as indicators of central tendency for the following test parameters with associated Action and Suspension Limits:

CONTROL CHART LIMTS FOR INDIVIDUAL MEASUREMENTS		
Sieve	Action Limit	Suspension Limit
3/4 inch (9.0 mm)	0%	0%
1/2 inch (12.5 mm)	+/-6%	+/-9%
3/8 inch (9.5 mm)	+/-6%	+/-9%
No.4(4.75 mm)	+/-6%	+/-9%
No.16(1.18mm)	+/-5%	+/-7.5%
No.50 (0.30 mm)	+/-3%	+/-4.5%
No.200 (0.075 mm)	+/-2%	+/-3%
Asphalt Content	+/-0.45%	+/-0.70%
Temperature of Mix	*+/-20' F*	*+/-25' F*

b. Range. Control charts for range shall be established to control process variability for the test parameters and Suspension Limits listed below. The range shall be computed for each lot as the difference between the two test results for each control parameter. The Suspension Limits specified below are based on a sample size of n =2. Should the Contractor elect to perform more than two tests per lot, the Suspension Limits shall be adjusted by multiplying the Suspension Limit by 1.18 for n =3 and by 1.27 for n =4.

c. Corrective Action. The Contractor Quality Control Program shall indicate that appropriate action shall be taken when the process is believed to be out of tolerance. The Plan shall contain sets of rules to gauge when a process is out of control and detail what action will be taken to bring the process into control. As a minimum, a process shall be deemed out of control and production stopped and corrective action taken, if:

(1) One point falls outside the Suspension Limit line for individual measurements or range; or

(2) Two points in a row fall outside the Action Limit line for individual measurements.

401-6.6 QUALITYCONTROL REPORTS. The Contractor shall maintain records and shall submit reports of quality control activities daily, in accordance with the Contractor Quality Control Program described in General Provisions, *Section 01450.*

METHOD OF MEASUREMENT

401-7.1 MEASUREMENT. Plant mix bituminous concrete pavement shall be measured by the number of tons (kg) of bituminous mixture used in the accepted work. Recorded batch weights or truck scale weights will be used to determine the basis for the tonnage.

Saw-cut grooving of bituminous pavement shall be measured by the number of square yards of saw-cut grooving as specified in-place, completed and accepted.

BASIS OF PAYMENT

401-8.1 **PAYMENT**. Payment for an accepted lot of bituminous concrete pavement shall be made at the contract unit price per ton (kg) for bituminous mixture adjusted according to paragraph 40 1-8.1 a, subject to the limitation that:

> The total project payment for plant mix bituminous concrete pavement shall not exceed 100 percent of the product of the contract unit price and the total number of tons (kg) of bituminous mixture used in the accepted work (See Note 2 under Table 6).

Payment for accepted saw-cut grooving shall be made at the contract unit price per square yard.

The price shall be compensation for furnishing all materials, for all preparation, mixing, and placing of these materials, and for all labor, equipment, tools, and incidentals necessary to complete the item.

a. **Basis of Adjusted Payment**. The pay factor for each individual lot shall be calculated in accordance with Table 6. A pay factor shall be calculated for both mat density and air voids. The lot pay factor shall be the higher of the two values when calculations for both mat density and air voids are 100

percent or higher. The lot pay factor shall be the product of the two values when only one of the calculations for either mat density or air voids is 100 percent or higher. The lot pay factor shall be the lower of the two values when calculations for both mat density and air voids are less than 100 percent.

TABLE 6. PRICE ADJUSTMENT SCHEDULE 1

Percentage of Material Within Specification Limits (PWL)	Lot Pay Factor (Percent of Contract Unit Price)
96 -100	106
90-95	PWL+ 10
75-S9	0.5 PWL+55
55 -74	1.4PWL-12
Below 55	Reject 2

1 ALTHOUGH IT IS THEORETICALLY POSSIBLE TO ACHIEVE A PAY FACTOR OF 106 PERCENT FOR EACH LOT, ACTUAL PAYMENT ABOVE 100 PERCENT SHALL BE SUBJECT TO THE TOTAL PROJECT PA YMENT LIMITATION SPECIFIED IN PARAGRAPH 401-S.1.

2 The lot shall be removed and replaced. However, the City Engineer may decide to allow the rejected lot to remain. In that case, if the City Engineer and Contractor agree in writing that the lot shall not be removed, it shall be paid at 50 percent of the contract unit price and the total project payment shall be reduced by the amount withheld for the rejected lot.

For each lot accepted the adjusted contract unit price shall be the product of the lot pay factor for the lot and the contract unit price. Payment shall *be* subject to the total project payment limitation specified in paragraph -8.1. Payment in excess of 100 percent for accepted lots of bituminous concrete pavement shall be used to offset payment for accepted lots of bituminous concrete pavement that achieve a lot pay factor less than 100 percent.

d. Payment. Payment will be made under:

Item 02745-01 *Polymer Modified Asphalt Surface Course-per ton*

Item 02745-02 *Asphalt Surface Course-per ton*

Item 02745-03 *Asphalt Pavement Surface Grooving-per square yard*

401-8.2 See also Section 01290.

TESTING REQUIREMENTS

ASTMC 29 Bulk Density ("Unit Weight") and Voids in Aggregate

ASTM C 88 Soundness of Aggregates by Use of Sodium Sulfate or Magnesium

Sulfate ASTM C 117 Materials Finer than 75!-lm (No.200) Sieve in Mineral Aggregates by

Washing ASTM C 127 Specific Gravity and Absorption of Coarse Aggregate

ASTM C 131	Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C 136	Sieve Analysis of Fine and Coarse Aggregates
ASTM C 183	Sampling and the Amount of Testing of Hydraulic Cement
ASTM C 566	Total Evaporable Moisture Content of Aggregate by Drying ASTM D 75 Sampling Aggregates
ASTM D 979	Sampling Bituminous Paving 0i1ixturcs
ASTM D 995	Mixing Plants for Hot-Mixed Hot-Laid Bituminous Paving Mixtures
ASTM D 1073	Fine Aggregate for Bituminous Paving Mixtures
ASTM D 1074	Compressive Strength of Bituminous Mixtures
ASTM D 1188	Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens
ASTM D 1461	Moisture or Volatile Distillates in Bituminous Paving Mixtures
ASTMD 2041	Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
ASTMD 2172	Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
ASTM D 2419	Sand Equivalent Value of Soils and Fine Aggregate
ASTMD 2489	Estimating Degree of Particle Coating of Bituminous-Aggregate Mixtures
ASTM D 2726	Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures
ASTM D 2950	Density of Bituminous Concrete in Place by Nuclear Methods
ASTM D 3203	Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
ASTM D 3665	Random Sampling of Construction Materials
ASTM D 3666	Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials
ASTM D 4125	Asphalt Content of Bituminous Mixtures by the Nuclear Method
ASTM D 4318	Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 4791	Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

ASTM D 4867	Effect of Moisture on Asphalt Concrete Paving Mixtures
ASTM D 5444	Mechanical Size Analysis of Extracted Aggregate
ASTM D 6926	Preparation of Bituminous Specimens Using MARSHALL Apparatus
ASTM D 6927	MARSHALL Stability and Flow of Bituminous Mixtures
ASTM E 11	Wire-Cloth Sieves for Testing Purposes
ASTM E 178	Dealing with Outlying Observations
ASTM E 1274	Measuring Pavement Roughness Using a Profilograph
AASHTO T 30	Mechanical Analysis of Extracted Aggregate
AASHTO T 110	Moisture or Volatile Distillates in Bituminous Paving Mixtures
The Asphalt Institute's	Mix Design Methods for Asphalt Concrete Manual No. 2 (MS-2)

MATERIAL REQUIREMENTS

ASTM D 242	Mineral Filler for Bituminous Paving Mixtures
ASTM D 946	Penetration Graded Asphalt Cement for Use in Pavement
Construction ASTM D 3381	Viscosity-Graded Asphalt Cement for Use in Pavement
Construction ASTM D 4552	Classifying Hot-Mix Recycling Agents
AASHTO M320	Performance Graded Asphalt Binder

END OF ITEM P-401

Sample Specification

CEMENT STABILIZED RECYCLED CRUSHED CONCRETE BASE COURSE

PART I GENERAL

1.1 SECTION INCLUDES

A. This section shall consist of a base course composed of recycled crushed concrete, cement, and fly ash uniformly blended and mixed with water. The mixed material shall be spread, shaped, and compacted in accordance with these specifications and in conformity to the lines, grades, dimensions, and typical cross sections shown on the drawings. Runway, taxiway, or apron pavements shall be built in a series of parallel lanes using a plan of processing that reduces longitudinal and transverse joints to a minimum.

1.2 MEASUREMENT AND PAYMENT

A. Measurement for cement-stabilized recycled crushed concrete base shown on drawings is on a square yard basis actually constructed and accepted by the City Engineer.

B. Refer to Section 01290-Payment Procedures for unit price procedures.

1.3 REFERENCES

A. ASTM C136 Sieve or Screen Analysis of Fine and Coarse Aggregates

B. ASTM *C295* Petrographic Examination of Aggregates for Concrete

C. ASTM 075 Sampling Aggregates

D. ASTM D423 Liquid Limit of Soils.

E. ASTM 0424 Plastic Limit and Plasticity Index of Soils

PART 2 PRODUCTS

2.1 MATERIALS

A. PORTLAND CEMENT

1. ASTM C 150, Type

I. B. FLY ASH

ASTM C 618 Class C and the applicable testing procedures modified as follows: Loss by ignition shall not be more than 3.0 percent.

Combined content of silica oxide (Si O2), ferric oxide (Fe2 0 3), and aluminum oxide (AI $_2$0 3) shall be not less than 50 percent.

Lime pozzolan strength, minimum compressive strength shall be 600 psi at 7 days, 130 +3 degrees F.

Fly ash produced from burning lignite will not be permitted.

C. CRUSHED CONCRETE

1. Crushed concrete shall consist of hand durable particles free of soft or disintegrated pieces, dirt, organic material, salt, or other objectionable material. The following graduation, in percent passing by weight, shall be governing criteria.

Sieve Size	Percent Passing by Dry Weight Crushed Concrete
2"	100
1-112"	95-100
1"	70-95
3/4"	55-85
#4	30-60
#40	10-25
#200	3-10

Crushed concrete delivered to the mixing plant shall be dry or moist. Contractor to use crushed concrete. Contractor will not be permitted to mix aggregates in any mix or pavement section.

D. WATER

1. Water for use in mixes shall be potable water.

2.2 DESIGN MIX

A. For pavements with asphalt surface, the base mix shall be proportioned in percent by dry weight. The water content is to be determined based on the maximum dry density when compacted in accordance with ASTM D1557.

B. The cement content for construction shall be that at which the mix develops a 28-day compressive strength of at least 1,000 psi. In no case shall the cement content be less than 5 percent. For pavements with concrete surface, the comprehensive strength should be in the range of 700 psi minimum in 28 days and 1,000 psi maximum in 28 days.

C. Material shall be compacted to 98 percent of the maximum, dry density in 6-inch by 12-inch steel molds and moist-cured. The specimens to be tested for unconfined compressive strength in accordance with ASTM D2166. Sufficient specimens to be made to obtain groups of three test results at 7, 14, and 28 days.

D. Not less than 6 percent nor more than 12 percent fly ash is to be added to the mix. The amount of fly ash to be that which produces the highest maximum dry density of the mix as determined by ASTM D1557.

2.3 MIXING PLANT

A. The Contractor shall provide a mixing plant of such type and capacity as to fulfill the requirement of the Contract. The plant to have sufficient controls and adjustment capabilities to meet the tolerances of this specification. The Contractor is to be responsible for the operation and maintenance of the plant.

B. Mixing plants are not be loaded above their noted capacities and are to be operated at the speed for which they were designed. Manufacturer plates showing the rated capacity and recommended speed are to be attached to each mixing plant. Increased output is to be obtained by a larger mixing plant or by additional mixing plants, not by overloading or speeding up the equipment on hand. Mixers to be equipped with mixing blades. Mixing blades are to be replaced when worn down 3/4 inch or more. Blades are to be cleaned of hardened mix a minimum of one time each day.

C. Mixing plants are to be equipped with sufficient instrumentation to measure and record accurately each material component loaded into the mixer. Instrumentation is to be calibrated at least one time each day during production of base material.

D. Prior to the start of paving operations, the manufacturer's representative is to certify that the mixing plant to be used by the Contractor on this project is in good operating condition and is capable of performing the work required by the plans and specifications.

E. Proportion of materials in dry weight shall be within plus or minus 10 percent of the percentages specified in the final mix design.

PART 3 EXECUTION

3.1 MIXTURE

A. Mix material until a thorough and uniform mixture of all materials incorporated in the mix is obtained. The minimum mixing time required to obtain a uniform mixture shall be determined from the tome the last component is introduced into the mixer. Modification of mixing time shall be made, if necessary, during the construction. The moisture content of the fly ash and aggregates in stockpile shall be checked daily and all metering devices shall be calibrated and reset daily. A shredding machine shall be used to pulverize the conditioned (moisturized) fly ash prior to its use in the mix. When dry powder fly ash is used, storage bins shall be provided.

B. If the City Engineer, during his inspections of base material placement, determines that the base mix does not conform to the requirements set forth in these Specifications or to the changes as may be directed by the City Engineer, said mix shall be rejected.

C. Dispose of all rejected base material offsite.

D. Should the City Engineer, at any time, determine that a wet load is unsuitable for use; such load shall be considered as a rejected mix and disposed of accordingly.

3.2 WEATHER LIMITATIONS

A. The base shall not be mixed or placed while the atmospheric temperature is below 40°F (4°C) or when conditions indicate that the temperature may fall below *3SoF* (2°C) within 24 hours or when the weather is rainy. The base shall not be placed on frozen subgrade or mixed when aggregate is frozen.

3.3 PREPARING UNDERLYING COURSE

A. The underlying course shall be checked and accepted by the City Engineer before placing and spreading operations are started. Any ruts or soft yielding places caused by improper drainage conditions, hauling, or any other cause shall be corrected before the base course is placed thereon.

3.4 PLACING

A. The mixture shall be transported to the job site in suitable vehicles and shall be deposited on the moistened subbase in uniform layers by means of approved mechanical spreaders. Not more than 60 minutes shall elapse between the start of moist mixing and the start of compaction of the cement-treated mixture on the prepared subgrade.

3.5 COMPACTION

A. Immediately upon completion of the spreading operations, the mixture shall be thoroughly compacted. The number, type, and weight of rollers shall be sufficient to compact the mixture to the required density.

B. AIRFIELD PAVEMENT: The field density of the compacted mixture shall be at least 98 percent of the maximum density of the laboratory specimens prepared from samples of base material taken from the material in place. The specimens shall be compacted and tested in accordance with ASTM D1557. The in-place field density shall be determined in accordance with ASTM D 1556 or ASTM D2167, or ASTM D 2922 and ASTM D 3017. Any mixture that has not been compacted shall not be left undisturbed for more than 30 minutes. The moisture content of the mixture at the completion of compaction shall not be below nor more than 2 percentage points above the optimum moisture content. The optimum moisture content shall be determined in accordance with ASTM D1557 and shall be less than that amount which will cause the mixture to become unstable during compaction and finishing. Compaction to be completed within 2 hours from the start of moist mixing.

C. ROADWAY PAVEMENT: The field density of the compacted mixture shall be at least 95 percent of the maximum density of the laboratory specimens prepared from samples of base material taken from the material in place. The specimens shall be compacted and tested in accordance with ASTM D698. The in-place field density shall be determined in accordance with ASTM D1556 or ASTM D2167. Any mixture that has not been compacted shall not be left undisturbed for more than 30 minutes. The moisture content of the mixture at the completion of compaction shall not be below nor more than 2 percentage points above the optimum moisture content. The optimum moisture content shall be determined in accordance with ASTM D698 and shall be less than that amount which will cause the mixture to become unstable during compaction and finishing. Compaction to be completed within 2 hours from the start of moist mixing.

D. LAYER THICKNESS: No layer shall be in excess of 8 inches or less than 4 inches when compacted. In multi layer construction, the surface of the compacted material shall be kept moist until covered with the next layer. Successive layers shall be placed and compacted so that the required total depth of the base course is completed the same day.

E. FINISHING: Finishing operations shall be completed during daylight hours and the completed base course shall conform to the required lines, grades, and cross-section. If necessary, the surface shall be lightly scarified to eliminate any imprints made by the compacting or shaping equipment. The surface shall then be recompactcd to the required density. The compaction and finishing operations shall be completed within 2 hours of the time water is added to the mixture and shall produce a smooth, dense surface that is free of surface checking, ridges, or loose material.

F. SURFACE TOLERANCE: The finished surface shall not vary more that *3/8* inch (10 mm) when tested with a 16-foot (5 m) straightedge applied parallel with or at right angles to the centerline of the stabilized area. Any deviation in excess of this amount shall be corrected by the Contractor at the Contractor's expense.

3.6 JOINTS

A. CONSTRUCTION JOINTS: At the end of each day's construction, a transverse construction joint shall be formed by a header or by cutting back into the compacted material to form a true vertical face free of loose material.

Longitudinal joints shall be formed by cuffing back into the compacted material to form a true vertical edge.

3.7 PROTECTION AND CURING

A. The completed base shall be cured with a bituminous prime coat applied as soon as possible and in no case later than 24 hours after completion of the finishing operations. The surface of the base course shall be kept moist until the bituminous material is applied.

B. The curing seal shall be maintained and protected.

C. Finished portion of the base course that is used by equipment in the construction of an adjoining section shall be protected to prevent marring or damaging the completed work. The stabilized area shall be protected from freezing during the curing period.

3.8 ACCEPTANCE SAMPLING AND TESTING

A. For every 1,000 square yards of surface area per lift, five test specimens are to be prepared from material being placed using standard concrete molds. Specimens to be compacted in accordance with ASTM 1557, sealed, and cured. The unconfined compression strength is to be determined for two samples at 7 days and three samples at 28 days. If the average strength of the three 28-day samples fails to meet the strength specified herein, the area represented by the specimens will be divided into four quadrants. Two cores will be taken from each quadrant and tested for unconfined compressive strength. If the average strength of the two cores within any quadrant fails to meet the strength specified, all base material in that quadrant will be remove and replaced at the Contractor's expense. Removed material will be disposed of offsite. The taking and testing of the cores will be at the Contractor's expense.

B. During the paving operations the in-place density of each layer of base material is to be tested at the rate of one test per 7,500 square feet. Testing to be in accordance with ASTM D 1556 or ASTM D 2167, or ASTM D 2922 and ASTM D 3017. Material tailing to meet the density criteria will be reworked to meet the requirement. Should the material, due to any reason or cause, lose the required stability, density, and finish before the next layer or course is placed or the work is accepted, it shall be recompacted and refinished at the sole expense of the Contractor.

C. TOLERANCE IN THICKNESS: The cement-stabilized recycled crushed concrete will be accepted for thickness on a lot basis. A lot will consist of 1,000 square yards. One core shall be taken at random by the City Engineer in each lot. When the measurement of the core from a lot is not deficient more than 0.5 inch (12 mm) from the plan thickness, full payment will be made. When such measurement is deficient more than 0.5 inch (12 mm) and not more than I-inch (25 mm) from the plan thickness, two additional cores shall be taken at random and used in determining the average thickness for that lot. The thickness of the cores shall be determined by average caliper measurement of cores tested in accordance with ASTM C 174. When the average measurement of the 3 cores is not deficient more than 0.5 inch (12 mm) from the plan thickness, full payment will be made. If the average measurement of the three cores is deficient more than 0.5 inch (12 mm) from the plan thickness, the entire lot shall be removed and replaced at the Contractor's expense or be permitted to remain in place at an adjusted payment of 75 percent of the contract unit price.

When the average thickness is deficient by more than 1 inch (25 mm), the entire lot shall be replaced.

END OF SECTION

Sample Specification

ITEM P-501 PORTLAND CEMENT CONCRETE PAVEMENT

(Follow FAA Standard Specifications *150/5370-10F,* dated
9/30/20011 or latest edition)

DESCRIPTION

501-1.1 This work shall consist of pavement composed of Portland Cement concrete, with reinforcement constructed on a prepared underlying surface in accordance with these specifications and shall conform to the lines, grades, thickness, and typical cross sections shown on the plans.

MATERIALS

501-2.1 AGGREGATES

a. Reactivity. Aggregates shall be tested for deleterious reactivity with alkalies in the cement, which may cause excessive expansion of the concrete. Tests of coarse and fine aggregate shall be made in accordance with ASTM C 1260. If the expansion of test specimens, tested in accordance with ASTM C 1260, does not exceed 0.10 % at 16 days from casting, the coarse or fine aggregates shall be accepted. If the expansion at 16 days is greater than 0.10%, tests of combined materials shall be made in accordance with ASTM C 1260 or ASTM C 1567 using the aggregates, cementitious materials, and/or specific reactivity reducing chemicals in the proportions proposed for the mixture design. If the expansion of the proposed combined materials test specimens, tested in accordance with ASTM C 1260 or ASTM C 1567 does not exceed 0.10 % at 16 days from casting, the proposed combined materials will be accepted. If the expansion of the proposed combined materials test specimens is greater than 0.10% at 16 days, the aggregates will not be accepted unless adjustments to the combined materials mixture can reduce the expansion to less than 0.10 % at 16 days, or new aggregates shall be evaluated and tested.

Listed below are sources that have been accepted (pre-qualified)* as *sources acceptable to the City of Houston for aggregates for this project. The pre-qualification does not relieve the requirement for Contractor submission of the applicable test results to ensure (and for Contractor assurance) that the aggregates delivered meet all of the requirements of this Section.

Coarse Aggregate

Vulcan Materials *
Knippa Pit, Texas

Vulcan Materials
Brownwood Plant, TX

Martin-
Marietta Chico
Plant, TX

Fine Aggregate

Vulcan Materials
Knippa Pit, Texas

Vulcan Materials **
Brownwood Plant, TX

Texas Crushed Stone **
Georgetown, TX

**** Trap Rock. ** Limestone Fines***

This list does not prohibit the Contractor from submitting other aggregate sources as long as the submitted documentation shows conclusively that the source produces aggregates in conformance with the requirements of this Section.

b. Fine Aggregate. Fine aggregate shall conform to the requirements of ASTM C 33. Gradation shall meet the requirements of Table 1 when tested in accordance with ASTM C 136, except as may otherwise be qualified under Section 5 of ASTM C 33.

TABLE 1. GRADATION FOR FINE AGGREGATE (ASTM C 33)

Sieve Designation (Square Openings)	Percentage by Weight Passing Sieves
3/8 in. (9.5 mm)	100
No. 4 (4.75 mm)	95-100
No. 8 (2.36 mm)	80-100
No. 16 (1.18 mm)	50-85
No. 30 (600 micro-m)	25-60
No. 50 (300 micro-m)	10-30
No. 100 (150 micro-m)	2-10

Fine aggregate shall be subjected to the sand equivalent test (Test Method Tex-203-F as outlined in the Texas Department of Transportation (TxDOT) "Manual of Testing Procedures", Volume 1. The sand equivalent shall not be less than 80.

c. Coarse Aggregate. Coarse aggregate shall *be* ***crushed limestone and shall*** conform to the requirements of ASTM C 33. Gradation, within the separated size groups, shall meet the requirements of Table 2 when tested in accordance with ASTM C 136. When the nominal maximum size of the aggregate is greater than 1 inch, the aggregates shall be furnished in two size groups.

Aggregates delivered to the mixer shall consist of crushed stone, crushed or uncrushed gravel; air cooled blast furnace slag, crushed recycled concrete pavement, or a combination thereof. The aggregate shall be composed of clean, hand, uncoated particles and shall meet the requirements for deleterious substances contained in ASTM C 33, Class 4S. Dust and other coating shall be removed from the aggregates by washing. ***The total of all deleterious substances shall not exceed 3.0% of the weight of aggregate, not counting material finer than the No. 200 sieve.*** The aggregate in any size group shall not contain more than 8 percent by weight of flat or elongated pieces when tested in accordance with ASTM D 4791. A flat or elongated particle is one having a ratio between the maximum and the minimum dimensions of a circumscribing rectangular prism exceeding 3 to 1.

The percentage of wear shall be no more than 35 when tested in accordance with ASTM C 131 or ASTM C 535.

Loss by decantation shall not exceed 1% and shall be determined by Test Method Tex-406-A as outlined in TxDOT "Manual of Testing Procedures", Volume 2. In the case of aggregates made primarily from the crushing of stone, if the material finer than the 200 sieve Is definitely established to be the dust of fracture, essentially free from clay or shale, as established by Part 11/ of Test Method Tex-406-A, the percent may be increased to 1.5.

The aggregates shall be furnished in two separate size groups as shown in Table 2. When aggregate blending is required to achieve specified gradation. The Contractor shall provide aggregate fractions with uniform specific gravities, i.e. specific gravities within a range of +/-0.05.

TABLE 2. GRADATION FOR COARSE AGGREGATE
ASTM C 33

Sieve Designation (square openings)		Percentage by Weight Passing Sieves	
		From 1-1/2" to No. 4 (38.1 mm – 4.75 mm)	
in	mm	1-1/2" – 3/4	3/4 – No. 8
2-1/2	63	---	---
2	50.8	100	---
1-1/2	38.1	90-100	---
1	25.0	20-55	100
3/4	19.0	0-15	90-100
1/2 1/2	12.5	---	---
3/8	9.5	0-	20-55
No. 4	4.75	5	0-10
No. 8	2.36	---	0-5

The aggregate that is used shall produce a concrete meeting all requirements of the drawings and specifications. Only one job-mix gradation of coarse aggregate will be used for Portland Cement concrete pavement mixes unless otherwise approved in writing by the City Engineer.

Aggregate susceptibility to Disintegration (D) Cracking. Aggregates that have a history of 0cracking shall not be used. Prior to approval of mixture design and production of Portland Cement concrete the Contractor shall submit written certification that the aggregate does not have a history of D-Cracking and that the aggregate meets the specified State requirements.

(1) Other sources of crushed stone aggregate shall be approved if the durability factor as determined by ASTM C 666 is greater than or equal to 95 and all other quality test requirements within these specifications are fulfilled. The FAA will consider and reserves final approval of other State classification procedures.

(2) Crushed gravel and sand-gravel aggregates shall not be required to meet freeze-thaw durability ratings. These aggregates shall be approved for use in concrete by the state highway agency in the state from which the aggregate originates and the state in which they are to be used and shall meet all other criteria within these specifications.

Storage Facilities. Where the coarse aggregate is delivered on the Job in two or more sizes or types. Each type and/or size shall be batched and weighed separately.

All aggregates shall be handled and stored in such a manner as to prevent size segregation and contamination by foreign substances. When segregation is apparent, the aggregate shall be re-mixed before use in concrete. At the time of its use, the aggregate shall be free from frozen material, and aggregate containing foreign materials will be rejected. Coarse aggregate that contains more than 0.5% free moisture by weight shall be stockpiled for at least 24 hours prior to use.

Adequate storage facilities shall be provided for all approved materials. The intermixing of non-approved materials with approved materials either in stockpiles or in bins will not be permitted. Aggregates from different sources shall be stored in different stockpiles unless otherwise approved by the City Engineer.

Aggregates shall be stockpiled in such a manner as to prevent segregation and maintain as nearly as possible a uniform condition of moisture.

Each aggregate stockpile shall be reworked with suitable equipment at such times as required by the City Engineer to remix the material to provide uniformity of the stockpile.

Unless otherwise approved by the City Engineer in writing, coarse aggregates will be dumped in traps and stockpiled with stacker conveyors. At no time shall the aggregate be pushed with a bulldozer or front-end loader.

501-2.2 CEMENT. Cement shall conform to the requirements of ASTM C 150 Type I or II.

If for any reason, cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used.

Only cements containing less than 0.6% equivalent alkali or cements that can demonstrate a positive reduction in the expansion created by alkali-silica reactions shall be used.

501-2.3 CEMENTITIOUS MATERIALS.

a. Fly Ash or Natural Pozzolan. Fly ash shall meet the requirements of ASTM C 618, Class F with the exception of loss of ignition, where the maximum shall be less than 6 percent for Class F. ***Lignite fly ash will not be permitted***, Fly ash such as is produced in furnace operations utilizing liming materials or soda ash (sodium carbonate) as an additive shall not be acceptable. The Contractor shall furnish vendor's certified test reports for each shipment of Fly Ash used in the project. The vendor's certified test report can be used for acceptance or the material may be tested independently by the City Engineer.

Fly ash shall compulsorily be used in the Portland Cement concrete as a partial replacement for cement, at the rate specified in this paragraph. The minimum cement content shall be met by considering Portland Cement, plus Fly ash, plus blast furnace slag as the total cementitious component. Twenty to Twenty-five percent (20-25%) of cementitious material, by weight, shall be fly ash.

b. Blast Furnace Slag (Slag Cement). Ground Granulated Blast Furnace (GGBF) slag shall conform to ASTM C 989, Grade 100 or 120. GGBF shall be used only at a rate between 25 and 55 percent of the total cementitious material by mass.

501-2.4 PREMOLDED JOINT FILLER. Premolded joint filler for expansion joints shall conform to the requirements of ASTM D 1752, Type II or III and shall be punched to admit the dowels where called for on the plans. The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint, unless otherwise specified by the ***City*** Engineer. When the use of more than one piece is required for a joint, the abutting ends shall be fastened securely and held accurately to shape by stapling or other positive fastening means satisfactory to the ***City*** Engineer.

501-2.5 JOINT SEALER. The joint sealer for the joints in the concrete pavement shall meet the requirements of Item P-605 and shall be of the type(s) specified in the plans.

501-2.6 STEEL REINFORCEMENT. Reinforcing shall consist of welded steel wire fabric conforming to the requirements of ASTM A 185.

The steel shall be properly stored to protect it from mechanical injury and rust. The steel shall be free from dirt, rust, scale or other deleterious materials at the time of placement.

501-2.7 DOWEL AND TIE BARS. Tie bars shall be deformed steel bars and conform to the requirements of ASTM A 615 or ASTM A 996, except that rail steel bars, Grade 50 or 60, shall not be used for tie bars that are to be bent or restraightened during construction.

Dowel bars shall be plain steel bars conforming to ASTM A 615 or ASTM A 966 and shall be free from burring or other deformation restricting slippage in the concrete. High strength dowel bars shall conform to ASTM A 714, Class 2, Type S, Grade I, II or III, Bare Finish. Before delivery to the construction site each dowel bar shall be painted with one coat of paint conforming to MIL-DTL-*24441/20A.SSPC* Paint 5 or SSPC Paint 25.Metal or plastic collars shall be full circular device supporting the dowel until the epoxy hardens.

The sleeves for dowel bars used in expansion joints shall be metal or other type of an approved design to cover 2 to 3 inches (50 mm to 75 mm) of the dowel, with a closed end and with a suitable stop to hold the end of the bar at least 1 inch (25 mm) from the closed end of the sleeve. Sleeves shall be of such design that they will not collapse during construction.

501-2.8 WATER. Water used in mixing or curing shall be clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product. Water will be tested in accordance with the requirements of AASHTO T 26. Water known to be of potable quality may be used without testing.

501-2.9 COVER MATERIAL FOR CURING. Curing materials shall conform to one of the following specifications:

a. Liquid membrane-forming compounds for curing concrete shall conform to the requirements of ASTM C309, Type 2, Class B, or Class A if wax base only.

b. White polyethylene film for curing concrete shall conform to the requirements of ASTM C 171.

c. White burlap-polyethylene sheeting for curing concrete shall conform to the requirements of ASTM C

d. Waterproof paper for curing concrete shall conform to the requirements of ASTM C 171.

501-2.10 ADMIXTURES. The use of any material added to the concrete mix shall be approved by the City Engineer. The Contractor shall submit certificates indicating that the material to be furnished meets all of the requirements indicated below. In addition, the City Engineer may require the Contractor to submit complete test data from an approved laboratory showing that the material to be furnished meets all of the requirements of the cited specifications. Subsequent tests may be made of samples taken by the City Engineer from the supply of the material being furnished or proposed for use on the work to determine whether the admixture is uniform in quality with that approved.

a. Air-Entraining Admixtures. Air-entraining admixtures shall meet the requirements of ASTM C 260 and shall consistently entrain the air content in the specified ranges under field conditions. The air-entrainment agent and any water reducer admixture shall be compatible

b. Chemical Admixtures. Water-reducing, set retaining and set-accelerating admixtures shall meet the requirements of ASTM C 494, including the flexural strength test. ***During hot weather concreting operations or normal operations in order to maintain specified slump and required workability, the City Engineer may allow use of*** **a** ***water-reducing admixture or*** **a** ***water-reducing and set-retanding mixture. The use of these admixtures shall be addressed and documented in development of the Mix Design.***

The water-reducing admixture shall conform to requirements of AASHTO M **194.** ***Type*** **A** ***and Type*** **F** ***and water- reducing and set-restanding admixtures shall conform to the requirements*** **of** ***AASHTO M*** **194.** ***Type 0 and Type*** **G.** ***Water-reducing or water-reducing and retanding admixture shall be added at the mixer separately from the air-entraining admixtures according to manufacturers printed instructions.***

501-2.11 EPOXY-RESIN. Epoxy-resin used to anchor dowels and tie bars in pavements shall conform to the requirements of ASTM C 881, Type I, Grade 3, Class C. Class A or B shall be used when the surface temperature of the hardened concrete is below 60 degrees F (16 degrees C).

501-2.12 MATERIAL ACCEPTANCE. Prior to use of materials, the Contractor shall submit certified test reports to the City Engineer for those materials proposed for use during construction. The certification shall show the appropriate ASTM test(s) for each material, the test results, and a statement that the material passed or failed.

The City Engineer may request samples for testing, prior to and during production, to verify the quality of the materials and to ensure conformance with the applicable specifications.

MIX DESIGN

501-3.1 PROPORTIONS. Concrete shall be designed to achieve a 28-day flexural strength that meets or exceeds the acceptance criteria contained in paragraph 501-5.2 for a flexural strength of 650 psi. The mix shall be designed using the procedures contained in Chapter *7* of the Portland Cement Association's manual, "Design and Control of Concrete Mixtures".

The Contractor shall note that to ensure that the concrete actually produced will meet or exceed the acceptance criteria for the specified strength; the mix design average strength must be higher than the specified strength. The amount of overdesign necessary to meet specification requirements depends on the producer's standard deviation of flexural test results and the accuracy that that value can be estimated from historic data for the same or similar materials.

The minimum cementitious material (cement plus fly ash) shall be 564 pounds per cubic yard (227 kg per cubic meter). The ratio of water to cementitious material, including free surface moisture on the aggregates but not including moisture absorbed by the aggregates shall not be more than 0.45 by weight.

Prior to the start of paving operations and after approval of all material to be used in the concrete, the Contractor shall submit a mix design showing the proportions and flexural strength obtained from the

concrete at 7 and 28 days. The mix design shall include copies of test reports, including test dates, and a complete list of materials including type, brand, source, and amount of cement, fly ash, ground slag, coarse aggregate, fine aggregate, water, and admixtures. The fineness modulus of the fine aggregate and the air content shall also be shown. The mix design shall be submitted to the City Engineer at least 15 business days prior to the start of operations. The submitted mix design shall not be more than 90 days old. Production shall not begin until the mix design is approved in writing by the City Engineer.

Should a change in sources be made, or admixtures added or deleted from the mix, a new mix design must be submitted to the City Engineer for approval.

Flexural strength test specimens shall be prepared in accordance with ASTM C 31 and tested in accordance with ASTM C 78. The mix determined shall be workable concrete having a slump for side-form concrete between 1 and 2 inches (25 mm and 50 mm) as determined by ASTM C 143. For vibrated slip-form concrete, the slump shall be between *1/2* inch (13 mm) and 1 *1/2* inches (38 mm).

501-3.2 CEMENTITIOUS MATERIALS.

a. Fly Ash. Fly ash ***shall*** be used in the mix design. When fly ash is used as a partial replacement for cement, the minimum cement content may be met by considering Portland Cement plus fly ash as the total cementitious material. The replacement rate shall be determined from laboratory trial mixes, but shall be between 20 and 30 percent by weight of the total cementitious material. If fly ash is used in conjunction with ground granular blast furnace slag the maximum replacement rate shall not exceed 10 percent by weight of total cementitious material.

b. Ground Slag. Ground blast-furnace slag ***shall*** be used in a mix design containing Type I or Type" cement. The slag, or slag plus fly ash if both are used, may constitute between 25 to 55 percent of the total cementitious material by weight. If the concrete is to be used for slipforming operations and the air temperature is expected to be lower than 55 degrees F (13 degrees C) the percent slag shall not exceed 30 percent by weight.

501-3.3 ADMIXTURES.

a. Air-Entraining. Air-entraining admixture shall be added in such a manner that will insure uniform distribution of the agent throughout the batch. The air content of freshly mix air-entrained concrete shall be based upon trial mixes with the materials to be used in the work adjusted to produce concrete of the required plasticity and workability. The percentage of air in the mix shall be 4.0%. Air content shall be determined by testing in accordance with ASTM C 231 for gravel and stone coarse aggregate and ASTM C 173 for slag and other highly porous coarse aggregate.

b. Chemical. Water-reducing, set-controlling, and other approved admixtures shall be added to the mix in the manner recommended by the manufacturer and in the amount necessary to comply with the specification requirements. ***The use of any of these admixtures must be approved by the City Engineer prior to their use in project concrete.*** Tests shall be conducted on trial mixes, with the materials to be used in the work, in accordance with ASTM C 494.

501-3.4 TESTING LABORATORY. The laboratory used to develop the mix design shall meet the requirements of ASTM C 1077. The laboratory accreditation will include ASTM C 78. A certification that it meets these requirements shall be submitted to the City Engineer prior to the start of mix design. The certification shall include evidence that the laboratory is inspected/accredited for the test methods required herein by a nationally recognized laboratory inspection accreditation organization.

CONSTRUCTION METHODS

501-4.1 EQUIPMENT. Equipment necessary for handling materials and performing all parts of the work shall be approved by the City Engineer as to design, capacity, and mechanical conditions. The equipment shall be at the jobsite sufficiently ahead of the start of paving operations to be examined thoroughly and approved.

Batch Plant and Equipment. The batch plant and equipment shall conform to the requirements of ASTM C 94.

(1) ***General. The batching plant shall include bins, weighing hoppers, and scales for the fine aggregate and coarse aggregate. If bulk cement is used a bin, hopper and separate scale for cement shall be included. The weighing hoppers shall be properly sealed and vented to preclude dusting during operation.***

(2) ***Bins and Hopper. Bins with adequate separate compartments for fine aggregate and coarse aggregate shall be provided in the batching plant. Each compartment shall discharge efficiently and freely into the weighing hopper. Means of control shall be provided so that as the quantity desired in the weighing hopper is approached the material may be added slowly and shut off with precision. A port or other opening for removing an overload of anyone of the several materials from the hopper shall be provided. Weighing hoppers shall be constructed to eliminate accumulations of materials and to discharge fully.***

(3) ***Scales. The scales for weighing aggregates and cement shall be of either the beam or the springless dial type. They shall be accurate within 0.5 percent throughout their range of use. When beam-type scales are used, provisions such as a "telltale" dial shall be made for indicating to the operator that the required load in the weighing hopper is being approached. A device on the weighing beams shall clearly indicate critical position. Poises shall be designed to be locked in any position and to prevent unauthorized change. The weight beam and "telltale" device shall be in full view of the operator while charging the hopper and the operator shall have convenient access to all controls.***

Scales shall be inspected and sealed as often as the City Engineer may deem necessary to assure their continued accuracy. The Contractor shall have on hand not less than ten 50pound (23 kg) weights for testing of all scales when directed by the City Engineer. Scales shall be equipped with an automatic recording device with printout capability to record the weight of each solid component of the batch. The device shall be sealed.

c. Mixers and Transportation Equipment.

(1) General. Concrete may be mixed at a central plant, or wholly or in part in truck mixers. Each mixer shall have attached in a prominent place a manufacturer's nameplate showing the capacity of the drum in terms of volume of mixed concrete and the speed of rotation of the mixing drum or blades.

A device accurate within 3 percent and satisfactory to the City Engineer shall be provided at the mixer for determining the amount of air-entraining agent or other admixture to be added to each batch requiring such admixtures.

Mixers shall be examined daily for the accumulation of hand concrete or mortar and the wear of blades.Accumulations greater than 1/8 inch shall be removed prior to resumption of concrete production.

Each mixer shall be equipped with a water measuring device so constructed that it will measure within one percent (1%) of the total amount required for each batch. Unless the Water is to be weighed, the water measuring equipment shall include an auxiliary tank with a capacity greater than that of the measuring tank, and from which the measuring tank will be filled by gravity flow. The measuring tank will be open to the atmosphere and shall be so placed and constructed that the water for a batch can be discharged into a calibrated tank or weighing device for checking the accuracy of water measurement without seriously delaying the paving operations. The Contractor shall have a calibrated tank or weighing device available at all times at a location satisfactory to the City Engineer.

(3) Central plant mixer. Central plant mixers shall conform to the requirements of ASTM C 94. ***Mixing shall be in an approved mixer capable of combining the aggregates, cementitious materials, and water into a thoroughly mixed and uniform mass within the specified mixing period and of discharging the mixture without segregation. Central plant mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed. The water system for a central mixer shall be either a calibrated measuring tank or a meter and shall not necessarily be an integral part of the mixer.***

The mixer shall be examined daily for changes in condition due to accumulation of hand concrete or mortar or wear of blades. The pickup and throwover blades shall be replaced when they have worn down *3/4* inch (19 mm) or more. The Contractor shall have a copy of the manufacturer's design on hand showing dimensions and arrangement of blades in reference to original height and depth.

(4) Truck mixers and truck agitators. Truck mixers used for mixing and hauling concrete and truck agitators used for hauling central-mixed concrete shall conform to the requirements of ASTM C 94.

(5) Nonagitator trucks. Nonagitating hauling equipment shall conform to the requirements of ASTM C 94.

a. Finishing Equipment. The standard method of constructing concrete pavements on FAA projects shall be with an approved Slip-form paving equipment designed to spread, consolidate, screed, and float-finish the freshly placed concrete in one complete pass of the machine so a dense and homogeneous pavement is achieved with a minimum of hand finishing. ***The finishing machine shall be equipped with one or more oscillating-type transverse screed.*** The paver-finisher shall be a heavy duty, self-propelled machine designed specifically for paving and finishing high quality concrete pavements. It shall weigh at least 2200 Lbs. per foot of paving lane width and powered by an engine having at least 6.0 horsepower per foot of lane width.

On projects requiring less than 500 square yards of cement concrete pavement or requiring individual placement areas of less than 500 square yards, or irregular areas at locations inaccessible to slip-form paving equipment, cement concrete pavement may be placed with approved placement and finishing equipment utilizing stationary side forms. Hand screeding and float finishing may only be utilized on small irregular areas as allowed by the ***City*** Engineer.

b. Vibrators.

Vibrator shall be either internal type with multiple spuds, or surface type vibrating pan or screed.

For overlay pavements up to 8 inches (20 cm) nominal thickness, internal vibrators shall be used. Operating frequency for internal vibrators shall be between ***7,000*** and 12,000 vibrations per minute. Average amplitude for internal vibrators shall be 0.025-0.05 inches (0.06-0.13 cm).

The number, spacing, and frequency shall be as necessary to provide a dense and homogeneous pavement and meet the recommendations of ACI 309, Guide for Consolidation of Concrete. Adequate power to operate all vibrators shall be available on the paver. The vibrators shall be automatically controlled so that they shall be stopped as forward motion ceases. The contractor shall provide an electronic or mechanical means to monitor vibrator status. The checks on vibrator status shall occur a minimum of two times per day or when requested by the ***City*** Engineer.

Hand held vibrators may be used in irregular areas only, but shall meet the recommendations of ACI 309, Guide for Consolidation of Concrete.

c. Concrete Saws. The Contractor shall provide sawing equipment adequate in number of units and power to complete the sawing to the required dimensions. The Contractor shall provide at least one standby saw in good working order and a supply of saw blades at the site of the work at all times during sawing operations.

d. Side Forms. Straight side forms shall be made of steel and shall be furnished in sections not less than 10 feet (3 m) in length. Forms shall have a depth equal to the pavement thickness at the edge, and a base width equal to or greater than the depth. Flexible or curved forms of proper radius shall be used for curves of 100-foot (31 m) radius or less. ***Flexible or curved forms shall be of a design acceptable to the City Engineer***. Forms shall be provided with adequate devices for secure settings so that when in place they will withstand, without visible spring or settlement, the impact and vibration of the consolidating and finishing equipment. ***Flange braces shall extend outward on the base not less than two-thirds the height of the form***.

Forms with battered top surfaces and bent, twisted or broken forms shall not be used, ***and shall be removed from the work. Repaired forms shall not be used until inspected and approved.*** Built-up forms shall not be used, except as approved by the ***City*** Engineer. The top face of the form shall not vary from a true plane more than *1/8* inch (3 mm) in 10 feet (3 m), and the upstanding leg shall not vary more than *1/4* inch (6 mm). The forms shall contain provisions for locking the ends of abutting sections together tightly for secure setting. Wood forms may be used under special conditions, when approved by the ***City*** Engineer.

e. Pavers. ***The maximum allowable paving lane width for this project is to be 25 feet.*** The paver shall be fully energized, self-propelled, and designed for the specific purpose of placing, consolidating, and finishing the concrete pavement, true to grade, tolerances, and cross section. It shall be of sufficient weight and power to construct the maximum specified concrete paving lane width as shown in the plans, at adequate forward speed, without transverse, longitudinal or vertical instability or without displacement. The paver shall be equipped with electronic or hydraulic horizontal and vertical control devices.

Prior to the start of paving operations, the manufacturer's representative is to certify that the slipform paver to be used by the Contractor on this project is in good operating condition and is capable of performing the work required by the drawings and specifications. The slipform paver shall be rechecked by the manufacturer's representative for proper operation and condition at least once every 90 days during its use on this project, and as requested by the City Engineer. Cost of certification and rechecks shall be included in the Contract Unit Prices for work under this specification item. There will be no separate pay for certification and re-checks; costs to be subsidiary to the item(s) which it is a component.

501-4.2 FORM SETTING. Forms shall be set sufficiently in advance of the concrete placement to insure continuous paving operation. After the forms have been set to correct grade, the underlying surface shall be thoroughly tamped, either mechanically or by hand, at both the inside and outside edges of the base of the forms. Forms shall be staked into place sufficiently to maintain the form in position for the method of placement.

Form sections shall be tightly locked and shall be free from play or movement in any direction. The forms shall not deviate from true line by more than *1/8* inch (3 mm) at any joint. Forms shall be so set that they will withstand, without visible spring or settlement, the impact and vibration of the consolidating and finishing equipment. Forms shall be cleaned and oiled prior to the placing of concrete.

The alignment and grade elevations of the forms shall be checked and corrections made by the Contractor immediately before placing the concrete.

501-4.3 CONDITIONING OF UNDERLYING SURFACE. The compacted underlying surface on which the pavement will be placed shall be widened approximately 3 feet (1 m) to extend beyond the paving machine track to support the paver without any noticeable displacement. After the underlying surface has been placed and compacted to the required density, the areas that will support the paving machine and the area to be paved shall be trimmed or graded to the plan grade elevation and profile by means of a properly designed machine. The grade of the underlying surface shall be controlled by a positive grade control system using lasers, stringlines, or guide wires. If the density of the underlying surface is disturbed by the trimming operations, it shall be corrected by additional compaction and retested at the option of the ***City*** Engineer before the concrete is placed except when stabilized subbases are being constructed. If damage occurs on a stabilized subbase, it shall be corrected full depth by the Contractor. If traffic is allowed to use the prepared grade, the grade shall be checked and corrected immediately before the placement of concrete. The prepared grade shall be moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from concrete. The underlying surface shall be protected so that it will be entirely free of frost when concrete is placed.

501-4.4 CONDITIONING OF UNDERLYING SURFACE, SIDE-FORM AND FILL-IN LANE CONSTRUCTION. The prepared underlying surface shall be moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from the concrete. Damage caused by hauling or usage of other equipment shall be corrected and retested at the option of the City Engineer. If damage occurs to a stabilized subbase, it shall be corrected full depth by the Contractor. A ***multiple-pin*** template ***weighing not less than 1,000 pounds per 20 feet or other approved template*** shall be provided and operated on the forms immediately in advance of the placing of all concrete. The template shall be propelled only by hand and not attached to a tractor or other power unit. Templates shall be adjustable so that they may be set and maintained at the correct contour of the underlying surface. The adjustment and operation of the templates shall be such as will provide an accurate retest of the grade before placing the concrete thereon. All excess material shall be removed and wasted. Low areas shall be filled and compacted to a condition similar to that of the surrounding grade. The underlying surface shall be protected so that it will be entirely free from frost when the concrete is placed. The use of chemicals to eliminate frost in the underlying surface shall not be permitted.

The template shall be maintained in accurate adjustment, at all times by the Contractor, and shall be checked daily.

501-4.5 HANDLING, MEASURING, AND BATCHING MATERIAL. The batch plant site, layout, equipment, and provisions for transporting material shall assure a continuous supply of material to the work. Stockpiles shall be constructed in such a manner that prevents segregation and intermixing of deleterious materials. ***Stockpiles shall be built up in layers of not more than 3 feet (90 cm) in thickness. Each layer shall be completely in place before beginning the next layer and shall not be allowed to "cone" down over the next lower layer. Aggregates from different sources and of different grading shall not be stockpiled together. Improperly placed stockpiles will not be accepted by the City Engineer.***

Aggregates shall be handled from stockpiles or other sources to the batching plant in such manner to secure the specified grading of the material. Aggregates that have become segregated or mixed with earth or foreign material shall not be used. All aggregates produced or handled by hydraulic methods, and washed aggregates, shall be stockpiled or binned for draining at least 12 hours before being batched. Rail shipments requiring more than 12 hours will be accepted as adequate binning only if the car bodies permit free drainage. ***The fine aggregate and coarse aggregate shall be separately weighed into hoppers in the respective amounts set by the Engineer in the job mix. Cement shall be measured by weight Separate scales and hopper, with a device to positively indicate the complete discharge of the batch of cement into the batch box or container, shall be used for weighing the cement***

Batching plants shall be equipped to proportion aggregates and bulk cement, by weight, automatically using interlocked proportioning devices of an approved type. When bulk cement is used, the Contractor shall use a suitable method of handling the cement from weighing hopper to transporting container or into the batch itself for transportation to the mixer, such as a chute, boot, or other approved device, to prevent loss of cement. The device shall be arranged to provide positive assurance that the cement content specified is present in each batch.

Batches may be rejected unless mixed within 1-1/2 hours of initial contact of cement with the aggregates. Batching shall be conducted so that the results in the weights of each material required will be within a tolerance of 1 percent for cement and 2 percent for aggregates.

Water may be measured either by volume or by weight the accuracy of measuring the water shall be within plus or minus 1 percent of required amounts. Unless the water is to be weighed, the water-measuring equipment shall include an auxiliary tank from which the measuring tank shall be filled. The measuring tank shall be equippewith an outside tap and valve to provide for checking the setting unless other means are provided for readily and accurately determining the amount of water in the tank. The volume of the auxiliary tank shall be at least equal to that of the measuring tank.

Methods and equipment for adding air-entraining agent or other admixtures to the batch, when required, shall be approved by the City Engineer. All admixtures shall be measured into the mixer with an accuracy of plus or minus 3 percent.

501-4.6 MIXING CONCRETE. The concrete may be mixed at the work site, in a central mix plant or in truck mixers. The mixer shall be of an approved type and capacity. Mixing time shall be measured from the time all materials, except water, are emptied into the drum. All concrete shall be mixed and delivered to the site in accordance with the requirements of ASTM C 94 ***except that the minimum required revolutions of mixing for transit mixed concrete may be reduced to not less than that recommended by the mixer manufacturer. The number of revolutions recommended by the mixer manufacturer shall be indicated on the manufacturer's serial plate attached to the mixer. The Contractor shall furnish test data acceptable to the City Engineer verifying that the make and model of***

the mixer will produce uniform concrete conforming to the provisions of ASTM C 94 at the reduced number of revolutions shown on the serial plate.

When mixed at the work site or in a central mixing plant the mixing time shall not be less than 50 seconds nor more than 90 seconds. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

The mixer shall be operated at the drum speed as shown on the manufacturer's nameplate on the approved mixer. Any concrete mixed less than the specified time shall be discarded at the Contractor's expense. The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity in cubic feet (cubic yards), as shown on the manufacturer's standard rating plate on the mixer. An overload up to 10 percent above the mixer's nominal capacity may be permitted provided concrete test data for segregation and uniform consistency are satisfactory and provided no spillage of concrete takes place. The batch shall be charged into the drum so that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform, and all water shall be in the drum by the end of the first 15 seconds of the mixing period. The throat of the drum shall be kept free of such accumulations as may restrict the free flow of materials into the drum.

Mixed concrete from the central mixing plant shall be transported in truck mixers, truck agitators, or nonagitating trucks. The elapsed time from the addition of cementitious material to the mix until the concrete is deposited in place at the work site shall not exceed 30 minutes when the concrete is hauled in nonagitating trucks, nor 90 minutes when the concrete is hauled in truck mixers or truck agitators. Retempering concrete by adding water or by other means will not be permitted. With transit mixers additional water may be added to the batch materials and additional mixing performed to increase the slump to meet the specified requirements provided the addition of water is performed within 45 minutes after the initial mixing operations and provided the water/cementitious ratio specified in the approved mix design is not exceeded, and approved by the City Engineer.

Computerized batch tickets shall be supplied for all concrete.

501-4.7 LIMITATIONS ON MIXING AND PLACING. No concrete shall be mixed, placed, or finished when the natural light is insufficient, unless an adequate and approved artificial lighting system is operated.

a. Cold Weather. Unless authorized in writing by the City Engineer, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches 40° F (4° C) and shall not be resumed until an ascending air temperature in the shade and away from artificial heat reaches 35° F (2° C).

The aggregate shall be free of ice, snow, and frozen lumps before entering the mixer. The temperature of the mixed concrete shall not be less than 50° F (10° C) at the time of placement. Concrete shall not be placed on frozen material nor shall frozen aggregates be used in the concrete.

When concreting is authorized during cold weather, water and/or the aggregates may be heated to not more than 150° F (66° C) ***prior to being placed in the mixer.*** The apparatus used shall heat the mass uniformly and shall be arranged to preclude the possible occurrence of overheated areas which might be detrimental to the materials.

b. Hot Weather. During periods of hot weather when the maximum daily air temperature exceeds 85° F (30°C), the following precautions shall be taken.

The forms and/or the underlying surface shall be sprinkled with water immediately before placing the concrete. The concrete shall be placed at the coolest temperature practicable, and in no case shall the temperature of the concrete when placed exceed 90°F (35°C). The aggregates and/or mixing water shall be cooled as necessary to maintain the concrete temperature at or not more than the specified maximum.

The finished surfaces of the newly laid pavement shall be kept damp by applying a water-fog or mist with approved spraying equipment until the pavement is covered by the curing medium. If necessary, wind screens shall be provided to protect the concrete from an evaporation rate in excess of 0.2 psf per hour as determined in accordance with Figure 2.1.5 in ACI 305R, Hot Weather Concreting, which takes into consideration relative humidity, wind velocity, and air temperature.

When conditions are such that problems with plastic cracking can be expected, and particularly if any plastic cracking begins to occur, the Contractor shall immediately take such additional measures as necessary to protect the concrete surface. Such measures shall consist of wind screens, more effective fog sprays, and similar measures commencing immediately behind the paver. If these measures are not effective in preventing plastic cracking, paving operations shall be immediately stopped.

d. Temperature Management Program. Prior to the start of paving operation for each day of paving, the contractor shall provide the City Engineer with a Temperature Management Program for the concrete to be placed to assure that uncontrolled cracking is avoided. As a minimum the program shall address the following items:

(1) Anticipated tensile strains in the fresh concrete as related to heating and cooling of the concrete material.
(2) Anticipated weather conditions such as ambient temperatures, wind velocity, and relative humidity.
(3) Anticipated timing of initial sawing of joint.

501-4.8 PLACING CONCRETE. The Contractor has the option of placing the concrete with either side (fixed) forms or slip-forms. At any point in concrete conveyance, the free vertical drop of the concrete from one point to another or to the underlying surface shall not exceed 3 feet (1 m). Backhoes and grading equipment shall not be used to distribute the concrete in front of the paver. Front end loaders will not be used unless the contractor demonstrates that they can be used without contaminating the concrete and base course and it is approved by the City Engineer.

Hauling equipment or other mechanical equipment can be permitted on adjoining previously constructed pavement when the concrete strength reaches a flexural strength of 550 psi (3,792 kPa), based on the average of four field cured specimens per 2,000 cubic yards (1,530 cubic meters) of concrete placed. Also, subgrade and subbase planers, concrete pavers, and concrete finishing equipment may be permitted to ride upon the edges of previously constructed pavement when the concrete has attained a minimum flexural strength of 400 psi.

a. Slip-Form Construction. The concrete shall be distributed uniformly into final position by a self propelled slip-form paver without delay. The alignment and elevation of the paver shall be regulated from outside reference lines established for this purpose. The paver shall vibrate the concrete for the full width and depth of the strip of pavement being placed and the vibration shall be adequate to provide a consistency of concrete that will stand normal to the surface with sharp well defined edges. The sliding forms shall be rigidly held together laterally to prevent spreading of the forms.

The plastic concrete shall be effectively consolidated by internal vibration with transverse vibrating units for the full width of the pavement and/or a series of equally placed longitudinal vibrating units. The space from the outer edge of the pavement to longitudinal unit shall not exceed 9 inches. The spacing of internal units shall be uniform and shall not exceed 18 inches.

The term internal vibration means vibrating units located within the specified thickness of pavement section.

The rate of vibration of each vibrating unit shall be within 8,000 to 12,000 cycles per minute and the amplitude of vibration shall be sufficient to be perceptible on the surface of the concrete along the entire length of the vibrating unit and for a distance of at least one foot. The frequency of vibration or amplitude shall vary proportionately with the rate of travel to result in a uniform density and air content. The paving machine shall be equipped with a tachometer or other suitable device for measuring and indicating the actual frequency of vibrations.

The concrete shall be held at a uniform consistency. The slip-form paver shall be operated with as nearly a continuous forward movement as possible. And all operations of mixing, delivering, and spreading concrete shall be coordinated to provide uniform progress with stopping and starting of the paver held to a minimum. If for any reason, it is necessary to stop the forward movement of the paver, the vibratory and tamping elements shall also be stopped immediately. No tractive force shall be applied to the machine, except that which is controlled from the machine.

When concrete is being placed adjacent to an existing pavement, that part of the equipment which is supported on the existing pavement shall be equipped with protective pads on crawler tracks or rubber-tired wheels on which the bearing surface is offset to run a sufficient distance from the edge of the pavement to avoid breaking the pavement edge.

Concrete constructed under this specification shall* be *placed on cement-stabilized crushed recycled concrete base, or other prepared surface as shown on* the *drawings. No concrete shall* be *placed before* the *stabilized base has attained the specified compressive strength, or 7 days, whichever occurs first.

b. Side-Form Construction. Side form sections shall be straight, free from warps, bends, indentations, or other defects. Defective forms shall be removed from the work. Metal side forms shall be used except at end closures and transverse construction joints where straight forms of other suitable material may be used.

Side forms may be built up by rigidly attaching a section to either top or bottom of forms. If such build-up is attached to the top of metal forms, the build-up shall also be metal. Width of the base of all forms shall be equal to at least 80 percent of the specified pavement thickness.

Side forms shall be of sufficient rigidity, both in the form and in the interlocking connection with adjoining forms, that springing will not occur under the weight of subgrading and paving equipment or from the pressure of the concrete. The Contractor shall provide sufficient forms so that there will be no delay in placing concrete due to lack of forms.

It is the intent* of *the specification to produce* a *high quality, dense, long lasting and smooth pavement suitable for the high speed operations* of *roughness-sensitive heavy jet aircraft. This requires that all joints and particularly all longitudinal joints meet the specified tolerance throughout their length. The City Engineer will designate the paving lanes in* an *apron, taxiway or the outer runway paving lanes to be used for the initial paving operations.

Before placing side forms, the underlying material shall be at the proper grade. Side forms shall have full bearing upon the foundation throughout their length and width of base and shall be placed to the required grade and alignment of the finished pavement. They shall be firmly supported during the entire operation of placing, compacting, and finishing the pavement.

Forms shall be drilled in advance of being placed to line and grade to accommodate tie bars where these are specified.

Immediately in advance of placing concrete and after all subbase operations are completed, side forms shall be trued and maintained to the required line and· grade for a distance sufficient to prevent delay in placing.

Side forms shall remain in place at least 12 hours after the concrete has been placed and in all cases until the edge of the pavement no longer requires the protection of the forms. Curing compound shall be applied to the concrete immediately after the forms have been removed.Side forms shall be thoroughly cleaned and oiled each time they are used and before concrete is placed against them. Concrete shall be spread, screeded, shaped and consolidated by one or more self-propelled machines. These machines shall uniformly distribute and consolidate concrete without segregation so that the completed pavement will conform to the required cross section with a minimum of handwork.

The number and capacity of machines furnished shall be adequate to perform the work required at a rate equal to that of concrete delivery.

Concrete for the full paving width shall be effectively consolidated by internal vibrators without causing segregation. Internal type vibrators' rate of vibration shall be not less than 7,000 cycles per minute. Amplitude of vibration shall be sufficient to be perceptible on the surface of the concrete more than one foot from the vibrating element. The Contractor shall furnish a tachometer or other suitable device for measuring and indicating frequency of vibration.

Power to vibrators shall be connected so that vibration ceases when forward or backward motion of the machine is stopped.

The provisions relating to the frequency and amplitude of internal vibration shall be considered the minimum requirements and are intended to ensure adequate density in the hardened concrete.

c. Consolidation Testing. The provisions relating to the frequency and amplitude of internal vibration shall be considered the minimum requirements and are intended to ensure adequate density in the hardened concrete. If a lack of consolidation of the concrete is suspected by the City Engineer, additional referee testing may be required. Referee testing of hardened concrete will be performed by cutting cores from the finished pavement after a minimum of 24 hours curing. Density determinations will be made based on the water content of the core as taken. ASTM C 642 shall be used for the determination of core density in the saturated-surface dry condition. Referee cores will be taken at the minimum rate of one for each 500 cubic yards of pavement, or fraction thereof.

The average density of the cores shall be at least 97 percent of the original mix design density, with no cores having a density of less than 96 percent of the original mix design density.

Failure to meet the above requirements will be considered as evidence that the minimum requirements for vibration are inadequate for the job conditions and additional vibrating units or other means of increasing the effect of vibration shall be employed so that the density of the hardened concrete as indicated by further referee testing shall conform to the above listed requirements.

501-4.9 STRIKE-OFF OF CONCRETE AND PLACEMENT OF REINFORCEMENT. Following the placing of the concrete, it shall be struck off to conform to the cross section shown on the plans and to an elevation such that when the concrete is properly consolidated and finished, the surface of the pavement shall be at the elevation shown on the plans. When reinforced concrete pavement is placed in two layers, the bottom layer shall be struck off to such length and depth that the sheet of reinforcing steel fabric or bar mat may be laid full length on the concrete in its final position without further manipulation. The reinforcement shall then be placed directly upon the concrete, after which the top layer of the concrete shall be placed, struck off, and screeded. If any portion of the bottom layer of concrete has been placed more than 30 minutes without being covered with the top layer or if initial set has taken place, it shall be removed and replaced with freshly mixed concrete at the Contractor's expense. When reinforced concrete is placed in one layer, the reinforcement may be positioned in advance of concrete placement or it may be placed in plastic concrete by mechanical or vibratory means after spreading.

Reinforcing steel, at the time concrete is placed, shall be free of mud, oil, or other organic matter that may adversely affect or reduce bond. Reinforcing steel with rust, mill scale or a combination of both will be considered satisfactory, provided the minimum dimensions, weight, and tensile properties of a hand wire-brushed test specimenare not less than the applicable ASTM specification requirements.

501-4.10 JOINTS. Joints shall be constructed as shown on the plans and in accordance with these requirements. All joints shall be constructed with their faces perpendicular to the surface of the pavement and finished or edged as shown on the plans. Joints shall not vary more than *1/2* inch (13 mm) fromtheir designated position and shall be true to line with not more than 1/4-inch (6 mm) variation in 10 feet (3 m). The surface across the joints shall be tested with a 10-foot (3 m) straightedge as the joints are finished and any irregularities in excess of *1/4* inch (6 mm) shall be corrected before the concrete has hardened. All joints shall be so prepared, finished, or cut to provide a groove of uniform width and depth as shown on the plans.

a. Construction. Longitudinal construction joints shall be slip-formed or formed against side forms with or without keyways, as shown in the plans. Transverse construction joints shall be installed at the end of each day's placing operations and at any other points within a paving lane when concrete placement is interrupted for more than 30 minutes or it appears that the concrete will obtain its initial set before fresh concrete arrives. The installation of the joint shall be located at a planned contraction or expansion joint. If placing of the concrete is stopped, the Contractor shall remove the excess concrete back to the previous planned joint.

b. Contraction. Contraction joints shall be installed at the locations and spacing as shown on the plans. Contraction joints shall be installed to the dimensions required by forming a groove or cleft in the top of the slab while the concrete is still plastic or by sawing a groove into the concrete surface after the concrete has hardened.

When the groove is formed in plastic concrete the sides of the grooves shall be finished even and smooth with an edging tool. If an insert material is used, the installation and edge finish shall be according to the manufacturer's instructions.

The groove shall be finished or cut clean so that spalling will be avoided at intersections with other joints. Grooving or sawing shall produce a slot at least 1/8 inch (3 mm) wide and to the depth shown on the plans.

c. Expansion. Expansion joints shall be installed as shown on the plans. The premolded filler of the thickness as shown on the plans shall extend for the full depth and width of the slab at the joint, except for space for sealant at the top of the slab. The filler shall be securely staked or fastened into position perpendicular to the proposed finished surface. A cap shall be provided to protect the top edge of the filler and to permit the concrete to be placed and finished. ***All devices used for the installation of expansion joints shall be approved by the City Engineer. They shall be easily removable without disturbing the concrete and held in proper transverse and vertical alignment.*** After the concrete has been placed and struck off, the cap shall be carefully withdrawn leaving the space over the premolded filler. The edges of the joint shall be finished and tooled while the concrete is still plastic. Any concrete bridging the joint space shall be removed for the full width and depth of the joint ***sealant reservoir. Before the pavement is opened to traffic. This space shall be swept clean and filled with approved joint sealing material.***

d. Tie bars. Tie bars shall consist of deformed bars installed in joints as shown on the plans. Tie bars shall be placed at right angles to the centerline of the concrete slab and shall be spaced at intervals shown on the plans. They shall be held in position parallel to the pavement surface and in the middle of the slab depth. When tie bars extend into an unpaved lane, they may be bent against the form at longitudinal construction joints, unless threaded bolt or other assembled tie bars are specified. These bars shall not be painted, greased, or enclosed in sleeves. When slip-form operations call for tie bars, two-piece hook bolts can be installed in the female side of the keyed joint provided the installation is made without distorting the keyed dimensions or causing edge slump. If a bent tie bar installation is used, the tie bars shall be inserted through the keyway liner only on the female side of the joint. In no case shall a bent tie bar installation for male keyways be permitted.

e. Dowel bars. Dowel bars or other load-transfer units of an approved type shall be placed across joints in the manner as shown on the plans. They shall be of the dimensions and spacing as shown and held rigidly in the middle of the slab depth in the proper horizontal and vertical alignment by an approved assembly device to be left permanently in place. The dowel or load-transfer and joint devices shall be rigid enough to permit complete assembly as a unit ready to be lifted and placed into position. A metal or other type, dowel expansion cap or sleeve shall be furnished for each dowel bar used with expansion joints. These caps shall be substantial enough to prevent collapse and shall be placed on the ends of the dowels as shown on the plans. The caps or sleeves shall fit the dowel bar tightly and the closed end shall be watertight. The portion of each dowel painted with rust preventative paint, as required under paragraph 501-2.7 and shown on the plans to receive a debonding lubricant, shall be thoroughly coated with asphalt Me-70, or an approved lubricant, to prevent the concrete from bonding to that portion of the dowel. If free-sliding plastic-coated or epoxy-coated steel dowels are used, a lubrication bond breaker shall be used except when approved pullout tests indicate it is not necessary. Where butt-type joints with dowels are designated, the exposed end of the dowel shall be oiled.

Dowel bars at contraction joints may be placed in the full thickness of pavement by a mechanical device approved by the City Engineer. The device shall be capable of installing dowel bars within the maximum permissible alignment tolerances. Dowels bars at longitudinal construction joints shall be bonded in drilled holes.

f. Installation. All devices used for the installation of expansion joints shall be approved by the City Engineer.

Transverse joints with dowels will require particular care to ensure the dowels are accurately placed and not disturbed during concrete placement. Transverse joint dowels will require use of an apparatus to firmly hold the dowels perpendicular to the joint and parallel to the slab surface. The most effective way to maintain proper alignment is with well-fabricated dowel baskets and dowel assemblies.

The top of an assembled joint device shall be set at the proper distance below the pavement surface and the elevation shall be checked. Such devices shall be set to the required position and line and shall be securely held in place by stakes or other means to the maximum permissible tolerances during the pouring and finishing of the concrete. The premolded joint material shall be placed and held in a vertical position; if constructed in sections, there shall be no offsets between adjacent units.

Dowel bars and assemblies shall be checked for position and alignment. The maximum permissible tolerances on dowel bar alignment shall be in accordance with paragraph 501-5.2e (6). During the concrete placement operation, it is advisable to place plastic concrete directly on dowel assemblies immediately prior to passage of the paver to help maintain dowel position and alignment within maximum permissible tolerances.

When concrete is placed using slip-form pavers, dowels and tie bars shall be placed in longitudinal construction joints by bonding the dowels or tie bars into holes drilled into the hardened concrete. Holes approximately 1/8-inch to 114-inch (3 to 6 mm) greater in diameter than the dowel or tie bar shall be drilled with rotary-type core drills that must be held securely in place to drill perpendicularly into the vertical face of the pavement slab. Rotary-type percussion drills may be used provided that spalling of concrete does not occur. Any damage of the concrete shall be repaired by the Contractor in a method approved by the ***City*** Engineer. Dowels or tie bars shall be bonded in the drilled holes using an epoxy resin material. Installation procedures shall be adequate to insure that the area around dowels is completely filled with epoxy grout. Epoxy shall be injected into the back of the hole and displaced by the insertion of the dowel bar. Bars shall be completely inserted into the hole and shall not be withdrawn and reinserted creating air pockets in the epoxy around the bar. The Contractor shall furnish a template for checking the position and alignment of the dowels. Dowel bars shall not be less than 10 inches (25 cm) from a transverse joint and shall not interfere with dowels in the transverse direction.

h. Sawing of Joints. Joints shall be cut as shown on the plans. Equipment shall be as described in paragraph 501-4.1. The circular cutter shall be capable of cutting a groove in a straight line and shall produce a slot at least *1/8* inch (3 mm) wide and to the depth shown on the plans. The top portion of the slot shall be widened by sawing to provide adequate space for joint sealers as shown on the plans. ***The Initial sawcut for all sawed joints shall be made as soon as possible after the concrete pavement has hardened sufficiently to support equipment and render a clean sawcut without chipping, spalling, or creating other damage to the concrete surface.*** and before uncontrolled shrinkage cracking of the pavement occurs Sawing shall be carried on both during the day and night as required.

The joints shall be sawed at the required spacing, consecutively in sequence of the concrete placement. Curing compound, if being used as the cure type, shall be reapplied in the initial sawcut and maintained for the remaining cure period. Curing compound shall not be applied, and used as the cure method, to any final concrete face that is to receive a sealant. ***If, while sawing a faint, A crack develops ahead of the saw, immediately discontinue sawing that joint when the designed joint sealant reservoirs are sawed, "rout-out" the top of the crack to create a sealant reservoir of the same dimensions as for the planned joints. Then seal the crack as if it was a planned faint. To help assure that these accidental" joints match the corresponding Joints in adjacent slabs, a short (approximately 1.5 ft) saw cut of the standard depth can be made on the opposite side of the slab before beginning sawing the complete joint from a given side.***

501-4.11 FINAL STRIKE-OFF, CONSOLIDATION, AND FINISHING.

a. Sequence. The sequence of operations shall be the strike-off, floating and removal of laitance, straight edging, and final surface finish. The addition of superficial water to the surface of the concrete to assist in finishing operations will not be permitted.

b. Finishing at Joints. The concrete adjacent to joints shall be compacted or firmly placed without voids or segregation against the joint material; it shall be firmly placed without voids or segregation under and around all load-transfer devices, joint assembly units, and other features designed to extend into the pavement. Concrete adjacent to joints shall be mechanically vibrated as required in paragraph 501-4.8.a. After the concrete has been placed and vibrated adjacent to the joints, the finishing machine shall be operated in a manner to avoid damage or misalignment of joints. If uninterrupted operations of the finishing machine, to, over, and beyond the joints, cause segregation of concrete, damage to, or misalignment of the joints, the finishing machine shall be stopped when the screed is approximately 8 inches (20 cm) from the joint. Segregated concrete shall be removed from the front of and off the joint, ***the screed shall be lifted and set directly* on *top of the taint***, and the forward motion of the finishing machine shall be resumed. Thereafter, the finishing machine may be run over the joint without lifting the screed, provided there is no segregated concrete immediately between the joint and the screed or on top of the joint.

c. Machine Finishing. The concrete shall be spread as soon as it is placed, and it shall be struck off and screeded by ***an approved*** finishing machine. The machine shall go over each area as many times and at such intervals as necessary to give to proper consolidation and to leave a surface of uniform texture. Excessive operation over a given area shall be avoided. When side forms are used, the tops of the forms shall be kept clean by an effective device attached to the machine, and the travel of the machine on the forms shall be maintained true without lift, wobbling, or other variation tending to affect the precision finish. During the first pass of the finishing machine, a uniform ridge of concrete shall be maintained ahead of the front screed for its entire length. When in operation, the screed shall be moved forward with a combined longitudinal and transverse shearing motion, always moving in the direction in which the work is progressing, and so manipulated that neither end is raised from the side forms during the striking-off process. If necessary, this shall be repeated until the surface is of uniform texture, true to grade and cross section, and free from porous areas.

d. Hand Finishing. Hand finishing methods will not be permitted, except under the following conditions: in the event of breakdown of the mechanical equipment, hand methods may be used to finish the concrete already deposited on the grade; in areas of narrow widths or of irregular dimensions where operation of the mechanical equipment is impractical. Concrete, as soon as placed, shall be struck off and screeded. An approved portable screed shall be used. A second screed shall be provided for striking off the bottom layer of concrete when reinforcement is used.

e. The screed for the surface shall be a least 2 feet (0.6 m) longer than the maximum width of the slab to be struck off. It shall be of approved design, sufficiently rigid to retain its shape, and shall be constructed either of metal or of other suitable material covered with metal. Consolidation shall be attained by the use of suitable vibrators.

f. Floating. After the concrete has been struck off and consolidated, it shall be further smoothed and trued by means of a longitudinal float using one of the following methods:

(1) Hand Method. Long-handled floats shall not be less than 12 feet (3.6 m) in length and 6 inches (15 cm) in width, stiffened to prevent flexibility and warping. The float shall be operated from foot bridges spanning but not touching the concrete or from the edge of the pavement. Floating shall pass gradually from one side of the pavement to the other. Forward movement along the centerline of the pavement shall be in successive advances of not more than one-half the length of the float. Any excess water or laitance in excess of 1/8-inch (3 mm) thick shall be removed and wasted.

(2) Mechanical method. The Contractor may use a machine composed of a cutting and smoothing float(s), suspended from and guided by a rigid frame and constantly in contact with, the side forms or underlying surface. If necessary, long-handled floats having blades not less than 5 feet (1.5 m) in length and 6 inches (15 cm) in width may be used to smooth and fill in open-textured areas in the pavement. When the crown of the pavement will not permit the use of the mechanical float, the surface shall be floated transversely by means of a long-handled float. Care shall be taken not to work the crown out of the pavement during the operation. After floating, any excess water and laitance in excess of 1/8-inch (3 mm) thick shall be removed and wasted. Successive drags shall be lapped one-half the length of the blade.

g. Straight-edge Testing and Surface Correction. After the pavement has been struck off and while the concrete is still plastic, it shall be tested for trueness with a Contractor furnished 16-foot (5 m) straightedge swung from handles 3 feet (1 m) longer than one-half the width of the slab. The straightedge shall be held in contact with the surface in successive positions parallel to the centerline and the whole area gone over from one side of the slab to the other, as necessary.

Advancing shall be in successive stages of not more than one-half the length of the straightedge. Any excess water and laitance in excess of 1/8-inch (3 mm) thick shall be removed from the surface of the pavement and wasted. Any depressions shall be immediately filled with freshly mixed concrete, struck off, consolidated, and refinished. High areas shall be cut down and refinished. Special attention shall be given to assure that the surface across joints meets the smoothness requirements of paragraph 501-5.2e (3). Straightedge testing and surface corrections shall continue until the entire surface is found to be free from observable departures from the straightedge and until the slab conforms to the required grade and cross section. The use of long-handled wood floats shall be confined to a minimum; they may be used only in emergencies and in areas not accessible to finishing equipment.

h. ***Stationing Stencil. Furnish stencils to impress centerline stationing at 100 foot intervals into the fresh concrete along each edge, with numerals approximately 2 in. high by 1 in. wide by 114 in. deep. There will be* no *separate payment for stenciling.***

501-4.12 SURFACE TEXTURE. The surface of the pavement shall be finished with either a brush or broom, burlap drag, or artificial turf finish for all newly constructed concrete pavements. It is important that the texturing equipment not tear or unduly roughen the pavement surface during the operation. Any imperfections resulting from the texturing operation shall be corrected

a. Brush or Broom Finish. If the pavement surface texture is to be a type of brush or broom finish, it shall be applied when the water sheen has practically disappeared. The equipment shall operate transversely across the pavement surface, providing corrugations that are uniform in appearance and approximately *1/16* of an inch (2 mm) in depth.

b. Burlap Drag Finish. If a burlap drag is used to texture the pavement surface, it shall be at least 15 ounces per square yard (555 grams per square meter). To obtain a textured surface, the transverse threads of the burlap shall be removed approximately 1 foot (0.3 m) from the trailing edge. A heavy

buildup of grout on the burlap threads produces the desired wide sweeping longitudinal striations on the pavement surface. The corrugations shall be uniform in appearance and approximately *1/16* of an inch (2 mm) in depth.

c. Artificial Turf Finish. If artificial turf is used to texture the surface, it shall be applied by dragging the surface of the pavement in the direction of concrete placement with an approved full width drag made with artificial turf. The leading transverse edge of the artificial turf drag will be securely fastened to a lightweight pole on a traveling bridge. At least 2 feet of the artificial turf shall be in contact with the concrete surface during dragging operations. A variety of different types of artificial turf are available and approval of anyone type will be done only after it has been demonstrated by the Contractor to provide a satisfactory texture. One type that has provided satisfactory texture consists of 7,200 approximately 0.85-inches-long polyethylene turf blades per square foot. The corrugations shall be uniform in appearance and approximately *1/16* of an inch (2 mm) in depth.

501-4.13 SKID-RESISTANT SURFACES. A skid-resistant surface shall be provided by construction of SAW-CUT GROOVES. For new concrete pavements that have hardened, transverse grooves shall be saw-cut in the pavement forming a *1/4* inch (6 mm) wide by *1/4* inch (6 mm) deep by *1-1/2* inches (37 mm) center to center configuration. The grooves shall be continuous for the entire runway length. They shall be saw-cut transversely in the runway pavement to within 10 feet (3 m) of the runway pavement edge to allow adequate space for equipment operation. The maximum transverse saw-cut grooves shall not exceed 130 feet (40 m). The tolerances for the saw-cut grooves shall meet the following:

• Alignment tolerance.

Plus or minus *1-1/2* inches (38 mm) in alignment for 75 feet (23 m).

• Groove tolerance

Minimum depth *3/16* inch (5 mm), except that not more than *60* percent of the grooves shall be less than *1/4* inch (6 mm).

Maximum depth *5/16* inch (8 mm). Minimum width *3/16* inch (5 mm). Maximum width *5/16* inch (8 mm).

• Center-to-center spacing

Minimum spacing *1-3/8* inches (35 mm) Maximum spacing *1-1/2* inches (38 mm).

Saw-cut grooves shall not be closer than 3 inches (76 mm) or more than 9 inches (229 mm) to transverse paving joints. Grooves shall not be closer than 6 inches (152 mm) and no more than 18 inches (457 mm) from in-pavement light fixtures. Grooves may be continued through longitudinal joints. Where neoprene compression seals have been installed grooves, shall not be closer than 3 inches (76 mm) or more than 5 inches (127 mm) from the longitudinal joints. Cleanup of waste material shall be continuous during the grooving operation. ***If flushing is used a temporary dam shall be constructed near the pavement edge to pond the waste slurry so that it can be picked up and disposed of. Water for cleanup shall be obtained by and at the Contractors expense.*** Waste material shall be disposed of in an approved manner. Waste material shall not be allowed to enter the airport storm or sanitary sewer system.

501-4.14 CURING. Immediately after finishing operations are completed and marring of the concrete will not occur, the entire surface of the newly placed concrete shall be cured for a 48-hour cure period ***or as specified by the City Engineer* in accordance with one of the methods below. Failure to provide sufficient *curing protection according to methods the Contractor elects to use*** shall be cause for immediate suspension of concreting operations. The concrete shall not be left exposed for more than *1/2* hour during the curing period.

When a two-saw cut method is used to construct the contraction joint, curing *protection* shall be applied to the sawcut immediately after the initial cut has been made. The sealant reservoir shall *be sawed after sufficient strength has developed to prevent spalling or raveling.* When the one cut method is used to construct the contraction joint, the joint shall be cured with wet rope, wet rags, or wet blankets. The rags, ropes, or blankets shall be kept moist for the duration of the curing period.

a. ***Curing Membrane Method. The entire surface of the pavement shall be sprayed uniformly with a white pigmented curing compound accepted by the City Engineer from a list of approved curing compounds immediately after the finishing of the surface and after surface bleeding is no longer evident The curing compound shall not be applied during rainfall. Curing compound shall be applied by mechanical sprayers under pressure at a rate specified by the City Engineer, but no less than 1 gallon (4 liters) to not more than 75 square feet (7 square meters).***

The rate of application will be determined at a minimum for half day increments (morning and afternoon) during paving operations based upon expected weather conditions and the type of curing compound used. Expected morning and afternoon weather conditions will be assessed by the City Engineer according to wind speed, ambient relative humidity, and air temperature representative of a given half day increment.

The spraying equipment shall be of the fully atomizing type equipped with a tank agitator capable of keeping the compound stirred continuously by mechanical means during application. The spraying equipment shall be suitably instrumented to monitor the rate of travel which will be established based on the required rate of application and the flow rate. Alternatively, if approved by the City Engineer the spray equipment can be instrumented to monitor the rate of flow which would be established based upon the required rate of application and the rate of travel. In either case, the monitored rate of flow will be calibrated against weighted measurements at the nozzles prior to the initiation of paving operations and when required by the City Engineer. Spray nozzles will be cleaned on a daily basis.

Uniformity of the sprayed curing compound consists of a visually-observable even distribution of the curing compound with no visible streaks or isolated bare areas. The height and spacing of the spray nozzles should accommodate sufficient overlap to ensure and even distribution of curing compound on the surface of the concrete.

At the time of use, the compound shall be in a thoroughly mixed condition with the pigment uniformly dispersed throughout the vehicle. The curing compound shall be of such character that the film will harden within 30 minutes after application. Should the film become damaged from any cause, including sawing operations, within the required curing period the damaged portions shall be repaired immediately with additional compound or other approved means. Hand spraying of odd widths or shapes and concrete surfaces exposed by the removal of forms will be permitted. When hand spraying is approved by the City Engineer a double application rate shall be used to insure coverage.

Upon removal of side forms, The sides of the exposed slabs shall be protected immediately to provide a curing treatment equal to that provided for the surface.

b. *Polyethylene Films. The top surface and sides of the pavement shall be entirely covered with polyethylene sheeting. The units shall be lapped at least 18 inches (457 mm). The sheeting shall be placed and weighted to cause it to remain in contact with the surface and sides. The sheeting shall have dimensions that will extend at least twice the thickness of the pavement beyond the edges of the pavement. Unless otherwise specified, the sheeting shall be maintained in place for 7 days after the concrete has been placed.*

c. *Waterproof Paper. The top surface and sides of the pavement shall be entirely covered with waterproofed paper. The units shall be lapped at least 18 inches (457 mm). The paper shall be placed and weighted to cause it to remain in contact with the surface covered. The paper shall have dimensions that will extend at least twice the thickness of the pavement beyond the edges of the slab. The surface of the pavement shall be thoroughly saturated prior to placing of the paper. Unless otherwise specified, the paper shall be maintained in place for 7 days after the concrete has been placed.*

d. *White Burlap Polyethylene Sheets. The surface of the pavement shall be entirely covered with the sheeting. The sheeting used shall be such length (or width) that it will extend at least twice the thickness of the pavement beyond the edges of the slab. The sheeting shall be placed so that the entire surface and both edges of the slab are completely covered. The sheeting shall be placed and weighted to remain in contact with the surface covered, and the covering shall be maintained fully saturated and in position for 7 days after the concrete has been placed.*

e. *Water Method. The entire area shall be covered with burlap or other water absorbing material. The material shall be of sufficient thickness to retain water for adequate curing without excessive runoff. The material shall be kept wet at all times and maintained for 7 days. When the forms are stripped, the vertical walls shall also be kept moist. It shall be the responsibility of the Contractor to prevent ponding of the curing water on the subbase. "*

f. *Maintenance of Surface Moisture. Minimize surface drying of the pavement before application of the curing system. To this end, consider the use of evaporation retardant on the pavement surface. Apply evaporation retardant at the rate recommended by the manufacturer. Reapply the evaporation retardant as needed to maintain the concrete surface in a moist condition until curing system is applied. Do not use evaporation retardant as a finishing aid. Precautions to prevent surface drying of the pavement may be needed to prevent undesirable effects on pavement life.*

g. *Curing in Cold Weather. The concrete shall be maintained at a temperature of at least 50 degrees F (10 degrees CJ for a period of 72 hours after placing and at a temperature above freezing for the remainder of the curing time. The Contractor shall be responsible for the quality and strength of the concrete placed during cold weather and any concrete injured by frost action shall be removed and replaced at the Contractor's expense.*

h. *Curing Effectiveness Testing. Contractor shall cooperate with efforts to monitor the effectiveness of the curing operations by both surface relative and surface dielectric measurements to determine if the relative humidity and the free moisture levels in the surface of the concrete pavement are sufficient to sustain hydration and strength gain. These efforts are expected to have minimal impact on the contractors operations.*

These measurements with be used ascertain the quality of the curing effort and determine the adequacy of the rate of application. It is anticipated that monitoring of this nature will initially be conducted at intervals of 500 linear feet of curing for up to 30 hours after placing in order to establish calibration procedures. Monitoring efforts may then focus on cured sections subjected to evaporation conditions exceeding the designated rate of curing in order to rate the impact on the quality of the concrete. Curing begins when the concrete curing system has been applied.

i. ***Measurement. Curing of concrete pavement will be measured by the gallon of curing compound in place.***

501-4.15 REMOVING FORMS. Unless otherwise specified, forms shall not be removed from freshly placed concrete until it has hardened sufficiently to permit removal without chipping, spalling, or tearing. After the forms have been removed, the sides of the slab shall be cured as outlined in one of the methods indicated in paragraph 501-

4.14. Major honeycombed areas shall be considered as defective work and shall be removed and replaced in accordance with paragraph 501-5.2(f).

501-4.16 SEALING JOINTS. The joints in the pavement shall be sealed in accordance with Item P-605.

501-4.17 PROTECTION OF PAVEMENT. The Contractor shall protect the pavement and its appurtenances against both public traffic and traffic caused by the Contractors employees and agents. This shall include watchmen to direct traffic and the erection and maintenance of warning signs, lights, pavement bridges, crossovers, and protection of unsealed joints from intrusion of foreign material, etc. Any damage to the pavement occurring prior to final acceptance shall be repaired or the pavement replaced at the Contractors expense. The Contractor shall have available at all times, materials for the protection of the edges and surface of the unhardened concrete. Such protective materials shall consist of rolled polyethylene sheeting at least 4 mils (0.1 mm) thick of sufficient length and width to cover the plastic concrete slab and any edges. The sheeting may be mounted on either the paver or a separate movable bridge from which it can be unrolled without dragging over the plastic concrete surface. When rain appears imminent, all paving operations shall stop and all available personnel shall begin covering the surface of the unhardened concrete with the protective covering.

501-4.18 OPENING TO TRAFFIC. The pavement shall not be opened to traffic until test specimens molded and cured in accordance with ASTM C 31 have attained a flexural strength of 550 pounds per square inch (3,792 kPa) when tested in accordance with ASTM C 78. If such tests are not conducted, the pavement shall not be opened to traffic until 14 days after the concrete was placed. Prior to opening the pavement to construction traffic, all joints shall either be sealed or protected from damage to the joint edge and intrusion of foreign materials into the joint. As a minimum, backer rod or tape may be used to protect the joints from foreign matter intrusion. The pavement shall be cleaned before opening for normal operations.

501-4.19 REPAIR, REMOVAL, REPLACEMENT OF SLABS.

a. General. New pavement slabs that are broken or contain cracks shall be removed and replaced or repaired, as specified hereinafter at no cost to the owner. Spalls along joints shall be repaired as specified. Removal of partial slabs is not permitted. Removal and replacement shall be full depth, shall be full width of the slab, and the limit of removal shall be normal to the paving lane and to each original transverse joint. The City Engineer will determine whether cracks extend full depth of the pavement and may require cores to be drilled on the crack to determine depth of cracking. Such cores shall be 4-inch

(100 mm) diameter, shall be drilled by the Contractor and shall be filled by the Contractor with a well consolidated concrete mixture bonded to the walls of the hole with epoxy resin, using approved procedures. Drilling of cores and refilling holes shall be at no expense to the owner. All epoxy resin used in this work shall conform to ASTM C 881, Type V.

b. Shrinkage Cracks. Shrinkage cracks, which do not exceed 4 inches in depth, shall be cleaned and then pressure injected with epoxy resin, Type IV, Grade 1, using procedures as approved. Care shall be taken to assure that the crack is not widened during epoxy resin injection. All epoxy resin injection shall take place in the presence of the City Engineer. Shrinkage cracks, which exceed 4 inches in depth, shall be treated as full depth cracks in accordance with paragraphs 4.19b and 4.19c.

c. Slabs with Cracks through Interior Areas. Interior area is defined as that area more than 6 inches (600 mm) from either adjacent original transverse joint. The full slab shall be removed and replaced at no cost to the owner, when there are any full depth cracks, or cracks greater than 4" in depth, that extend into the interior area.

d. Cracks Close To and Parallel to *Transverse* Joints. All cracks essentially parallel to original *transverse* joints, extending full depth of the slab, and lying wholly within 6 inches either side of the joint shall be treated as specified hereinafter. Any crack extending more than 6 inches (600 mm) from the *transverse* joint shall be treated as specified above in subparagraph "Slabs With Cracks Through Interior Area."

(1) Full Depth Cracks Present, Original Joint Not Opened. When the original uncracked *transverse* joint has not opened, the crack shall be sawed and sealed, and the original *transverse* joint filled with epoxy resin as specified below. The crack shall be sawed with equipment specially designed to follow random cracks. The reservoir for joint sealant in the crack shall be formed by sawing to a depth of 3/4 inch (19 mm), plus or minus *1/16* inch (1.6 mm), and to a width of *5/8* inch (16 mm), plus or minus *1/8* inch (3.2 mm). Any equipment or procedure which causes raveling or spalling along the crack shall be modified or replaced to prevent such raveling or spalling. The joint sealant shall be a liquid sealant as specified. Installation of joint seal shall be as specified for sealing joints or as directed. If the joint sealant reservoir has been sawed out, the reservoir and as much of the lower saw cut as possible shall be filled with epoxy resin, Type IV, Grade 2, thoroughly tooled into the void using approved procedures. If only the original narrow saw cut has been made, it shall be cleaned and pressure injected with epoxy resin, Type IV, Grade 1, using approved procedures. If filler type material has been used to form a weakened plane in the transverse joint, it shall be completely sawed out and the saw cut pressure injected with epoxy resin, Type IV, Grade 1, using approved procedures.

Where a parallel crack goes part way across paving lane and then intersects and follows the original *transverse* joint which is cracked only for the remained of the width, it shall be treated as specified above for a parallel crack, and the cracked original joint shall be prepared and sealed as originally designed.

(2) Full Depth Cracks Present, Original *Transverse* Joint Also Cracked. At a *transverse* joint, if there is any place in the lane width where a parallel crack and a cracked portion of the original joint overlap, the entire slab containing the crack shall be removed and replaced for the full lane width and length.

e. Removal and Replacement of Full Slabs. Where it is necessary to remove full slabs, unless there are keys or dowels present, all edges of the slab shall be cut full depth with a concrete saw. All saw cuts shall be perpendicular to the slab surface. If keys, dowels, or tie bars are present along any

edges, these edges shall be sawed full depth 24 inches (150 mm) from the edge if only keys are present, or just beyond the end of the dowels or tie bars if they are present. These joints shall then be carefully sawed on the joint line to within 1 inch (25 mm) of the depth of the dowel or key.

The main slab shall be further divided by sawing full depth, at appropriate locations, and each piece lifted out and removed. Suitable equipment shall be used to provide a truly vertical lift, and approved safe lifting devices used for attachment to the slabs. The narrow strips along keyed or doweled edges shall be carefully broken up and removed using light, hand-held jackhammers, 30 LB (14 kg) or less, or other approved similar equipment.

Care shall be taken to prevent damage to the dowels, tie bars, or keys or to concrete to remain in place. The joint face below keys or dowels shall be suitably trimmed so that there is not abrupt offset in any direction greater than 1/2 inch (12 mm) and no gradual offset greater than 1 inch (25 mm) when tested in a horizontal direction with a 12- foot (3.6 m) straightedge.

No mechanical impact breakers, other than the above hand-held equipment shall be used for any removal of slabs. If underbreak between *1-1/2* and 4 inches (37 and 100 mm) deep occurs at any point along any edge, the area shall be repaired as directed before replacing the removed slab. Procedures directed will be similar to those specified for surface spalls, modified as necessary.

If underbreak over 4 inches (100 mm) deep occurs, the entire slab containing the underbreak shall be removed and replaced. Where there are no dowels, tie bars, or keys on an edge, or where they have been damaged, dowels of the size and spacing as specified for other joints in similar pavement shall be installed by epoxy grouting them into holes drilled into the existing concrete using procedures as specified. Original damaged dowels or tie bars shall be cut off flush with the joint face. Protruding portions of dowels shall be painted and lightly oiled. All 4 edges of the new slab shall thus contain dowels or original keys or original tie bars.

Placement of concrete shall be as specified for original construction. Prior to placement of new concrete, the underlying material (unless it is stabilized) shall be re-compacted and shaped as specified in the appropriate SECTION of these specifications. The surfaces of all four joint faces shall be cleaned of all loose material and contaminants and coated with a double application of membrane forming curing compound as bond breaker. Care shall be taken to prevent any curing compound from contacting dowels or tie bars. The resulting joints around the new slab shall be prepared and sealed as specified for original construction.

f. Repairing Spalls along Joints. Where directed, spalls along joints of new slabs, and along parallel cracks used as replacement joints, shall be repaired by first making a vertical saw cut at least 1 inch (25 mm) outside the spalled area and to a depth of at least 2 inches (50 mm). Saw cuts shall be straight lines forming rectangular areas. The concrete between the saw cut and the joint, or crack, shall be chipped out to remove all unsound concrete and at least *1/2* inch (12 mm) of visually sound concrete. The cavity thus formed shall be thoroughly cleaned with high-pressure water jets supplemented with compressed air to remove all loose material. Immediately before filling the cavity, a prime coat of epoxy resin, Type III, Grade I, shall be applied to the dry cleaned surface of all sides and bottom of the cavity, except any joint face. The prime coat shall be applied in a thin coating and scrubbed into the surface with a stiff-bristle brush. Pooling of epoxy resin shall be avoided. The cavity shall be filled with low slump Portland Cement concrete or mortar or with epoxy resin concrete or mortar. Concrete shall be used for larger spalls, generally those more than *1/2* cu. ft. (0.014 m3) in size and mortar shall be used for the smaller ones.

Any spall less than 0.1 cu. ft. (0.003 m3) shall be repaired only with epoxy resin mortar or a Grade III epoxy resin. Portland Cement concrete and mortar mixtures shall be proportioned as directed and shall be mixed, placed, consolidated, and cured as directed. Epoxy resin mortars shall be made with Type III, Grade 1, epoxy resin, using proportions and mixing and placing procedures as recommended by the manufacturer and approved by the City Engineer The epoxy resin materials shall be placed in the cavity in layers not over 2 inches (50 mm) thick. The time interval between placement of additional layers shall be such that the temperature of the epoxy resin material does not exceed 140°F (60°C) at any time during hardening. Mechanical vibrators and hand tampers shall be used to consolidate the concrete or mortar. Any repair material on the surrounding surfaces of the existing concrete shall be removed before it hardens. Where the spalled area abuts a joint, an insert or other bond breaking medium shall be used to prevent bond at the joint face. A reservoir for the joint sealant shall be sawed to the dimensions required for other joints, or as required to be routed for cracks. The reservoir shall be thoroughly cleaned and sealed with the sealer specified for the joints. If any spall penetrates half the depth of the slab or more, the entire slab shall be removed and replaced as previously specified.

501-4.20 EXISTING CONCRETE PAVEMENT REMOVAL AND REPAIR.

All operations shall be carefully controlled to prevent damage to the concrete pavement and to the underlying material to remain in place. All saw cuts shall be made perpendicular to the slab surface.

a. Removal of Existing Pavement Slab.

When it is necessary to remove existing concrete pavement and leave adjacent concrete in place, unless there are dowels or keys present, the joint between the removal area and adjoining pavement to stay in place, including dowels, tie bars or keys, shall first be cut full depth with a standard diamond-type concrete saw. If keys or dowels are present at this joint, the saw cut shall be made full depth 6 inches (150 mm) from the joint if only keys are present, or just beyond the end of dowels if dowels are present. The edge shall then be carefully sawed on the joint line to within 1 inch (25 mm) of the top of the dowel or key. Next, a full depth saw cut shall be made parallel to the joint at least 24 inches (600 mm) from the joint and at least 12 inches (300 mm) from the end of any dowels. All pavement between this last saw cut and the joint line shall be carefully broken up and removed using hand-held jackhammers, 30 lb. (14 kg) or less, or the approved light-duty equipment which will not cause stress to propagate across the joint saw cut and cause distress in the pavement which is to remain in place. Where dowels or keys are present, care shall be taken to produce an even, vertical joint face below the dowels or keys. If the Contractor is unable to produce such a joint face, or if underbreak or other distress occurs, the Contractor shall saw the dowels or keys flush with the joint. The Contractor shall then install new dowels, of the size and spacing used for other similar joints, by epoxy resin bonding them in holes drilled in the joint face as specified in paragraph "Placing dowels and Tie-bars. All this shall be at no additional cost to the Owner. Dowels of the size and spacing indicated shall be installed as shown on the drawings by epoxy resin bonding them in holes drilled in the joint face as specified in paragraph "Placing Dowels and Tie Bars". The joint face shall be sawed or otherwise trimmed so that there is no abrupt offset in any direction greater than 1/2-inch (12 mm) and no gradual offset greater than 1 inch (25 mm) when tested in a horizontal direction with a 12 ft. (3.6 m) straightedge.

b. Edge Repair.

The edge of existing concrete pavement against which new pavement abuts shall be protected from damage at all times. Areas that are damaged during construction shall be repaired at no cost to the Owner; repair of previously existing damage areas will be considered a subsidiary part of concrete pavement construction.

(1) Spall Repair. Spalls shall be repaired where indicated and where directed. Repair materials and procedures shall be as previously specified in subparagraph "Repairing Spalls along Joints.

(2) Underbreak Repair. All underbreak shall be repaired. First, all delaminated and loose material shall be carefully removed. Next, the underlying material shall be recompacted, without addition of any new material. Finally, the void shall be completely filled with paving concrete, thoroughly consolidated.

Care shall be taken to produce an even joint face from top to bottom. Prior to placing concrete, the underlying material shall be thoroughly moistened. After placement, the exposed surface shall be heavily coated with curing compound.

(3) Underlying Material. The underlying material adjacent to the edge of an under the existing pavement which is to remain in place shall be protected from damage or disturbance during removal operations and until placement of new concrete, and shall be shaped as shown on the drawings or as directed. Sufficient material shall be kept in place outside the joint line to prevent disturbance (or sloughing) of material under the pavement that is to remain in place. Any material under the portion of the concrete pavement to remain in place, which is disturbed or loses its compaction shall be carefully removed and replaced with concrete as specified in paragraph "Underbreak Repair." The underlying material outside the joint line shall be thoroughly compacted and moist when new concrete is placed.

MATERIAL ACCEPTANCE

501-5.1 ACCEPTANCE SAMPLING AND TESTING. ***The in-place concrete shall be homogeneous without segregation and honeycombing. The City Engineer reserves the right to take random cores to verify the quality of the in-place pavement These cores are In addition to those required*** All acceptance sampling and testing, with the exception of coring for thickness determination, necessary to determine conformance with the requirements

specified in this section will be performed by the City Engineer. Concrete shall be accepted for strength and thickness on a lot basis.

If a core reveals segregations and/or honeycombing that is in the opinion of the City Engineer detrimental to the pavement structure, additional cores will be taken to define the area of deficiency. Areas so defined as containing segregated concrete and/or honeycombing shall be rejected, removed, and replaced at the Contractors expense. The City Engineer will be the sole judge as to the acceptability of the quality of the pavement

A lot shall consist of: a day's production not to exceed 5,000 square yards (1,184 square meters)

Testing organizations performing these tests shall meet the requirements of ASTM C 1077, including accreditation. The accreditation will include ASTM C 78. The Contractor shall bear the cost of providing curing facilities for the strength specimens, per paragraph 501-5.1 a (3), and coring and filling operations, per paragraph 501-5.1 b (1).

a. Flexural Strength.

(1) Sampling. Each lot shall be divided into four equal sublots. One sample shall be taken for each sublot from the plastic concrete delivered to the job site. Sampling locations shall be determined by the ***City E***ngineer in accordance with random sampling procedures contained in ASTM D 3665. The concrete shall be sampled in accordance with ASTM C 172.

(2) Testing. Two (2) specimens shall be made from each sample. Specimens shall be made in accordance with ASTM C 31 and the flexural strength of each specimen shall be determined in accordance with ASTM C 78. The flexural strength for each sublot shall be computed by averaging the results of the two test specimens representing that sublot.

Immediately prior to testing for flexural strength, the beam shall be weighed and measured for determination of a sample unit weight. Measurements shall be made for each dimension; height, depth, and length, at the mid-point of the specimen and reported to the nearest tenth of an inch. The weight of the specimen shall be reported to the nearest 0.1 pound. The sample unit weight shall be calculated by dividing the sample weight by the calculated volume of the sample. This information shall be reported as companion information to the measured flexural strength for each specimen.

The samples will be transported while in the molds. The curing, except for the initial cure period, will be accomplished using the immersion in saturated lime water method.

Slump, air content, and temperature tests will also be conducted by the quality assurance laboratory for each set of strength test samples, per ASTM C 31.

(3) Curing. The Contractor shall provide adequate facilities for the initial curing of beams. During the 24 hours after molding, the temperature immediately adjacent to the specimens must be maintained in the range of 60 to 80 degrees F (16 to 27 degrees C), and loss of moisture from the specimens must be prevented. The specimens may be stored in tightly constructed wooden boxes; damp sand pits, temporary buildings at construction sites, under wet burlap in favorable weather, or in heavyweight closed plastic bags, or using other suitable methods, provided the temperature and moisture loss requirements are met.

(3) Acceptance. Acceptance of pavement for flexural strength will be determined by the City Engineer in accordance with paragraph S01-S.2b.

b. Pavement Thickness

(1) Sampling. Each lot shall be divided into four equal sublots and one core shall be taken by the Contractor for each sublot. Sampling locations shall be determined by the ***City*** Engineer in accordance with random sampling procedures contained in ASTM D 366S. Areas, such as thickened edges, with planned variable thickness, shall be excluded from sample locations.

Cores shall be neatly cut with a core drill. The Contractor shall furnish all tools, labor, and materials for cutting samples and filling the cored hole. Core holes shall be filled by the Contractor with a non-shrink grout approved by the ***City*** Engineer within one day after sampling.

(2) Testing. The thickness of the cores shall be determined by the ***City*** Engineer by the average caliper measurement in accordance with ASTM C 174.

(3) Acceptance. Acceptance of pavement for thickness shall be determined by the ***City*** Engineer in accordance with paragraph S01-S.2c.

c. Partial Lots. When operational conditions cause a lot to be terminated before the specified number of tests have been made for the lot, or when the Contractor and the ***City*** Engineer agree in writing to allow overages or minor placements to be considered as partial lots, the following procedure will be used to adjust the lot size and the number of tests for the lot.

Where three sublots have been produced, they shall constitute a lot. Where one or two sublots have been produced, they shall be incorporated into the next lot or the previous lot and the total number of sublots shall be used in the acceptance criteria calculation, i.e., n=S or n=6.

d. Outliers. All individual flexural strength tests within a lot shall be checked for an outlier (test criterion) in accordance with ASTM E 178, at a significance level of 5 percent. Outliers shall be discarded, and the PWL shall be determined using the remaining test values.

501-5.2 ACCEPTANCE CRITERIA.

a. General. Acceptance will be based on the following characteristics of the completed pavement:

(1) Flexural strength	(4) Grade
(2) Thickness	(5) Edge slump
(3) Smoothness	(6) Dowel bar alignment

Flexural strength and thickness shall be evaluated for acceptance on a lot basis using the method of estimating percentage of material within specification limits (PWL). Acceptance using PWL considers the variability (standard deviation) of the material and the testing procedures, as well as the average (mean) value of the test results to calculate the percentage of material that is above the lower specification tolerance limit (L).

Acceptance for flexural strength will be based on the criteria contained in accordance with paragraph 501-5.2e (1). Acceptance for thickness will be based on the criteria contained in paragraph 501-5.2e (2). Acceptance for smoothness will be based on the criteria contained in paragraph 501-5.2e (3). Acceptance for grade will be based on the criteria contained in paragraph 501-5.2e (4).

The ***City*** Engineer may at any time, notwithstanding previous plant acceptance, reject and require the Contractor to dispose of any batch of concrete mixture which is rendered unfit for use due to contamination, segregation, or improper slump. Such rejection may be based on only visual inspection. In the event of such rejection, the Contractor may take a representative sample of the rejected material in the presence of the ***City*** Engineer, and if it can be demonstrated in the laboratory, in the presence of the ***City*** Engineer, that such material was erroneously rejected, payment will be made for the material at the contract unit price.

b. Flexural Strength. Acceptance of each lot of in-place pavement for flexural strength shall be based on PWL. The Contractor shall target production quality to achieve 90 PWL or higher.

c. Pavement Thickness. Acceptance of each lot of in-place pavement shall be based on PWL. The Contractor shall target production quality to achieve 90 PWL or higher.

d. Percentage of Material within Limits (PWL). The percentage of material within limits (PWL) shall be determined in accordance with procedures specified in *Section 01457*.

The lower specification tolerance limit (L) for flexural strength and thickness shall be: Lower Specification Tolerance Limit (L)

Flexural Strength	0.93 x strength specified in paragraph 501-3.1
Thickness	Lot Plan Thickness in inches – 0.50 inches

e. Acceptance Criteria.

(1) Flexural Strength. If the PWL of the lot equals or exceeds 90 percent, the lot shall be acceptable. Acceptance and payment for the lot shall be determined in accordance with paragraph 501-8.1.

(2) Thickness. If the PWL of the lot equals or exceeds 90 percent, the lot shall be acceptable. Acceptance and payment for the lot shall be determined in accordance with paragraph 501-8.1.

(3) Smoothness. As soon as the concrete has hardened sufficiently, the pavement surface shall be tested in the transverse direction with a 16-foot straightedge or other specified device. Surface smoothness deviations shall not exceed *1/4* inch from a 16-foot straightedge at any location, including placement along and spanning any pavement joint or edge.

Areas in the slab showing high spots of more than *1/4* inch but not exceeding *1/2* inch in 16 feet shall be marked and immediately ground down with an approved grinding machine to an elevation that falls

within the tolerance of *1/4* inch or less. Where the departure from the correct cross section exceeds *1/2* inch, the pavement shall be removed and replaced at the expense of the Contractor when so directed by the ***City*** Engineer.

In addition to the 16-foot straight edge, the Contractor shall furnish a 25' wheel base California type profilograph and competent operator to be used to measure longitudinal pavement surface deviations. The profilograph shall be operated under the supervision of the ***City*** Engineer and in accordance with the manufacturer's instructions. The profilograph shall be operated at a speed no greater than a normal walk. Original profilograms for the appropriate locations interpreted in accordance with ASTM E 1274 shall be furnished to the ***City*** Engineer. The profilograms shall be recorded on a scale of one inch equal to 25 feet longitudinally and one inch equal to one inch or full scale vertically. Records shall be maintained showing all smoothness measurements.

(a) The surface of Runway and Taxiway pavements of continuous placement of 50 feet or more shall be tested and evaluated as described herein. Two passes shall be made in each paving lane greater than 20 feet in width; each pass shall be six feet from and parallel with the centerline of the paving lane. The average of the two passes shall be considered as the profilograph result for the paving lane. For paving lanes less than 20 feet in width, one pass along the centerline shall be required. Tests shall be run the next working day following concrete placement. Each trace shall be completely labeled to show paving lane, wheel pass, and stationing.

(b) The Contractor shall furnish paving equipment and employ methods that produce a riding surface for each section of pavement having an average profile index meeting the requirements of paragraph *B.1* c. A typical subsection will be considered to be the width of the paving lane and *1/10* mile long. The profile index will be determined in accordance with ASTM E 1274 using a 0.2-inch blanking band. Within each *1/10* mile subsection, all areas represented by high points having a deviation in excess of 0.4 inch in 25 feet or less shall be removed by the contractor using an approved grinding device or a device consisting of multiple diamond blades. The use of a bush hammer or other impact devices will not be permitted. After removing all individual deviations in excess of 0.4 inch, additional corrective work shall be performed if necessary to achieve the required ride quality. All corrective work shall be completed prior to determination of pavement thickness.

(c) On those pavement subsections where corrections were necessary, second profilograph runs will be performed to verify that the corrections have produced an average profile index of 15 inches per mile or less. If the initial average profile index was less than 15, only those areas representing greater than O.4-inch deviation will be re-profiled for correction verification.

(d) When the average profile index does not exceed Z inches per mile, payment will be made for that section at the contract unit price for the completed pavement. When the average profile index exceeds 15 inches per mile, but does not exceed fifteen inches per mile, the Contractor may elect to accept a contract unit price adjustment in lieu of reducing the profile index.

(e) Individual sections shorter than 50 feet and the last 15 feet of any section where the contractor is not responsible for the adjoining section, shall be straight edged in accordance with Section 501.5.2e(3).

(f) If there is a section of 250 feet or less, the profilogram for that section shall be included in the evaluation of the previous section. If there is an independently placed section of 50 to 250 feet in length, a profilogram shall be made for that section and the pay adjustment factors for short sections of paragraph 8.1 c shall apply.

(g) Any corrective work required shall be performed prior to joint sealing and grooving operations.

(h) All cost necessary to provide the profilograph and related to furnishing the appropriate profilograms as required in this provision are incidental to concrete pavement construction and no direct compensation will be made therefore.

(4) Grade. An evaluation of the surface grade shall be made by the ***City*** Engineer for compliance to the tolerances contained below. Records shall be maintained showing all grade measurements.

Lateral Deviation. Lateral deviation from established alignment of the pavement edge shall not exceed plus or minus 0.10 foot (30 mm) in any lane.

Vertical Deviation. Vertical deviation from established grade shall not exceed plus or minus 0.04 foot (12 mm) at any point.

(5) Edge Slump. When slip-form paving is used, not more than 15 percent of the total free edge of each 500 foot (150 m) segment of pavement, or fraction thereof, shall have an edge slump exceeding 1/4-inch (6 mm), and none of the free edge of the pavement shall have an edge slump exceeding 3/8-inch (10 mm). (The total free edge of 500 feet (150 m) of pavement will be considered the cumulative total linear measurement of pavement edge originally constructed as nonadjacent to any existing pavement; i.e., 500 feet (150 m) of paving lane originally constructed as a separate lane will have 1,000 feet (300 m) of free edge, 500 feet (150 m) of fill-in lane will have no free edge, etc.). The area affected by the downward movement of the concrete along the pavement edge shall be limited to not more than 18 inches (457 mm) from the edge. When excessive edge slump cannot be corrected before the concrete has hardened, the area with excessive edge slump shall be removed and replaced at the expense of the Contractor when so directed by the ***City*** Engineer.

(6) Dowel Bar Alignment. Dowel bars and assemblies shall be checked for position and alignment. The maximum permissible tolerance on dowel bar alignment in each plane, horizontal and vertical, shall not exceed 2 percent or *1/4* inch per foot (20 mm per meter) of a dowel bar. Vertical alignment of dowels shall be measured parallel to the designed top surface of the pavement, except for those across the crown or other grade change joints. Dowels across crowns and other joints at grade changes, shall be measured to a level surface. Horizontal alignment shall be checked perpendicular to the joint edge.

f. Removal and Replacement of Concrete. Any area or section of concrete that is removed and replaced shall be removed and replaced back to planned joints. The Contractor shall replace damaged dowels and the requirements for doweled longitudinal construction joints in paragraph 501-4.10 shall apply to all contraction joints exposed by concrete removal.

CONTRACTOR QUALITY CONTROL

501-6.1 QUALITY CONTROL PROGRAM. The Contractor shall develop a Quality Control Program in accordance with Section *01450-Contractors Quality Control*. 100 of the General Provisions. The program shall address all elements that affect the quality of the pavement including but not limited to Management.

a. Mix Design	e. Proportioning	i. Dowel Placement and Alignment
b. Aggregate Gradation	f. Mixing and Transportation	j. Flexural or Compressive Strength
c. Quality of Materials	g. Placing and Consolidation	k. Finishing and Curing
d. Stockpile	h. Joints	l. Surface Smoothness

501-6.2 QUALITY CONTROL TESTING. The Contractor shall perform all quality control tests necessary to control the production and construction processes applicable to this specification and as set forth in the Quality Control Program. The testing program shall include, but not necessarily be limited to, tests for aggregate gradation, aggregate moisture content, slump, and air content.

A Quality Control Testing Plan shall be developed as part of the Quality Control Program.

a. Fine Aggregate.

(1) Gradation. A sieve analysis shall be made at least twice daily in accordance with ASTM C 136 from randomly sampled material taken from the discharge gate of storage bins or from the conveyor belt.

(2) Moisture Content. If an electric moisture meter is used, at least two direct measurements of moisture content shall be made per week to check the calibration. If direct measurements are made in lieu of using an electric meter, two tests shall be made per day. Tests shall be made in accordance with ASTM C 70 or ASTM C 566.

b. Coarse Aggregate.

(1) Gradation. A sieve analysis shall be made at least twice daily for each size of aggregate. Tests shall be made in accordance with ASTM C 136 from randomly sampled material taken from the discharge gate of storage bins or from the conveyor belt.

(2) Moisture Content. If an electric moisture meter is used, at least two direct measurements of moisture content shall be made per week to check the calibration. If direct measurements are made in lieu of using an electric meter, two tests shall be made per day. Tests shall be made in accordance with ASTM C 566.

c.Slump. Four slump tests shall be performed for each lot of material produced in accordance with the lot size defined in Section 501-5.1. One test shall be made for each sublot. Slump tests shall be performed in accordance with ASTM C 143 from material randomly sampled from material discharged from trucks at the paving site. Material samples shall be taken in accordance with ASTM C 172.

d. Air Content. Four air content tests shall be performed for each lot of material produced in accordance with the lot size defined in Section 501-5.1. One test shall be made for each sublot. Air content tests shall be performed in accordance with ASTM C 231 for gravel and stone coarse aggregate and ASTM C 173 for slag or other porous coarse aggregate, from material randomly sampled from trucks at the paving site. Material samples shall be taken in accordance with ASTM C 172.

e. Four unit weight and yield tests shall be made in accordance with ASTM C 138. The samples shall be taken in accordance with ASTM C 172 and at the same time as the air content tests.

501-6.3 CONTROL CHARTS. The Contractor shall maintain linear control charts for fine and coarse aggregate gradation, slump, and air content.

Control charts shall be posted in a location satisfactory to the ***City*** Engineer and shall be kept up to date at all times. As a minimum, the control charts shall identify the project number, the contract item number, the test number, each test parameter, the Action and Suspension Limits, or Specification limits, applicable to each test parameter, and the Contractors test results. The Contractor shall use the control charts as part of a process control system for identifying potential problems and assignable causes before they occur. If the Contractors projected data during production indicates a potential problem and the Contractor is not taking satisfactory corrective action, the *City* Engineer may halt production or acceptance of the material.

a. Fine and Coarse Aggregate Gradation. The Contractor shall record the running average of the last five gradation tests for each control sieve on linear control charts. Specification limits contained in Tables 1 and 2 shall be superimposed on the Control Chart for job control.

b. Slump and Air Content. The Contractor shall maintain linear control charts both for individual measurements and range (Le. difference between highest and lowest measurements) for slump and air content in accordance with the following Action and Suspension Limits.

CONTROL CHART LIMITS			
Control Parameter	Individual Measurements		Range Suspension Limit
	Action Limit	Suspension Limit	
Slip Form:			
Slump	+0 to -1 inch (025mm)	+0.5 to -1.5 inch (1338mm)	+/-1.5 inch (38 mm)
Air Content	+/-1.2%	+/-1.8%	+/-2.5%
Fixed Form			
Slump	+ 0.5 to -1 inch (1325mm)	+1 to -1.5 inch (2538mm)	+/-1.5 inch (38mm)
Air Content	+/-1.2%	+/-1.8%	+/-2.5%

The individual measurement control charts shall use the mix design target values as indicators of central tendency.

501-6.4 CORRECTIVE ACTION. The Contractor Quality Control Program shall indicate that appropriate action shall be taken when the process is believed to be out of control. The Contractor

Quality Control Program shall detail what action will be taken to bring the process into control and shall contain sets of rules to gauge when a process is out of control. As a minimum, a process shall be deemed out of control and corrective action taken if anyone of the following conditions exists.

a. Fine and Coarse Aggregate Gradation. When two consecutive averages of five tests are outside of the Tables 1 or 2 specification limits, immediate steps, including a halt to production, shall be taken to correct the grading.

b. Fine and Coarse Aggregate Moisture Content. Whenever the moisture content of the fine or coarse aggregate changes by more than 0.5 percent, the scale settings for the aggregate batcher(s) and water batcher shall be adjusted

c. Slump. The Contractor shall halt production and make appropriate adjustments whenever:

(1) one point falls outside the Suspension Limit line for individual measurements or range; or

(2) two points in a row fall outside the Action Limit line for individual measurements.

d. Air Content. The Contractor shall halt production and adjust the amount of air-entraining admixture whenever: (1) one point falls outside the Suspension Limit line for individual measurements or range; or

(2) two points in a row fall outside the Action Limit line for individual measurements.

Whenever a point falls outside the Action Limits line, the air-entraining admixture dispenser shall be calibrated to ensure that it is operating correctly and with good reproducibility.

METHOD OF MEASUREMENT

501-7.1 Portland Cement concrete pavement shall be measured by the number of square yards (square meters) of reinforced pavement as specified in-place, completed and accepted.

a. The area of new pavement to be paid for shall be the number of square yards of specified pavement thicknesses of Reinforced Concrete Pavement, as specified, in-place, complete and accepted, less any deduction(s), as hereinafter described for deficient thickness or strength.

b. Cementitious Materials. The quantity of cement, fly ash, and blast furnace slag used in the work will not be measured separately, but will be considered incidental to the items requiring PCC pavement

c. Reinforcing Steel Dowels, and Tie Bars. The quantity of dowels, reinforcing steel, and tie bars used in the work will not be measured for payment, but will be considered Incidental to the items requiring PCC pavement

d. Sawcutting and sealing joint. The quantity of saw cutting and sealing for all joint types will not be measured for payment, but will be considered incidental to the items requiring PCC pavement

e. ***Thickened-Edge Joints. Concrete Thickened-Edges will not be measured separately for payment but will be considered incidental to the items requiring PCC pavement***

f. ***Curing compound shall be measured by the number of gallons completed and accepted.***

g. Saw-cut grooving shall be measured by the number of square yards (square meters) of saw-cut grooving as specified in-place, completed and accepted.

BASIS OF PAYMENT

501-8.1 PAYMENT. Payment for accepted concrete pavement shall be made at the contract unit price per square yard (square meter) adjusted in accordance with paragraph 501-8.1 a, subject to the limitation that:

The total project payment for concrete pavement shall not exceed 100 percent of the product of the contract unit price and the total number of square yards (square meters) of concrete pavement used in the accepted work (See Note 2 under Table 3).

Payment shall be full compensation for all labor, materials, tools, equipment, and incidentals required to complete the work as specified herein and on the drawings, except for saw-cut grooving.

This payment shall be full compensation for furnishing required temporary lighting and other equipment; firnishing and applying all water required; for furnishing, loading, unloading, storage, hauling, and handling all concrete ingredients, including Portland Cement, and all freight and royalty involved; for mixing, placing, finishing and texturing (except for saw-cut grooving) concrete; sawing, curing, cleaning, and sealing joints; dowel caps and load transfer devices required, wire and devices for placing, holding, and supporting the steel bars, load transfer devices, and any joint filler material in proper position; for coating steel bars when required by the drawings or specifications; and for all manipulations, appliances, tools, traffic provisions, impressioning Stationing on taxiway edges, and incidentals necessary to complete the work

a. Basis of Adjusted Payment. The pay factor for each individual lot shall be calculated in accordance with Table 3. A pay factor shall be calculated for both flexural strength and thickness. The lot pay factor shall be the higher of the two values when calculations for both flexural strength and thickness are 100 percent or higher. The lot pay factor shall be the product of the two values when only one of the calculations for either flexural strength or thickness is 100 percent or higher. The lot pay factor shall be the lower of the two values when calculations for both flexural strength and thickness are less than 100 percent.

TABLE 3. PRICE ADJUSTMENT SCHEDULE[1]

Percentage of Material Within Specification Limits (PWL)	Lot Pay Factor (Percent of Contract Unit Price)
96 – 100	106
90 – 95	PWL + 10
75 – 90	0.5PWL + 55
55 – 74	1.4PWL - 12
Below 55	Reject[2]

[1] ALTHOUGH IT IS THEORETICALLY POSSIBLE TO ACHIEVE A PAY FACTOR OF 106 PERCENT FOR EACH LOT, ACTUAL PAYMENT IN EXCESS OF 100 PERCENT SHALL BE SUBJECT TO THE TOTAL PROJECT PAYMENT LIMITATION SPECIFIED IN PARAGRAPH 501-8.1.

[2] The lot shall be removed and replaced. However, the ***City*** Engineer may decide to allow the rejected lot to remain. In that case, if the ***City*** Engineer and Contractor agree in writing that the lot shall not be removed, it shall be paid for at 50 percent of the contract unit price AND THE TOTAL PROJECT PAYMENT LIMITATION SHALL BE REDUCED BY THE AMOUNT WITHHELD FOR THE REJECTED LOT.

For each lot accepted, the adjusted contract unit price shall be the product of the lot pay factor for the lot and the contract unit price. Payment shall be subject to the total project payment limitation specified in paragraph 501-8.1. Payment in excess of 100 percent for accepted lots of concrete pavement shall be used to offset payment for accepted lots of concrete pavement that achieve a lot pay factor less than 100 percent.

b. Payment. Payment shall be made under:

Item 02756-1 4" Reinforced Portland Cement Concrete Pavement -per square yard

Item 02756-2 6" Reinforced Portland Cement Concrete Pavement in WW Shoulder -per square yard

Item 02756-3 8" Reinforced Portland Cement Concrete Pavement -per square yard Item 02756-4 9" Reinforced Portland Cement Concrete Pavement -per square yard Item 02756-5 16" Reinforced Portland Cement Concrete Pavement -per square yard Item 02756-6 17" Reinforced Portland Cement Concrete Pavement -per square yard Item 02756-7 19" Reinforced Portland Cement Concrete Pavement -per square yard Item 02756-8 21" Reinforced Portland Cement Concrete Pavement -per square yard Item 02756-9 27" Reinforced Portland Cement Concrete Pavement -per square yard Item 02756-10 Curing Compound -per gallon

Item 02756-11 Sawcut Grooving -per square yard

Item 02756-12 Diamond Joints for in-pavement fixtures -per each

TESTING REQUIREMENTS

ASTM C 31 Making and Curing Concrete Test Specimens in the Field ASTM C 39 Compressive Strength of Cylindrical Concrete Specimens ASTM C 70 Surface Moisture in Fine Aggregate

ASTM C 78 Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading) ASTM C 88 Test for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

ASTM C 131 Test for Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine

ASTM C 136 Sieve Analysis of Fine and Coarse Aggregates

ASTM C 138 Test for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

ASTM C 143 Test for Slump of Hydraulic Cement Concrete

ASTM C 172 Sampling Freshly Mixed Concrete

ASTM C 173 Test for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C 174 Measuring Thickness of Concrete Elements Using Drilled Concrete Cores

ASTM C 227 Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

ASTM C 231 Test for Air Content of Freshly Mixed Concrete by the Pressure Method

ASTM C 289 Potential Alkali-Silica Reactivity of Aggregates (Chemical Method) ASTM C 295 Petrographic Examination of Aggregates for Concrete

ASTM C 114 Chemical Analysis of Hydraulic Cement

ASTM C 535 Test for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

ASTM C 566 Total Evaporable Moisture Content of Aggregates by Drying

ASTM C 642 Test for Density, Absorption, and Voids in Hardened Concrete

ASTM C 666 Resistance of Concrete to Rapid Freezing and Thawing

ASTM C 1077 Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

ASTM C 1260 Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

ASTM D 3665 Random Sampling of Paving Materials

ASTM D 4791 Test Method for Flat or Elongated Particles in Coarse Aggregate

ASTM E 178 Dealing With Outlying Observations

ASTM E 1274 Test for Measuring Pavement Roughness Using a Profilograph

AASHTO T 26 Quality of Water to be Used in Concrete

MATERIAL REQUIREMENTS

ASTM A 184 Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement

ASTM A 185 Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement ASTM A 497 Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement

ASTM A 615 Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement ASTM A 704 Specification for Welded Steel Plain Bar or Rod Mats for Concrete Reinforcement

ASTM A 714 Specification for High-Strength Low-Alloy Welded and Seamless Steel Pipe

ASTM A 996 Specification for Rail-Steel and Axle Steel Deformed Bars for Concrete Reinforcement

ASTM C 33 Specification for Concrete Aggregates ASTM C 94 Specification for Ready-Mixed Concrete

ASTM C 150 Specification for Portland Cement

ASTM C 171 Specification for Sheet Materials for Curing Concrete

ASTM C 260 Specification for Air-Entraining Admixtures for Concrete

ASTM C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete

ASTM C 494 Specification for Chemical Admixtures for Concrete

ASTM C 595 Specification for Blended Hydraulic Cements

ASTM C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete

ASTM C 881 Specification for Epoxy-Resin Base Bonding System for Concrete

ASTM C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

ASTM D 1751 Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)

ASTM D 1752 Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction

ACI 305R Hot Weather Concreting

ACI 306R Cold Weather Concreting

ACI 309 Guide for Consolidation of Concrete

MIL-DTL-24441/20a (1999)_Paint, Epoxy-Polyamide, Green Primer, Formula 150, Type lll Department of Defense

END ITEM P-501

Sample Specification

LIME CEMENT FLYASH STABILIZED RECYCLED CRUSED CONCRETE BASE COURSE

PART 1

GENERAL

DESCRIPTION

101. General:

1. This item governs natural aggregate materials, lime, cement, and fly ash which comprise the lime- cement-fly ash (LCF); stockpiling; mixing; placing; and compaction to lines, grades and typical cross- sections shown on the drawings.

2. Subject to the conditions specified herein, a mixing plane shall be erected by the Contractor at the staging area location shown on the drawings. The Contractor is the owner and sole operator of the mixing plant and is responsible for maintenance of the mixing plant, haul route, and operation yard. At the completion of this contract, the Contractor will remove the mixing plant from airport property. The plant site will be cleaned up and left in an acceptable condition at no additional cost to the Owner. Clean-up will include grading, topsoil, and seeing if so directed by City Engineer.

102. METHOD OF MEASUREMENT AND PAYMENT

A. The lime-cement-fly ash (LCF) stabilized recycled crush concrete base course will be measured by the square yard, in place. ***The amount of lime, cement, and fly ash to be paid for shall be the number of tons of lime, cement, and fly ash used as authorized.***

B. Payment for the lime-cement-fly ash (LCF) stabilized recycled crushed concrete base course will be paid for by the square yard and includes all equipment, labor, and materials to construct the LCF pavement, complete, in-place, including the cost of the sawing and sealing of the LCF expansion joints.

C. ***Payment for the lime, cement, and fly ash shall be made at the contract unit price per ton of lime, cement, and fly ash as shown in the bid tabulation form. The prices shall be full compensation for furnishing the materials; for all delivery, placing and incorporation of the materials; and for all labor, equipment, tools and incidentals necessary to complete this item.***

103. QUALITY

ASSURANCE Testing

1. Cement, lime, fly ash, and aggregates are to be tested at the source of supply for conformance with this specification prior to loading for delivery to the construction site. Contractor will notify City Engineer at least 72 hours in advance of loading to permit sampling and inspection. Owner will be reimbursed by Contractor for all transportation and live-in expenses incurred by the City Engineer in association with this testing requirement when the source of supply is over 100 miles from the project site.

2. Prior to the start of paving operations, the initial mix design proportions for the LCF mix are to be verified based on a series of unconfined compression tests using the mixture proportions defined in Table 1. ***The City's testing laboratory will perform the trial batch runs. The City Engineer will select the LCF mix based on the trial batch runs.*** The aggregate will be comprised of recycled crushed concrete (RCC). The RCC must meet requirements of FAA specification P-209 (Table 2) to be accepted for use in LCF. If the RCC does not meet P-209 (Table 2), the City Engineer may require blending of the RCC with an approved source of sand in order to meet P-209 specification gradation shown in Table 2.

TABLE 1- LCF TEST MIXES				
Mix	% Lime	% Cement	% Fly ash	% Recycled Crushed Concrete
A	3.5	0.5	8.5	87.5%
B	4	0.5	12	83.5%
C	3	0.5	10	86.5%

Proportions are percent by dry weight.

TABLE 2 – FAA P-209 Specifications\1\		
Sieve Size	Design range Percentage by Weight Passing Sieves	Job Mix Tolerance Percent
2 in (37.0 mm)	100	+/-5
1-1/2 (37.0 mm)	95-100	+/-8
1 in (25.0 mm)	70-95	+/-8
¾ in (19.0 mm)	55-85	+/-8
No. 4 (4.75 mm)	30-60	+/-8
No. 30 (0.60 mm)	12-30	+/-5
No. 200 (0.075mm)	0-8	+/-3

\1Where environmental conditions (temperature and availability of free moisture) indicate potential damage due to frost action, the maximum percent of material, by weight, of particles smaller than 0.02 mm shall be 3 percent. It also may be necessary to have a lower percentage of material passing the No. 200 sieve to help control the percentage of particles smaller than 0.02mm.

The job mix tolerances in Table 2 shall be applied to the job mix gradation to establish a job control grading band. The full tolerance still will apply if application of the tolerances results in a job control grading band outside the design range.

The fraction of the final mixture that passes the No. 200 (0.075 mm) sieve shall not exceed 60 percent of the fraction passing the No. 30 (0.60 mm) sieve.

Test specimens will be compacted at optimum moisture content (0 to 2 percent wet) to 100 percent (-0, +2 percent) of maximum dry density as determined under ASTM D1557. Specimens will be formed using a standard 6-inch mold, sealed, and oven-cured at 120 degrees F. Six test specimens will be prepared for each mix (A, B, and C) for each aggregate source combination used. ***Five of the specimens will be moisture room-cured, one will be cured in an oven at 120 degrees F, the moisture room-cured specimens will be tested at 7-,14- and 28-day; the oven-cured specimens will be tested at 28-day. For this project, the minimum target unconfined compression strength of moisture room- cured***

specimens are 250 psi, 275 psi and 350 psi at 7-,14- and 28-day, respectively; the minimum target unconfined compression strength for the oven cured specimen at 28-day is 400 psi. The LCF mix proportions using the various aggregate source combinations will be adjusted, as necessary, based on the strength results of these tests.

The Contractor will notify the City Engineer a minimum of 35 days prior to the start of the paving operations to allow for testing required under this paragraph. Contractor will designate the initial stockpile at the construction site for testing. Testing under paragraph 1.03.A2 will be repeated for every 30,000 tons of LCF produced and/or when the City Engineer directs the tests to be performed.

3. Samples will be taken from every 500 tons of LCF mix produced for pavement construction, and checked for moisture content, mix proportions, and density. In addition four test specimens will be prepared using standard 6-inch molds. Specimens will be compacted ***as specified in Section 1.03A2, two of the specimens will be moisture room-cured and two will be cured in oven at 120 degrees F, and all specimens will be tested for unconfined compression strength at 7-day. The minimum target unconfined compression strength of the moisture room-cured and oven-cured specimens at 7-day are 250 psi and 300 psi, respectively. If there is a significant strength variation between the design and production mix, it shall be reported to the City Engineer immediately. The situation shall be evaluated and remedial action which may include new mix design may be required.***

4. During the paving operations, samples from the stockpiles in use and the LCF mix produced will be taken in the early morning and mid-afternoon. Stockpile samples will be tested for moisture content and LCF mix will be tested to determine the optimum density in accordance with ASTM 1557. The results of these tests will be used to establish the optimum density requirement for the Contractor's paving operations for the succeeding period covered by the tests. In addition, the test results may be used by the Engineer to adjust the mix proportions as necessary. The frequency of testing maybe adjusted by the ***City*** Engineer based on accumulated test results.

5. During the paving operations, the in-place density of each LCF layer will be tested at a rate of one test per 7,500 square feet. Test will be in accordance with ASTM D 1556 or ASTM D 2922. Testing in accordance with ASTM D 2922 is permitted only after correlation for moisture content using conventional methods.

B. Environmental Requirements:

1. Do not place any LCF course material during or immediately after heavy or extended rainfall.

2. Place LCF course material only when the temperature for the succeeding 24 hours is not anticipated to drop below 32 degrees F.

3. The placement of the top layer of LCF shall be so scheduled that the stress absorbing membrane interlayer will be placed in a period of less than 1 week after the completion of the LCF top layer. If for any approved reason any portion of the LCF top layer cannot be overlaid in 7 days the LCF surface will be sealed with an approved bituminous material at a rate between 0.10 and 0.25 gallons per square yard. The LCF shall be water cured for a minimum of 7 days.

4. Any LCF layer left exposed to accumulated rainfalls of3 inches for any 24-hour period, or6 inches total prior to placing the next LCF layer or PCC surface or bond breaker, or to rainfall intensity of 2 inches per hour will be inspected by the City Engineer prior to placing the next LCF layer or PCC surface or bond breaker. Samples will be taken for every 4,000 square yards of exposed LCF and tested for a minimum lime content of 3 percent, recompact exposed LCF.

The lime content shall be tested following ASTM D 3551-90 'Test Method for Lime Content of Uncured Soil-Lime Mixtures', the test results must be judged against an approved calibration curve developed following the ASTM specification and approved by the City Engineer.

If so directed, the Contractor will remove and dispose of the top 2 inches of exposed material. The trimmed surface will be recompacted and 2 inches of new material is to be added to the required thickness of the succeeding lift. Removal and disposal of material will be at no additional cost to the Owner.

5. Any LCF layer exposed to continuous temperatures below 32 degrees F for a period of 48 hours or exposed to temperature below 32 degrees F within 24 hours of placement will be inspected by the City Engineer. If so directed, the Contractor will rebuild the LCF layer as described in paragraph 1.03B4.

C. Quality Control Requirements:

1. The various LCF lifts shall be compacted to the thickness shown on the contract drawings within the following tolerances:

   a. First lift on embankment: Plus or minus 1.0 inch.

   b. Subsequent lifts: Plus or minus ½ inch.

   c. Top lift: Plus Yi-inch minimum plus 1.0-inch maximum.

   d. Total thickness of all LCF lifts: Plus or minus ½ *inch*.

   Some rippling of less than *Y2* inch in thickness variation on the surface of any LCF lift is acceptable provided there is no loose material and thickness tolerances are satisfied.

2. The compaction control test specified under paragraph 1.03A2 shall be the governing criteria for the placement of all LCF courses.

3. For the density tests used as reference during the construction, all LCF courses shall be compacted to a minimum density of 98% of optimum.

4. The final surface of the top LCF lift will be followed by a PCC surface or bond breaker layer shall not deviate by more than ½ inch in any direction when tested with a 16 foot straight edge. Prior to full production operations, the Contractor shall establish compaction-rolling pattern to achieve density requirements.

5. Grade Control: Contractor will provide sufficient grade control to assure the requirements of paragraph 1.03C are met as well as the line and grades shown on the drawings.

104. SUBMITTAL

A. Provide certified mill reports on cement, lime, fly ash, and sieve analysis on aggregates. B.

Provide material and six samples to an approved laboratory for review and testing.

PART 2 PRODUCTS

201. Materials

A. Portland Cement: ASTM C150, Type I

B. Lime: Lime will be high calcium lime meeting the chemical composition and physical requirements of ASTM C 977.

C. Fly Ash: Type "C" sub-bituminous coal. ASTM C 593 and the applicable testing procedures modified as follows:

1. Loss by ignition shall not be more than 2.0%.

2. Combined content of silica oxide (SiO_2), calcium oxide (CaO), and aluminum oxide, (Al_2O_3) shall not be less than 50%.

3. SO_3 content shall be less than 3.0%.

4. Lime pozzolan strength, minimum compressive strength shall be 600 psi at 7 days, 130 + 3 degrees F. D.

Recycled Crushed Concrete (RCC):

1. See Table 2.

3. Aggregates delivered to the hoppers of the LCF plant shall be dry or moist. E.

D. Water: Water for use in LCF mixes shall be potable water.

E. Joint Materials:

1. Joint filler to be closed cell PVC foam, Horn Type 327 or equal, of sizes and dimensions shown on contract drawings.

2. Joint sealer to be rubber asphalt meeting requirements of Federal Specification SS-

S-1401. PART 3 EXECUTION

301. CONSTRUCTION METHODS

A. Proportioning of LCF Mix:

1. LCF mix shall be proportioned in percent by dry weight as follows subject to verification in accordance with paragraph 1.03A2.

Hydrated Lime	3.0%
Portland Cement	0.5%
Fly Ash	10%
Recycled Crushed Concrete	86.5%

2. Required water content is expected to range between 8 percent and 10 percent by weight of the LCF mix, as determined by the Aviles Engineering Corporation design, to result in optimum density. Actual water content ***at the time of LCF compaction*** shall satisfy the tolerance to be -1 .0 percent and +2.0 percent by weight with reference to the optimum moisture content determined in accordance with paragraph 1.03A2.

3. Proportions in dry weight shall be within plus or minus 10 percent of the percentages specified under paragraph 3.1A. For example, the range of fly ash content shall be 9.10 percent to 11.0 percent. Lime shall not be lower than 3.0 percent.

B. Mixing Plant:

1. The Contractor shall provide an onsite LCF mixing plant of such type and capacity as to fulfill the requirements of the contract. The plant is to have sufficient controls and adjustment capabilities to meet the tolerances of this specification. The Contractor is to be responsible for operation and maintenance of the LCF plant.

2. If a batch plant is elected, the dry weight calibration and print-out shall be identified individually for each component.

3. For volumetric pugmill operation, the speed and feeding volume shall be calibrated separately to comply with the dry weight requirements and tolerances as specified under 3.01A. Frequent calibration of feed lines shall be maintained by the Contractor.

4. Mixing plants are not to be loaded above their noted capacities and are to be operated at the speeds for which they were designed. Manufacturer plates showing the rated capacity and recommended speeds are to be attached to each mixing plant. .Increased output is to be obtained by a larger mixing plant or by additional mixing plants, not by overloading or speeding up the equipment on hand. Mixers to be equipped with mixing blades. Mixing blades are to be replaced when worn down 3/4 inch or more. Blades are to be cleaned of hardened mix a minimum of one time each day.

5. Mixing plants are to be equipped with sufficient instrumentation to measure and record accurately each material component loaded into the mixer. Instrumentation is to be calibrated at least one time each day during production of base material.

6. Prior to the start of paving operations, the manufacturer's representative is to certify that the mixing plant to be used by the Contractor on this project is in good operating condition and is capable of performing the work required by the drawings and specifications.

Proportion of materials in dry weight shall be within plus or minus 10 percent of the percentages specified in the final mix design.

C. Mixing:

1. Mix LCF material until a thorough and uniform mixture of all materials incorporated in the mix is obtained.

2. The minimum mixing time shall be determined from trial runs of the LCF plant. Modification of mixing time shall be made, if necessary, during the construction.

3. The moisture content of the fly ash and aggregates in stockpile shall be checked daily and all metering devices shall be calibrated.

5. A vibrator shall be used to insure the smooth flow of lime from the storage tank.

5. A shredding machine shall be used to pulverize the conditioned (moisturized) fly ash prior to its use in the mix. When dry powder fly ash is used, storage bins shall be provided.

6. A bar screen shall be installed on the hoppers to remove any size larger than 2 inches. All unsuitable materials shall be disposed of and transported away from the mixing plant site.

7. If the City Engineer, during his inspections of LCF placement, determines that the LCF mix does not conform to the requirements set forth in these specifications, or to the changes as directed by the Engineer, said mix shall be rejected.

8. Dispose of all rejected mixes at locations on the airport designated by the City Engineer and spread over said area in lifts not exceeding two feet in height.

9. A load in which the water content exceeds the required amount by more than the allowable tolerance specified in paragraph 3.1A2 may nevertheless be accepted subjected to the following conditions:

a. The mixed material shall be spread in an approved area to a thickness of 2 to 3 inches and left undisturbed to dry to the optimum moisture.

b. Upon approval of the City Engineer that the material has dried to an acceptable amount, additional material shall be placed on top of the said wet load and blended and worked into the wet load to produce a mixture having the optimum moisture content.

c. Should the City Engineer at anytime determine that a wet load is unsuitable for use, such load shall be considered as a rejected mix and disposed of accordingly.

E. Transporting Mix: Load and transport the LCF mix from the LCF plant in vehicles and in a manner that will maintain the moisture and prevent aggregate segregation and loss of fines during transit.

F. Preparation of Embankment Surface:

1. Prior to placement of LCF material, and after grading to required lines and grades, compact the top of embankment as specified for the embankment construction.

2. Thoroughly and evenly moisten, but do not pond, the prepared embankment surface on which the LCF mixture is to be placed immediately prior to placing of the LCF mixture. F. Placing and Compaction:

   1. Immediately prior to placing each lift, dampen but do not pond the previously placed course.

   2. If the previously placed course is older than 7 days, clean the surface with rotary broom prior to placing the new course.

3. Deposit each lift by means of mechanical spreader that will not damage the previously placed course, in a uniform loose condition to a depth that will compact to the required thickness within the specified tolerances for all layers except the top one. The top layer shall be finished at least ½ inch greater than the required thickness as shown on the contract drawings if the SAMI layer is not to be overlaid within 7 days.

4. The mixes shall be spread and compacted within 20 hours after the discharge from mixer at the plant.

5. Compact each lift by two passes of an approval vibrating steel roller and continue rolling with a pneumatic tired roller until a density of at least 98% of optimum, as determined in accordance with paragraph 1.03A$ is obtained. Add or remove material and recompact as necessary to meet course thickness within specified tolerances. The pneumatic tired roller shall be a self-propelled roller with air on the run, of sufficient weight and tire inflation pressure to obtain the density required. The rolling pattern described are guidelines for the contractor. The contractor is responsible for establishing the equipment and rolling pattern to achieve required densities.

6. In case of top LCF layer, after compaction by means of the vibratory roller, remove the excess thickness by fine grading so as to satisfy thickness tolerance and then continue compaction by means of rubber tired rollers until density and smoothness requirements are satisfied.

7. If the surface of top LCF layer is below the allowable tolerance, it shall be scarified to a depth of two inches in the deficient areas and additional material shall be spread and compacted so as to satisfy all requirements herein.

8. No vehicles shall be permitted on the compacted top LCF surface. The compacted LCF later shall not be used as haul route nor for moving construction equipment until the PCC surface is placed.

G. Preparation for PCC Surface Course

The compacted LCF surface shall be fine graded to the design elevations. A SAMI layer shall be placed on the LCF prior to the placement of the PCC surface.

H. Construction Joints:

1. At the end of each day's construction, a straight transverse construction joint shall be formed by installing a temporary wooden bulkhead or by cutting back 12 inches into the complete work to form a true vertical face for the following construction day.

2. The construction joint shall be staggered in subsequent lifts.

3. Do not place edge of any LCF lift closer than one foot from the edge of lower lift. I. Expansion Joints:

a) Expansion joints shall be installed at the locations shown on the construction drawings.

b) Joints shall be placed in true vertical and horizontal alignment.

c) Joint fillers and sealers shall be of sizes shown on Contract Drawings and shall be installed in accordance with the recommendations of the manufacturers of each.

d) Oversized joints shall be backfilled with cement grout as indicated on the contract drawings.

I. Rehandling of Material

1. When directed by the City Engineer, during dry weather or high wind velocities, for a period of 14 days after placement, apply moisture but no ponding to the surface as necessary.

2. Maintain the surface in good condition and repair damaged areas. Damaged areas to be repaired by scarifying to a depth of 2 inches and replacing with additional material and compacting so as to satisfy all requirements of this specification. Contractor to notify City Engineer of damaged areas and schedule for repairs.

3. Keep all unnecessary traffic off the surface. K. Placement of Electrical Ducts in LCF Courses:

4. In excavation required for the placement of electrical conduit in the LCF course, the material removed shall be replaced with concrete having a compressive strength at 28 days of 3,000 psi.

5. A minimum of 48 hours shall be allowed to cure the concrete before any subsequent work is erformed on the LCF courses in the vicinity of the ducts.

END OF SECTION 3

Sample Specification

AIRFIELD LIGHTING REMOTE CONTROL SYSTEM

PART 1 -GENERAL

1.1 SUMMARY

A. It is the intention of this Section to describe Airfield Lighting Remote Control System (ALRCS) that are required as a result of the changes for the project in airfield circuitry, any changes to the in pavement runway Guard light system, and addition and reconfiguration of constant current regulators.

B. The ALRCS for the project shall be installed in the new west vault, the air traffic control tower cab and equipment room and the electrical maintenance shop area.

C. The existing ALRCS in the south and north vaults shall be modified to support the upgraded ALRCS architecture and communication capabilities

D. Provide all labor, materials, tools and equipment, whether or not directly specified in this Section or shown on the plans, required for the design, supply, installation, testing, training and commissioning of a complete, functioning ALRCS, unless it is specifically mentioned that the work or a portion thereof shall not be include 1 or shall be by others.

E. Supply all ALRCS components including, but not limited to, video display monitors with touch-screen adapters, industrial computers, programmable logic controllers (PLC), monitoring devices, telephone line modems, interfaces, intercabinet connecting cables, networking components, miscellaneous hardware, cabinets, and materials.

F. Supervise the installation of all components of the described above. Provide final connection of all communication cables to the ALRCS shown on drawing.

G. Work directly with Control Tower personnel to develop an operator control interface that is similar to the existing panel and is acceptable to the A TCT personnel.

H. Commission the upgrades to the ALRCS including systematic electrical and mechanical checkout and proving the systems under actual or simulated VFR and appropriate CAT, operating conditions. Verify that all monitored and/or controlled points are accurately depicted and functional on all applicable tower and maintenance graphic screens. Verify that all alarm conditions are accurately displayed on the tower and maintenance graphic screens as required.

I. Provide training for personnel in the operation and maintenance of the upgraded ALRCS system including the provision of complete documentation, classroom instruction, and field training.

1.2 UNIT PRICES

A. Refer to Section 01290, Payment Procedures for unit price procedures.

1.3 SECTION INCLUDES

A. Installation of the Airfield Lighting Remote Control System (ALRCS) for the new west vault

B. Replacement of the existing touch-screen at tower cab with new touch-screen control panels.

C. Modification of the ALRCS PLC cabinets in the north and south vaults to remove the PLC/5 translation PLC assembly from those locations, and provide new interface support and functionality of the existing ALRCS elements to the new Control Logix PLC architecture. Make any changes to the vault PCs in the north and south vaults to provide a fully functional system. Provide new radio backup system and antenna at those locations.

D. Replace the existing ALRCS elements in the maintenance shop with new PC, printer, enclosure for network and radio components and radio backup link.

E. Training of maintenance operations and tower personnel in the operation and maintenance of the new and modified equipment.

1.4 RELATED SECTIONS

A. 16031 -Airfield Electrical Installation Testing

B. 16075 -Electrical Identification

C. 16091 -Work in Existing Building

D. 16461 - Vault Equipment

E. 16531 -Runway Guard Lights Control System

1.5 RELATED DOCUMENTS

A. AC *150/5340-30,* Design and Installation Details for Airport Visual Aids

B. AC *150/5345-53,* latest edition, Airport Lighting Equipment Certification Program.

C. AC *150/5345-56,* latest edition, L-890 Airfield Lighting Control and Monitoring System

D. National Fire Protection Association (NFPA), NFPA 70, National Electrical Code.

E. National Electrical Manufacturer's Association (NEMA), ICS-1-lndustrial Control and Systems General Requirements.

1.6 DEFINITIONS

A. The following words and abbreviations have particular meaning and relevance to the work of this Section: ALPC Airfield Lighting Power Center/Vault

ALRCS Airfield Lighting Remote Control System

APP Approach lighting

APU Automatic power units

ATC Air traffic control

ATCT Air traffic control tower

ATS Automatic Transfer System

CAT Category

CC Current Contactor

CCR Constant current regulator

CPU Central processing unit

CRT Cathode ray tube

EEPROM Electrical Erasable Programmable Read-Only Memory

FAA Federal Aviation Administration

HAS Houston Airport Systems, Owner

I/O Input/output

PCI PCI Expansion Slot on CPU

MTBF Mean Time between Failure

NEMA National Electrical Manufacturers Association

NFPA National Fire Protection Association

PC Personal computer, commercial grace computer

PLC Programmable logic controller

RAM Random access memory

RVR Runway visual range indicator

RWY Runway edge lighting

SAW Surface acoustic wave

TAXI Taxiway lighting

TFT Transition Film Technology

UPS	Uninterruptible power supplies
VFR	Visual flight regulator
VRAM	Video rapid access memory

1.7 UPGRADES TO THE ALRCS

A. The ALRCS in the new west vault shall be installed to interoperate with the existing upgraded ALRCS elements in the south and north vaults, as shown on contract drawings

B. The ALRCS shall be upgraded to support the functionality associated with airfield lighting circuit reconfiguration identified on the contract drawings. All displays, preset functions, maintenance functions and CCR functions that are impacted by the reconfiguration shall comply with the specification performance end operational requirements.

C. The modification of Runway Guard Light bar(s) as described in the contract drawings shall be supported by all ALRCS systems, displays and software as required in compliance with the specification performance and operational requirements. Note there are new functions to be supported in the Runway Guard Light System, refer to section 16531 for details.

D. The modification of the Runway Guard Light Bars shall include reporting of failed lamp discretely from failed addressable device where field hardware supports this feature. The ALRCS upgrades at all locations shall support this reporting.

E. The ALRCS shall support the reconfiguration/ replacement of the affected CCRs, in compliance with all specification performance and operational requirements.

F. The alarm reporting and analysis function shall include for enhanced sorting of alarm fields and reporting of maintenance related events.

G. Digital displays shall be included to the DCMUs in all panel locations to provide more complete status of the panel I/O at each location.

H. The ALRCS shall be upgraded to sL4>port enhanced DCMU maintainability functions.

I. The ALRCS shall support an input signal from the automatic transfer switches to indicate a transfer is in progress.

J. Enhance the operation of the ALRCS to support automatic transfer switch operation using the signal identified in previous paragraph, to reduce the occurrence of circuit breaker tripping of the CCRs during an ATS switchover.

K. The ALRCS in the A TCT shall be upgraded with new panels and network components as shown in the drawings.

L. The Maintenance PC in the electrical shop shall be upgraded with new workstation, printer network components as shown on contract drawings.

1.8 ALRCS SYSTEM DESCRIPTION

A. The ALRCS shall meet the requirements of FAA AC 150-5345-56, Specification for L-890, Airfield Lighting Control and Monitoring System. Type 0 and fail safe types A and B.

B. The requirements for L-890 shall be considered as general minimum requirements to be met. The ALRCS shall also fully comply with the requirements in this specification 16917, which includes the specific requirements of this airport.

C. ALRCS System Overview

1. The ALRCS architecture is specified to include a fully redundant design of critical system components. Refer to the drawings sheets to view the overall topology of the system. The primary function of the ALRCS is to provide the remote control and monitoring capability of the equipment in the airfield lighting vaults. The primary location for user interface to the system is at the cab of the air traffic control tower. Secondary control for the system, protected by an authentication process, is from each lighting vault, and the tower equipment room

2. The ALRCS shall be a state-of-the-art system, microprocessor based and software controlled, able to operate as a stand-alone system and to be expandable to be connected as a subsystem to an integrated workstation. All hardware or software changes required in the future as a result of airport expansions or changes must be possible without contacting the original equipment manufacturer or supplier.

3. The ALRCS shall include the functionality to fully support the addressable lighting control and monitoring system required for In Pavement Runway Guard Lights. The ALRCS system as supplied shall be include the performance capability to support additional addressable lighting control monitoring applications including controllable stop bars, sectionalized taxiway routing control, and single lamp monitoring, without requiring system architectural changes

4. The system shall be configured and installed in such a manner as to facilitate and minimize impact to a future upgrade process. The ALRCS PLC Control engines shall be supplied with the processing capacity, memory and other resources to support the potential growth indicated in the specification.

5. The major new elements of the ALRCS, described further in these specifications shall be comprised of:

a. ATCT Touchscreens

1) Three Touch Screen operator panels shall be provided for control of the airfield lighting. These panels shall be comprised of LCD Active Matrix TFT monitors with Surface Acoustic Wave (SAW) touch-screens for input of control commands and graphic display of the airfield lighting status. These panels shall contain all graphics processing. Only power and Ethernet connections shall be needed. No video extender or tower equipment room PC is permitted. The panel shall support external keyboard and mouse operation, which shall be supplied, for configuration or maintenance purposes; however, these shall not be needed during normal tower operation.

2) The Touchscreens shall be mounted in the console area in a suitable operating position in the ATCT cab, either in the console or provisioned with a tilt/ swivel support to facilitate adjustment of the screen to reduce glare. This will be determined by ATCT personnel.

a. Tower Equipment Room Touchscreen A tower equipment room Touchscreen shall be provided in the tower equipment room for maintenance and backup control the ALRCS. The PC shall be in the ALRCS rack mounted in the tower equipment room as indicated in the contract drawings. The panel shall be identical to the tower touchscreen and easily interchangeable in the event of a failure. This station shall be capable of being operated simultaneously with the tower touchscreen. A keyboard and optical mouse shall also be provided for configuration purposes, including a suitable slide out drawer that includes a mouse pad.

b. New West Vault ALRCS Cabinet. A cabinet shall be provided in the new west vault containing the redundant ALRCS Programmable Logic Control (PLC) Engines. The ALRCS include the redundant uninterruptible supplies, redundant fiber optics, telephone line, radio modem communication equipment and other components necessary for control and monitoring of the airfield lighting equipment including but not limited to constant current regulators, utility power, and automatic transfer switch, series circuit modems and generator set, The front of the cabinet shall be provisioned with remote control switches to operate all regulators in the vault, in the event of a control system or communicators failure .

c. ALRCS interface units. ALRCS interface electronics shall be provided for utility power, and automatic transfer switch, generator set, interface shall be supplied with dual Ethernet ports, to connect the interfaces to each of the redundant vault network switches

d. Vault -PC. Vault PC to be located in the vault shall be provided for system status indication power supplies, data logging, and statistical analysis for preventive maintenance. The PC is an industrial PC rack mounted as indicated in the contract drawings. The monitor shall be an LCD Active Matrix TFT monitor, 17 inches for input of control commands and graphic display of the airfield lighting status. A keyboard and optical mouse shall also be provided for configuration purposes, including a suitable slide out drawer that includes a mouse pad area. The PC shall be supplied with a redundant network interface and shall operate from the 24Volt DC power available in the PLC cabinet.

e. ALRCS Vault Local network. The new west vault shall include two local Ethernet networks. Each network shall be supported by separate set of Ethernet switches. No hubs are permitted. All CCRs and other devices interfacing to the ALRCS shall connect to each switch set. The switch shall also provide a connection to the ALRCS vault control PLC. The systems that interface to the Vault Local Network shall support failover mechanism so that in the event one of the networks is inoperative, the other network is used automatically

f. Runway Guard Light Addressable Device Vault Communications Interface. Hardware shall be provided to communicate to the addressable devices used for in pavement RGLs in the field. A communications interface shall be provided for each series circuit used for RGLs. The communications interface shall only connect to the series circuit through an isolation transformer. The communications interface shall provide two Ethernet interfaces that connect it to the Vault local network switch sets.

g. ALRCS Backbone Network. Single mode fiber optic cable, specified in a different section, shall be used between the vaults, tower and maintenance shop locations, as shown on contract drawings. Two strands in each bundle shall be used between each of the locations stated. Each pair serves as a fiber optic backbone for the ALRCS. Each location shall include two Ethernet switches with fiber transceivers to support the network backbone. Specification drawings indicate general configuration of the ALRCS and routing of the fiber optic communicators cables.

i. ALRCS Backup Radio Network. The ALRCS backup radio network shall be provided to protect against a complete loss of the fiber optic network. The radio network shall be interfaced to one of the backbone network switches in each location. In the event that both fiber networks are inoperative, the radio backup shall be switched into operation automatically. This network shall include a high level of security via encryption, MAC address filtering and other suitable means. The frequency shall be 4.9 GHz on a licensed channel. The IP addresses on the radio side shall be segregated from the ALRCS side of the radio modem. The contractor shall provide all mounting hardware, power, cable, conduits, lighting protection, obstruction lights as indicated on contract drawings.

j. ALRCS Local network. All Ethernet devices interfacing to the ALRCS shall connect using industrial Ethernet switching technology. No Ethernet hubs are permitted

1.9 SYSTEM REQUIREMENTS

A. The ALCMS design criteria to meet the minimum general, operational, and equipment functional requirements are as follows.

B. General Requirements

1. The ALCMS shall provide remote control and monitoring of the designated airfield lighting equipment in the vault under VFR, and CAT I/ II/ III operating conditions, as applicable

2. The ALCMS shall be based on an "open architecture" concept to allow simple integration and interfacing of all system components. All components shall be of industrial grade and extended temperature ranges and have high MTBF ratings.

3. Customized system and graphics software for control and maintenance operations.

4. The ALCRS supplier shall coordinate software and programming development with the control tower operations personnel and operations and maintenance personnel to ensure that user-operated control and maintenance functional requirements are provided.

5. All other specifications and requirements in the design package shall be supported by the ALCMS. Functionality requirements from the RGLS and CCRs shall be integrated into the ALCMS, to meet the specified operational, functional and maintainability requirements.

6. All equipment indoors shall have an operating temperature range O°C to +50°C ambient, with relative humidity, 10% to 90%, non-condensing.

C. Control Software

1. All software required to operate, maintain, analyze, and trouble-shoot the system, including source code, shall be provided as part of this contract. All control and monitoring software shall be off-the-shelf, non- proprietary and become the property of the owner.

2. All interlocking, monitoring and control logic shall be programmed in electrical ladder logic format and shall reside in the PLCs provided. A failure of a tower, vault or maintenance computer that displays the airfield graphics shall not affect the PLC operation and the operation of the rest of the system.

3. The software contained in the graphics computers shall consist solely of graphic generation, touch- screen operator input, configuration utilities and remote access software. All logic shall be performed in the ALCMS control engines.

4. System functions and display information shall be completely configurable on-line by maintenance personnel without the need to power down any device. This provides the ability to change the operation of the system without the need to make any program changes. These configuration changes shall be made simply by selecting a checkbox or by entering data into a configuration screen the following features shall be provided:

a. Enable control capability from each location including control tower, equipment room and vault.

b. Independently enable or disable circuits to allow monitoring and control of the circuit

c. Independently enable or disable each monitoring feature for each circuit

f. Independently set the on-delay time, soft-start increment times for each circuit.

g. Independently set the warning and alarm thresholds for each individual circuit and for each brightness level. It is acceptable to make these settings from the CCR keypad.

f. Independently enable or disable alarming of each monitoring function for viewing by tower, vault, and maintenance personnel. This allows the site to specify which alarms are viewable at each different location.

g. Enter or modify the circuit description / regulator information for each circuit.

h. Calibrate monitoring functions to match site true-RMS meters. It is acceptable to make these settings from the CCR keypad.

i. Configure all custom push buttons allowing the site to easily change how the system functions.

j. Enable ability to cancel user's pushbutton's selections after a pre-determined time of inactivity and the SEND button has not been pressed to initiate the commands. The time limit shall also be configurable by site.number.

k. Swap spare regulators into service by simply changing field cables and specifying the new regulator

5. Airport personnel shall be able to make any most site adaptation change as may be required in the future without the need to contact the original manufacturer of the Airfield Lighting Control and Monitoring System. All original program files and source code necessary to make any changes must be provided as part of this contract.

6. Access to all software shall be provided with suitable security measures to prevent inadvertent access to advanced maintenance features, configuration screens and settings. Any ability to make changes to the software must be protected using appropriate passwords and security features. These passwords shall be provided to airport personnel to allow them to make future modifications and additions. Security features shall include the following:

a. Site assignable usernames with different security levels, allowing individuals access to different system capabilities (Le. view only, lighting control only, control and monitoring, configuration, calibration).

b. Remote access protected by passwords and data encryption. Keys.

c. Desktop lock feature prevents users from accessing any Windows programs, functions, or preset.

1.10 MAINTENANCE REQUIREMENTS

A. The ALCMS shall include the capability to diagnose and locate system faults including all ALRCS network components, and connections to vault equipment, from the any maintenance workstation, authorized PC and the vault PC of the ALCMS. All system software on system computers that resides on the SSD disk shall be loaded by CDs or suitable mass storage media, provided by the supplier. The system shall not require any special configuration or file management by maintenance personnel to restore the system software. A restore of the SSD disk image to the current system revision level, shall be accomplished by system restore CDs, and shall start an autorun or with a single restore command shall restore the entire system image. The system then shall be ready to operate.

B. It shall be possible for failed replaceable components to the diagnosed by maintenance personnel using the software tools training supplied.

1.11 OPERATIONAL REQUIREMENTS

A. The following operational requirements define the operation of the control system as used by the Air Traffic Control Personnel. These items are subject to change and additional customization as required by the owner and FAA tower personnel. Any additions or changes shall be part of the scope of this contract.

B. Brightness Control

1. 3/5-step brightness level control
2. Separate control for each system as required
3. Provide individual brightness level pushbuttons

C. Send Pushbutton

1. Must be pressed before any commands are sent to the control engine.
2. Allows entire airfield to be configured prior to initiating changes.

D. Cancel Pushbutton airfield

1. Pressing this button will cancel the user's inputs and revert all buttons to the current status.
2. This allows the user to change their mind, as long as the SEND push-button has not been pressed.
3. The Cancel feature (if enabled) will also cancel any user inputs after a pre-determined time ofinactivity without the SEND push-button being pressed.

E. Operating Mode Selection Pushbuttons

1. Provide one for each runway direction or Operating Mode
2. Pre-programmed default settings for VFR, and CAT I, II, III Conditions
3. Allows quick switching of runway direction or modes
4. Lighting patterns to be maintained when switching direction
6. Interlocking to be provided to prevent lights of opposite of runway directions from being energized. Other interlocking to be provided as necessary for safe operations or regulator loading restrictions.

F. Runway and Taxiway Menus

1. Pop-up menus
2. SEND or CANCEL to automatically close menus
3. Provision to manually close menu

G. Runway Visual Range (RVR) Menu

1. Pop-up menu or permanent display
2. SEND or CANCEL to automatically close menu
3. Provision to manually close menu
4. Provision for Day / Night Operation
5. Provision for up to 5 visibility settings
6. SMGCS (less than 1200, above 600 feet RVR)
7. Less than 1 mile
8. 1 to 2 miles
9. to 3 miles
10. to 5 miles
11. Greater than 5 miles

H. Runway Edge Lighting

1. Separate ON/OFF control for each runway
2. 5-step or 3-step brightness level control

I. Runway Centerline Lighting

1. Separate ON/OFF control for each runway
2. 5-step brightness level control

J. Touch Down Zone

1. Separate ON/OFF control for each runway
2. 5-step or 3-step brightness level control

K. Taxiway Lighting

1. Separate ON/OFF control
2. 3-step or 1-step brightness level control for edge lights
3. 5-step brightness level control for centerline lights

L. Runway Guard Lights

1. Separate ON/OFF control for in-pavement RGLs
2. 5-step brightness level control for in-pavement RGLs

M. Land and Hold Short Controls (LAHSO)

1. Separate ON/OFF control for LAHSOs
2. Monitor available status and display as required

1.12 ALRCS FUNCTIONAL REQUIREMENTS

A. Operator Control Panel

1. Each operator control panel shall be capable of independently controlling and displaying the entire airfield lighting installation or any predefined potion.

2. Operator Control panel functions shall include:

   a. Control and monitoring of runway lighting
   b. Control and monitoring of taxiway lighting
   c. Control and monitoring of the runway Guard Light System
   d. Control and monitoring of the generator, transfer switch, power
   e. Alarm indication of critical element failures including all battery low indications, loss of power, generator fail, fiber optic, radio modem communication fail.
   f. ALRCS or network failure
   g. Alarm indication of regulator or other circuit failures.
   h. Alarm of SMGCS lighting components
   i. Control and monitoring of the guidance sign circuits
   j. Control panels shall display a graphic representation of the airfield lighting installation.
   k. Only circuits that are actually "ON" (current is flowing in circuit) shall be indicated as being "ON" on the display.

3. Indication shall be as follows:

   a. Runways Edge-white bar
   b. Runway Centerlines -Green bar
   c. Taxiways Edge-blue bar
   d. Taxiway Centerlines -Green bar
   e. Touchdown zones -red bar
   f. In pavement RGLs Yellow Bar
   g. Signs (to be agreed upon)

4. Circuits that are currently not under A TC control from the tower shall be indicated on the mimic display as "LOCAL"

5. Airfield lighting control commands shall be entered at the touch-screen monitors using touch-buttons on the displayed pages.

6. Separate control touch-buttons shall be provided for each controllable lighting element as detailed in Operational Requirements above.

7. Push-buttons shall change color according to the following status indications:
   a. Gray to indicate push-button is not selected and lighting circuit light is OFF.
   b. Yellow to indicate push-button has been pressed to turn on the lighting but no commands have been sent to the PLC.
   c. Green to indicate the command was initiated and acknowledged by the PLC at the Vault.
   d. Dark green to indicate push-button has been pressed to turn off the lighting but no commands have been sent to the PLC.
   e. Flashing red to indicate that the corresponding airfield circuit is not operating as requested by the pushbutton.
   f. Each display page shall have touch-buttons for command selection, SEND (acknowledge) and navigation to other display pages.
   g. Provision shall be made to allow the tower personnel to calibrate the touch-screen simply by pressing a push-button on the screen.
   h. Develop the displays and system/graphics software and coordinate this phase of the work with the A TC, maintenance and operations Personnel.

B. Air Traffic Control Tower (ATCT) Panels

1. The LCD panels shall include an embedded graphics engine that supports all of the required display and communications functions. This panel shall include an Ethernet interface to be connected to the network switch in the ATCT Equipment room. The A TCT panel shall perform the following functions:
   a. Generation of LCD graphics display.
   b. Receiving command signals from the touch-screen to control the airfield lighting.
   c. Decoding and acknowledging receipt of command signals.
   d. Transmitting control command signals to the Tower PLC that are sent via the dual Ethernet connection onto the fiberopic cable to the Vault PLC for execution.
   e. Reception of data from the ALCMS network regarding the status of the airfield lighting and associated equipment. The Tower panels shall display only that information, which is has operational necessity for control and monitoring and situational awareness of the airfield lighting components and electrical power sources.
   f. Provide real time status of the airfield lighting.
   g. Program for calibration of the touch-screen.

C. Remote Access:

1. The software shall provide remote access capability to the Tower Computer using a dialup modem connection as follows:
   a. Maintenance electricians and other personnel as determined by the Airport Authority shall have the ability to remotely connect to the tower computer using a dialup V.92 modem, which is part of the maintenance workstation.
   b. Remote access shall be password protected and available only to those authorized by the Airport Authority.
   c. All graphic screens, displays and information that are locally available shall also be available from the remote location.
   d. Ability to view, control, maintain and troubleshoot the system shall be provided remotely, provided proper security passwords are provided.

e. Ability to perform file transfers and product updates from the manufacturer via modem shall be provided.

D.Tower Equipment

1. The equipment room under the tower cab shall include an interface to control and monitor the local 110 points as indicated, if required. This interface shall include redundant Ethernet network support. The network connection shall be interfaced to the ALRCS network switch in the equipment room.

E. Vault PLC. All vault 110 shall be via the dual vault Ethernet network and switches. The PLC Control engines shall be redundant including failover mechanism. The functions below are entirely supported on the network. These functions include but are not limited to:

1. Provide output signals to control the regulators:
   a. Regulator On (CC)
   b. Regulator Brightness Level B 1
   c. Regulator Brightness Level B2
   d. Regulator Brightness Level B3
   e. Regulator Brightness Level B4
   f. Regulator Brightness Level B5

2. Provide regulator monitoring input signals:
   a. Analog output current
   b. Analog output voltage
   c. Regulator status
   d. Control Switch not in remote
   e. Input voltage present
   f. Output current sensor when necessary
   g. Analog Insulation Resistance
   h. CCR alarm Status

3. Provide monitoring input signals for the following
   a. Generator ON
   b Generator Low Fuel
   c. Automatic Transfer Switch-Commercial power on line
   d. Automatic Transfer Switch-Generator Transfer
   e ALRCS Equipment-120VAC power failure
   f. Low PLC battery
   g. Low 24VDC UPS Battery

4. Provide Control output signals for the following:
   a. Generator Start
   b. Generator Stop

5. The PLC shall be provided with an EEPROM module providing non-volatile program backup. The program shall be reloaded directly from EEPROM simply by cycling the PLC power supply switch off and th61 on.

F. Communications Network

1. The ALCMS network shall use standard TCP/IP between the each location to pass data between all ALRCS elements

2. Communication between locations shall be via a redundant fiber optic network using 2 strands each of single mode cable indicated in the drawings that connect between each of the locations. A backup radio modem connecting the locations where ALRCS equipment is present shall be supplied and shall switch on line in the event that fiber paths is failed.

3. Communication shall automatically switch between the main and backup (redundant) fibers and backup radio modem as follows:

a. Failure of one fiber optic transmit or receive line shall cause communication to switch to the alternate transmit or receive fiber.

b. Failure of both the transmit lines or the receive lines shall cause automatic switch over to the backup radio modem.

c. Repair or recovery of the fiber optic lines shall cause communication to automatically switch back to the fiber optic cable.

d. Communication switching shall be transparent to the control tower personnel. All systems shall remain fully operational regardless of the mode of operation. Any failure shall be alarmed at the tower and all user panels and PC's.

e. A watchdog timer shall be provided for both the copper Ethernet links and fiber optic lines and the backup radio link to ensure that both communication networks and the backup radio link are fully operational.

G. Runway Guard Light System Functionality

1. The ALRCS shall support all functions specified in 16531. The ARLCS shall support RGL system by providing status to airfield status screens that reflect the operational state of each RGL bar as defined in the RGL specification 16531. For tower or overall situational awareness, only the state of the RGL bar is displayed. Alarms are conveyed based on those bar states. The performance requirements identified in 16531 for the time of reporting status shall apply.

2. For Maintenance screens displayed anywhere in the ALRCS, the status of the bar as defined in the RGL specification, as well as individual fixture status shall be displayed in all modes of visibility. The performance requirements identified in 16531 for the time of reporting status shall apply.

3. The status of the series circuit communications interface shall also be reported as a component.

4. During a power up of the circuit, the status of the RGL controls is unknown, until they initialize and report. Subject to the reporting timing requirement~ the ALRCS shall not report any failed components or states during power up or power down of the RGL circuits until it has been determined that an actual failure has occurred.

H. Failsafe Functions:

1. In the event of communication/control system failure, the CCRs shall enter the failsafe state. This function shall be present in the CCR, and is included here for clarity of the system functionality

a. Each regulator failsafe function shall be independently programmable such that upon communication or system failure, the regulator shall automatically revert to either remain in the last state or switch to OFF, Brightness B1, B2, B3, 84 or B5.
b. If failsafe mode occurs, all regulators and circuits will set to their failsafe settings.
c. The failsafe settings shall be determined by the airport operations a maintenance staff and shall be field adjustable without changing the software.
d. A watchdog timer shall be installed to check the status of the control system and communications and the failsafe mode shall be entered if malfunction occurs.

2. When the control system returns to normal, control shall automatically be transferred back to the tower.

1.13 MAINTENANCE DISPLAY

A. Maintenance displays with, printer, and software in the vault shall provide real time and historical information on the status of the ALRCS.

B. In the vault the maintenance display is installed in the PC equipment rack and visible through the door.

C. Airfield lighting systems status information shall be presented on display screens and accessed by means of graphical icons located at the bottom of each page.

D. Various screens shall be provided to display sections of the single line diagram for the airfield lighting power distribution. Single lines shall show the incoming power sources generators, regulators, circuit selectors and feeder circuits as seen physically in the ALCMS.

E. Single Line Diagrams

1. Regulators shown on the single line diagrams shall indicate the following conditions. Selecting the single line will bring up the corresponding regulator status screen.

Regulator Status	**Graphical Representation**
Input voltage present	Breaker -green
Input voltage not present	Breaker -Flashes red
Regulator off *I* not required	Regulator single line -black
Regulator energized and current is present	Regulator single line -green
Regulator energized and current is not Present	Regulator single line -yellow
Regulator is in alarm	Regulator single line -flashing red

2. The PLCs shown on the single line diagram shall indicate their operation a state.

F. Regulator Status Displays. One Regulator Status Screen shall be provided for each regulator and shall include the following information:

1. Pictorial representation of the regulator
2. Regulator Cell Number
3. Field Circuit Number and Description
4. Local (manual) selection
5. Input voltage loss
6. Over-current, over-voltage or door inter-lock shut-down
7. CCR alarm
8. Selected brightness level (by ATCT)
9. Actual brightness level/series circuit output current
10. Output voltage
11. Output Current
12. Output KVA
13. Output KW
14. Elapsed time on each brightness level
15. Number of regulator operations
16. Insulation Resistance of field circuit
17. Current Sensor Status
18. Elapsed time on each brightness level
19. Number of operations
20. Selecting the regulator description shall automatically bring up the corresponding regulator status screen.
21. Selecting a different circuit selector on the pictorial shall automatically bring up the corresponding status
22. Reset capability shall be provided to reset the Elapsed Time meters and operations counters.

G. Communications Status Displays. A communication Status Screen shall be provided and (shall include:

1. Pictorial representation of the communication system
2. PLC Battery Status
3. 24VDC Battery Status at both Tower and vault
4. 120VAC Power Supply Status at both Tower and vault
5. Current Mode of Communication
6. Status of all network switches on the ALCMS network
7. Status of all network switches on the Vault networks
8. Status of all network links (between all switches and all devices)
9. Fiber Optic Channel A Receive Error (for each location)
10. Fiber Optic Channel B Receive Error (for each location)
11. Fiber Optic Channel A Impending Fault (for each location)
12. Fiber Optic Channel B Impending Fault (for each location)
13. Fiber Optic Watchdog Timer
14. Radio Modem Watchdog Timer
15. Push-buttons shall be provided for enhanced diagnostics and troubleshooting by automatically forcing failures on any of the fiber optic lines and forcing the fiber optic modules to trap and hold intermittent errors.

H. Alarm Summary. Alarm Status Screen shall display a list of all current malfunctions and provide:

1. Date and time of the malfunction
2. Type of Failure or Alarm
3. Lighting system, CCR, circuit selector
4. Computer or PLC fault
5. Communications fault
6. Location, e.g. Control Tower, vault
7. Description of malfunction

I. Event Summary

1. Event Status Screen shall display a list of all events and provide:
a. Date and time of the event
b. Operator circuit switching *I* brightness changes
c. Security information
d. System event information provided by hardware
e. Description of the event

J. Historical Reports

1. Menu selected screens shall be provided to display all the activities and malfunctions which occurred during a defined time period including. The reports shall be have the capability of being sorted by any field listed for ease of maintenance.
a. All lighting system operations
b. All control system malfunctions (computers, PLCs, communication systems, power supplies)
c. Elapsed time on each brightness level for each CCR/series lighting circuits d. CCR activity, number of operations for each regulator, and malfunctions
e. Generator operations and malfunctions
f. Coordinate with and develop software, screen displays, and menus in cooperation with Airport maintenance personnel, to fully incorporate user requirements.

K. Trending

1. The software shall provide simultaneous real-time trending, history logging and history replay of control system data.
a. rending shall be available in real-time, in the background, *a* from historical data.
b. The software shall be capable of displaying real time data and historical data on the same trend, allowing full comparison of current and historical data.
c. The software shall be capable of trending any point or parameter of the control system that is either monitored or controlled.
d. Trending shall be configurable by the site maintenance electricians to aid in troubleshooting and analysis of airfield lighting circuit or equipment problems.
e. Coordinate with and develop software, screen displays, and menus in cooperation with Airport Authority engineering maintenance personnel, to fully incorporate user requirements.

L. Control from Vault Computer

1. In normal operation, control of the airfield lighting shall not be permitted from the vault computer. Control shall be solely assigned from the control tower for maintenance of the system.

M. Remote Access

1. The software shall provide remote access capability to the Maintenance Computer using a dialup modem connection.
   a. Maintenance electricians and other personnel as determined by the airport shall have the ability to remotely connect to the maintenance computer using a dialup V.92 modem.
   b. Remote access shall be password protected and available only to the ALCMS system supplier or those authorized by the Airport.
   c. All graphic screens, displays and information that are locally available shall also be available from the remote location.
   d. The ability to view, control, maintain and troubleshoot the system shall be provided remotely, provided proper security passwords are provided
   e. The ability to perform file transfers and product updates from the manufacturer via modem shall be provided.

N. Event Data Related

1. The ALCMS shall include support for archiving log events, reports and other pertinent system events for the purposes of off line storage.
2. Archiving shall be supported to any storage volume connected to any workstation in the ALCMS. Events shall be stored for a predefined amount of time. Storage time shall be defined by the airport and shall be configurable from 1 day to 1 year
3. This includes but is not limited to CD R/W drives, removable flash storage devices and network storage appliances
4. Viewing events, including warnings and alarms, shall be able to be viewed via a user HMI interface.
5. Subset Viewing -Subset of events, including warnings and alarms, shall be able to be viewed via a subset HMI interface that allows the user to specify a date and time range to view. In addition, subsets of events shall be viewable based on configurable criteria, such as events involving a particular component, failure type, or any other searchable elements or combinations of elements, allowing the user to see the history of events with common characteristics.
6. Logging -All active and cleared events shall be stored to a database designed for optimal retrieval performance. These events shall be viewable as defined in d and e above.
7. Date/Time Stamp -Stored events shall be stamped with the date and time of occurrence.
8. Purging -The ALCMS shall provide a method (automatic or manual) for erasing the events database to allow for SSD disk space recovery

1.13 RESPONSE TIME PERFORMANCE REQUIREMENTS

A. Tower command on touch screen to CCR changing state and actual back indication shall be less than two seconds

B. Vault or tower equipment room selection of any status screen until status of all elements is displayed shall be less than two seconds

C. Equipment on the any network fails until appropriate alarm or status is displayed shall be less than 30 seconds

D. Equipment on the any network is restored until appropriate alarm or status displayed is cleared shall be less than 30 seconds

E. Any event resulting in an automatic network failover shall be completed in less than 30 seconds. Any temporary loss of status or control beyond the failover delay is not permitted. No control or status change of state as a result of a failover event is permitted.

F. Any event resulting in a restoration of an automatic network failover shall be completed in less than 30 seconds. Any temporary loss of status or control beyond the failover delay is not permitted. No control or status change of state as a result of a failover event is permitted

G. The PLC control engines shall keep system status synchronized between each other in order to meet the failover performance requirements

H. No false status or nuisance alarms are permitted.

1.14 SUBMITTALS

A. Design Submittal. All significant equipment to be supplied shall be listed followed by descriptive data sheets. The equipment list shall include each component name, supplier, model number, a description of the operation, quantity supplied and any special setup, operation and maintenance characteristics.

B. The submittal shall include a description, by specification paragraph number, of how each of the requirements in the specification will be met.

C. Software submittals shall provide a complete description of the system on a functional level.

D. All submittal items shall be subject to approval of the Engineer. Materials and methods identified and described not meeting the requirements of this specification or, in the opinion of the engineer, are not suitable for the intended application, may be rejected, in whole or in part. The supplier shall be required to modify the submittal including changes to materials and methods to the satisfaction of the engineer.

E. Shop Drawings and Product Data

1. For any new or modified wiring, provide drawings showing mounting details of Control Tower touch- screen video display monitors, general arrangement of control panels, identification and location of device and panel, "bill of materials." For control panels, provide as a minimum a plan view and a front view with doors removed. Show overall dimensions and component mounting details, cable routings, connections, and terminations.
2. Provide detailed power schematics of computer or PLC control cubicles, showing incoming power supplies, circuit breakers, cooling fan and control, battery charger and control.
3. Provide detailed control schematic and wiring diagrams including all control, monitoring, and communications interconnections and terminations between PLC I/O and airfield lighting control and monitoring points and terminals; PLC and computer interconnections, fiber optic communication connections, computer to touch-screen video display monitor interconnections. Provide control and monitoring schematic diagrams in electrical ladder format.
4. Provide preliminary and final touch-screen video display monitor "page" layouts. Include graphic displays, touch, "pushbuttons," status displays (brightness level, on/off, alarm); graphic display representation for each field lighting element, and, for pushbuttons (back-indication from computer to acknowledge operator input; back- indication from computer or PLC to confirm action taken; alarm).
5. Submit 3 copies of all drawings and data to the Engineer for review.

F. Operation and Maintenance Manuals

1. Provide 3 copies of Operations and Maintenance Manuals.
2. Provide a detailed description of the ALRCS operation principles and information on troubleshooting, servicing, and maintenance of the equipment, including computers, touch-screen video display monitors, computers or PLCs, and related equipment, and the actions required in the event of faults.
3. Manuals shall be in full color including color photographs of all equipment at site and full color screen captures of all ALCMS operator and maintenance graphic screens
4. Provide a typical step-by-step procedure describing use and systematic troubleshooting of the system. Maintenance manuals shall describe in detail specifically how ALCMS symptoms are diagnosed, isolated and repaired.
5. Provide individual manuals for specific equipment as appropriate. Provide identified tabs and sections in master manuals for individual equipment data/manuals.
6. Include schematics and detailed power and control/monitoring diagrams for all equipment supplied.
7. Provide full and complete system software and associated source codes. Software shall be complete so that the owner can modify or change the program or graphics as required without the need to contact the ALCMS manufacturer.
8. Include detailed material lists with parts numbers.

1.15 PROJECT RECORD DOCUMENTS.

A. All drawings, materials lists, and software documentation shall be updated to as built condition to include any factory assembly modifications and field installation modifications.

1.16 QUALITY ASSURANCE

A. Airport lighting equipment and materials covered by FAA specifications shall have prior approval of the Federal Aviation Administration, Airports Service, Washington, D.C. 20591, and shall be listed in Advisory Circular *150/5345-53*, latest edition, Airport Lighting Equipment Certification Program. All items that are FAA approved at the time of bidding that meet the project specifications are acceptable.

B. All hardware and software proposed must be commercially available off-the-shelf products and must be available from various Suppliers.

C. Systems of the type and configuration proposed must have been operational at other airports for at least a period of 5 (five) years.

1.17 QUALIFICATIONS

A. Manufacturers must have a minimum of five PLC based airfield lighting control systems installed and fully operational.

B. Submit a detailed experience list for approval by the owner including the following information: location, date of final acceptance, and a description of the hardware and software used in the control system.

1.18 REGULATORY REQUIREMENTS

A. Conform to requirements of NFPA 70.

B. Perform all work in conformance with guidelines established by the FAA for an ALCMS.

1.19 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, protect, and handle products to site under provisions of Section 16010 GENERAL PROVISIONS.

B. Accept products on site in factory containers. Inspect for damage.

1.20 WARRANTY

A. Provide written warranty that the ALRCS equipment and components supplied and installed are warranted against defects and malfunction for a period of 12 months from date of completion of commissioning.

1.21 SPARE PARTS

A. Provide a recommended spares kit for the

ALRCS. PART 2 -PRODUCTS

2.1 VAULT PC

A. Furnish and install one industrial computer (PC) as specified, and software, to provide real time and historical information on the status of ALRCS. The vault PC shall not use a rotating fixed disk the vault PC shall be supplied with a solid state drive (SSD) for program storage and operating system use

B. All functionality and capability identified in this specification shall be included

C. Include and install all components identified in this specification.

2.2 TOWER EQUIPMENT

A. Video Display Monitors (Control Tower)

1. Three 17" Active matrix TFT LCD color panel, equivalent, high resolution, suitable for operation in sunlight conditions and capable of displaying 256 colors. Coordinate actual display size with ATC tower facilities, based on available panel space, a smaller panel may be needed.
2. 1024 x 768 resolution at 80Hz, non-interlaced, SVGA software compatible.
3. Mounting: on adjustable assembly for optimal viewing.
4. Monitor to be complete with integral Surface Acoustic Wave (SAW) type touch-screen.
5. Graphics engine is embedded in this assemble with -Ethernet port to connect to the ALRCS network
6. Uninterruptable Power Supply (UPS) for touch screen monitor, 4 hours backup with monitoring support into the ALRCS for battery and UPS status. Use 120V outlet feeding the existing UPS.

2.3 Equipment (Control Tower and Vault).

A. Provide and install as described in this specification and on contract drawings.

1. PLC Controls Enclosures.

a. The computer or PLC controls enclosure shall be rated NEMA 12, with single door front access design and nominal dimensions shown on drawings
b. The enclosure shall be equipped with the following:
1) Door locking system.
2) Rear component mounting plates.
3) Cooling fan and controls for filtered positive air pressurization.
4) Terminal blocks, clips, rails, ducts, and other material as required to provide properly terminated and supported wire and cable routing.
5) Grounding straps as required.
6) All wires and cables are to be labeled identifying the signal name or suitable designation so that it can be reconnected if removed without tracing the wire.

1. Control System Power

a. Provide two 120 VAC, 60 Hz, 1-phase power to the PLC controls enclosure from the existing 120/240V panel-board. Terminate the circuit in a suitable circuit breaker mounted inside the enclosure.
b. Provide two 24 VDC power supply (as hot standby redundant) within the PLC (controls enclosure for each redundant PLC system (four total) and wire to terminals. Distribute as required to the computer or PLC rack and to all inputs and outputs. The 24 VDC power supply is to be provided by gel cell battery with float charger system and is to be capable of providing 10 hours of uninterrupted power to the computer or PLC and control monitoring circuits, in the event of utility power failure.
c. The charger must have sufficiently low ripple that it can supply the load requirements of the system while the battery is removed for service. Similarly, the charger must be capable of being removed for service without disruption to the control system.
d. A battery low voltage sensor shall be provided to alarm when the battery voltage drops below 23.5 VDC.

2.4 VAULT CONTROLS

A. Provide and install all vault equipment as described in this specification and contract drawings.

B. The PLC control engines shall be Allen Bradley Control Logix.

2.5 MAINTENANCE PC

A. Furnish and install one workstation computer (PC) as specified with 8.5 X 11” color Laser printer. All hardware and software to provide real time and historical information on the status of ALRCS. The maintenance PC shall not use a rotating fixed disk the maintenance PC shall be supplied with a solid state drive (SSD) for program storage and operating system use.

B. All functionality and capability identified in this specification shall be included

C. Include and install all components identified in this specification.

D. Provide Enclosure, fiber network switches and redundant power supplies for maintenance PC area, as shown on drawings

2.6 NETWORK COMPONENTS

A. he fiber-optic network shall use 2-fiber 8/125 um cable suitable for 1300 nm optical wavelength and industrial data highway fiber-optic modules.

1. Fiber Optic communication modules shall be suitable for operation in a redundant, fault tolerant, self-healing design. All fibers shall be connected and operational in this configuration, the system shall remain fully operational with severing of all fibers between any two nodes. The fiber optic modules shall be provided with complete on-line diagnostic features.

2. The ALRCS network Switch shall be Hirschmann RS20-0900W S2EDAEHH04.0; or approved

E. The Network backup radio shall be the Esteem 192EP or approved equal

2.7 WIRING METHODS AND PRACTICES

A. All Ethernet cables shall be stranded, factory terminated Category 6 patchcords. No Horizontal cables are permitted.

B. Conductors: install copper conductors not smaller than#12 AWG for 120 V power circuits and #20 AWG for control wiring. Insulation: rated 600 V, 90°C.

C. Color Code

1. AC power circuits:	black
2. AC control circuits:	red
3. DC control circuits:	blue
4. Interlock circuits energized from an external source:	yellow
5. Ground conductors:	green
6. Current-carrying grounded conductors:	white

D. Terminal Blocks

1. Provide terminal blocks rated 600 V for both power and control wiring.
2. Locate terminal blocks so that connections are readily accessible.
3. Provide minimum 15% spare terminals for future use
4. Group power and control terminals separately. Identify all terminals using clear indelible markings.

E. Device Nameplates

1. Identify all power, control, and communications devices by means of labels or lamacoid nameplates. Label backplate mounted devices in a visible location adjacent to the device.
2. Lamacoid nameplates: 3-mm thick, white face, black lettering, 5-mm high letter, minimum.

3. All ALRCS cables must be labeled at both ends as to the signal name
4. Provide a network diagram laminated in plastic showing all network connections. This should be placed in the each cabinet of the ALRCS for wiring at that location.

F. Panel Wiring

1. Contained in noncombustible plastic wiring duct with removable covers and filled to no more than 60% capacity.
2. Where the use of wiring ducts is impractical, wires shall be neatly bundled and mechanically supported.
3. All installed I/O points shall be wired to terminal blocks including points installed but left as spare.

G. Grounding

1. Ground controls enclosure and individual components.
2. Observe grounding procedures in accordance with the manufacturer's Assembly and Installation Manual.
3. Provide separate bond to ground for enclosure door with electrical devices mounted thereon.
4. Provide a bolted ground lug at the bottom of the enclosure and connect to building ground bus using insulated ground wire.

2.8 SOURCE QUALITY CONTROL

A. Tests of all equipment covered by these specifications shall be witnessed by a representative of the owner. The contractor shall provide advance notice of a minimum of two weeks prior to the schedule of factory testing. All costs associated with this testing shall be the contractor's expense for two (2) personnel to attend all testing.

B. Perform a complete examination of the system to determine compliance with the specifications and drawings with respect to materials, workmanship, dimensions and marking.

C. Conduct a complete review of all graphic screens to determine compliance with air traffic control and maintenance requirements prior to shipment.

D. Verify sequence of operations to ensure complete functionality and performance of system. Perform complete testing of fiber optic and backup communication systems using cables of reduced length.

E. Perform any additional tests that the owner representative may require to satisfy themselves of the adequacy and satisfactory operation of the system.

PART 3 – EXECUTION

3.1 INSTALLATION

A. Installation of the new ALRCS and removal of the old system shall be coordinated with the Air Traffic Control personnel and the owner maintenance personnel as follows:

1. Existing control system shall remain operational until the new system has been installed and verified for correct operation. The changeover period shall be coordinated with the FAA and the owner and shall only occur during the widows agreed upon.

2. During the changeover, provision shall be made for local operation from the regulator vaults.

3. Refer to phasing plans for staging of ALCMS work.

4. 4.9 GHz backup *radio* and antenna sighting and mounting shall be done providing line of sight between the tower antenna and the vault antenna, the supplier shall follow the manufacturer's requirements for site design, and install the system so the ALRCS can meet the all performance requirements of this specification. All licenses and coordination with the owner or any required agency for installation and operation shall be obtained and coordinated by the contractor in advance of the installation as to not impact the installation schedule.

5. Install Tower computers or PLC controls cubicle in the tower. Connect to supply.

6. Terminate fiber optic cable into Tower PLC c01trols cubicle.

7. Install touch-screens, cables as required. Connect to *120JAC* UPS power in tower.

8. Install the new PLC controls cabinet in regulator vault, while maintaining operation of the existing control system components. Provide temporary connections necessary to achieve continuity of operation. Connect 120VAC power to the new computer or PLC panel.

9. Terminate fiber optic cable into vault computer or PLC controls cubicle.

10. Install and wire all regulators, circuit selector, and other monitoring kits.

11. Install and connect all control and monitoring wiring as required between the regulators and the computer or PLC controls cabinet.

12. Make grounding connections as previously outlined in this Section.

13. Install vault PC, in cabinet and printer on computer desk provided by others. Supply and install new 120VAC receptacle end conduit.

14. Install fiber-optic communication cables in new and/or existing underground ducts and in cable trays and conduits as indicated on the drawings

15. Provide fiber optic patch panels, terminations and testing. Test existing fiber optic strands planned for ALRCS operation.

16. After completion of transfer to the new control system, disconnect and remove the old control system components and wiring.

3.2 TESTING AND COMMISSIONING

A. Prepare and submit a proposed testing and commissioning procedure for the ALCMS. Prepare these documents listing the testing and commissioning procedures and expected test results. As a minimum, tests shall include the following:

1. Point-to-point wiring continuity tests.

2. Insulation and grounding tests.

3. Fiber-optic network communications tests.

4. Verification of all remote control functions for each controllable element.

5. Touch-screen monitor operations, screen display sections, command select acknowledgment, action confirmed representations, and alarm indications.

6. Maintenance Center computer tests.

B. Acceptance testing--. Following final installation and calibration of the ALRCS, the supplier shall perform a demonstration of system performance to the satisfaction of the Engineer. An acceptance test shall be conducted to determine if the system meets the functional and performance requirements of the specification. Satisfactory performance of control functions, monitoring and display functions, alarming, and reporting functions shall be demonstrated. All performance requirements in this specification are subject to testing and verification. If the system does not meet the performance requirements of this specification, the supplier shall make modifications so that the requirements can be met, and shall bear all associated costs including the cost of performing the test again, and associated costs for additional time required by the engineer. Any changes to the system as submitted shall be subject to the approval of the engineer.

3.3 TRAINING

A. Provide a qualified factory-trained service engineer to conduct on-site familiarization, operation, and maintenance training program for the ALRCS. Training will be for the Airport's Control Tower and the Maintenance personnel and shall be conducted after the system is fully commissioned.

1. Provide 2 sets of 4 hours of on-site training for Air Traffic Control personnel covering operational procedures including allowance for shift work periods.
2. Provide 2 sets of 4 hours of on-site training for maintenance personnel covering operational, maintenance and troubleshooting procedures.
3. Provide 2 sets of4 hours of on-site training for maintenance personnel covering software and system configuration of lighting components.
4. As a minimum, training shall include the following:

a. Familiarization with the Operation and Maintenance Manuals.
b. Review of schematic drawings -how to read them and how to use them to troubleshoot system function and control problems.
c. Review of software documentation
d. Physical check-over of equipment, noting device locations and relationships to schematics.
e. Equipment functional tests and checks.
f. Equipment operating instructions.
g. Equipment routine service requirements.
h. Equipment troubleshooting instructions and procedures -review equipment self-diagnostic features and indications, define most likely problems, symptoms and corrective actions.
i. Trouble shooting shall include causing simulated faults throughout the system so that they can be diagnosed by maintenance personnel.
j. On site refresher courses lasting two days minimum shall be conducted at a minimum, annually, to ensure that the maintenance personnel remain familiar with the system troubleshooting. This activity shall also include system fault diagnostic training with simulated faults.

PART 4 -MEASUREMENT AND PAYMENT

4.1 METHOD OF MEASUREMENT

A. Measurement for the item covered in this section and subsidiary items shall be furnishing all products and for preparation, assembly and installation of these products, including but not limited to all radio components, licensing and coordination, all controllers, touch screens computers, enclosures, switches hardware, printers, all ALRCS network components, power supplies, connecting to controlled and monitored equipment, Uninterruptable power supplies for the ATCT touch screen monitors, cables, testing, site factory and site acceptance testing, category 6 and fiber optic patch cords, labor, equipment, tools, and incidentals necessary to complete the ALRCS described in the specification and contract drawings to provide a complete and functional system. Included in this item is the labor and materials specified for the new west vault, the tower cab and equipment room, the maintenance PC and associated elements in the maintenance shop, and the upgrading and modifications to the existing ALRCS components in the north and south vaults. Additional material and labor in the tower: 600V wiring and conduit and power and all connections.

B.Measurement for the installation of the regulators in the Airfield Lighting Vault, the generator for the vault and other equipment to be controlled and monitored by the ALRCS, shall be included in other sections

4.2 METHOD OF PAYMENT

A. Payment for items covered in this section and subsidiary items shall be paid for per lump sum as shown below and shall be full compensation for furnishing all products and for preparation, assembly installation and testing of this item, and for all labor, equipment, tools, and incidentals necessary to complete this item in accordance with the provisions and intent of the plans and specifications. Payment will be made under:

16917-01 Airfield Lighting Control and Monitoring System (ALRCS) Per Lump Sum.

END OF APPENDIX TO SECTION 2 – GUIDE SPECIFICATIONS

3.1 CONCRETE

3.2 Concrete Materials and Unit Stresses

3.2.1 Non-Prestressed Concrete - Non-prestressed concrete for structural elements shall be designed for a minimum twenty-eight (28) day compressive strength (fc') of 4000 psi, or as dictated by design requirements. All exposed exterior concrete shall be designed with 3% to 6% entrained air. Adequate equipment and procedures shall be provided for protecting concrete during temperature extremes. Admixtures shall be used with care, and compatibility shall be verified by testing laboratories.

3.2.2 Prestressed Concrete - Prestressed concrete for structural elements shall be designed for a minimum twenty-eight (28) day compressive strength (fc') of 5000 psi.

3.3 Drilled Piers

3.3.1 Drilled piers shall be straight shaft type only. Use no belled piers.

END OF SECTION 3

4.0 MASONRY

NOT CURRENTLY USED

END OF SECTION 4

5.1 STRUCTURAL SYSTEMS

5.2 General Information - This chapter defines general design criteria that applies to the design of structural systems at the HAS Airports. Chapter 1 should be consulted for specific System-wide regulations, procedures, and standards that also apply.

5.3 Building Structures - This section shall apply to all building structures at any of the Airports which provide for pedestrian access in any form.

5.2.1 Loads - The following special loadings shall take precedence over those mentioned in the current Building Code for the special cases mentioned:

5.2.1.1 Live Loads – Live loads shall be approved by HAS but as a minimum shall comply with the minimum requirements of the code..

5.2.1.1.1 Live loads shall be modified as needed due to additional requirements.

5.2.1.2. Wind Loads

5.2.1.2.1 Basic Wind Velocity: Determined in accordance with Section 6 of ASCE 7.

5.2.1.2.2 Exposure Category: C

5.2.1.3. Wind Loads Airside Face - Wind load for Terminal buildings at the airside face only shall be 50 psf applied to any 15 square foot area for components and cladding, per FAA AC 150/5300-13, Chapter 8, "The Effects and Treatment of Jet Blast. This load need not apply at inset penthouse structures forty (40) feet above the apron level. This load is a result of aircraft jet blast plus meteorological conditions.

5.2.1.4 Roof Loads -Live loads for roof levels where additional future floors will or may be constructed shall be 100 psf minimum or the code required load for the proposed future occupancy whichever is greater.

5.2.2 Materials and Unit Stresses

5.2.2.1 Concrete - Non-prestressed concrete for structural elements shall be designed for a minimum twenty-eight (28) day compressive strength (fc') of 4000 psi, or as dictated by design requirements. All concrete exposed to the elements shall be designed with 3% to 6% entrained air. Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near-freezing weather.

5.2.2.1.1 Prestressed concrete for structural elements shall be designed for a minimum twenty-eight (28) day compressive strength (fc') of 5000 psi.

5.2.2.1.2 Concrete subject to freezing temperatures while wet shall have 3.5 percent to 6.5 percent air entrainment at point-of-placement, unless noted otherwise. Admixtures shall be used with care and compatibility shall be verified by testing laboratories.

5.2.2.2 Structural Steel - Structural steel shall conform to the following:

1. W, WT Shapes: ASTM A 572, Grade 50, ASTM A 992.
2. S, M, HP, and Channels: ASTM A 36, A 572 Grade 50.
3. Angles and Plates: ASTM A 36, A 572 Grade 50.
4. Pipes: ASTM A 53, Grade B.
5. Tubes: ASTM A500. Grade B.
6. Erection Bolts: ASTM A 325.
7. High Strength Bolts: ASTM A 325
8. Anchor Bolts and Rods: ASTM A 36, A 307, A 193, F 1554.
9. High Strength Low Alloy (HSLA) Steel: ASTM A 588 steel will be allowed with prior approval for high-mast light poles and base plates. HSLA steel shall not be used in areas of high moisture or water unless a proper surface treatment is utilized. Concrete pier pedestals for high-mast light poles shall be at least thirty six (36) inches above finish grade.

5.2.2.3 Prestressing Tendons - Tensile stress in prestressing tendons due to jacking force shall not exceed 0.94 f_{py} (specified yield strength of prestressed tendons), psi. Prestressed members shall be designed using 7-wire strand having an ultimate tensile strength of 270,000 psi and conforming to ASTM A-416.

5.2.2.3.1 Low relaxation strands may be considered in design if they meet ASTM A421, ASTM A416, and ACI Building Code 3.5.5 and Commentary.

5.2.2.4 Reinforcing Steel - All reinforcing steel shall comply with ASTM A615 Grade 60 and shall be shop fabricated when delivered to the site.

5.2.2.4.1 Clear concrete cover on reinforcing shall be as follows, unless otherwise shown:

Concrete cast against and permanently exposed to earth	3 inches
Concrete exposed to earth or weather:	
#6 through #18 bars	2 inches
#5 bar, W31 or D31 wire, and smaller	1-1/2 inches
Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists:	
#14 and #18 bars	1-1/2 inches
#11 bar and smaller	3/4 inches
Beams, columns: Primary reinforcement, ties, Stirrups, spirals	1-1/2 inches
Shells, folded plate members:	
#6 bar and larger	3/4 inches
#5 bar, W31 or D31 wire, and smaller	1/2 inch
Beams and girders	1-1/2 inch interior, 2" exterior

5.2.3 Structural Foundation Systems

5.2.3.1 Foundations - Allowable foundation capacities shall be determined from geotechnical investigations under the direction of a professional geotechnical engineer registered in the State of Texas.

5.2.3.1.1 Foundations shall be designed to prevent uplift and differential settlement, as well as load bearing requirements.

5.2.3.1.2 Minimum ground cover over footings shall be 12".

5.2.3.1.3 The subgrade for all buildings shall be pressure injected with lime slurry or Cement Treated Base (CTB). The lime slurry shall be pressure injected at least three (3) feet beyond the building line. The requirements for injection grid density, depth of injection, additional injections, curing times, and stabilization or pH results shall be based upon geotechnical recommendations.

5.2.3.2. Horizontal Framing Systems - Floor systems at Terminal buildings shall be designed to eliminate excessive vibrations from pedestrian and people-mover cart traffic. The design shall fall within the slightly perceptible range or better of the foot fall vibration scale.

5.2.3.2.1 Framing systems shall be designed considering requirements for future floor openings. Future beam and column connections shall not be drilled expansion bolts, but embedments with adequate shear and tensile capacities. Existing beams, columns, walls and slabs shall not be connected with explosive or dry powder inserts.

5.2.3.3 Precast Double-Tees:

5.2.3.3.1 No bottom connections into legs.

5.2.3.3.2 Side penetrations into legs shall utilize pre-drilled holes where possible.

5.2.3.3.3 No powder actuated inserts into legs or decks.

5.2.3.3.4 Existing double-tee roof and floor systems shall be evaluated for loads, penetrations, or attachments by a registered structural engineer, licensed to practice in the state of Texas.

5.2.4 Detailing - Detailing for structural steel shall comply with the latest edition of AISC "Detailing for Steel Construction".

5.2.4.1 Connections - Steel moment connections shall be designed using the Allowable Stress Design (ASD) Specification or the Load and Resistance Factor Design (LRFD) Specification for Structural Steel Buildings.

5.2.4.1.1 Concrete embedments shall have sufficient anchorage ties to prevent cracking or rapid failure. Corrosion resisting finishes shall be used on all structural embedments.

5.2.4.1.2 All connections, whether designed by the consulting engineer, the suppliers, or structural detailers, shall be designed and sealed by a professional structural engineer registered in the State of Texas.

5.2.4.2 Openings - Openings in structural slabs shall be detailed such that spalling of concrete edges shall be prevented. Diagonal reinforcement shall be provided at corners, re-entrant slabs and floor penetrations.

5.2.4.3 Expansion Devices and Materials -In addition to ACI 318, the designer should refer to ACI 504.R for various joint treatments and to ACI 224.R and ACI 224.1R for crack controls.

5.3 Parking Structures - All criteria specified in Section 5.2 - Building Structures shall also apply to parking structures except as amended in the following.

5.3.1 Material Selection - Structural steel shall not be considered for the vertical and horizontal framing system unless approved by the HAS Project Manager.

5.3.2 Steel - All exposed miscellaneous steel used for concrete supports and connections shall be galvanized and retouched after installation.

5.3.3 Corrosion Protection -Calcium chloride and admixtures containing chlorides should not be used in concrete for parking structures. Admixtures shall be used with care and compatibility shall be verified by testing laboratories.

5.3.3.1 Protection of embedded metals including concrete cover over reinforcement, post-tensioning tendons, pretensioned connections for precast systems, dissimilar metals, and embedded metal conduit should meet or exceed the minimum ACI 318 requirements.

5.3.3.2 ACI 362.1R, ˜Guide to the Design of Durable Parking Structures should be consulted for pertinent information concerning corrosion inhibitors, cathodic protection and protection of concrete. The guidelines for applied sealers or membrane treatments shall be followed.

5.3.4 Expansion Devices and Materials -Expansion joint seals and isolation joints shall be designed to prevent the following defects or failures:

5.3.4.1 Migration, bleeding into or staining abutting materials.

5.3.4.2 Deformation sufficient to become unsightly or cause leakage.

5.3.4.3 Chalking, picking up dust or excessive color change.

5.3.4.4 Adhesive or cohesive failures.

5.3.4.5 In addition to ACI 318, the designer should refer to ACI 504.R for various joint treatments and to ACI 224.R and ACI 224.1R for crack controls.

5.3.5 Elastomeric Bearings -Bearings shall be designed as a plain pad with a seventy (70) durometer elastomer or laminated pads with a sixty (60) durometer elastomer.

5.3.6 Parapet Systems - Systems which are integral or monolithic with supporting structural systems shall be designed such that damage to the parapet will not adversely affect the supporting system. The use of isolation joints and membrane protection is important at roof connections.

5.3.7 Drainage Systems - Systems shall be designed and located such that structural elements (i.e., reinforcing steel, tendons, beam flanges, lighting column base plates, etc.) shall take precedence. Use the least number of bends for unimpeded flow. Clean outs shall be placed at every 100-feet.

5.4 Aircraft Bridge Structures - This section shall apply to all bridges, tunnels, culverts, vaults and all other structures supporting aircraft or under runways, taxiways or aprons. Such structures shall conform to the minimum requirements set forth in this Manual and FAA AC 150/5300-13 (latest edition). Unless specifically approved by the City Engineer all aircraft rated bridges shall be structural steel.

5.4.1 Airplane Design Group - Structures at IAH shall be designed and proportioned to accommodate Airplane Design Group VI as defined in FAA AC 150/5300-13. Structures at HOU shall be designed and proportioned to accommodate Airplane Design Group III. Structures at EFD will be designed and proportioned to accommodate the Design Critical Aircraft.

5.4.1.1 Each element of the structure shall be designed to accommodate the most demanding airplane under this design group. This may result in more than one airplane being used in designing a particular structure (i.e., bridge width may be controlled by the airplane with the longest wing span, whereas another airplane may have higher wheel loads, thus controlling beam design).

5.4.2 Live Loads - Structures shall be designed for the following airplane loads:

5.4.2.1 Spans less than two (2) feet in the shortest direction, including manholes lids and grates - uniform live load of 250 psi.

5.4.2.2 Span lengths two (2) to ten (10) feet in the shortest direction - the greater of a uniform live load varying between 250 psi and 50 psi in inverse proportion to the span length or the maximum number of wheel loads for the airplane which can be applied to the structure.

5.4.2.3 Span lengths greater than ten (10) feet in the shortest direction - wheel loads for the design airplane.

5.4.3 Impact - For those elements listed in Group A (defined below), the live load shall be increased by the following percentages. This increase will account for impact loads and vibration:

30 percent - Parking aprons and low speed taxiways.
40 percent - High speed taxiways and runways.
100 percent - Touchdown areas of runways.

5.4.3.1 Live loads shall not be increased by impact for those items in Group B (defined below):

GROUP A

1. Superstructure, columns and pedestals which support the superstructure with rigid, fixed or expansion bearings, or which are rigidly attached to the superstructure, and legs of rigid frames.
2. The portions above the ground line of piers that are rigidly connected to the superstructure as in rigid frame or continuous structures.

GROUP B

1. Abutments, retaining walls, piers, pile caps and pilings which are not rigidly connected to the superstructure.
2. Buried foundations, footings and supporting soil, and structures with three (3) feet or more of earth cover.

5.4.3.2 Impact for structures covered with fill shall vary from the percentage shown at ground level to zero (0) percent at a depth of ten (10) feet.

5.4.4 Braking Force - Longitudinal forces due to braking shall be included in the design of all structures subject to direct wheel loads. This braking force shall be the following percentages of live load without impact:

30 percent - Parking aprons and low speed taxiways.
70 percent - High speed taxiways and runways.

5.4.5 Clearances - Vertical clearances for aircraft bridges over roadways and horizontal clearances to piers from these roadways shall be the same as those described in Section 2.4.6 - Obstruction Clearances.

5.4.6 Materials - Construction material specifications, strengths, handling, storage and testing shall comply with the latest version of the American Association of State Highway and Transportation Officials (AASHTO) "Standard Specifications for Highway Bridges".

5.4.7 Design Load Combinations - In addition to live and dead loads, the following loadings shall be taken into account: earth pressure, buoyancy, wind (including jet blast and uplift), shrinkage, temperature, longitudinal force, stream flow, construction loads and any special loads. Loads shall be applied in such a manner as to produce the maximum stresses.

5.4.7.1 Loading combinations shall be the same as those described in latest version of the AASHTO's "Standard Specifications for Highway Bridges," and interim specifications.

5.5 Highway Bridges - This provision shall apply to structures with spans greater than twenty (20) feet and whose function is to carry roadway traffic. This section does not apply to parking structures or ramp systems within them.

5.5.1 Specifications - Highway bridges shall be designed in accordance with AASHTO's "Standard Specifications for Highway Bridges," with interim specifications.

5.5.2 Live Loads - All bridges on arterial roads shall be designed for an HS20-44 live load plus impact.

5.5.2.1 Bridges along secondary roads shall be designed for an HS20-44 live load plus impact unless waived by the City Engineer, in which case the design live load shall be HS15-44 plus impact.

5.5.3 Bridge Widths - Generally, bridge width from face of rail to face of rail shall be at least as wide as the approach roadway's usable shoulder.

5.5.4 Clearances - For horizontal and vertical clearance requirements, see Section 2.4.6 - Obstruction Clearances.

5.5.5 Materials - This section shall govern materials used in the construction of highway bridges and incidental items relating to these structures.

5.5.5.1 Concrete - Concrete materials, quality, classes of, and proportioning shall comply with the applicable sections of the Texas Department of Transportation (TxDOT) "Standard Specifications for Construction of Highways, Streets, and Bridges". At the discretion of the City Engineer, Construction Specifications may be taken from "Standard Construction Specifications for Wastewater Collection Systems, Water Lines, Storm Drainage, Street Paving, and Traffic", latest edition, published by the City of Houston Department of Public Works and Engineering, except as modified herein. No variance from these specifications or the modifications herein may be made without the approval of the City Engineer for the Houston Airport System (referred to throughout as the City Engineer).

5.5.5.2 Structural Steel - Structural steel, forgings, castings, anchor bolts, pipe, tubing, bolting of and welding of shall comply with the applicable sections of the TxDOT "Standard Specifications for Construction of Highways, Streets, and Bridges".

5.5.5.3 Reinforcing Steel - Reinforcing steel material and bending shall comply with the applicable sections of the TxDOT "Standard Specifications for Construction of Highways, Streets and Bridges".

5.5.5.4 Prestressing Steel - Prestressing steel, packing, storing, handling, working drawings and construction methods shall comply with the applicable sections of the TxDOT "Standard Specifications for Construction of Highways, Streets, and Bridges".

5.6 Pedestrian Bridges - Pedestrian bridge length, width, height and construction materials shall comply with the Building Code.

5.6.1 Materials - Construction material specifications, strengths, handling, storage and testing shall comply with the TxDOT "Standard Specifications for Construction of Highways, Streets and Bridges".

5.6.2 Design Loads and Loading Combinations - The minimum live load shall be 100 psf. Where equipment and small vehicles are anticipated to use this structure, live loads shall be increased accordingly.

5.6.2.1 In addition to live and dead loads, the following loadings shall be taken into account: earth pressure, buoyancy, wind (including jet blast and uplift), shrinkage, temperature, stream flow, construction loads and any special loads. Loads shall be applied in such a manner as to produce the maximum stresses.

5.6.2.2 Loading combinations shall be the same as those described in AASHTO's "Standard Specifications for Highway Bridges", and interim specifications.

5.6.3 Clearances - Vertical clearances over roadways shall be one (1) foot greater than outlined in Section 2.5.6 - Obstruction Clearances.

5.7 Retaining Walls - Retaining wall design and materials shall comply with the applicable sections of the Building Code and the geotechnical investigation report for that project.

5.7.1 The effect of wall movement due to expansive soils shall be taken into account and, when necessary, appropriate design steps shall be taken to minimize them.

5.7.2 The factor of safety for overturning shall be 1.5 minimum and 2.0 maximum. The factor of safety for sliding and circular soil arc failure shall be a minimum of 1.5. Expansion joints shall be provided every ninety (90) feet maximum and contraction joints every thirty (30) feet maximum.

5.8 Tunnels - Tunnels shall include all below grade, enclosed structures used by pedestrians, vehicles or to hold utilities.

5.8.1 Due to the varied applications of tunnels, the design criteria shall be established on a project to project basis.

5.8.2 Items of particular interest which should be addressed are: waterproofing, ventilation, lighting and utilities, drainage, exiting, fire protection, cathodic protection/corrosion control and overburden loading.

5.9 Crosswalks - All crosswalks installed in terminal curbsides, either arrival or departure, where passengers must cross lanes that have moving traffic shall be equipped with in-pavement lights attached to a sensor so that the lights operate when a pedestrian is in the crosswalk.

END OF SECTION 5

6.0 WOOD AND PLASTICS

NOT CURRENTLY USED

END OF SECTION 6

7.1 THERMAL AND MOISTURE PROTECTION

7.2 Roof Systems General: Many different types of roofing systems have been utilized at the HAS airports. The acceptable choice and application of a particular roofing system will depend on the type, use, location and configuration of the building. Roof systems meeting the minimum criteria outlined below may be specified on new construction or as roof replacement on existing buildings. Acceptable roof systems for consideration include, but are not limited to, on low-slopes (up to 1-1/2 in. per foot): ASTM D6754-02 Standard Specification for Ketone Ethylene Ester (KEE) 4. 45 mils (1.1 mm), nominal, exposed face color: White, base sheet roofing.

Polyisocyanurate Board Insulation: ASTM C 1289, Type II, Class 1, Grade 2, felt or glass-fiber mat facer on both major surfaces, tapered insulation: Provide factory-tapered insulation boards fabricated to slope of 1/4 inch per 12 inches (1:48) unless otherwise indicated. provide preformed saddles, crickets, tapered edge strips, and other insulation shapes where required. Provide flexible walkways: factory-formed, nonporous, heavy-duty, slip-resisting, surface-textured walkway pads, approximately 3/16 inch (5 mm) thick, and acceptable to membrane roofing system manufacturer.

Standing seam metal roof systems may be selected with prior approval from the HAS Project Manager. Gravel or rock ballasted roofs of any kind are not acceptable. Key considerations in the selection, design and specification of roofing systems follow:

7.2.1 Roofing Assembly - The roofing assembly and its components must be capable of withstanding and accommodating all of the service conditions to which they will be exposed, including rain, snow, hail, ice, wind, sun, thermal shock, service traffic and applied loads. The roof system components must provide optimum thermal resistance to heat gain or loss within the building, consistent with good roofing practices.

7.2.2 Drainage: Ponding is defined as standing water on roofs for more than 24 hours and is the frequent source of leaks and the cause of premature failure of roof systems. Roof system manufacturers recognize the seriousness of this common problem and generally exclude leaks or failure caused by ponding water from their warranties. Ponding water is not acceptable.

7.2.3 Minimum Standards and Recommendations Included by Reference: Roof system selection, design, detailing and specification shall, at a minimum, be a system consistent with the types specified herein and comply with the requirements and recommendations of the following standards:

7.2.3.1 National Roofing Contractors Association (NRCA), Roofing and Waterproofing Manual, 4th Edition or current version

7.2.3.2 Architectural Sheet Metal Manual, Fifth Edition, Sheet Metal and Air Conditioning Contractors National Association (SMACNA) or current version.

7.2.4 New Construction or Roof Replacement on Existing Buildings: Criteria outlined below are common for both new construction and for roof replacement.

7.2.4.1 Roofs adjacent to aircraft ramps (i.e. terminals, cargo and hangar structures, electrical vaults etc.) shall be smooth surfaced, coated, or paver ballasted. Gravel and rock ballast surfaces are not permitted, since high winds may displace rock material onto operational surfaces, causing damage to aircraft and aircraft engines.

7.2.4.2 Roof attachment shall equal or exceed ASCE 7 requirements for the Houston area. Acceptable uplift rating for high exposed roofs or roofs subject to jet blast must be calculated from FM Loss Prevention Data Sheets.

7.2.4.3 Roof materials and assemblies shall be listed by Underwriters Laboratories as a Class A

7.2.4.4 Wind Speeds and Uplift: Refer to local City of Houston Building Codes for latest requirements in this Hurricane Zone. roofing material or roof assembly.

7.1.4.4 Provide insulation thickness to achieve thermal resistance of R-19 minimum, but in no case less than that required by the Energy Code.

7.1.4.5 Where different roof types join together, provide proper seams, parapets, area dividers, or expansion joints.

7.1.4.6 Provide roof traffic protection at all parapets, around equipment and at all areas subject to frequent wear.

7.1.4.7 Minimum flashing heights shall be 8 inches above roof surface to the extent possible by existing design conditions, but in no case shall flashing height be less than required by the roof system manufacturer for the applicable warranty. For ballasted roofs, "roof surface" is defined as the surface of the paver area.

7.1.4.7.1 Internal gutters are not allowed.

7.1.4.7.2 Warrantees and Guaranties for Board Maintained Roofs:

a. Require Roof Manufacturer's "Total System, No Dollar Limit (NDL)" warranty for maximum time limit available (15 -30 year, depending on roof system). Warranty shall cover wind speeds up as required by current codes. Roofing contractor shall provide two (2) year guarantee against leaks and defects in workmanship.

b. Roof related sheet metal, copings, edge strips and metal edges: Contractor shall provide 5-year guarantee against leaks and defects in materials and workmanship. Sheet metal exposed to public view shall have a factory-applied finish with a 20-year warranty covering fading, discoloration, peeling or other defects.

7.1.4.7.3 Preference is given to "Energy Star" roofing materials "White" in color, solar radiation reflective. Reflective roof system finishes must comply with FAA guidelines.

7.1.5 New Construction: The following criteria are minimum requirements that must be met by new building construction.

7.1.5.1 All criteria outlined in above.

7.1.5.2 Slope: Provide a minimum ¼ inch per foot slope designed and built into the structure of the facility whenever possible. If it is not possible, the ¼ inch slope must be achieved using crickets, saddles, or a fully tapered insulation system.

7.1.5.3 Drains:

a. Size and Quantity: As required by the Plumbing Code.

b. Locate drains a minimum of 36 inches from equipment and perimeters to allow proper sump and flashing details.

c. Provide crickets and saddles between drains with resultant ¼ in per foot slope to direct all water flow to the drain.

d. Provide 36 inch by 36-inch minimum sump around each drain.

e. Overflow drain systems must comply with the Plumbing and Building Codes.

7.1.5.4 Deck Types: Structural decks may be constructed of metal, or concrete. Deflection of the tstructural deck must be considered and should be limited to 1/240 of the span.

7.1.5.5 Metal Penetration Dams (Pitch Pans): Do not install metal penetration dams without prior approval of the HAS Project Manager. If a metal penetration dam must be used, a properly detailed and installed metal umbrella counter flashing cover is required.

7.1.5.6 Roof penetrations: Locate roof penetrations to allow for proper flashing installation.

7.1.6 Roof Replacement: The following criteria apply to roof replacement when the above criteria cannot be implemented.

7.1.6.1 Deck Conditions: Existing condition and type of deck (to the extent determinable by limited investigation), slope, and allowable superimposed load (if available from Airport archives) must be documented prior to roof system selection. Document ponding or other problem areas.

7.1.6.2 Drainage: In some cases, existing slope in the roof deck is less than ¼ in. per foot, and achieving ¼ in. per foot with tapered insulation is not possible without raising parapet heights to maintain 8 inch flashing height above the roof surface. These conditions must be addressed on a case-by-case basis to determine if the HAS Project Manager will permit raising parapets. Building maintenance projects (including roof replacement with like kind roofing) do not require increasing slope to ¼ in. per foot if the existing roof slope complies with the Building Code in force when the building was constructed and is a currently permissible roof system type.

7.1.6.3 Overflow Drains: Building maintenance projects (including roof replacement projects with like kind roofing) do not require upgrading the overflow drain system to meet current code if the drain system complies with the Building and Plumbing Codes in force when the building was constructed, and the overflow drainage system is not changed by the new roofing. However, new scuppers or internal overflow drainage should be added when deemed feasible.

7.1.6.4 Roof mounted equipment:

7.1.6.4.1 Accurately locate, size and measure existing flashing height above roof surface as defined above.

7.1.6.4.2 As designated by the HAS Project Manager, all obsolete equipment shall be removed, and penetrations through the deck shall be properly patched. Penetrations less than or equal to 6 inches in least dimension shall be covered with 10 gauge galvanized sheet metal extending 6 inches beyond the opening in each direction. Fasten to deck with approved fasteners 6 inches on center, minimum 2 per side. Penetrations larger than 6 inches shall be capped with a prefabricated metal curb covered by an approved deck material, insulation in the required thickness to achieve a thermal resistance of R-19, EPDM membrane and 24 gauge galvanized metal cap, sloped to drain.

7.1.6.4.3 All equipment with flashing height of less than 8 inches above the new roof surface shall be raised to a flashing height of 8 inches minimum.

7.1.6.4.4 Limit shutdown of roof mounted equipment to hours specified by the HAS Project Manager.

7.1.6.4.5 Metal counter flashing covering the top flashing edge by 2 inches minimum must protect all curb-mounted equipment flashing.

7.1.6.4.6 Walkway pads or concrete pavers shall be placed around all roof-mounted equipment requiring periodic service.

7.1.6.4.7 Antennas mounted on the roof shall be mounted on bases designed for this purpose. Antennas attached to piping or other equipment shall be removed.

7.1.6.5 Roof Penetrations:

7.1.6.5.1 All pipe and conduit penetrations shall be through covered metal pipe enclosures similar to SMACNA Figure 4-14A. Metal penetration dams (pitch pans) will be permitted only with the approval of the HAS Project Manager and must have metal umbrella counter flashing covers.

7.1.6.5.2 Lightning protection down leads shall be flashed with PVC pipe enclosures and capped with PVC domed caps.

END OF SECTION 7

8.1 DOORS AND WINDOWS

8.2 Entries - HAS encourages automatic sliding doors at two-way traffic areas where the public is carrying baggage or boxes. Automatic swinging doors are acceptable in one-way traffic areas only. Turnstiles should not be used except where required for security purposes. HAS has a preference for Stanley products.

Entries and openings into the building (i.e., baggage carriers, service openings, etc.) should be sealed by the use of vestibules, curtains, or other means to be reviewed by the HAS Project Manager. Conditioned air loss is a severe problem and needs to be addressed during design. If hanging curtains are utilized, a double row is suggested with a minimum five (5) foot separation.

8.3 Door Locks – Door locks for all HAS owned buildings shall have Best Lock Products cores. Coordinate hardware schedule with HAS Project Manager.

END OF SECTION 8

9.1 FINISHES

9.2 Building Finishes - Guidelines for building finishes are specified elsewhere. Refer to Chapter 1 for other references containing additional design criteria.

9.3 Finish and Concealment of Exterior Mechanical Equipment - All visible equipment, whether roof or ground mounted, must be painted alike and screened from view wherever possible. Color for such equipment, including roll-up doors, mechanical equipment, metal canopies, piping, electrical equipment, etc., and any other equipment of specialized function, shall match. Specially designed screens, suitable plant materials, and architectural enclosures can be used for screening purposes depending on the facility and location. Roof mounted equipment must be concealed behind parapet walls or in a screened enclosure of approved materials. Equipment should be grouped in clusters, preferably a single cluster to minimize the number of visible screens.

9.4 Floors in kitchens, food preparation and storage areas, counter, restrooms, and beverage service areas (wet areas) - shall be installed over a membrane waterproofing system that will result in a fully waterproofed surface, sealed at the drains, including a 6" high cove base backed with the membrane waterproofing. The flooring shall be an epoxy non-slip coating system that can be applied over concrete substrate, existing tile, etc.

END OF SECTION 9

10.0 SPECIALTIES

10.1 Design Guidelines for Public Restrooms in Airport Terminal Buildings

10.1.1 Location

10.1.1.1 Restroom facilities should be evenly and conveniently distributed throughout the main public areas. A maximum walking distance of 150 feet to a restroom should be used as a guideline; therefore restrooms should be approx. 300 feet apart in linear areas.

10.1.1.2 Each location should include; men, women, and family toilet rooms. These three rooms should always be grouped together; the entries should be adjacent to each other so that they are visible to the passengers. The family toilet room should be signed with the men's, women's, accessibility symbols and labeled "toilet".

10.1.1.3 Entries should be designed to prevent line-of-sight from the public areas.

10.1.1.4 Entries to the men's and women's rooms should not have doors, but switch-back or "T" access halls, that are wide enough for two people to pass. The "T" access is preferred for rooms with larger number of fixtures due to the improved circulation. Switch-back is acceptable for rooms with smaller number of fixtures.

10.1.1.5 Circulation in rooms with larger number of fixtures should be arranged in a loop to avoid dead-end conditions.

10.1.2 Fixtures

10.1.2.1 The fixture counts within each room should be calculated based on the function and occupancy of the area/function the restroom supports.

10.1.2.2 The family toilet room will always contain one lavatory counter, one toilet, a diaper changing station and a bench/shelf for nursing mothers or an attendant to wait (this will also satisfy the baggage shelf requirement).

10.1.2.3 Toilets and urinals shall have automatic flush with manual flush button using external futures. Valves shall be Toto self energizing flush valves TETIGNG-32 or similar Toto product.

10.1.2.4 Lavatory faucets shall be automatic with pre-set warm water.

10.1.2.5 Sinks shall be large oval or round porcelain or stainless steel under counter bowls without stoppers.

10.1.2.6 Sinks should be spaced a minimum of 42" on center to allow adequate counter surface.

10.1.2.7 Toilets shall have elongated bowl and non-contouring seat.

10.1.2.8 For urinals, provide extended bowl wall-mounted units.

10.1.3 Accessories:

10.1.3.1 Counter tops shall be solid surface material or granite with backsplash on all walls. Backsplash shall be a minimum of 4" high.

10.1.3.2 Locate center pull paper towel dispensers (similar to Bay West model #680) on the mirror wall above the trash holes with clear visibility. Provide another sidewall unit if this location are not ADA compliance.

10.1.3.3 Provide stainless steel accessories: jumbo tissue dispenser (similar to Bay West model #887), toilet seat protectors, and feminine product receptacles.

10.1.3.4 A 6" diameter trash hole should be located in the countertop between the sinks, with a trash receptacle located in a lockable under-counter cabinet.

10.1.3.5 A semi-recessed wall trash receptacle shall be located at the exits.

10.1.3.6 Provide large wall mirrors in front of lavatories.

10.1.3.7 Provide hooks adjacent to lavatory for hanging bags, purses, and briefcases. Provide a 12" deep purse shelf at back of counter and/or on sidewalls.

10.1.3.8 Provide easily operated access panels to conceal pipes and water shut off values under each sink. If locks are installed they shall be STANLEY/BEST products.

10.1.3.9 Provide a full-height dressing mirror out of the main circulation path.

10.1.3.10 Provide liquid soap pump (that fill from the top) at each sink so that the spout drips into the sink.

10.1.3.11 Provide one GFI duplex receptacle at the least trafficked end of the counter.

10.1.4 Toilet Partitions:

10.1.4.1 Partitions should be stainless steel or solid surface material. Doors are to have solid cores, normally marine plywood. No honeycomb or paper inserts are to be used.

10.1.4.2 Partitions should be ceiling hung with extension to the floor every third compartment and at the end corner to stabilize the panels.

10.1.4.3 Partition shall be 12" above floor and extend up to 78" for privacy.

10.1.4.4 Latches should be easy sliding bars (ADA compliance).

10.1.4.5 Standard cubicle shall have minimum clear dimensions of 38" wide and 66" deep, to provide enough room in front of the toilet to maneuver the door and carry-on luggage.

10.1.4.6 Purse/coat hook on partition side panel behind door swing 60" above floor level.

10.1.4.7 Provide a 12" deep baggage wall shelf behind toilets and urinal bank.

10.1.4.8 Stainless steel grab bars in accessible stalls.

10.1.4.9 Provide privacy partitions between each urinal.

10.1.5 Floor Material:

10.1.5.1 Flooring shall be ceramic, porcelain tile rated for heavy duty use or terrazzo. Natural stone is semi-porous, therefore should not be used on floors. Terrazzo is the preferred flooring for all restroom floors.

10.1.5.2 Porcelain or ceramic tiles with rectified edges should be large; 12" x 12" minimum to reduce grout lines. Accent tiles may be smaller.

10.1.5.3 Joints should be tight; 1/4" maximum. Grout shall be medium gray non-sanded grout.

10.1.5.4 Square edge tile should be used to minimize joint expression. Rustic or heavy cushioned edges should not be used.

10.1.5.5 Very light or dark tones do not look clean therefore should not be used.

10.1.5.6 Tile with multiple colors, veining, mottling or specks appear cleaner than solid tiles. Solids should not be used.

10.1.5.7 Tile with textured glossy finish should be used in lieu of flat matt.

10.1.5.8 Base should be same as floor.

10.1.5.9 Colors of tile or terrazzo and floor pattern should be carefully selected to reduce spotting and support a clean appearance.

10.1.5.10 Flooring shall be installed over a membrane waterproofing system that will result in a fully waterproofed surface, sealed at the drains, including a 6" high cove base backed with the membrane waterproofing.

10.1.6 Other Materials:

10.1.6.1 Walls shall be non-porous materials (ceramic tile, solid surface, plastic laminate panels, hard stone, etc.) from floor to 84" minimum. Above 84": paint or appropriate wall coverings are acceptable. If grout is used it must be non-sanded regardless of color.

10.1.6.2 Color, patterns, finish of wall tile should maximize a clean-looking, well-lighted appearance. Use glossy/polished wall tile that appear cleaner than matt finish.

10.1.6.3 The entries from the terminal should reinforce wayfinding by expressing a "restroom" cue. Materials should be coordinated with the terminal finishes and may not be the same as the restroom materials.

10.1.6.4 Inside the "T" access corridor shall be a transition area between the terminal and the toilet room. These transition walls can be acoustical wall treatments or other durable materials that can tolerate rolling bags and provide acoustical treatment.

10.1.6.5 Somewhere in the transition area (at eye level) the finishes should reinforce the overhead signage package to confirm a passenger is headed into the correct room.

10.1.6.6 All restrooms shall be finished with the same materials, colors, patterns. If a distinction

between men and women is provided it should be in the transition area.

10.1.6.7 Ceilings must be accessible. Gyp. Board features with appropriate regular edge 2x2 acoustical lay-in.

10.1.6.8 Encourage a "trim" or molding feature above 84" (crown molding, wall molding element)

10.1.7 Lighting:

10.1.7.1 Rooms should be well lighted, especially at the lavatories.

10.1.7.2 Provide a wall sconce fixture on lavatory mirror wall for lighting of faces. Provide warm white lamp that is readily available from multiple sources. No special order lamps should ever be used.

10.1.7.3 Use energy efficient fluorescent or LED lamps in concealed lighting coves, down lights and accent fixtures.

10.1.7.4 The light level should be even throughout the room to reinforce the clean/airy appearance.

10.1.8 Other amenities:

10.1.8.1 Provide a built-in diaper changing station, 42" long x 24" deep in every men, women, and family room. Install in a remote, recessed but visible location (near a sink would be ideal).

Provide a trash receptacle with lid and a paper towel dispenser at this location. Surface material should be same as lavatory counter. Provide a raised lip (approx. 2" high) at the open edge as a stop.

10.1.8.2 Provide a "Kid Care Kit" dispenser and Diaper dispenser (with 2 sizes) in the family toilet room only.

10.1.8.3 Provide feminine napkin and tampon vending units in women and family toilet rooms along with a small trash receptacle in each woman's stall.

10.1.8.4 Provide a floor drain(s) for maintenance of spills in the toilet areas with appropriate slope to drain. Provide music system speakers in the toilets.

10.1.8.5 Recommended air changes in all restroom shall be consistent with the requirements of the Uniform Mechanical Code Book, latest edition.

10.1.8.6 Locate electric water coolers in conjunction with restrooms.

10.1.8.7 Provide fragrance dispensers.

10.1.8.8 Comply with accessibility standards in the Building Code.

END OF SECTION 10

11.1 CORROSION CONTROL

11.2 General - These criteria shall be utilized in the design of corrosion control systems for new installations and/or maintenance and repairs to existing cathodic protection installations.

11.2.1 The design of new or refurbishment of existing cathodic protection systems shall be performed or supervised by a Corrosion Engineer. Corrosion Engineer refers to a person, who, by reason of knowledge of the physical sciences and the principles of engineering and mathematics, acquired by professional education and related practical experience, is qualified to engage in the practice of corrosion control. Such people may be a licensed professional engineer or may be a person certified as qualified by NACE International, hereinafter referred to as NACE, if such licensing or certification includes suitable experience in corrosion control on buried or submerged metallic piping systems and metallic tanks.

11.2.2 These criteria are not intended to restrict creative engineering design. Should alternative materials or design concepts be deemed advantageous, they shall be presented the City Engineer for review and comment prior to approval. Due to the results of testing designed to determine the corrosion potential of soils at IAH and HOU it is strongly recommended that Designers have soil along the route of any major pipe runs, or in the area of any underground installations tested to determine corrosiveness, Sulfate Ion concentration, pH, and the concentration of Chloride Ions. Previous tests have shown highly to extremely corrosive soils at HOU and corrosive to extremely corrosive soils at IAH. While testing to date indicates negligible levels of Sulfate Ion concentration it should be confirmed. Testing at IAH indicated very low pH values (approximately 4.5) indicating very acidic soil conditions, and testing at both airports showed high concentrations of Chloride Ions. These factors need to be considered in the design and material selection process.

11.3 Corrosion Control of Process System Equipment and Piping

11.3.1 Material Selection - All equipment and piping in the following systems shall incorporate appropriate corrosion control methods:

Boiler Feed Water	Waste Water Steam and
Condensate	Condenser Water Potable
Water	Fire Protection Water
Chilled Water	Gas and Compressed Air
Hot Water	Fuel Oil

In the above services, copper base or aluminum alloys must not be attached to ferrous materials, or to each other.

Where the interconnection of different metals is necessary, they shall be electrically isolated using approved dielectric materials, or the cathodic metal shall be required internally coated where isolation is not practical.

Material selection shall be reviewed by a Corrosion Engineer to insure that acceptable durability shall be achieved.

11.3.2 Corrosion Inhibitors and Additives - Process systems such as boiler feedwater, condensate, condenser water and chilled/hot water require the addition of chemical additives that help to reduce internal iron pipe or tank corrosion. Provisions shall be made for conveniently and safely injecting these inhibitors and additives in these systems for maintaining the required protective residuals. Provisions shall also be made for sampling these processes for testing of residual levels. All corrosion inhibitors or additives shall be specified by or approved by a Corrosion Engineer. These systems shall not discharge to the storm sewer system.

11.3.3 Access for Inspection - All equipment that may be subject to corrosion, or may require periodic maintenance, shall have reasonable access for inspection.

Boilers shall be equipped with firebox doors and access openings to superheat and preheat sections. Flue gas ductwork shall be provided with reasonable access openings.

Heat exchangers, coolers, condensers and evaporators shall be equipped with at least one (1) removable head from where the tube sheets and tube ends may be inspected.

Corrosion inhibitors are not completely effective in preventing dissimilar metals (galvanic) corrosion. Water boxes shall be provided with protective coatings and cathodic protection whenever dissimilar materials of construction shall be used in direct aqueous contact.

Cooling towers shall be provided with sufficient access and ladders so that the basin, trays, mist section and fans can be inspected and maintained.

11.4 Miscellaneous

11.4.1 Electrical Grounding Systems and DC Powered Equipment –

1 Buried electrical ground rods shall be stainless steel 3/4-inch diameter, ten feet long. Grounding Pressure Connectors shall be copper alloy castings, designed specifically for the items to be connected, and assembled with Durium or silicone bronze bolts, nuts and washers. Welded connections shall be by exothermic process utilizing molds, cartridges and hardware designed specifically for the connection to be made. In areas with poor conductivity, a low- resistance non-corrosive, and carbon dust based Grounding Enhancement Material (GEM) shall be added to improve grounding effectiveness. GEM shall contain cement, which hardens when set to provide a permanent, maintenance-free, and low-resistant grounding system that never leaches or washes away.

2. Buried cable shall be insulated, and cable-to-ground rod connections shall be coated.

3. DC powered equipment shall be insulated from other structures so that no DC current flows through the earth to other structures.

11.4.2 Nonmetallic Materials - In some instances, metallic and non-metallic materials are acceptable for the same service. In general, preference should be given to the non-metallic material if its durability is approximately equivalent to that of the metallic material.

Immersed or buried composite structures such as steel reinforced concrete should be made electrically continuous by appropriate bonding between sections. A minimum of two (2) inches of concrete shall cover all ferrous materials used as reinforcement

11.4.3 Design Life - The following criteria have been established as a guide:

A maximum internal corrosion rate of one (1) mil per year based on maximum depth of penetration is acceptable to permit realization of at least fifty (50) years service life free from major replacements for piping systems.

Corrosion control of exterior surfaces of equipment, piping, structural and miscellaneous steel shall be accomplished by providing a high-quality paint system. Buried piping and fittings shall be protected by electrically insulating coatings supplemented with cathodic protection. Concrete encasing shall not be an alternative to coating or cathodic protection.

11.5 Painting - In general, surfaces of equipment, piping, structural and miscellaneous steel shall be painted with a protective coating. All surfaces shall be primed with a final coat applied in the field. Aluminum, stainless or galvanized steel shall not be painted except as indicated otherwise.

11.6 Underground Piping Systems Protective Coatings - All buried, pressurized, ferrous metal piping systems (except pre-insulated pipe) shall be externally protected with a bonded pipeline type system of high dielectric strength. The purpose of this coating is to isolate the pipe from the soil.

11.6.1 Cast iron and ductile iron pipe, fittings, valves and fire hydrants shall be coated specifically with twenty (20) to thirty (30) mils (dry) of a pipeline quality asphalt-based coating equivalent to Royston R28. In areas where the possibility of soil contamination by jet fuel exists, a mastic coating combining coal tar with asphalt materials equivalent to Royston A-51 Plus shall be applied to the fitting to the same thickness. Coatings with one hundred percent coal tar mastics are incompatible with the asphalt primers found on the fittings, and are therefore not acceptable.

11.6.2 Field joint repair on jet fuel lines shall be coated with a mastic coating equivalent to Royston A51 Plus, two-component systems such as coal tar epoxy or the pipe coating manufacturer's recommended repair coating. All coatings submitted for approval must have documentation on coating characteristics and application thickness.

11.6.3 Unbonded or loose fitting coatings such as poly bagging are not approved coatings. Equivalent coatings shall be reviewed by the City Engineer for approval.

11.7 Cathodic Protection - Both impressed current and galvanic anode cathodic protection systems (CPS) may be used to supplement coatings used for corrosion control. Impressed CPS shall have a design life of greater than twenty (20) years. Maximum design life for galvanic anode systems utilizing magnesium or zinc anodes is greater than fifteen (15) years. Cathodic protection systems for immersed service shall be designed for a minimum ten (10) years. In all cases, provisions shall be made for replacement of anodes and reference electrodes.

11.7.1 Selection - The selection of the type of cathodic protection system to be employed shall be specified by a Corrosion Engineer following preparation of preliminary piping layout drawings. Such selection shall be reviewed by the City Engineer for approval. Before deciding which type, galvanic or impressed current, cathodic protection system will be used and before the system is designed, certain preliminary data must be gathered.

A. *Physical dimensions of structure to be protected.* These data are used to calculate the surface area to be protected.

B. *Drawing of structure to be protected.* The installation drawings shall include sizes, shapes, material type, and locations of parts of the structure to be protected.

C. *Electrical isolation and Bonding.* This is detailed in section 11.6.9.

D. *Short circuits.* All short circuits shall be eliminated from existing and new cathodic protection systems.

E. *Corrosion history of structures in the area.* The study should reinforce predictions for corrosivity of a given structure and its environment; in addition, it may reveal abnormal conditions not otherwise suspected.

F. *Electrolyte resistivity survey.* A structure's corrosion rate is proportional to the electrolyte resistivity. As electrolyte resistivity increases, the corrosion rate decreases

G. *Electrolyte pH survey.* In general, steel's corrosion rate increases as pH decreases when soil resistivity remains constant.

H. *Structure versus electrolyte potential survey.* For existing structures, the potential between the structure and the electrolyte shall give a direct indication of the corrosivity. According to NACE Standard No. RP-01, the potential requirement for cathodic protection is a negative (cathodic) potential of at least 0.85 volt as measured between the structure and a saturated copper- copper sulfate reference electrode in contact with the electrolyte.

I. *Current requirement.* The average current density required for cathodic protection is 2 milliamperes per square foot of *bare* area.

J. *Coating resistance.* A coating's resistance decreases greatly with age and directly affects structure-to-electrolyte resistance for design calculations. The coating manufacturers supply coating resistance values.

K. *Protective current required.* The product of the surface area multiplied by current density obtained previously in *I* above gives the total current required.

L. *The need for cathodic protection.* For existing structures, the current requirement survey (I above) shall verify the need for a cathodic protection system. For new systems, standard practice is to assume a current density of at least 2 milliamperes per square foot of bare area shall be needed to protect the structure. (However, local corrosion history may demand a different current density.) In addition, cathodic protection is *mandatory* for underground gas distribution lines (Department of Transportation regulations—Title 49, *Code of Federal Regulations,* Oct 1979) and for water storage tanks with a 250,000-gallon capacity or greater. Cathodic protection also is required for underground piping systems located within 10 feet of existing structures.

11.7.2 Buried or Immersed Ferrous Metal Piping - All buried pressurized or immersed ferrous metal piping systems (except pre-insulated pipe) shall be properly coated, electrically isolated, bonded if necessary, and cathodically protected to prevent electrolytic corrosion.

11.7.3 Systems Normally Requiring Protection - Systems to be protected include but are not limited to:

Jet Fuel Lines	Interior of Aboveground Water Storage Tanks
Natural Gas or Heating Fuel Lines	Potable Water Lines
Fire Protection Water Lines	Compressed Air Lines
Pneumatic Lines	Waste Oil Storage Tanks and Piping Systems
Underground Fuel Storage Tanks and Appurtenances	Hydraulic Elevators/Lifts and Piping Systems

11.7.4 Impressed Current Anodes - Impressed current anodes shall be located to minimize stray current pick-upon on unprotected or foreign metal structures. Care shall be taken to not place impressed current anodes near prestressed concrete pipe or reinforced concrete pipe, which could be damaged by excessive levels of cathodic protection current.

11.7.5 Preparation for Testing - A sufficient number of test lead wires shall be installed on ferrous metal structures such as pipelines, so that interference situations can be analyzed and corrected. Cathodic protection interference problems and their solutions are rarely similar, precluding "rigid" or "set" specifications for mitigation. Multiple structures in an area of interference can be very complex, requiring extensive coordinated testing under the direction of a Corrosion Engineer.

11.7.6 Protective Potentials

11.7.6.1 Ferrous Metals - NACE Standard RP 01 69-92 shall be used to determine protective potentials for ferrous metals. While this Standard lists three (3) primary criterions' as acceptable, HAS has selected only (1) one that will meet its requirements.

The method selected for determining a protective potential shall be as follows:

A negative polarized potential (immediate "off" potential) of at least 850 millivolts relative to a saturated copper-copper sulfate reference electrode.

Soil contact points (pavement inserts) over ferrous structures such as welded pipelines, valves and fittings shall be placed at intervals of fifty (50) feet in areas where concrete or asphalt pavements prevent direct contact with the soil. If necessary, a more definitive spacing shall be determined on an individual basis by a Corrosion Engineer, where external factors that have an adverse influence on the line. Soil contact points shall be a molded polyethylene pavement insert 1-¾ inches in diameter by six (6) inches long.

Where temporary placement of a reference electrode in soil directly over the structure is not possible, a copper-copper sulfate permanent reference electrode shall be considered for installation.

11.7.6.2 Non-Ferrous Metals - Protective potentials for nonferrous metals shall be established by a Corrosion Engineer and shall be in accordance with NACE Standard RP 01 69-92. Specific references can be found in Section 6 - Criteria and other considerations for cathodic protection.

11.7.7 Galvanic Anodes

11.7.7.1 Galvanic anodes shall be installed at all isolated fittings such as 45's, 90's, T's, gate valves and fire hydrants, clusters of up to four isolated fittings located within ten (10) feet of each other, short piping sections, small, well-coated structures and in areas where interference with other structures might result from the use of impressed current systems. The anodes shall consist of a galvanized steel cored, magnesium or zinc rods packed in cloth bags containing a specially prepared backfill material.

11.7.7.2 All galvanic anodes shall be attached to the structure requiring protection through the connection of the anode lead wire to a calibrated 0.1 ohm shunt to one (1) of the structure lead wires that are thermite welded to the structure. The top of all galvanic anodes are buried a minimum of twelve (12) inches below the structure either vertically or horizontally.

11.7.8 Impressed Current Systems

11.7.8.1 General - Impressed current systems shall consist of transformer-rectifier power sources, anodes placed in suitable backfill, and appropriate wiring to connect the rectifier(s) to the structures and the anodes. A complete, coordinated system must be provided.

11.7.8.2 Rectifier - The rectifier(s) selection shall be based on the field survey data and design calculations performed by a Corrosion Engineer during the design phase of the project. The rectifier shall be selected to operate at efficient settings, but shall provide surplus capacity for reasonable future expansion. As a minimum, provide approximately twenty (20%) percent surplus capacity for protected structures.

The rectifier shall contain internal circuit breakers, an output ammeter and voltmeter, and shall be mounted in a suitable cabinet or enclosure.

All rectifiers shall be provided with a properly sized, NEMA 3R rated A.C. service breaker, which shall be placed in close proximity to the rectifier.

11.7.8.3 Anodes - Impressed current anodes shall consist of either high silicon, chromium-bearing cast iron or linseed oil treated graphite, complete with high molecular weight polyethylene lead wires installed with the cable-to-anode connection properly sealed or encapsulated by the anode manufacturer. Specialty anodes shall be approved by a Corrosion Engineer if conditions require their use.

11.7.8.4 Ground Beds - Anodes are installed in drilled, augured or trenched holes at depths commensurate with soil resistively, water tables and the structure geometry. Anode holes shall be filled with the required quantity of a well compacted granular, low resistance coke breeze backfill, as specified, installed so as too uniformly surround the anode.

Where the groundbed is to be installed under concrete or asphalt, the anode holes shall be vented to permit the release of gas generated at the anode surface. Backfill above the coke breeze shall consist of pea gravel to assist in venting of generated gases and to permit percolation of water.

11.7.9 Electrical Isolation and Bonding

11.7.9.1 Electrical Isolation - Structures requiring protection may require isolation from other underground metals by physical separation or by suitable dielectric materials. Above ground piping, fittings or equipment requires electrical isolation from underground connected and cathodically protected piping, fittings or other structures by the use of isolating pipe flanges.

In general, dielectric fittings shall be installed to be accessible after backfilling. The preferred location is on the vertical riser twelve (12) to twenty four (24) inches above grade, before wall penetration into a building. If it is not practical to install the isolating fitting in an accessible location, one (1) set of two (2) test wires shall be thermite welded to each side of the isolating fitting and extended to an at-grade test station to facilitate testing. The cathodically protected side of the isolating fitting shall have white test lead wires; the unprotected side shall have green test lead wires.

When necessary to install dielectric fittings inside a building, the pipeline shall be isolated from reinforcing steel, masonry, concrete, etc. by passing through a non-conducting sleeve of plastic, or a metal sleeve with an insulating modular rubber seal to support, center and isolate the pipe from structural steel. Dielectric fittings should be inside the building as close as practical to the building wall. These points shall be accessible for inspection and repair.

Where it is necessary to interconnect dissimilar metals underground, dielectric fittings shall be installed at the connection point. All buried insulating fittings shall be coated with an approved

coating material equivalent to Royston R-28, A-51 Plus or Mavor Kelly B-50. Final decision of proper coating shall be made by a Corrosion Engineer. Painting of above-grade insulating fittings shall be done with electrically nonconductive paints. Aluminum or zinc-rich paints are not approved for this application.

All pipes entering meter vaults, penetrating building floor slabs and building walls shall be sleeved with modular rubber links to electrically isolate the pipe from contact with building/vault steel. The modular links shall be equivalent to Thunderline Link-Seals.

11.7.9.2 Bonding - Insulated copper cables for reinforced concrete cylinder pipe shall be welded or brazed across all mechanical joints in underground ferrous piping systems and at all isolated ferrous metal fittings such as 45's, 90's, T's, gate valves and fire hydrants that will be cathodically protected. Bolted connections are not acceptable.

Bonds shall consist of a #8 stranded copper wire with HMWPE insulation and shall be 12 - 18 inches in length with ample slack after all welds have been made.

Bonds may be installed between adjacent or crossing piping systems to allow protection of several systems from the same current source. Drain bonds shall be installed on any structures that may be subject to cathodic interference effects.

In the area of influence of an impressed current groundbed, reinforcing steel in buried nonmetallic structures should be bonded so that the structure is electrically continuous. These structures include reinforced concrete pipe, prestressed concrete pipe and reinforced concrete cylinder pipe.

11.7.9.3 Casings - When a cathodically protected pipeline passes under a roadway, runway or taxiway, it shall be placed inside a casing if required for mechanical strength. The carrier pipe (cathodically protected pipe) shall be electrically isolated from the casing. Casing insulators shall be specified for installation on the carrier pipe prior to placement in the casing.

Casings or rigid galvanized conduits shall be provided for all cathodic protection header cables under a roadway, runway or taxiway.

Casing end seals shall be specified to prevent moisture from entering either end of the casing. Casings shall not be coated. Ferrous metal carrier pipes inside the casing shall be coated with the same quality coating as is applied to the remainder of the piping system. Ferrous metal casings shall be cathodically protected. Utilization of PVC casings is encouraged.

Test stations shall be installed at one (1) end of each ferrous metal casing containing a cathodically protected pipe. Specify the test leads for the end of the casing that will be most accessible for future testing. Each test station shall have two (2) white insulated lead wires from the carrier pipe and two (2) red insulated lead wires from the casing.

11.7.10 Test Stations - Test stations shall be installed flush to grade in a concrete slab, at predetermined locations to facilitate inspection of the system. Two (2) test wires shall be connected to each buried structure or cluster of fittings by thermite welding and brought to the surface in an appropriate terminal box. All test stations shall be filled with clean native soil free of rocks, asphalt or concrete.

11.7.10.1 When foreign structures are adjacent to protected structures, test wires shall be attached to both structures to facilitate interference testing and/or mitigation bonding, if necessary.

11.7.10.2 Aboveground test stations shall be specified wherever their use is permissible and will not conflict with aircraft or vehicular traffic. At-grade test stations shall be specified in locations where aboveground test stations are not appropriate.

11.7.10.3 Non-AOA Test Stations - All test stations installed that are not in the A.O.A., shall have a lockable cast iron lid with the cast-in legend "C. P. Test". A nonmetallic extension tube (minimum length of eighteen (18) inches), shall be attached to the head of each test station. Provisions shall be made for connecting the anode and structure lead wires inside the test station on a nonconductive terminal board.

11.7.10.4 AOA Test Stations - Test stations for installation in the A.O.A. shall be an L-868 Class II Ground Support Light Base by Crouse-Hinds, Inc. or equivalent. The fixture shall include and adjustable base sufficiently long to extend through the concrete and into native soil. The fixture shall include a lockable steel lid with the welded legend "C. P. Test" in one (1) inch high letters.

11.7.10.5 Test Station Lead Wires - The test station structure and anode lead wires shall be black in color and a No. 12 AWG stranded copper wire with NFPA 70 type THW or equivalent insulation. Copper sleeve adapters shall be used when thermite welding #8, or smaller, wires to structures.

Reference electrode lead wires shall be No. 14 AWG stranded copper wire with NFPA 70 type RHH-RHW insulation.

The following color code shall be used to identify test station lead wires:

STRUCTURE	WIRE COLOR
Protected Structure	white
Reference Electrode	yellow
Casing	red
Unprotected Side of Insulator	green
Anode Lead Wire	black
Foreign Structure	blue

11.7.10.6 Cathodic Protection Interference and Cooperative Testing - Where more than one (1) independently cathodically protected structure is in the same area, currents flowing around one (1) structure may affect another. This is particularly true when impressed current systems are used because of their greater operating current capacity and driving voltage. To overcome this problem, two (2) lead wires shall be attached to each structure and brought to a surface test station.

Care must be taken to insulate DC powered equipment from ground or provide low resistance metallic paths for current return. Provision shall be made in the specification for interference testing by a Corrosion Engineer.

Coordination tests shall be carried out through local committees where they exist. These groups, representing all concerned area utilities and industries, coordinate testing and arbitrate solutions as required. As a rule, the organization owning a current source is responsible for the expenditures necessary for correction of a problem that it creates.

11.7.11 Water Storage Tanks - Steel water storage tanks shall be internally coated and provided with cathodic protection. The design of the cathodic protection system must not be detrimental to the applied coatings in the wetted area of the internal surfaces when the system is properly adjusted. The design life for the cathodic protection anodes shall be a minimum of ten (10) years. Water storage tanks shall be equipped with high and low water alarms capable of being transmitted as directed by the HAS Project Manager.

11.7.11.1 Anodes shall be installed in the tank to provide uniform current distribution to all immersed surfaces.

11.7.11.2 DC current shall be supplied by a suitable transformer - rectifier power supply located adjacent to the tank. The rectifier shall be either a constant current, constant potential or 100% manually controlled unit, at the option of a Corrosion Engineer. Manually adjusted rectifiers are the least expensive to install, operate and maintain. Manually adjusted rectifiers shall be specified unless special conditions dictate otherwise.

11.7.11.3 A permanent copper-copper sulfate reference electrode(s) shall be installed close to the wall of the tank (between anode strings) for monitoring purposes.

11.7.11.4 The anodes shall be suspended from a roof mounted fiberglass deck mounts designed so that the anodes may be inspected or replaced without entering or draining the tank.

11.8 Above Ground Storage Tanks

11.8.1 Bottom Exterior - The bottoms of above ground storage tanks set on moisture retaining pads are subject to corrosion. Tanks should be set on self-draining concrete or asphalt pads. If this is not done, external tank bottoms shall be sandblasted and coated with an approved coating system, and provisions shall be made to apply cathodic protection. All tanks not set on self-draining concrete or asphalt pads, shall have a minimum of one (1) permanent reference electrode installed beneath the center of the tank.

When tanks are to be located on properly drained pads, one (1) coat of an approved inorganic zinc coating shall be applied to the externally sandblasted surface prior to erection. The dry film coating thickness range shall be from 2.5 - 4.0 mils. Otherwise, cathodic protection shall be provided for the external tank bottom.

11.8.2 Tank Interior - The interior of all storage tanks shall be sandblasted and protected with an approved protective coating. If the tanks are equipped with floating roofs, the coating system shall have sufficient abrasion resistance to withstand movement of the roof.

11.8.3 Tank Exterior - The exterior surface of the tanks shall be coated with an approved coating.

11.9 Underground Storage Tanks - All metallic underground fuel storage tanks (UST) or fittings shall be coated and cathodically protected or installed in containment piping systems in conformance with local, state and federal regulations.

11.9.1 Ferrous metal UST's and appurtenances shall be coated with a cold applied coal tar mastic coating.

11.9.2 If an approved (holiday free) factory fiberglass cladding system of at least 100 mils thick is applied, no cathodic protection is required. The appurtenances attached thereto shall be coated with a compatible coating and cathodically protected.

11.9.3 As an alternate, fiberglass reinforced plastic tanks may be installed. Ferrous metal appurtenances attached thereto shall be coated and cathodically protected or installed in containment piping systems. Where submerged turbine pumps are employed, a polarization cell equivalent to Kirk Cell® K-5 shall be installed in the grounding circuit of the electrical power supply.

11.10 Hydraulic Elevators and Lifts - All direct buried hydraulic elevators or lifts shall be coated with either a coal tar-based coating or other approved coating. The lift shall be isolated from all electrical equipment with insulating fittings. Cathodic protection shall be applied.

11.11 Fuel Hydrant Boxes - Flush mounted steel hydrant boxes to be located below grade shall be externally coated with a coal-tar-based coating and cathodically protected. Cathodically protected piping entering and leaving the box shall be electrically isolated from the hydrant connection. All piping within the box shall be bonded together. Cathodic protection shall be provided to both the piping and fittings in contact with the soil.

11.1 Piling - Any steel in buried piles, directly exposed to the earth, shall be coated with a nominal 16 mil DFT single coat coal tar epoxy and cathodically protected if the strength of the full steel cross-section has been used in meeting structural requirements. The steel component of piles, if directly exposed to the soil, shall be bonded together by welding a reinforcing bar between all components or by provision of adequate bonding cables.

END OF SECTION 11

12.0 SECURITY, CLOSED CIRCUIT TV, AND AUTOMATED ACCESS CONTROL SYSTEM

Not Used – Refer to Section 16

END OF SECTION 12

13.1 FIRE PROTECTION AND FIRE DETECTION SYSTEMS

13.2 General Information - This Chapter defines general criteria that apply to the design of fire protection systems and fire detection systems at IAH, HOU, and EFD airports. Chapter 1 should be consulted for specific Airport regulations and standards that also apply.

13.3 Fire Protection Systems - All equipment and materials shall be Underwriters' Laboratories (UL) or Factory Mutual (FM) approved and listed and shall bear the appropriate stamp or label. Installation specifications can be found in the Appendix to this Chapter. Entire sprinkler, fire hose cabinet, fire riser and standpipe piping must have seismic design as per Category F.

13.3.1 Sprinkler Systems – The fire sprinkler system in airport passenger terminals and HAS occupied, operated and maintained buildings shall be designed for a minimum ordinary hazard type occupancy as defined by NFPA 13.

13.3.1.1 All sprinkler pipes that penetrate masonry or concrete walls or floors shall be sleeved with schedule 40 steel pipe.

13.3.1.2 All sprinkler piping below 2-1/2" in diameter shall be Schedule 40 steel pipe.

13.3.1.3 Main drains and inspector test valves shall terminate to the exterior of the building. Discharge shall not be near any pits.

13.3.1.4 The system shall be calculated utilizing water supply test data obtained from flow tests conducted at the construction site by the consultant or fire protection contractor with the data, time and date of the test noted on the shop drawings. Method of testing shall include the use of at least one (1) residual pressure reading hydrant and one (1) flow hydrant.

13.3.1.5 Provide a Bypass around the check valve in the fire department connection line with a control valve in the normally closed position. The bypass is required for the performance of a full flow test of the system demand through the back flow preventer. Exception: If the main drain can achieve the flow demand of the system, no bypass is required.

13.3.2 Dry Pipe Sprinkler Systems – Piping and pipe fittings for dry pipe sprinkler systems shall be galvanized steel.

13.3.2.1 Each dry-pipe system shall have its own air pressure supervisory switch to monitor and report both high and low air pressure conditions. The switch shall be located between the air supply check valve and sprinkler alarm valve.

13.3.2.2 A manual shut-off valve shall be provided between the hi/low switch and the main air supply line leading to the compressor. The air compressor shall be hard wired directly to a lockable disconnect box or to a dedicated branch circuit.

13.3.2.3 All concealed low point drains shall be visually identified and provided with a sign to identify system.

13.3.2.4 Air compressors shall be connected to the existing piping system via stainless steel mesh connectors and installed with no bends. All air compressors shall be installed on spring vibration isolation pads.

13.3.2.5 Sprinkler pipes shall be thoroughly flushed in accordance with NFPA 13 and NFPA 25 each time the system is expanded or modified.

13.3.3 Wet Pipe Sprinkler System - Use of heat tape on sprinkler system piping shall not be permitted.

13.3.4 Pre-action Sprinkler Systems -System piping may be supervised with air. Piping shall be galvanized. Pre-action valve assemblies shall not to be installed in public areas or ceiling plenums. All pre-action system drains shall terminate to a suitable drain that can accommodate removal of system water.

13.3.5 Standpipe Systems – Fire hoses, where required, shall be stored in a hose cabinet. Hose cabinets exposed to the weather shall be marine grade enclosures.

13.3.6 Fire Department Connections -All Fire Department Connections (FDC) shall be equipped with a four inch (4") "Hydro STORTZ" quick connect fitting with a 30 degree down angle.

13.4 Fire Alarm System – Fire alarm systems shall be provided, tested, and approved in compliance with NFPA 72 and the Fire Code. Fire alarm submittals are required and shall be reviewed and approved by the Fire Marshall.

13.5 Fire Prevention During Construction – Comply with Chapter 14 of the Fire Code - Fire Safety During Construction and Demolition for buildings under construction and NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations for non-building related construction.

13.5.1 Underground water mains and hydrants shall be installed and operational prior to proceeding with construction work above grade.

13.5.2 Where required, standpipes shall be installed and shall be accessible for fire protection as the work progresses.

13.5.3 Approved fire extinguishers shall be provided in clear view on each floor at each usable exit in accordance with NFPA 10.

13.6 Special Considerations – The following special considerations shall be included in the project design where applicable:

13.6.1 Floor Penetrations for Conveyors – Where conveyors penetrate rated assemblies or floors, provide closely spaced sprinklers in combination with draft stops as follows:

13.6.1.1 The draft stops shall be located immediately adjacent to the opening shall be at least 18" deep and shall be of noncombustible material that will stay in place before and during sprinkler operation. Sprinklers shall be spaced approximately 6 ft. apart and placed 6 to 12 in. from the draft stop on the side away from the opening. An area smoke detector shall be placed in the ceiling above the floor opening and wired to the fire alarm system.

13.6.1.2 Alternate for Floor Penetrations at Conveyors: Conveyor openings may be provided with fire/smoke shutters that can be manually closed or automatically closed by smoke detectors installed in accordance with NFPA 72 in lieu of method described above. Smoke detectors operating fire/smoke shutters should be monitored by the Fire Alarm Control Panel.

13.6.2 Baggage Conveyor Systems in Terminal Buildings- Baggage conveyor belts shall be protected with sprinklers spaced no closer than 6 feet and no farther than 8 feet on centers in above ceiling areas. Sprinkler heads shall clear baggage and other items. Sprinkler head guards shall be installed.

END OF SECTION 13

APPENDIX to SECTION 13

HAS FIRE ALARM INSTALLATION SPECIFICATIONS

I. General – Buildings occupied, operated or maintained by HAS and ALL buildings classified as "terminal buildings" (A3 under the 2000 International Building Code) shall require a complete manual and automatic fire alarm system which interfaces with the HAS central fire alarm system.

Terminal buildings built prior to September 2000 will comply with specifications as identified in Section II.

Terminal buildings built after September 2000 will comply with specifications as identified in Section III.

All other HAS occupied or maintained buildings will comply with specifications as identified in Section IV.

II. Fire Alarm Specification for Terminals completed prior to 9/2000. A. System Operation.

The installation shall be complete and operable, performing all functions as described below:

1. Report alarm condition to the Central Fire/Security System in the event of activation of water flow devices, duct smoke detectors, manual call stations, intelligent sensors, ancillary extinguishing systems, or other such functions. Audibly and visually annunciate at the local panel the alarm condition, and display the loop and physical device address.

2. Report trouble condition to the Central Fire Security system in the event of circuit faults in alarm system devices, intelligent sensors and modules, initiating, indicating, and intelligent loop circuits. Visually annunciate at the local panel the trouble condition, and display the loop and physical device address.

3. Report supervisory condition to the Central Fire/Security System in the event of activation of supervisory devices. Visually annunciate at the local panel the supervisory condition and display the loop and physical device address.

B. Fire Alarm Control Panel

1) The fire alarm data gathering panel (DGP) shall function as the communication interface between the Central Fire Security System and the Intelligent System devices. The DGP shall be intelligent, with its own microprocessor and memory. The DGP shall be UL listed independently as a Fire Alarm Control Unit as well as a critical component of a proprietary multiplex system.

2) The DGP shall supervise each initiating device, monitor module or control modules on an intelligent loop circuit such that alarm and trouble conditions are individually annunciated.

3) Up to 99 sensors and modules shall be supported in a Clip Mode on a single intelligent loop or 159 devices and 159 modules in Flash Scan Mode in a single intelligent loop... Each sensor and module shall be capable of being operated in alarm condition simultaneously. The DGP shall provide all power necessary for intelligent devices connected to it.

4) The DGP is located: IAH

- Terminal A South Notifier 3030
- Terminal A North Notifier 3030
- Terminal A Central Notifier 3030
- Terminal B Central Notifier 3030
- Terminal B APM Station Notifier 3030
- AB Garage Notifier 3030
- Terminal C Central Notifier 3030 (2) panels
- C East Baggage Notifier 640 panel
- C In-Line Baggage Notifier 640 panel
- North Vault 640 panel
- Agriculture 640 panel
- FIS Cargo One Stop 640 panel
- Fire Station 92 Notifier 640 panel
- Fire Station 99 Notifier 640 panel
- Fire Station 54 Notifier 640 panel
- FIS 3030 panel
- Terminal D 3030 panel
- Administration 640 panel
- PPM Notifier 3030 panel
- A&G Notifier 3030 panel
- Tech Services Notifier 640 (2) panel
- EV2 Notifier 640 panel

HOU

EFD

The DGP is operated, maintained, and the property of the HAS.

5) The DGP shall communicate with the Central Fire/Security system via fiber optic cable.

6) The DGP is a Notifier 3030 or 640 fire alarm control panel.

C. **Intelligent System Devices.**

1. Each device shall be assigned a unique address via dedicated switches.

2. Devices shall receive power and communicate over the same pair of wires.

3. Devices shall be capable of being added to the intelligent loop circuit by tee tapping from any point in the circuit without affecting any existing device address or function.

4. Each device shall contain screw terminals on rising plates for positive termination of up to a 12 AWG wire.

D. **Sensors**

1. All intelligent sensors shall mount on a common base to facilitate the changing of sensor type if building conditions change. The base shall be incompatible with conventional detectors to prevent the mounting of non-intelligent devices.

2. Each sensor shall contain a LED, which blinks each time the device is scanned by the DGP. If the device is in alarm, the LED shall remain on to indicate the alarm condition.

3. Each sensor shall contain a magnetically actuated test switch such that the device can be tested from the sensor location.

4. Each sensor shall be capable of being tested for alarm condition via command from the DGP.

5. Each sensor shall respond to the DGP poll for information with its device type identification to preclude inadvertent substitution of another sensor type. The DGP shall operate with the installed device but shall indicate a trouble condition until the proper type is installed or the programmed sensor type is changed.

6. Each sensor shall respond to the DGP poll for information with an analog representation of measure smoke density, particles of combustion or temperature.

7. Photoelectric smoke sensors shall contain an optical sensing chamber with a nominal sensitivity of 2.3 percent/foot obscuration. The photoelectric smoke sensor shall be a Notifier FSP 851 or approved equivalent.

8. Ionization smoke detectors shall contain a unipolar dual chamber configuration with a nominal sensitivity of 1.5 percent/foot obscuration. The ionization smoke sensor shall be a Notifier FST-851 or approved equivalent.

9. Thermal sensors shall be Honeywell TC808A or approved equivalent.

10. Duct smokes, and area smoke detectors will be provided with remote testing annunciators easily accessible from floor level and shall be addressable.

E. **Monitor Modules.** The intelligent monitor module shall provide an addressable input for normally open or normally closed contact devices, such as manual pull stations, water-flow devices, supervisory devices, or other such alarm/supervisory devices.

1. The Monitor module shall provide a supervised initiating circuit, able to connect to either two wire supervised or four wire fault tolerant circuits.

2. The Monitor module shall contain an LED, which shall blink upon DGP scan. The LED shall latch on upon determination of an alarm condition.
3. The Monitor module shall mount in a standard 4” X 4” deep electrical box.
4. The Monitor module shall be a Notifier FMM-1A or approved equivalent for class A or B wiring.

F. **Control Modules**.

1. The intelligent control module shall provide an addressable output for a separately powered alarm indicating circuit or control relay.
2. he Control module shall provide a supervised indicating circuit. An open circuit fault shall be annunciated at the DGP. The control module shall connect to either two wire or four wire fault tolerant circuits.
3. Control Modules shall be Notifier FRM-1A providing two form-C Relay contacts that switch together and can be use as dry contacts to operate Fail Safe door power on Electro Magnetic locks.
4. The module shall have a LED, which shall blink on DGP poll. Upon activation of the module, the LED shall be latched on.
5. The control module shall mount in a 4” X 4” deep electrical box.

G. **Intelligent Loop Circuits**

1. The DGP shall have two (2) intelligent loops on a 640 on a 640 panel or ten (10) loops on a 3030 panel...
2. Intelligent loop circuits shall be labeled at all junction locations by panel number and loop number.

H. **Initiating Devices**

1. Ionization Duct Smoke Detectors shall be rated at 24VDC and be listed for applications involving air handling systems. Detector shall be installed in accordance with its listing.
2. Manual Stations shall be of rugged die cast metal construction designed for semi-flush mounting. Each manual station shall connect to a TC809A monitor module. The initiating circuit shall be wired Class ‘A’ fault tolerant.
3. Wet sprinkler systems shall have vane type sprinkler flow switches. Flow switches should be set to activate between 60 and 90 seconds. The device shall have a SPDT, which shall close upon water flow.
4. Dry sprinkler system alarm switches shall be pressure activated and installed in accordance with the trim specifications of the dry pipe valve.

6. Supervisory switches for fire protection systems shall be installed in accordance with their listing. Lanyard type supervisory switches are not permitted.
7. Dry system air pressure switches shall be installed to monitor both high and low air pressure conditions.

8. Each initiating device shall connect to FMM-1 monitor module.
9. Supervisory devices may be connected to a single monitor module when located in the same room. Supervisory circuit shall be two wire supervised circuits, with the appropriate end of line resistor installed at the last device on the loop.

I. **Alarm Notification Devices**

1. Notifications devices shall be installed on two wire supervised circuits with the appropriate end of line resistor mounted at the last device on the loop.
2. The notification device shall be audible visual type.
3. Notifications devices shall connect to Notifier FCM-1(A) control modules.

J. **Wiring**

1. Wiring shall be in accordance with the National Electric Code, these specifications and the approved wiring diagram.
2. No wiring other than detector and alarm circuits are permitted in fire alarm conduits. Wire shall be color-coded; minimum 14 AWG-THHN stranded copper wire, 600-volt insulation for device initiating and indicating circuits. Transposing or changing color codes is not permitted.
3. Wiring shall be completely installed; field connections made and tested for stray voltage, short circuits, and ground faults prior to connection to the intelligent modules. Stranded wires shall terminate at both the device and module with spade terminals sized to fit both the wire and screw terminal.

   1). Intelligent loop circuits shall be Honeywell AK3747B cable or approved equivalent. The Contractor shall coordinate the connection of branch intelligent loop circuits to the main loop circuits with HAS Technology Section.

   2). Color-coding of device initiating fault tolerant loops shall be that two conductors are of one color and the other two conductors are of a different color. Colors shall be continuous throughout the entire loop. Where more than one initiating look is routed in a single conduit, the colors associated with any loop contained in the conduit shall be different from the colors of any other initiating loop contained in the conduit.

1. Control and other panels shall be mounted with sufficient clearance and access for observation and testing. Fire alarm junction boxes shall be clearly marked for distinct identification.
2. All fire alarm junction boxes should be mounted in approved locations for ease of maintenance from floor level.
3. All junction boxes shall be made up in a uniformly and orderly manner.
4. Backbone termination boxes should be of sufficient size to allow for termination on to terminal strips.
5. All loop wiring shall be identified by ins and outs. (Ins meaning they are coming from the panel.)
6. Solid Red and Black are reserved for and must be used for 24-volt panel power and with the use of audiovisual circuits.

7. Wiring shall be in EMT conduit, minimum ¾ inch. The entire raceway shall be grounded. Conduits shall enter panels from the sides or bottom. Where flexible conduits are used to connect device loop wiring to alarm devices, the Contractor shall use ½ inch flexible conduit.

8. Intelligent sensors shall be mounted in the ceiling of the protected area and not closer than four feet from any air conditioning register and installed in accordance with their listing.

9. Monitor modules connected to interior manual stations shall be mounted in the ceiling panel or wall surface immediately above the manual station.

10. Where manual stations are installed on the building exterior, the associated monitor module shall be mounted in transparent enclosure to maintain the environmental limitations of the module. The manual pull station shall be mounted in an approved enclosure in the immediate vicinity of the module.

11. Multiple monitor modules located in valve rooms shall be housed in a NEMA 4 enclosure with gland panel and sized to contain the required number of modules.

K. System Programming

1. Coordination with HAS Technology Section is required for programming. Contact the HAS Technology Division for information and additional programming requirements.

III. Fire Alarm Specifications for Terminals built after 9/2000. A. Operation and Fire Alarm Panel

1. The Fire Alarm Data Gathering Panel (DGP) shall function as an integral component of the HAS Central Fire/Security System and the Intelligent System devices referenced hereinafter. The panel shall be UL 864 UOJZ and UUKL listed.

2. The DGP shall supervise Alarm Trouble and Supervisory conditions.

3. All panels should be made up in a uniformly and orderly manner.

4. A 120 VAC dedicated circuit shall power the fire alarm panel. A label will be affixed inside the fire alarm panel as to the panel designation and breaker number of the 120 VAC power source.

5. The panel shall contain batteries to provide stand-by emergency power, sized to maintain the local fire alarm system operational upon loss of primary power. The batteries shall have the capacity to operate the system under standby condition for 24 hours and under alarm conditions for a minimum of 5 minutes. Transfer from normal to battery power shall be automatic. When a transfer occurs the panel shall report a trouble alarm to the Central Fire/Security System. The panel shall provide float/equalizing charge for the batteries.

6. The panel shall provide ground fault detection for the panel and device initiating circuits and shall report ground faults to the Central Fire/Security System.

7. Initiating Device circuits shall be “four wire” whereby the circuits are supervised for opens and grounds and lop initiating will continue to operate with a trouble such as a single open or a single ground. Supervisory and indicated circuits shall be two wire supervised, with the appropriate end of line resistor installed at the last device on the loop.

8. Fire alarm panel shall not be used for junction boxes or pull boxes. There is to be absolutely no splicing inside the panel.

9. When terminating stranded wiring in the panel for all initiating and indicating devices "*Sta-Kon*" type lugs shall be used for the proper lug size and wire size.

10. The DGP is located as approved by HAS.

11. The DGP shall communicate with the Central Fire/Security System via fiber optic cable.

B. **System Devices**.

1. Addressable Devices shall receive power and communicate over the same pair of wires.

2. Additional devices shall be capable of being added to the intelligent loop circuit by tee tapping from any point in the circuit without affecting any existing device address or function.

3. Each device shall contain screw terminals on rising plates for positive termination of up to 12 AWG wire.

4. Duct and area smoke detectors will be provided with remote test and reset panels when detector is not readily accessible from floor level.

5. No intelligent devices are allowed in confined spaces. Should a device be needed in a confined space a remote monitor module shall be provided in an approved location.

6. All intelligent device base plates shall be labeled with device address and panel loop number. The type of module shall be identified as either a control module or monitor module.

7. All intelligent sensors shall mount on a common base to facilitate the change of sensor type if building conditions change. Base shall be incompatible with conventional detectors to prevent the mounting of non-intelligent devices.

8. Each sensor shall contain an LED, which blinks each time the device is scanned by the DGP. If the device is in alarm, the LED shall remain on to indicate the alarm condition.

9. Each sensor shall be capable of being tested for alarm condition via command from the DGP.

10. Each sensor shall respond to the DGP poll for information with its device type identification to preclude inadvertent substitution of another sensor type. The DGP shall operate with the installed device but shall indicate a trouble condition until the proper type is installed or the programmed sensor type is changed.

11. Each sensor shall respond to the DGP poll for information with an analog representation of measured smoke density, particles of combustion, or temperature.

12. Photoelectric smoke sensors shall contain an optical sensing chamber with a nominal sensitivity of 2.3 percent/foot obscuration.

C. **Monitor Modules**

1. The intelligent monitor module shall provide an addressable input for normally open or normally closed contact devices

2. The monitor module shall provide a supervised initiating circuit, able to connect to either two wire supervised or four wire fault tolerant circuits.

3. The monitor module shall contain an LED, which shall blink upon DGP scan. The LED shall latch on upon determination of an alarm condition.

4. The monitor module shall mount in a standard 4” X 4” deep electrical box.

D. **Control Modules**.

1. The intelligent control module shall provide an addressable output for a separately powered alarm indicating circuit or control relay.

2. The control module shall provide a supervised indicating circuit. An open circuit fault shall be annunciated at the DGP. The control module shall connect to either two wire or four wire fault tolerant circuits.

3. The control module shall provide a control relay. The relay shall have a SPDT form “C” contact, rate at two amps at 28 VDC.

4. The module shall have an LED, which shall blink on DGP poll. Upon activation of the module, the LED shall be latched on.

5. The control module shall mount in a standard 4” X 4” deep electrical box.

E. **Initiating Devices**

1. Ionization Duct Smoke Detectors shall be rated at 24 VDC and be listed for applications involving air handling systems. Detector shall be installed in accordance with its listing.

2. Manual stations shall be of rugged die cast metal construction designed for semi-flush mounting. The initiating circuit shall be four wire fault tolerant. Each manual station shall connect to a monitor module applicable to the DGP and shall be addressable.

3. Wet sprinkler systems shall have vane type sprinkler flow switches. Flow switches should be set to activate between 60 and 90 seconds. The device shall have a SPDT, which shall close upon water flow.

4. Dry sprinkler system alarm switches shall be pressure activated and installed in accordance with the trim specifications of the dry pipe valve.

5. Supervisory switches for fire protection systems shall be installed in accordance with their listing. Lanyard type supervisory switches are not permitted except as approved by the HAS Technology Section.

6. Dry system air pressure switches shall be installed to monitor both high and low air pressure conditions.

7. Each initiating device shall connect to a separate monitor module. The initiating circuit shall be four wire fault tolerant.

8. Supervisory devices may be connected to a single monitor module when located in the same room. Supervisory circuit shall be two wire supervised circuits, with the appropriate end of line resistor installed at the last device on the loop.

F. **Wiring**

1. Wiring shall be in accordance with the National Electric Code, these specifications, and the approved wiring diagram.
2. No wiring other than fire alarm indicator, indicating, low voltage power, and communications circuits are permitted in fire alarm conduit.
3. Wiring shall be completely installed; field connections made and tested for stray voltage, short circuits, and ground faults prior to connection to the intelligent modules. Stranded wires shall terminate at both the device and module with spade terminals sized to fit both the wire and screw terminal.
4. Color-coding of device initiating fault tolerant loops shall be: two conductors are of one color and the other two conductors are of a different color. Colors shall be continuous throughout the entire loop. Where more than one initiating loop is routed in a single conduit, the colors associated with any loop contained in the conduit shall be different from the colors of any other initiating loop contained in the conduit.
5. All loop wiring shall be identified by ins and outs. Ins is defined as coming from the panel.
6. Red and Black must be used for 24-Volt panel power.
7. No voltage supply from any other source than the primary power 120 VAC and the panel 24 VDC power supply shall be utilized.
8. Intelligent loop circuits should be labeled at all junction locations by the panel number and loop number.
9. Intelligent loop circuits shall be provided with adequate junction boxes be expandable and provide a means for connecting to the loop in the junction box.
10. Control and other panels shall be mounted with sufficient clearance for observation and testing. Fire alarm junction boxes shall be clearly marked for distinct identification.
11. Wiring shall be in EMT conduit, minimum 1 inch. Flexible conduits, mounting boxes, junction boxes and panels shall be securely fastened with appropriate fittings to insure positive grounding throughout the entire system. Conduits shall enter the panels from the sides or bottom. Where flexible conduits are use to connect device loop wiring to alarm device, the contractor is permitted to use ½ inch flexible conduit. Refer to Chapter 16- ELECTRICAL for additional requirements for conduit.
12. All fire alarm junction boxes should be mounted in approved locations for ease of maintenance from floor level.
13. Backbone termination boxes should be of sufficient size to allow for termination.
14. All junction boxes shall be made up in a uniformly and orderly manner.

G. **Device Installation**

1. Intelligent sensors shall be mounted in the ceiling of the protected area and not closer than four feet from any air conditioning register (Supply or Return). Contractor shall define actual device locations in accordance with the manufacturer recommendations and NFPA approved methods.

2. Monitor modules connected to internal manual stations shall be mounted in the ceiling panel or wall surface immediately above the manual station.

3. Where manual stations are installed on the building exterior, the associated monitor module shall be mounted in a transparent enclosure to maintain the environmental limitations of the module. The manual pull station shall be mounted in an approved enclosure in the immediate vicinity of the module.

IV. Other buildings occupied or maintained by HAS.

A. Operation

1. Activation of any initiating device shall report to the HAS Central Fire/Security System.

2. Audibly annunciate the alarm condition and light a pilot light on the local fire alarm panel pinpointing the zone in alarm.

3. Activation of supervisory alarms or trouble conditions shall report to the HAS Central Fire/Security System and light a pilot light on the local fire alarm panel.

4. Notification devices shall be provided and notify the occupants in the event of an alarm.

B. **Fire Alarm Panel**

1. The Fire Alarm Data Gathering Panel (DGP) shall function as an integral component of the HAS Central Fire/Security System. The panel shall be UL 864 UOJZ and UUKL listed.

2. The panel shall be modular; factory wired; of dead front construction using solid-state components. The panel shall communicate with the Central Fire alarm system using voice grade dual, full duplex Telephone data circuits or fiber optic cables.

3. The panel shall be capable of monitoring and controlling fire alarm and security zones as required. Space within the panel shall be provided to allow for installation of equipment to accommodate zone expansion by 25%.

4. All panels should be made up in a uniformly and orderly manner.

5. Fire alarm panels shall not be used for junction boxes or pull boxes. No splicing is permitted inside the panel

6. Wiring terminations in the panel from all initiating and indicating devices shall use “STA-KON” type lugs sized for the proper screw size and wire size.

7. The fire alarm panel shall be powered by 120 VAC dedicated circuit. A label shall be affixed inside the fire alarm panel as to the panel designation and breaker number of the 120 VAC power source.

8. Initiation device circuits shall be “four wire” whereby the circuits are supervised for opens and grounds and all loop initiating devices will continue to operate with a trouble such as a single open or a single ground.

9. The panel shall contain batteries to provide stand by emergency power sized to maintain the local fire alarm system operational upon loss of primary power. The batteries shall have the capacity to operate the system under standby condition for 24 hours and under an alarm condition for a minimum of 5 minutes.

10. The panel shall provide ground fault detection for the panel and device initiating circuits and shall report ground faults to the Central Fire/Security System.

11. Where the panel is located in a facility remote from the Central Utility Tunnel, the panel shall transmit data to the Central Fire/Security System by circuits leased by the owner from the Local Telephone Service. The contractor shall arrange for installation of these circuits by coordinating with HAS PS&T Division.

12. Where the panel is located in a facility accessible to any Utilities Tunnel the panel shall transmit data to the Central Fire/Security System by proprietary data cable furnished by the contractor and connected to the existing fire alarm fiber optic cable in the Utilities Tunnel.

13. The contractor shall obtain from HAS Technology Division the necessary addressing information to properly address the fire alarm panel. The contractor shall provide to the HAS Technology Division the correct programming information for the Airport's a minimum of ten (10) days prior to the expected check out of the system.

14. No voltage supply from any other source than the primary power 120 VAC, the panel 24 VDC power supply, or approved Notification Appliance Power Supplies shall be utilized.

C. **Initiating Devices.**

1. Ionization Duct Smoke detectors shall be installed in accordance with their listing. The detector shall be rated at 24 VDC. The amplifier switching circuit shall be entirely solid-state and operate with a detector line voltage of 24 VDC.

2. Area Smoke Detectors shall be photoelectric type and be installed in accordance with their listing and NFPA 72. Detectors shall be equipped with a functional test device circuit capable of simulating a minimum acceptable amount of smoke for alarm. The test device circuit shall provide individual local test of all components of the detector and shall not require generation of actual smoke within the building.

3. Duct smoke and area smoke detectors will be provided with remote testing and reset when the detectors not readily accessible from floor level.

4. Detectors shall mount on a standard 4" octagon or 4" square outlet box.

5. Detectors shall operate on a line voltage of 24 VDC. A means shall be provided to supervise the 24 VDC detector power for each zone.

6. Manual Pull Stations shall be of rugged die cast metal construction designed for semi-flush mounting. Manual Station shall be installed in accordance with their listing.

7. Sprinkler Alarms on wet type sprinkler systems shall have vane type sprinkler flow switches. Flow switches shall have retards adjustable up to 90 seconds, and be furnished with one normally open switch that will close upon water flow. Dry System alarm switches shall be of a pressure activated type and installed in accordance with the trim specifications of the dry pipe valve.

8. Valve supervisory devices shall be installed in accordance with their listing. Lanyard type supervisory switches are not permitted unless approved.

9. Dry system air pressure supervision shall be a pressure switch and installed to monitor and report both high and low air pressure conditions

10. Each device shall contain screw terminals on rising plates for positive termination of up to 12 AWG wire.

11. Fireman lock box shall be a series security circuit. EOL resistor should be protected against shorts.

D. **Notification Devices**

1. Notification appliances shall be installed in accordance with their listing and per NFPA 72.

E. **Wiring**

1. Wiring shall be in accordance with the National Electric Code, these specifications and the approved wiring diagram.

2. No wiring other than fire alarm loop, initiating, indicating, power, and communications circuits are permitted in fire alarm conduits. Device wire shall be color-coded, minimum 14 AWG THHN copper wire, 600-volt insulation for initiating and indicating circuits. Transposing or changing color-coding of wires is not permitted.

3. Wiring shall be completely installed; field connections made and tested for voltage and stray signals before final connections to the remote panel is made. Wires shall terminate both at the pane and the devices with spade type insulated "STA-KON" lugs sized to fit both the wire and screw terminal.

4. Color-coding of device initiating fault tolerant loops shall be: two conductors are of one color and the other two of a different color. Colors shall be continuous throughout the entire loop. Where more than one initiating loop is routed in a single conduit, the colors associated with any loop contained in the conduit shall be of different colors than any other loop in the conduit.

5. All loop wiring shall be identified by ins and outs. (Ins meaning they are coming from the panel).

6. Solid red and black are reserved for and must be used for 24-volt panel power with the use of audiovisual circuits.

7. Control and other panels shall be mounted with sufficient clearance and access for observation and testing. Fire alarm junction boxes shall be clearly marked for distinct identification.

8. Wiring shall be in EMT conduit, minimum ¾ inch. The entire raceway shall be grounded. Conduits shall enter panel from the sides or bottom only. Where flexible conduits are used to connect device loop wiring to alarm devices, the contractor shall use ½ inch flexible conduit.

9. All fire alarm junction boxes should be mounted in approved locations for ease of maintenance from floor level.

10. All junction boxes shall be made up in a uniformly and orderly manner.

11. Backbone termination boxes should be of sufficient size to allow for termination on to terminal strips.

F. Documentation and Acceptance Testing for All Systems

A. Documentation

Upon completion, provide a complete point to point wiring diagram of the installation. One copy shall be furnished to HAS Physical Plant Maintenance Section for inclusion in Facilities Maintenance records and one copy shall be furnished to the Planning and Programming Section, GIS unit.

All final As-built drawings shall show conduit routing, junction boxes, termination boxes sprinkler devices, wire flow and EOL resistors

B. Acceptance Test

1. Following completion of the wiring and prior to termination of devices, an installation inspection is required. Contact the HAS Project Manager to request inspections.

2. Upon completion, the contractor in the presence of HAS PPM, HAS Facilities, HAS Fire Protection Maintenance Contractor and appropriate HAS Planning Design and Construction Division representatives shall conduct such test and inspections necessary to verify the installation is complete and fully operational to the given intent and has been installed in accordance with the specifications and approved drawings.

3. All equipment and materials necessary to conduct these tests shall be furnished wholly by the contractor.

4. The following device keys shall be provided by the contractor upon completion and acceptance.
   a. One key for each duct smoke detector installed.

   b. One key or tool for each manual pull station installed.

   c. One key or tool for each water flow device installed.

   d. One key for each supervisory device installed. e.

   One key or tool for each panel installed.

5. Following completion of the installation and progressively during the course of installation, the contractor shall remove all trash, debris, and surplus material occasioned by this operation so that at all times the environment presets a safe, neat, and orderly condition conducive to other activities. Upon completion of the Sprinkler System and before acceptance, Hydraulic plates shall be installed on every riser stating the engineering calculations

END OF APPENDIX to SECTION 13

14.0 CONVEYING SYSTEMS

END OF SECTION 14

NOT CURRENTLY USED

15.1 MECHANICAL SYSTEMS

15.2 General Information - This Chapter defines general design criteria that apply to the design of heating, ventilation, air conditioning (HVAC), and plumbing systems at the HAS airports as well as those HVAC systems to be served by the Central Utilities Plant (CUP) located at IAH. Chapter 1 should be consulted for specific Airport regulations and standards that also apply.

Mechanical System Design shall consider, Construction, Commissioning and Operation phases of Building Life Cycle. Quality Design shall achieve Internal Environmental Quality and Thermal Comfort balance. Design of Mechanical Systems shall allow submeters and data collection within the building.

Existing HVAC and plumbing information is available through the GIS Section of the individual airports or through the Planning Design and Construction Division. However, it shall be expressly understood that HAS cannot accept any responsibility for the locations shown on "as built" drawings. It shall be the designers' responsibility to verify locations or the adequacy of file information prior to design and construction of HVAC systems. The designer shall coordinate the development of the design at all stages with the HAS Project Manager.

When heating or air conditioning load to the existing HVAC system is changed the engineer is required to verify the adequacy of the existing piping delivery system. The methods used for verification shall be approved by the HAS project manager.

The Basis of Design is the latest International Building Code as amended by the City of Houston and the latest Uniform Mechanical Code as amended by the City of Houston and the Houston Commercial Energy Conservation Code.

MEP Drawings shall be presented at ¼" scale showing all equipment, ductwork, cable trays, fire protection, chilled water, heating water, electrical conduits, control cabinets, etc., for approval by HAS.

Precautions shall be taken to protect all existing and new equipment in the area surrounding the proposed construction site.

Special precautions shall be taken when digging below the surface in and around all Terminal Structures. Contractor shall be required to verify all subterranean soil obstructions with ground penetrating radar examining equipment before digging begins. The initial test with the radar will be done to verify obstructions in the first three feet of depth. After the surveyed soil has been removed the equipment shall be withdrawn and the radar will survey the next three feet of depth. This procedure will continue for the full depth of the proposed dig. If questions arise regarding this requirement contact the HAS project manager for clarification.

Contractor shall guarantee all work for one year from the final acceptance date.

The SMACNA IAQ Guidelines for Occupied Buildings Under Construction, 2nd edition ANSI/SMACNA 008–2008, will be used for providing design and project management guidance in maintaining satisfactory indoor air quality (IAQ) of occupied buildings undergoing renovation or construction. Whenever a new section is constructed at the airports.

For the unoccupied buildings, after construction ends, prior to occupancy and with all interior finishes installed, install new filtration media and, perform a building flush-out by supplying a total air volume of 14,000 cubic feet of outdoor air per square foot of floor area while maintaining an internal temperature of at least 60° F and relative humidity no higher than 60%.

If occupancy is desired prior to completion of the flush-out, the space may be occupied following delivery of a minimum of 3,500 cubic feet of outdoor air per square foot of floor area. Once the space is occupied, it must be ventilated at a minimum rate of 0.30 cubic feet per minute (cfm) per square foot of outside air. During each day of the flush-out period, ventilation must begin a minimum of 3 hours prior to occupancy and continue during occupancy. These conditions must be maintained until a total of 14,000 cubic feet per square foot of outside air has been delivered to the space.

Conduct baseline IAQ testing after construction ends and prior to occupancy using testing protocols consistent with the EPA Compendium of Methods for the Determination of Air Pollutants in Indoor Air.

15.3 HVAC Systems IAH:

15.3.1 Chilled Water Systems - The water flow through the centrifugal chillers at IAH is a variable flow primary chilled water system. The CUP utility distribution system at IAH serves Terminals A through E and the FIS, and runs in an east/west direction generally parallel to the terminal complex generally in the ceiling of the train tunnel. The design chilled water supply temperature is 42 F .

The IAH Terminals have their own supply pumps tapping off the main headers (primary system), which are intended to provide the building internal pressure and flow requirements. A VFD controls these pumps in order to maintain sufficient pressure for operation of the building system.

15.3.2 Heating Hot Water Systems IAH - The heating water system at IAH is a constant flow primary system with shell and tube heat exchangers supplying a secondary building variable flow system. The design temperature of the primary supply is 240 ^{O}F. However, all secondary systems shall be designed for the possibility of a primary supply temperature of 300 ^{O}F. Higher temperature conditions can occur during periods of very cold weather. The secondary water temperature of the shell and tube heat exchangers shall be designed for 180°F return with a 240°F supply.

15.3.3 Hot Water Heaters - Economical and practical consideration should be given to use locally mounted natural gas fired heating hot water heaters to reduce the load on and tie into the central heating system.

ASME diaphragm type expansion tanks located in each building pump room are to be utilized for each building Hot Water System (HWS). The tank controls the Hot Water Return pressure between 20 psig to 80 psig.

Chemical feeder shot tanks are to be provided on all secondary, tertiary systems.

15.3.4 Chilled and Hot Water Metering –Flow, differential pressure and differential temperature measurement is required for all chilled and hot water applications served by the CUP. Flow is measured through the use of orifice plates or insertion turbine meters. Temperature is measured through the use of 100 ohm platinum RTD's mounted in supply and return piping that send signals to the CUP Distributed Control System (DCS). The DCS calculates the energy usage using the flow and temperature measured.

15.3.5 Closed Loop Glycol Systems –
When Point of Use Pre Conditioned Air is not utilized, Centralized Jet Bridge or booster Jet Bridge aircraft cooling systems shall use a closed loop heat transfer fluid that shall be 25% by volume glycol with deionzed water. Bridge mounted fan coil units with electric heat shall provide HVAC requirements. Glycol expansion tanks shall be sized for maximum outside air temperatures for the glycol fluid due to lengthy time exposure of glycol to airside environments. Overflow catch tanks with alarms are required to contain potential spills.

15.4 General HVAC System Requirements – All areas used primarily to accommodate people-oriented activities such as offices, concessions, concourses, cafeterias, etc., shall be air conditioned and heated. Areas classified as storage or manufacturing shall be mechanically ventilated and heated to the minimum requirements of the Building Code. The criteria for a particular HVAC system will vary somewhat from building type to building type or project to project which may change certain parameters of initial design considerations.

15.4.1 Terminal Buildings - New HVAC systems or renovations of existing systems serving existing Terminal areas should conform to the basic operating parameters of the systems currently in operation. System design for new Terminal facilities should conform to the basic design parameters and equipment and material criteria described herein. Heat pumps, roof top units and plenum mounted condensing units are not allowed without approval from the HAS project manager. Use of 3 way chilled water valves are prohibited. Terminal buildings shall be kept in positive pressure and shall be monitored magnahelic gauges using pressure differential sensors in multiple strategic locations inside the building and at least two sensors (with high select) on the north and south sides of the terminal when practical. Terminals shall be designed in a way that pressurization is not lost at the times passengers use boarding bridges. Gate sensors shall give signals to Outside Air Units sensors and amount of fresh air shall be adjusted accordingly to prevent pressure loss. At a minimum, ASHRAE 62.1 ventilation requirements shall be exceeded by 30%. Pretreatment shall use chilled water for humidity control Use of desiccants is not allowed.

15.3.2 Buildings Other Than Terminals - Building use and HAS PPM and PDC recommendations shall be used as guides in selecting the type of HVAC system for buildings other than Terminals or those not served by the CUP. In many instances, rooftop direct expansion (DX) packaged systems are satisfactory, pending approval by the Project Manager. When packaged systems are used, the control system supplied by the manufacturer is acceptable and shall have provisions and compatibility for main HAS control system monitoring. Thermostatic zoning must not be compromised when using packaged equipment. Buildings shall be kept in positive pressure and shall be monitored magnahelic gauges using pressure differential sensors in multiple strategic locations inside the building and at least two sensors (with high select) on the north and south sides of the terminal when practical. Split systems are preferred to roof top units. The following criteria shall apply where applicable and subject to HAS Project Manager's approval:

1. Chilled water systems are required for fifty (50) tons and above
2. Air cooled systems can be used to one hundred (100) tons unit capacities
3. Water-cooled systems are required above one hundred (100) tons unit capacities

If available, natural gas is preferred as a source of heating.

15.4 Design Conditions

15.4.1 Heating - The winter inside comfort design temperature shall be 72 °F DB, unless otherwise indicated. Humidification is not required except for special purpose facilities.

15.4.2 Cooling - The summer inside comfort design temperature shall be 75 °F DB, unless otherwise indicated. The design relative humidity will be 50 percent. The coil shall be designed so the building annual RH range shall not exceed 60 percent RH. Face and by-pass coils should be used on all VAV systems to prevent high humidity conditions during partial load (i.e. control supply air temperature with face and by-pass). The use of face and by-pass coils may be reviewed on a case by case basis.

15.4.3 Outside Design Temperatures –

Summer – 98°F DB, 80°F WB
Winter – 20°F DB

15.5 Energy Conservation - Every project of new construction shall meet the energy performance standards set forth by the Houston Commercial Energy Conservation Code. Selection of mechanical equipment shall be based on the standards in the code and be the most proven efficient equipment available in the market today.

Special energy conserving features shall be considered where applicable, such as variable frequency drives, heat recovery, etc. Motors shall be of high efficiency and power factor. Direct Digital Control (DDC) Energy Management Systems are required in all new or renovated Board facilities other than the terminals. Construction and control specifications will be provided by the HAS Planning Design and Construction Division.

15.6 Piping - Piping shall meet the corrosion prevention requirements if underground and shall meet the following requirements:

1. High pressure steam piping – black seamless steel pipe, Schedule 80 welded joints
2. Low pressure steam piping - black seamless steel pipe, Schedule 80 welded joints
3. Condensate (steam) - K copper or schedule 80 steel welded joints
4. High pressure condensate piping - black steel pipe, Schedule 80, threaded. No cast iron fittings above 15 psig
5. Low pressure condensate piping - black steel pipe, Schedule 80, threaded
6. Chilled water piping - black steel pipe Schedule 40, welded
7. Chilled water (inside) - steel or K or L copper
8. Chilled water (underground) - pre-insulated black steel pipe Schedule 40, welded joints
9. Hot water piping - black steel pipe Schedule 40, welded joints
10. Hot water (inside) - steel or K copper
11. Hot water (underground) - pre-insulated black steel pipe Schedule 40, welded joints
12. Refrigerant piping - Type K copper. Entire piping, fittings and valves shall have minimum 300 psi rating.

15.6.1 Flushing of Piping - New welded piping shall be flushed before placing it into service at 12 fps flow for a minimum of 15 minutes. New chilled water and heating hot water piping shall be chemically pacified after flushing. HAS chemical treatment representatives shall be consulted before placing longer lengths of pipe into service.

15.6.2 Hangers and Supports -A pipe stress analysis shall be performed to determine pipe hanger support system and spacing requirements. All hangers and supports shall comply with Manufacturer's Standardization Society (MSS) standards. Vertical pipes must be supported at each floor with pipe clamps. TSA inspection point piping restraints shall be designed as per seismic Category F.

Pipe saddles shall be galvanized metal (for insulated pipe) extending at least twelve (12) inches in length and covering a minimum of half-pipe circumference. Protection shields shall be provided for all insulated pipe. Generally, the gauge shall be as follows:

Pipe Diameter	USS Gauge
Up to 3 inches	No. 22
3 inches through 6 inches	No. 16
Above 6 inches	No. 12

15.6.3 Pipe Identification - All piping in buildings shall be identified by the use of pipe marker bands, with direction of flow arrows. Pipe marker color-coding shall follow standard industry practice ANSI A13.1 "Scheme for Identification of Piping Systems".

15.6.4 Pipe Anchors -A pipe stress analysis shall be performed to determine proper pipe anchor locations.

15.6.5 Expansion Joints -A pipe stress analysis shall be performed to determine the expansion joint system and spacing requirements.

Joints shall be piston-ring, internally guided, double joint expansion joint or a packless expansion joint.

Chilled water and heating water expansion joints shall provide 200 percent absorption capacity of piping expansion between anchors. All chilled and hot water piping joints shall be welded; therefore, special consideration must be given to pipe layout for expansion and contraction.

15.7 Pumps - Pumps are required to meet the following criteria:

15.7.1 Horizontal Split Case

1. Pumps shall be base mounted single stage double suction with an impeller diameter of less than 85% of the published impeller selection range.
2. Pump volute shall be cast iron axially split case with ANSI flanges.
3. Pump shall have bronze casing wear rings.
4. Pump impeller shaft shall be Type 416 stainless steel with stainless steel shaft sleeves.
5. Pump impeller material shall be cast bronze.
6. Pump bearings shall be re-greasable ball bearings rated for 40,000 hours at rated flow/pressure conditions.
7. Pump mechanic al seals and springs shall use stainless housing, BUNA bellows and gaskets, and a carbon ceramic seal.

15.7.2 End Suction Pumps

1. Pump volute shall be cast iron
2. Pump impeller shaft shall be SAE 1144 steel with aluminum bronze sleeve
3. Pump impeller shall be cast bronze.
4. Pump shall have same mechanicals as split case design. 15.7.3 Vertical In Line Pumps

1. Pump volute shall be cast iron
2. Pump impeller shaft shall be SAE 1144 steel with aluminum bronze sleeve
3. Pump impeller shall be stainless steel.
4. Pump shall have a design to permit maintenance without removing the motor.

15.7.3 Condensate Pumps and Receivers - Condensate units shall be of the duplex type with two (2) bronze fitted, close coupled centrifugal pumps with pressure gauge taps with stop cocks on both suction and discharge sides.

Receiver tank fabricated of cast iron or steel, as applicable, and equipped with required float switches and alternator to provide automatic alteration of pumps. The receiver shall be provided with condensate return, vent, overflow, and valved drain connections.

15.7.4 Chilled Water and Hot Water Pumps - "Stand-by" pumps are required on most facilities, and especially for facilities containing computer rooms. Some applications of chilled water pumps may require emergency power if supplying computer rooms.

Provide pressure gauge taps with stopcocks and gauges on suction and discharge sides of pump. Pumps for chilled and hot water systems shall be controlled via tie-in to the CUP Distributed Control System. All requirements must be verified and approved by the HAS Project Manager.

Provide thermometer wells on suction and discharge sides of pumps. Chilled and hot water pumps shall be insulated. Impellers shall be one piece, hydraulically and statically balanced and keyed to the shaft.

Pumps shall be of a high efficiency design. The pump motor assembly shall be mounted on a common steel or cast iron base. Pump and motor bearings shall be grease lubricated complete with alemite fittings. Two (2) pumps of similar capacity and head are recommended rather than one (1) large pump of total building capacity.

Variable volume pumping systems with variable frequency electric drives are required. Where multiple pumps are utilized, a single drive may be utilized with the capability for base loading one pump on constant speed with the other on variable speed.

Pumps shall be non-overloading when operated in parallel or individually.

15.8 Air Handling Units - Air Handling Units shall adhere to the following requirements:

15.8.1 Air Handlers (Package and Built-up Equipment)

1. Provide a hand operated "auto/on/off" switch and remote control terminations at each air handler location with properly sized integral heaters. Also provide a fused disconnect switch at each location. AHU Fans that provide more than 5000 cfm of air shall be AHRI certified semi custom watertight and airtight units and shall have fan array system.

2. Provide a Type 304 stainless steel drain pan (insulated on both sides) with a drain line not less than ¾ inch in diameter or size of tap on drain pan. Use a plugged tee for all changes in direction rather than ninety (90) degree ell. Condensate shall be drained to the sanitary sewer. All condensate lines shall be insulated.

3. Air handling equipment should be equipped with filters as per ASHRAE 52.2. High efficiency filters shall be provided on equipment over 5,000 cfm, medium efficiency filters on less than 5,000 cfm. Filters are to be provided with magnetic gauges (alarmed) which shall measure pressure drop across the filter. Filters shall be two (2) inch thick throwaway, efficient, pleated type contained in rigid media frame with supporting maze across leaving faces of media. Two (2) inch filters shall be used in equipment below 5,000 cfm.

4. Medium efficiency filter design is – 500 ft/min, 0.28” w.g. initial resistance, MERV -8, preferred roll type for outside air handlers

5. High efficiency filter design is – 500 ft/min, 0.68” w.g. initial resistance, MERV–14.

6. Generally, space conditioning filters shall be two (2) inch thickness with dimensions of 20" x 20", 20" x 25", 16" x 20" or 16" x 25" preferred.

7. AHU Fans that provide more than 5000 cfm of air shall be AHRI certified, semi custom, self structured, watertight and airtight units and shall have fan array system. There should not be any condensation forming on the exterior of the unit.

8. Casing Base Rail – Full length galvanized welded steel, bolting not permitted.

9. Casing Wall – exterior wall thickness of 18 gauge, interior wall 20 gauge using G90 galvanized steel.

10. Insulation – minimum of 2” thick expanded foam or non-compressed fiberglass insulation.

11. Access Doors – Galvanized steel double wall with an access section of a minimum of 24”.

12. Coil Casings – Type 304 stainless steel.

13. Fans – spring mounted fan drives with internal flexible connection on fan discharge. Belts use is discouraged for motor-fan interface.

14. Bearings – 200,000 hours at maximum horsepower and speed, grease lubricated pillow block bearings with grease fittings accessible from outside the unit. Bearing shall be protected from induced currents.

15. Water Coils – counter flow with side coils into casing through removable panels and blank off sheets, maximum water velocity of 8 ft/sec. and either 1/2" or 5/8" outside diameter tubes, 12 fins/inch with copper headers, 1/2" tube thickness – 0.020", 5/8" tube thickness 0.025". Maximum airflow shall not exceed 500ft/min.

16. Outside Air Handling Units – In addition to above Outside Air Units (OSA) shall have the following systems:

17. Pre filters - medium efficiency roll type

18. Air purification systems shall be capable of –

a. Controlling microorganisms such as mold, bacteria, vapors, and other airborne particulates.
b. Controlling gas phase contaminants including volatile organic compounds found in airport applications.
c . Capable of reducing static space charges. Complies with UFC 4-010-01 (8 October 2003 including change 1, 22 January 2007) Standard 18. Emergency Air Distribution Shutoff for Antiterrorism Force Protection.
d. As tested by the Department of the Army, U.S. Army Dugway Proving Ground, Dugway, UT in conjunction with minimum MERV 13 rated filtration, the photocatalytic oxidation system must be able to remove or neutralize better than 98% of airborne bacterial spores.
e. At a minimum must be able to filter the following:

Jet and Automotive Exhaust
Aldehydes
Acetic Acid
Carbon Monoxide
Sulfur oxides
VOCs
Bioeffluents
Acetaldehyde
Acetic Acid
Acetoned
Allyl Alcohol
Ammonia
Amyl Alcohol
Butyric Acid
Diethyl Ketone
Ethyl Acetate
Ethlyl Alcohol
Formaldehyde
Methyl Alcohol
Hydrogen Sulfide
Methane
Methyl Alcohol
Phenol
Toluene

d. UL Certification

The entire assembly shall bear the UL Classification Mark and be investigated in accordance with ANSI/UL 1598, "Luminaires," and ANSI/UL 1995, "Heating and Cooling Equipment," under the Air Duct Mounted Accessories category (ABQK). Compliance is to be verified by the UL Online Certifications Directory

19. High efficiency filters
20. Hot water coil (pre-treat coil)
21. Chilled water coil
22. VFD controlled fan motor
23. CO2 monitor to maintain minimum CO2 levels

a. 18. Generally, electric motor speeds in excess of 1800 rpm are to be discouraged.

b. 19. Chilled water and hot water coils shall be of the continuous copper tube type with copper or aluminum fins.

c. 20. All coils shall be of the cleanable and drainable type. Each tube shall be accessible without piping disconnect. Headers shall be removable at the opposite end (as exemplified by Trane type "K").

d. 21. Access covers to water coils on the AHU housing shall be readily removed for access to coil headers without piping disconnects or demolition of surrounding structures.

e. 22. Cooling coil design shall be based on the following criteria:

24. C o il Entering water temperature – 42.5^{o}F
25. C o il Water temperature rise – 16°F
26. Maximum water pressure drop – 10 ft.
27. Maximum air pressure drop – 1" WC
28. Maximum face velocity – 500 ft/min.

a. 23. Heating coil design shall be based on the following criteria:
- Entering water temperature – 240°F
- Water temperature drop – 60°F
- Maximum water pressure drop – 5 ft.
- Maximum air pressure drop – 0.5" WC

15.8.2 Room Fan and Coil Units (Floor and Wall Mounted Equipment) - Generally, the use of fan and coil units (FCU) is discouraged.

FCU's shall have a high-medium-low-off switch where adjustment can be made without removal of access door or unit housing. This switch shall be easily accessible for room or area occupant personal adjustment.

FCU's shall be equipped with permanent galvanized type filters.

15.9 Water to Water Hot Water Generators for Space Heating in Terminal Buildings - Shall adhere to the following requirements:

1. Shell and tube or plate frame construction
2. The tank shall be ASME stamped at or above the scheduled working pressure.
3. Factory furnished and approved accessories, including ASME temperature and pressure relief valve, shall be used.
4. Entering water temperature – 240F, leaving water temperature – 180F. Will be operable at 300F.

15.10 Package HVAC System Equipment - Where building use, type, and HAS/PDC and HAS/PPM review justifies the use of package equipment, the following shall apply:

1. Rooftop Systems (generally discouraged) - The rooftop equipment shall be completely self-contained, with factory wired controls and factory assembled components and piping. Equipment shall have two (2) inch thick pleated replaceable media filters. Compressors shall have five (5) year warranty, including parts and labor (5 tons and under). System shall be screened from public view to the satisfaction of the HAS project manager.

2. Split Systems (preferred) - Split systems shall consist of furnace, coiling section plenum with direct expansion cooling coil, air-cooled condensing unit or heat pump, piping, controls, etc. All components shall be factory wired and assembled. Furnaces shall have filter rack complete with one (1) inch thick throwaway filters. Compressors shall have five (5) year warranty, including parts and labor (5 tons and under).

3. Efficiency shall be as required by ASHRAE 90.1, latest edition.

15.11 Ductwork - All ductwork systems shall be constructed and installed in accordance with SMACNA and ASHRAE guides. Specifically according to SMACNA's "HVAC Duct Construction Standards – Metal and Flexible Ducts". For all AHU ductwork pressure class be medium class shall constructed to 4" wg (min) seal class shall be Class A. Any variable air volume system duct of 1" (250 Pa) and 1/2" w.g. (125 Pa) construction class that is upstream of the VAV boxes shall meet Seal

Class B.

Duct material shall be zinc-coated sheet steel of the thickness of the metal and stiffeners as indicated in the SMACNA Manual. The seams shall be sealed per SMACNA's Table 1-2 Standard Duct Sealing Requirements"

Wherever ductwork is connected to fans, air handling units or other equipment that may cause vibration in the duct, the connection to the equipment shall be by means of a flexible connection constructed of fire resistant flexible canvas or other approved material. The connection shall be suitable for the pressures at the point of installation.

Plenum return is not accepted. Returns will be ducted as well. All ducts shall be insulated. Airflow measuring stations accompanied with temperature sensors shall be installed and interfaced to Building Management System wherever a branch of duct handles 10% of the total cfm of the dedicated AHU.

All ductwork installed below the floor in crawl spaces or below grade shall be constructed with watertight joints and shall be tested and proved tight before floors are poured. The underfloor duct system may be constructed of fiberglass, PVC or other approved non-metallic material.

All variable volume terminal units shall be equipped with at least a five (5) diameter length of straight rigid duct immediately upstream of the volume control devices.

All discharge ductwork shall have acoustical lining inside duct for minimum of 15 feet or past first ninety (90) degree elbow on downstream side of air handling unit.

Flexible ductwork shall comply with UL 181 Class 1, and shall meet or exceed NFPA 90A-90B rating. Maximum length of flexible duct shall be 5 feet. All diffusors shall have dampered insulated boxes with minimum box height of 1'.

Ducts that are on the critical path shall be leak tested as per SMACNA guidelines.

15.12 Pipe Insulation

15.12.1 Insulation - All insulations, jackets, adhesives, coatings, vapor barrier mastics, etc., shall meet the requirements of NFPA Bulletin 90-A, ASTM E 84, and UL 723, with a flame spread of twenty- five (25) or less and smoke developed rating of fifty (50) or less.

All piping and vessels with a surface temperature less than ambient temperature shall have a vapor barrier covering. The vapor seal shall be continuous, unbroken, and adhere to surface so that the insulation is airtight to omit the possibility of vapor draining into the insulation material.

Form fitted polyurethane insulation shall be used on all coil header piping to the extent necessary to include all valves, flow control valves and other appurtenances utilized to evaluate the performance of the coil.

15.12.2 Chilled Water Piping - Generally, chilled water pipes shall be covered with two (2) inch thick insulation. ASHRAE Standards shall be followed if it results in greater thickness. Concealed and exposed piping shall be insulated with rigid phenolic with ASJ jackets. Outdoor and unconditioned indoors shall be cellular glass. Jacket laps and butt strips should be adhered with vapor barrier adhesive or position sealing system. Tee fittings are not allowed due to bull head pressure.

Galvanized steel saddles (16 gauge - 18 inches long) shall be installed at all pipe supports to protect the insulation. Higher density insulating materials should be used at pipe supports, if required to prevent crushing/cutting of insulation. All exterior exposed pipes shall have aluminum metal jacket as specified below. Direct buried chilled water piping shall be pre-insulated with urethane foam, 1½ inches thick.

15.12.3 Hot Water Piping – Indoor concealed or exposed – rigid phenolic with ASJ jacket. Outdoor or unconditioned indoors shall be cellular glass with aluminum or stainless jacket. Tee fittings are not allowed due to bull head pressure.

15.12.4 Steam and Condensate Piping - High pressure steam piping greater than 100 psig shall be covered with calcium silicate, three (3) inches thick. Calcium silicate insulation shall be used as required for surface temperatures of five hundred (500) degrees °F and above. Fittings for calcium silicate insulation pipe shall be preformed or shop fabricated calcium silicate of same thickness of pipe insulation. All steam, and hot condensate water piping, in tunnels or exposed, shall have a smooth finish aluminum metal jacket on calcium silicate. Minimum jacket thickness shall be .016 inch.

15.13 Insulation

15.13.1 Pump Insulation - Chilled and hot water pumps shall be insulated with flexible elastomeric cellular insulation. Pumps less than thirty (30) hp may not be insulated, however, insulation shall terminate at unions, flanges, etc, in a neat sealing manner, with pump bed plate section designed to drain all moisture.

15.13.2 Duct Insulation - Generally, all ductwork except exhaust ductwork shall be lined in accordance with temperatures involved and current Fire Code. Ductwork insulation materials shall be selected for the function involved, considering sound absorption coefficients, velocities, etc. Particular attention shall be given to internal insulation where fire dampers, fuse links, volume adjusters, etc., are installed to ensure that insulation is securely fastened.

15.13.3 Low Velocity (Internal) - Internal ductwork insulation is not permitted.

15.13.4 Low Velocity (External) - Where external rectangular ductwork insulation is required, particular attention shall be given to joints, terminating edges, operation of air control devices, etc. External duct wrap may be used where insulation is not exposed to abuse. Unless otherwise required, insulation shall be two (2) inches thick, three (3) pound density glass fiber rigid board duct insulation complete with reinforced foil-kraft integral heavy vapor proof covering on the outside surface. Insulation shall have a minimum compressive strength of 140 psf at a ten (10) percent deformation. Securely fasten all edges, joints, etc. to provide a vapor proof duct.

NOTE: This method is least desirable unless required to prevent condensation or peeling of interior insulation due to velocity.

15.13.5 High Velocity (External) - Generally, high velocity ductwork requiring external insulation shall be insulated with blanket wrap fiberglass insulation, 1½ inches thick, one (1) pound density or minimum thermal resistance of 6.0, complete with scrim kraft jacket. Facing overlapping joints shall be at least two (2) inches and held in place with outward clinching staples on approximately four (4) inch centers. Underside of ducts exceeding twenty-four (24) inches in diameter shall be spot cemented and finally secured with sheet metal screws and washers.

15.13.6 High Velocity (Internal) – Internal ductwork insulation is not allowed.

15.13.7 High Velocity (Flexible Duct) - This ductwork shall be UL 181, Class I, with rating to meet or exceed NFPA 90A-90B and reinforced with a perforated sheet metal inner jacket.

15.14 Air Devices and Boxes - The preferred system in the Terminal buildings at IAH and HOU is the use of double duct systems. The use of electric heat should be considered as an option when determined to be economical and practical over a hot water systems. Boxes located above finished ceilings will have adequate ceiling access panels or other means of access to box for maintenance and removal.

Verify all installed or affected ductwork for design CFM air quantities (by independent TAB Contractor). Except for lift out ceiling installation, all access panels will be hinged.

15.15 Controls - Controls shall meet the following requirements:

15.15.1 Building Automation System - Where directed by the tenant Project Manager (for small projects), provisions for any connections to existing automation system controls shall be as required. Otherwise a complete Building Automation System is required and communicating with the existing Control System. All building control systems shall be electronic DDC. Control valves shall be electrically operated/motor actuated in all applications except severe duty such as 600F high pressure steam systems, sewage systems, etc.

15.15.2 Building Control Components – All building control components shall be native BACnet devices designed to perform as defined in the 2004 version of the ASHRAE BACnet. No gateways will be allowed for communication with controllers or the existing Alerton Control System. Communication between controllers, global controllers or routers shall be via dedicated Ethernet LAN. Interface between other BACnet devices (VFD drives, lighting controls, etc.) shall be via MS/TP (Master Slave/Token Passing 78.6 kbs) wherever possible, Ethernet only if appropriate. No other LAN types such as ARCnet or LON are acceptable.

15.15.3 Building Control System – The Building Control System Operator's Console shall be an extension and compatible to the existing Alerton native BACnet system using Microsoft Windows as the operating system. The energy management and control system application program shall be written to communicate specifically utilizing BACnet protocols. The control system shall be specifically based on latest ANSI/ASHRAE Standard 135-, BACnet.

15.15.4 Graphics – Graphics shall be consistent with existing graphics and reside on the existing Alerton BACnet server and Webtalk server.

15.15.5 Network – The existing high speed BMS system shall be used to connect to global controllers.

15.15.6 Individual Space Control - Individual space control is desired for each individual totally enclosed office space or room. Individual VAV units, two position damper or self contained non-system powered variable volume diffusers (8 foot ceiling height maximum) may be utilized.

15.16 Vibration Isolation - To prevent excessive noise or transmission of vibration to the building structure due to the operation of machinery or equipment, or due to interconnected piping, ductwork, or conduit, proper vibration isolation shall be provided.

Static deflection of vibration isolators shall conform to minimum guidelines recommended in the latest ASHRAE Guide and Data Book for the actual floor spans involved, and NFPA 90A. Consideration shall be given to sound transmission by following ASHRAE Guidelines in Design.

The vibration isolation system shall consist of foundation, base, spring isolators and rubber and shear pads, as necessary to provide maximum isolation conforming to ASHREA guidelines.

15.17 Noise Control - Mechanical noise levels shall be controlled by proper design of the noise producing mechanical and electrical equipment such as fans, mixing boxes, diffusers, pumps, transformers, emergency generators, etc. so as not to exceed acceptable levels as set forth by industry standard criteria. The acceptable noise level shall be described in terms of NC (Noise Criteria) as defined by the ASHRAE Handbook, Systems Volume, (Sound and Vibration Control Chapter) latest edition (American Society of Heating, Refrigeration and Air Conditioning Engineers)

15.18 Tests and Balance - The balancing, testing and adjusting of the heating, ventilating and air conditioning systems shall be performed by an independent technical firm or balancing agency not involved in the design. Balancing firm shall be Associated Air Balance Council (AABC) certified. All tests shall comply with certification agencies standards and practices. Details regarding testing procedures shall be approved by the HAS project manager. Test results witnessed and verified by HAS inspector.

PLUMBING

15.4 General Information -This SECTION defines general design criteria that applies to the design of plumbing at the HAS airports. All Tenant Projects shall include design for the replacement of all existing plumbing and design elements, including but not limited to grease lines and grease traps.

15.5 Energy Conservation - The plumbing system designer shall consider using such techniques as controlling hot water temperatures, water pressures, providing faucets with flow restrictors. The economic use of thermal insulation, automatic shutdown of water heating and circulating systems, occupancy sensor for automatic flushing, use of automatic closing faucets, and using minimum energy consuming equipment to provide maximum energy efficiency shall be considered. The plumbing system designer should understand how the building consumes energy. When this is understood, energy conservation design practices should become integrated into the building allowing it to operate more efficiently and use less energy, while meeting the needs of the user.

15.6 Piping - Piping should meet the following requirements:

1. Domestic cold water (inside) - K or L copper with silver solder (95-5) no lead.
2. Domestic cold water (outside) - cast iron mechanical joint Class 150 or PVC.
3. Domestic hot water (inside) - K copper.
4. Domestic hot water (outside above ground only) - K copper or steel.
5. Sanitary sewer (inside) - cast iron above grade, PVC below grade.
6. Sanitary sewer (outside) - PVC.
7. Subsoil drainage - perforated PVC, PVC.
8. AC unit drains - Hard drawn copper drainpipe.
9. Equipment vents - steel.

NOTE: 50-50 solder shall not be used for any pipe jointing. No direct buried copper piping shall be permitted inside or outside facilities. The use of ferrous metal pipe and fittings under slabs shall be reviewed on a case by case basis.

15.21.1 Hangers and Supports -All pipe must be adequately supported throughout. Generally, hangers shall be split ring or clevis type. However, trapeze hangers constructed of steel channels with welded spacers and steel rods may be used. All hangers and supports shall comply with Manufacturer's Standardization Society (MSS) standards. Vertical pipes must be supported at each floor with pipe clamps.

Provide pipe saddles fabricated from galvanized metal (for insulated pipe) extending at least twelve (12) inches in length and covering a minimum of a half-pipe circumference. Generally, the gauge shall be as follows:

Pipe Diameter	USS Gauge
Up to 3 inches	No. 22
3 through 6 inches	No. 16
Above 6 inches	No. 12

15.21.2 Pipe Identification -All piping in buildings shall be identified by the use of pipe marker bands with direction of flow arrows at ten (10) foot intervals in concealed spaces; twenty (20) foot intervals in exposed areas and on each side of any penetrated wall, ceiling or floor. Pipe marker color- coding shall follow industry practice ANSI A13.1 "Scheme for Identification of Piping Systems". It is particularly important to label pipes that serve restrooms and concessions for quick response to leaks and/or other issues.

15.22 Water Heaters

Standard Water Heaters -Shall adhere to the following requirements:

1. Water heaters shall be glass lined storage type.
2. Gas water heaters shall have automatic gas shut-off device and be equipped with an American Gas Association certified draft hood. Water heaters shall utilize electric ignition devices.
3. Electric water heaters shall be UL listed.

4. All standard water heaters shall have a ten (10) year limited warranty.
5. All energy saver water heaters shall meet ASHRAE Standards for Energy Efficiencies, latest edition.
6. Water heater drains shall have valves and shall be plumbed to a floor drain with copper piping.
7. All water heaters shall be readily accessible.
8. Electric water heaters located in ceiling/attic spaces shall be accessible by permanent ladder or stairway, an unobstructed walkway (minimum 24" in width) and a 30" x 30" minimum work platform with lights located over the walkway and service area. Locate the switch at the access opening.

15.23 Plumbing Fixtures and Accessories – All plumbing and fixtures must be inline with the latest HAS restroom design guidelines. All exposed metal work at fixtures shall be brass with chromium plate. All faucets, fittings, supply stops for fixtures, and similar devices shall be one (1) manufacturer unless otherwise required. Each fixture shall contain standardized interchangeable operating units made up of separate renewable stem, seat, washer retainer, and nut. All faucets and fittings must close with the water pressure. All fixtures shall be installed with supply stops/valves accessible at the fixtures.

All fixtures and accessories listed apply to Board owned, operated or maintained buildings. Some fixture and accessory preferences may change over time depending upon current maintenance warehouse stocking. Tenants may have different preferences and shall be consulted.

On renovation projects, an effort shall be made to match existing fixtures and trim. On renovation projects where fixtures and trim cannot be matched and on new projects, fixtures shall be water conserving American Standard or an approved equal.

15.23.1 Water Closets -Wall-hung water closets are preferred. Water closets shall be white, vitreous china, siphon jet, elongated bowl, with white open-front seat without cover.

Flush valves for water closets in Terminal buildings shall be as follows:

1. Toto self-energizing flush valves TETIGNC-32 or similar Toto product.
2. Concealed rough brass hydraulically operated flush valve, one (1) inch wheel handle back-check stops, adjustable tailpiece, solenoid motor operator, sensor, vacuum breaker, elbow flush connection and spud coupling for 1½ inch concealed back spud.

3. Automatic sensor for operation of each water closet, with required transformers, controls and complete wiring diagrams for separate operation in each toilet, all as recommended and approved by flush valve manufacturers.
4. Flush valves as described above are approved, or an approved equal may be used.
5. Flush valves in other facilities shall be Toto self energizing flush valves TETIGNG-32 or similar Toto product, wall mounted flush valves.

15.23.2 Urinals -Wall-hung urinals are preferred. Urinals shall be white, vitreous china, wash-out type. Flush valves for urinals in Terminal buildings shall be as follows:

1. Toto self energizing flush valves TETIGNG-32 or similar Toto product
2. Concealed rough brass hydraulically operated flush valve, ¾ inch wheel handle back-check stops, adjustable tailpiece, solenoid motor operator, sensor, vacuum breaker, elbow flush connection and coupling for ¾ inch concealed back spud, wall and spud flanges for each urinal.
3. Automatic sensor for operation of each urinal with required transformers, controls and complete wiring diagrams for separate operation in each toilet, all as recommended and approved by flush valve manufacturers.
4. Flush valves as described above are approved, or an approved equal may be used.
5. Flush valves in other facilities shall be Toto self-energizing flush valves TETIGNG-32 or similar Toto product, wall mounted flush valves.
6. Meet accessibility requirements.

15.23.3 Lavatories – Wall-hung white enameled cast iron or white enameled cast iron self-rimming lavatories with twenty (20) inches by eighteen (18) inches rectangular basin with splash back are preferred. Faucets shall be "Kohler" brand or equivalent self closing adjustable from five (5) seconds to fifteen (15) seconds.

15.23.4 Electric Water Coolers (EWC) -Wall hung Halsey-Taylor or equivalent electric water coolers are preferred. Electric water coolers shall meet accessibility requirements. Some Terminal buildings have a central water cooling system. The Designer shall investigate the possibility of connecting to this system where it is available.

15.23.5 Service Sinks - Service sinks shall be white enameled cast iron, twenty (20) inches by twenty-two (22) inches, blank back with wall hanger supports. Faucet shall be a "Kohler" brand or equivalent wall-mounted rough plated faucet with valve units, vacuum breaker, wall brace, threaded spout with pail hook.

Trap shall be adjustable standard for three (3) inch pipe connection with cleanout plug and strainer, enameled inside.

Rim guard shall be nine (9) inches and twelve (12) inches stainless steel rim guard, front and sides.

15.23.6 Mop Basins - Mop basins shall be one-piece mop service basin, size twenty-four (24) by twelve (12) inches high outside, with Type 304 stainless steel, 20 gauge cap, continuous on all sides, with wall flashing on back and sides as required. Provide silicone base for full seal at floor. Grout entire installation level.

Service faucet shall be chrome plated “Kohler” brand or equivalent with vacuum breaker, integral stops, adjustable wall brace, pail hook, and ¾ inch hose thread on spout, eight (8) inch spread. Hose and hose bracket shall be thirty (30) inches long flexible, heavy-duty % inch rubber hose, cloth reinforced, with ¾ inch chrome coupling at one end. Five (5) inch long bracket by three (3) inch wide, with rubber grip.

Mop hanger shall be twenty-four (24) inches long by three (3) inches wide, 18 gauge No. 302 stainless steel attached with flat head, slotted machine screws.

15.24 Pumps

15.24.1 In-Line Circulating Pumps -Pumps shall be low lead or stainless steel for domestic water service. Provide a line size ball valve on suction and discharge side of pump. Provide unions or bolted flange connection on each side of pump. Pressure taps and thermometer wells are not required on in-line circulators. Sleeve type bearings are acceptable for in-line pumps.

15.24.2 Submersible Pumps -Generally, submersible pumps are avoided where possible except electric power manholes where high voltage switches or tap boxes are installed. Diaphragm actuated pumps are preferred rather than float actuated pumps.

15.24.3 Sump Pumps -Generally, duplex sump pumps are required when located in a mechanical/electrical equipment room containing high voltage switchgear or motor control panels. A simplex pump may be used if area does not contain critical equipment.

Provide a mechanical alternator on duplex pumps and provide a separate circuit and circuit breaker for each pump. Provide check valves, and bypass pipe work and valves as required (in-line check valves are not recommended). Pumps shall be complete with automatic float switch with rod, rod guide and copper float.

Pumps shall be of the wet-pit type complete with gas tight sump cover, curb ring, grease lubricated, including alemite fittings extended to pump base plate.

Pumps shall be heavy-duty, fully submersible, vertical centrifugal, open non-corrosive vortex impeller type with vertical drip- proof type motor with anti-friction grease lubricated bearings.

Where sump pumps are installed to provide protection for mechanical/electrical equipment, a high water alarm bell shall be provided in the area and alarm contacts should be provided for a central monitoring system.

Where pumps of any type are installed in a lift station it shall be equipped with a high water alarm, a red flashing beacon to indicate alarm status and remote/visual monitoring capabilities, such as M80 or similar notification systems.

15.24.4 Sewer Ejector Pumps -Sewer ejector pump design and selection design criteria are the same as those listed for "Sump Pumps" except sewer ejector pumps shall be of the standard three (3) inch, non-clog vortex type or grinder type specifically designed and installed for purpose intended.

15.25 Floor and Roof Drains

15.25.1 Floor Drains -All toilet rooms shall be equipped with at least one (1) floor drain, or minimum number as required by code. A trap primer system shall be provided for floor drains in public rest rooms.

Do not locate drains under machinery, cabinets, appliances etc. or within six (6) inches of any wall. All floor drains must be readily accessible. Drains shall have sealed leaves to prevent odors resulting from infrequent use.

15.25.2 Roof Drains -Roof drains shall be compatible with roof system and shall not be located within the structure.

The Designer shall use six (6) inches per hour as a minimum rainfall intensity guideline for sizing roof drains.

15.26 Backflow Preventers - Where the service line provides potable water for a domestic service a check valve shall be installed when the service line is tapped off a water main. A backflow preventer shall be installed on any domestic water line serving other closed or chemically treated systems that could foreseeably contaminate the potable water line.

15.27 Shock Absorbers -Provide eighteen (18) inch air chamber at each hot and cold water outlet adjacent to fixture outlet. Diameter of chamber shall be a minimum of 1½ times that of the service line to the fixture device.

Chamber and cap shall be of the same material as supply piping.

Hydraulic shock absorbers may be used in accordance with Water Hammer Arresters Standard, PDI-WH-201, latest revision.

15.28 Insulating Unions and Adapters - Provide dielectric insulating unions or adapters as required between copper and steel pipe and equipment. Dielectric insulators/adapters shall contain nylon insulation.

15.29 Pipe Sleeves - Provide pipe sleeves for all pipes passing through masonry and concrete construction.

The annular space between pipes and sleeves must be permanently sealed and sleeves below grade must be watertight.

Pipe joints should not be made closer than twelve (12) inches to a wall, ceiling or floor penetration, unless such pipe is welded.

15.30 Vibration Isolation -To prevent excessive noise or transmission of vibration to the building structure due to the operation of machinery or equipment, or due to interconnected piping, ductwork, or conduit, proper vibration isolation shall be provided. HVAC, fire and plumbing transmission lines that are located in the proximity of TSA security areas shall have seismic design as per category F.

Static deflection of vibration isolators shall generally conform to minimum design criteria recommended in the latest ASHRAE Guide and Data Book for the actual floor spans involved.

A single vibration isolation manufacturer shall supply vibration isolation equipment for any one project. The vibration isolation manufacturer and his representative shall have been engaged in the business of vibration isolation for no less than five (5) years.

15.31 Grease Traps - Wastewater from disposers, sinks, dishwashers, floor drains and floor sinks in food service facilities shall drain to a grease collection system or through a grease trap or grease interceptor serving one or more facilities. Installation shall comply with the Plumbing Code. Kitchen areas shall have under sink automated grease traps.

END OF SECTION 15

16 ELECTRICAL & COMMUNICATIONS

PART 1 - ELECTRICAL

16.1. General Information - This Chapter defines general design criteria that apply to the design of electrical systems at HAS airports. Chapter 1 should be consulted for specific Airport regulations and standards that also apply.

The electrical design criteria in this section are organized into three (3) distinct sections: interior electrical, exterior electrical and airfield electrical.

16.1.1. Power System Studies – a load flow, short circuit, coordination study, and arc flash study for the electrical power system shall be preformed.

The load flow analysis shall be performed first and be performed as follows.

Load Flow Analysis: The purpose of the load flow calculations shall be to analyze the steady-state (quiescent) performance of the power system under various operating conditions and to study the effects of changes in equipment configuration. The load flow studies shall be able to determine the following:

a) Component or circuit loadings

b) Steady-state bus voltages

c) Reactive power flows

d) Transformer tap settings

e) System losses

f) The load flow analysis shall be conducted under two modes of operation. The loading under the first mode of operation shall be based on the instantaneous load values collected during the field effort. The loading under the second mode of operation shall be based on an 80% design criteria of the load centers.

From the results of the load-flow/voltage drop calculations, an analysis and report shall be prepared, based on the NEC, to indicate areas of overloaded conductors/load-centers and areas of excessive voltage drop in the conductors

The short circuit and coordination study reports shall provide an evaluation of the electrical power systems and the model numbers and settings of the protective devices. The report shall be a certified report summarizing the short circuit and coordination study and conclusions or recommendations which may affect the integrity of the electric power distribution system. As a minimum, the report shall include the following:

1. The equipment manufacturer's information used to prepare the study.
2. Assumptions made during the study.
3. Short circuit calculations listing short circuit levels at each bus.

4. Coordination study time-current curves including the instrument transformer ratios, model numbers of the protective relays, and the relay settings associated with each breaker.
5. Comparison of short circuit duties of each bus to the interrupting capacity of the equipment protecting that bus.
6. All data which was used as input to the report. This data shall include cable impedances, source impedances, equipment ratings, etc.
7. The short circuit study shall be performed in accordance with latest applicable IEEE and ANSI standards. Provide calculation methods and assumptions, the base per unit quantities selected, one-line diagrams, source impedance data including power company system characteristics, typical calculations, tabulations of calculation quantities and results, conclusions, and recommendations. Calculate short circuit interrupting and momentary (when applicable) duties for an assumed 3-phase bolted fault at each supply switchgear lineup, unit substation primary and secondary terminals, low-voltage switchgear lineup, switchboard, motor control center, distribution panelboard, pertinent branch circuit panelboard, and other significant locations throughout the system.
8. The study shall be in compliance with the IEEE 141-86 (Recommended Practice for Electric Power Distribution for Industrial Plants), IEEE 242-86 (Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, OSHA 29 CFR Part 1910, NEC, NFPA 70E, and IEEE 1584

16.1.1.1. Short Circuit Study – The available short circuit current shall be calculated using the "direct method" by IEEE 242 on all projects having services greater than 100 kVA at 480 volts or 50 kVA at 208 volts. The fault current shall be shown on the drawings at each applicable bus and should include the contributions from all premises motors, stand-by generators, and the utility power source. As a minimum, each short circuit study shall include the following:

1. One-Line Diagram:
   a. Location and function of each protective device in the system, such as relays, direct-acting trips, fuses, etc.
   b. Type designation, current rating, range or adjustment, manufacturer's style and catalog number for all protective devices.
   c. Power, voltage ratings, impedance, primary and secondary connections of all transformers.
   d. Type, manufacturer, and ratio of all instrument transformers energizing each relay.
   e. Nameplate ratings of all motors and generators with their subtransient reactances. f. Sources of short circuit currents such as utility ties, generators, and etc.
   g. All significant circuit elements such as transformers, cables, breakers, fuses, etc.
   h. Emergency as well as normal switching conditions.
   i. The time-current setting of existing adjustable relays and direct-acting trips, if applicable.

2. Impedance Diagram:

   a. Available MVA or impedance from the utility company.
   b. Local generated capacity impedance.
   c. Bus impedance.
   d. Transformer and/or reactor impedances.
   e. Cable impedances.
   f. Equipment impedances.

g. System voltages.
h. Grounding scheme (resistance grounding, solid grounding, or no grounding).

3. Calculations:

a. The paths and situations where short circuit currents are the greatest shall be determined. Assume bolted faults and calculate the 3-phase and line-to-ground short circuits of each case.
b. The maximum and minimum fault currents shall be calculated.

16.1.1.2. Coordination Study - As a minimum, the coordination study for the power distribution system shall include the following on 5-cycle, log-log graph paper**:**

1. Time-current curves for each protective relay or fuse showing graphically that the settings will provide protection and selectivity within industry standards. Each curve shall be identified, and the tap and time dial settings shall be specified.
2. Provide time-current curves graphically indicating the coordination proposed for the system. Include with each curve sheet a complete title and one-line diagram with legend identifying the specific portion of the system covered by that particular curve sheet. Include a detailed description of each protective device identifying its type, function, manufacturer, and time-current characteristics. Tabulate recommended device tap, time dial, pickup, instantaneous, and time delay settings.
3. Time-current curves and points for cable and equipment damage.
4. Circuit interrupting device operating and interrupting times.
5. Indicate maximum fault values on the graph.
6. Sketch of bus and breaker arrangement.
7. In the protective device evaluation and coordination study include utility company device characteristics, system medium-voltage equipment relay and device characteristics, low-voltage equipment circuit breaker trip device characteristics, pertinent transformer characteristics, pertinent motor and generator characteristics, and characteristics of other system load protective devices. Include at least all devices down to largest branch circuit and largest feeder circuit breaker in each motor control center, and main breaker in branch panelboards.
8. Include all adjustable settings for ground fault protective devices. Include manufacturing tolerance and damage bands in plotted fuse characteristics. Terminate device characteristic curves at a point reflecting the maximum symmetrical or asymmetrical fault current to which the device is exposed.
9. When emergency generator is provided, include phase and ground coordination of the generator protective devices. Show the generator decrement curve and damage curve along with the operating characteristic of the protective devices. Obtain the information from the generator manufacturer and include the generator actual impedance value, time constants and current boost data in the study. Do not use typical values for the generator.
10. For motor control circuits, show the MCC full-load current plus symmetrical and asymmetrical of the largest motor starting current and time to ensure protective devices will not trip during major or group start operation.

16.1.1.2. Arc Flash Study – An Arc Flash Hazard Analysis for each piece of electrical equipment shall be performed in accordance with OSHA 29 CFR Part 1910, NEC, NFPA 70E, and IEEE 1584 and shall submit an Arc Flash Hazard Analysis report as specified herein. The Arc Flash Hazard Analysis shall be performed in association with, or as a continuation of, the short circuit study and protective-device coordination study.

Arc Flash Hazard Analysis calculations shall lead to a selection of a level of Personal Protective Equipment (PPE) that is a balance between the calculated incident energy exposure and the work activity being performed, while meeting the concerns of:

- Providing adequate protection
- Avoiding the need for more protection than is warranted

Results of the Arc Flash Hazard Analysis shall be used to identify the flash-protection boundary and the incident energy at assigned working distances throughout any position or level in the overall electrical generation, transmission, distribution, or utilization system.

The analysis shall include, but shall not be limited to, the following:

- A tabulation of the symmetrical RMS bolted fault current available and X/R ratio at each piece of electrical equipment.
- A tabulation of the arc fault current available at each piece of electrical equipment.
- A list containing the incident energy and the flash-protection boundary for all electrical equipment.
- A list containing each piece of electrical equipment, its corresponding incident energy, hazard rating, and the required Personal Protective Equipment.

Arc Flash Analysis Software: The Arc Flash Hazard Analysis shall be performed using the latest version of SKM Power*Tools for Windows, ETAP software, or approved equal.

Arc Flash Hazard Report: Complete and accurate arc flash analysis information in the Arc Flash Hazard Report shall be submitted. The report shall be submitted to HAS for review before the final report is prepared. The calculated values for flash-protection boundary, working distance, incident energy, and required Personal Protective Equipment shall be submitted and will be prominently displayed on electrical equipment.

Final selection of required Personal Protective Equipment shall be subject to review and acceptance by HAS.

Arc Flash Labeling: After approval of the Arc Flash Hazard Report, Arc flash warning labels shall be furnished and installed on the applicable electrical equipment. All electrical equipment shall be provided with the appropriate ANSI compliant arc flash labeling. Labels shall include the flash protection boundary distance, incident energy, and minimum required Personal Protective Equipment

16.1.2. Preservation of Power Quality - All low voltage power and distribution system designs of facilities with computers and other sensitive electronic loads shall require the installation of isolation transformers and dedicated grounding systems that shall comply with IEEE 1100.

16.1.3. Harmonic Current Limits -The harmonic current distortion of any individual device or piece of equipment specified in the design documents shall not exceed values given in IEEE 519.

16.2. Interior Electrical - The information contained within this section applies to all electrical work inside of the building limit lines.

16.2.1. Conduit - Conduit shall be galvanized rigid metal (RMC) or intermediate metal (IMC) steel except as follows:

16.2.1.1 All underground circuits shall be installed in conduit. Direct buried cable is prohibited. All underground conduit shall be sized at least one trade size larger than NEC requirements for conduit fill.

16.2.1.2 Electrical Metallic Tubing (EMT) may be used where permitted by code except where subject to mechanical or physical damage 6'-0" above floor, if exposed. EMT may not be used in concrete or underground. EMT fittings shall be steel compression type only.

16.2.1.3 Direct buried metallic conduits require PVC coating or approved equal coating to protect against corrosion. A hazard warning tape must be installed 6" below grade directly above the conduit when the trench is backfilled. The section of vertical conduit from 6" below grade shall be rigid or PVC 6' above grade.

16.2.1.4 PVC conduit, Schedule 40 or thicker, may be used underground, direct buried or concrete encased. Conduit bends shall be IMC, PVC coated except as follows:

16.2.1.5 RMC and IMC shall comply with the following spacing guidelines when using pull boxes, hand holes or fittings;

1. Outdoor feeder installations shall have a maximum spacing of 400'.

2. Indoor/outdoor branch circuit installations shall have a maximum spacing of 90'.

3. Indoor feeder circuit installations shall have a maximum spacing of 150'.

4. The above guidelines do not preclude meeting NEC #342.24 & 344.22 limits on the maximum number of bends in a conduit run.

5. All boxes (except in-ground) shall be supported independent of the conduit to the structure of the building.

6. Device boxes shall be a minimum of 4" x 4" x 1-1/2" (use a device ring) and independently supported to the structure of the building.

16.2.1.6 Liquidtight flexible metal conduit (for damp or wet locations) shall be used for connection to all movable, rotating or vibrating equipment, including dry type transformers. Flex connection shall not be used as equipment grounding conductor. Liquidtight flexible metal conduit shall be 6 feet or less in length except where code allows exceptions and a separate equipment grounding conductor shall be run with liquidtight flexible metal conduit.

16.2.1.7 Flex metal or MC type cable, 6 feet or less in length, shall only be used for connection of light fixtures above ceilings. A separate equipment grounding conductor shall be run with flex metal conduit.

16.2.1.8 All concrete encased PVC schedule 40 conduits shall have a minimum of 1 #3 rebar in each corner of duct, running parallel to the conduit runs.

16.2.1.9 Minimum conduit size shall be: ¾ inch for home runs and feeders ½" for branch runs.

16.2.1.10 All RMC and IMC conduit couplings shall be threaded type only.

16.2.2. Wire - Copper shall be used for all wiring, except aluminum wire 1/0 and larger may be used for temporary service conductors.

16.2.2.1. Minimum size #12 AWG, except control wiring may be #14-#18 AWG depending on the application. All conductors #10 AWG and smaller shall be solid type unless used for control wiring. Wire sizes #8 AWG and larger shall be stranded construction. Control wiring shall be stranded.

16.2.2.2. Total voltage drop shall be less than five (5%) percent. Limit feeder drop to less than two (2%) percent and branch circuit drop to less than three (3%) percent.

16.2.2.3. All circuits serving "HID" lighting fixtures shall be limited to a loading of sixty (60%) percent or less of the "Full Load" capacity of the circuit (including circuit breakers, switches, relays, etc.). HID fixtures include high pressure sodium, metal halide and mercury vapor lamps.

16.2.2.4. All direct buried counterpoise group wire used at the Airport shall be No. 6 AWG , stranded bare copper wire conforming to ASTM #B-3 and B-8.

16.2.2.5. Interior power wiring for power and lighting shall be color coded as follows:

480Y / 277V, 3Ø, 4W	208Y / 120V, 3Ø, 4W	240 / 120V, 1Ø, 3W
AØ - Brown	AØ - Black	AØ - Black
BØ - Orange	BØ - Red	CØ - Red
CØ - Yellow	CØ - Blue	N - White
N – Gray	N – White	Grnd – Bare
Grnd - Bare	Grnd - Bare	Iso. Grnd - Green
Iso Grnd – Green	Iso. Grnd - Green	

Panels - Panel main bus may be copper or aluminum with a main breaker. Main breaker and branch circuit breaker shall be bolt on type and thermal - magnetic type with inverse time delay and instantaneous trips. Sizing and arrangement of mains and branch breakers shall be as indicated on the drawings. Panels shall have conductor color code identification. The following shall be used as guidelines for bus bracing and breaker interrupting rating, when interrupting rating calculations are not available;

1. 600V & 480Y- 277V AC – 22,000 AIC
2. 208Y/120V & 240V/120V AC – 14,000 AIC

Switchgear – Switchgear shall be Metal Enclosed with a main bus that shall be copper and shall be tin plated at joints. The main bus shall have bracing of 100,000, 65,000 and 45,000 amp symmetrical short circuit rating. Switchgear shall have all equipped spaces and 25% spare breaker capacity.

The incoming section shall include a power monitoring relay with trending capability, 1-CPT, 2-PTs, 1-VM & VMS, 1-86 & 51G relays, 3- 50/51 relays, 3-CT ?/5, 1-AC ammeter & 3-phase ammeter switch. Circuit breakers shall be stored energy, drawout type, manually operated air circuit breakers. Breakers shall have long time, short time and ground solid state trip elements. Each breaker shall be capable of being racked into the fully connected, test, and fully disconnected positions. Interlocking shall be provided which prevents the breaker from moving unless the breaker is in the open position. All breakers shall have a power monitoring relay device with trending capability.

(Electrical mechanical relay shall not be used when solid stated relays are required. Refer to low voltage and high voltage switchgear on actual job for more details)

16.2.3.2. Fused switches shall utilize current limiting fuses with "rejection" type pins where applicable. A spare fuse panel and a set of three (3) spare fuses of each size used on a project will be furnished.

16.2.3.3. Freestanding switchboard construction shall be specified for bus sizes larger than 800 amps.

16.2.3.4. Redundant services, from two different substations, shall be available from CenterPoint Energy to the Airport electrical distribution system to the Terminal Buildings, FAA Buildings, Emergency Facilities, Crash/Fire/Rescue Stations, Airport Trains, Central Utilities Plant and other critical use facilities. Eight hour or more (to be determined based on need) alternate emergency sources may be considered for true uninterruptible power supply. Terminal building service entrance switchgear shall be double ended drawout air circuit breaker type. Transformers, main breakers and bus on each side of the tie breaker shall be sized to serve the total service load. CenterPoint Energy provides the main services switches and transfer switch (circuit breakers). The owner and/or tenant shall provide all distribution switchgear from this point to the building electrical systems.

16.2.3.6. Freestanding equipment shall be installed on 4” or 6” concrete pad.

16.2.4. Service Entrance - Primary and Secondary service entrance conduits shall be concrete encased. Verify requirements for service entrance with CenterPoint Energy . The primary duct bank shall be marked with red dye.

16.2.5. Notification Requirement - Notify CenterPoint Energy if access to their manholes or vaults is required.

16.2.6. Light Fixtures - Shall include interior, exterior attached to buildings, exterior steps, stairways and parking structures.

16.2.6.1. The Designer shall obtain a list of lamps from the Airport’s Facilities Administration Section through the Airport Contact that are in stock and limit design to lamps that are currently being used for interior lighting. Requirement may be waived if special design warrants, subject to City Engineer approval.

16.2.6.2. Do not specify ballasts that are manufactured exclusively for a particular fixture, or fixtures that require a particular ballast. Avoid use of unusual fixtures, tubes, voltages. All ballast shall be individually fused. Note that the preferred installation where fluorescent fixtures are approved are electronic ballast and T-8 tubes.

16.2.6.3. Lighting system shall be designed in accordance with IES recommendations to provide an energy efficient system with minimum maintenance.

16.2.6.4. Battery (sealed, recombination lead calcium type) operated emergency lights and exit lights will be used to illuminate all means of egress, unless other stand-by power or redundant power systems are available.

16.2.6.5. Exit lights shall be installed on a dedicated circuit with no other equipment connected to it. Provide constant un-switched power to keep battery charged if battery backup is provided. All exit lights shall be "LED" types with a minimum twenty (20) year warranty.

16.2.6.6. Consider use of occupancy sensor controls and dimming for energy management.

16.2.6.7. Use double twin tube type compact florescent lamps in lieu of incandescent where low level down-lighting is require, and dimming is not required.

16.2.6.8. Long term lamp and fixture maintenance should be considered in location of all fixtures. Use very long life lamps in areas difficult to re-lamp and areas along roadways. All proposed installations are required to be supported by a life cycle cost analysis.

16.2.7. Metering - Revenue metering shall be provided at all external tenant facilities. Install metering equipment enclosure in accordance with CenterPoint guidelines All revenue meters shall be smart metering type where trending will be possible through an SCADA system.

16.2.7.1. In Terminal buildings, provide sub-metering for approximately each 30,000 square foot area (approximately one (1) gate). Provide two (2) sub-meters for each area, one (1) for lighting and one for remainder of load.

16.2.7.2. Smart meters shall be kilowatt-hour and kilowatt demand with pulse transmitter. Smart meters must be able to be connect to a SCADA system for trending and monitoring.

16.2.8. Distribution Transformers - Distribution transformers will be three (3) phase, 1500, 2500, or 3000 kVA, 12.47 KV – 5 KV or 12.47 KV – 480/277 V, provided by CenterPoint. Furnish equipment pads in accordance with CenterPoint requirements.

16.2.8. Dry Type Transformers – Dry type transformers will be three (3) phase or single , 15, 25, 50, or 75 kVA, 480/277 V, 208/120V or 240/120V provided by HAS or HAS' contractor. Furnish 4" equipment pads.

16.2.9. Grounding - Consideration shall be given to local conditions affecting grounding methods. Ground resistance shall not exceed limits as established by IEEE for type of facility.

16.2.9.1. Ground rods shall be ¾" x 10' stainless steel, minimum.

16.2.9.2. All ground connections shall be bolted (where accessible) or by the exothermic process.

16.2.9.3. Exothermic welds shall be coated against corrosion where direct buried.

16.2.9.4. All premises ground rods or other NEC approved grounding electrodes shall be bonded together to form the grounding electrode system to limit the potential differences between them and their associated wiring system. There shall be no isolated ground or grounding systems.

16.2.9.5. Quality Assurance:

A. Reference Standards: All grounding work shall conform to or exceed the applicable requirements of the current edition of the NEC- National Fire Protection Association (NFPA) – 70 National Electrical Code (NEC) and the following Commercial Standards

1. **ANSI/IEEE 80 - Guide for Safety in AC Substation Grounding**
2. **ANSI/UL 467 - Safety Standard for Grounding and Bonding Equipment**
3. **IEEE 142 - Grounding of Industrial and Commercial Power Systems**

All equipment furnished shall be listed by and shall bear the label of Underwriters' Laboratories, Incorporated, (UL) or of an independent testing laboratory acceptable to HAS in writing.

B. The grounding system design depicted on the contract drawings is the minimum design required for each building or structure. Each system shall comply with the maximum resistance of 5 ohms to ground. Systems exceeding the maximum resistance specified shall be supplemented with additional grounding provisions and retested until the maximum specified resistance is achieved.

C. Testing: Documented results on the completed ground systems for resistance to ground using an electrical ground resistance tester shall be submitted. The grounding system maximum resistance shall not exceed five ohms under normally dry conditions when measured by the resistance tester. Resistance values above five ohms shall be brought to HAS's attention. All grounded cables and metal parts shall be tested for continuity of connection. Test shall be witnessed by the HAS inspector. The three point testing method is preferred when testing the grounding system or systems.

16.2.10 Lightning Protection - A Lightning Protection System shall be provided for all building structures on the Airport. The lightning protection system shall comply with the 1995 Edition of NFPA 780, Standard for the Installation of Lightning Protection Systems of the National Fire Protection Association. Installation shall be made under the direct supervision of a Certified Master Installer, whose certification has been granted by the Lightning Protection Institute (LPI). Except for cable fasteners, all components of the lightning protection system shall be listed and labeled by Underwriters Laboratories, Inc.

16.2.10.1. For additions to buildings already having a lightning protection system, provide lightning protection in the new construction only and bond to the existing system.

16.2.10.2. Upon completion of the work, the prime contractor is required to transmit on his letterhead an affidavit bearing the notarized signature of the LPI Certified Master Installer that the lightning protection system complies with NFPA 780 and, in building additions, that it has been bonded to the existing system.

16.3. Exterior Electrical - The information contained within this section applies to all electrical work outside of the building limit lines, excluding airfield lighting.

16.3.1. Exterior Lighting Systems -All airport light sources shall be aimed in a manner that will not interfere with FAA Air Traffic Control Tower operations or piloting activities. Where lighting sources are directed toward runway ends or FAA towers, they shall be shielded as may be necessary to deflect the light source down and away from those areas. Lighting systems shall be designed in accordance with IES recommendations to provide an energy efficient system with minimum maintenance.

16.3.1.1. Poles shall be located to provide adequate working clearance for maintenance without disrupting roadway traffic. Poles required to be installed in areas not accessible with bucket truck shall be equipped with mechanical fixture lifting device in accordance with Airport Standards. All high poles modified with fixture lowering devices shall be inspected by the manufacturer of the device. This manufacturer shall issue a certificate as to the proper installation to factory specification with an appropriate warranty period to cover installation and factory defects. HAS prefers a five (5) year warranty period as a minimum.

16.3.1.2. Building or pole mounted fixtures shall be spherical shaped and have a bronze finish. All exterior lighting shall be high pressure sodium. The Designer shall obtain a list of lamps from the Airport's Facilities Administration Section through the Airport Contact that are in stock and limit design to lamps that are currently being used for exterior lighting. Requirement may be waived if special design warrants, subject to City Engineer approval.

16.3.1.3. New underground lighting systems shall be installed in direct buried Schedule 40 PVC. Splices shall be made in pole base or concrete splice box with heavy duty traffic cover. or fixtures that require a particular ballast. Ballasts shall be located at the base of high poles rather than at fixture. Avoid use of unusual fixtures, tubes, voltages, et cetera.

16.3.1.4 Conduit bends shall be IMC, PVC coated, except as follows:

Two (2) inches or less, and runs less than 150 feet long with two (2) or less ninety degree (0 degree) bends.

16.3.1.5 Do not specify ballasts that are manufactured exclusively for a particular fixture, or fixtures that require a particular ballast. Ballasts shall be located at the base of high poles rather than at fixture. Avoid use of unusual fixtures, tubes, voltages, et cetra.

16.3.1.6. Conductor shall be copper and sized based on NEC recommended maximum allowable voltage drop.

16.3.1.7. All ground connections shall be bolted (where accessible) or by the exothermic process. Considerations shall be given to local conditions affecting grounding methods. Ground resistance shall not exceed limits as established by IEEE Standard 142. All ground rods shall be stainless steel, ¾" x 10' 0" minimum.

16.3.1.8. An equipment grounding conductor shall be routed with the phase conductors and bonded to each lighting pole to facilitate the operation of the upstream over-current protective device. The earth shall not be used as the sole equipment grounding conductor.

16.3.1.9. Fixture and system voltage shall match existing for maintenance purposes.

16.3.1.10. Anchor Bolts and Poles – Design Standards:

16.3.1.10.1. ACI 318, most current edition.

16.3.1.10.2. AISC, most current edition.

16.3.1.10.3. AASHTO, Specification for Design and Construction of Structural Supports for Highway Luminaries

16.3.1.10.4. Corrosion Protection - Nuts and top ten (10) inches of anchor bolts shall be hot dipped galvanized. All base plates shall be exposed to air, no grout allowed.

16.3.1.10.5. Anchorage - Anchor bolts shall have full embedment as required by ACI. Specify nut torque requirement.

16.3.1.11. Roadways -The existing roadway lighting system is 480/277 volt, three phase, with power extending to pole bases underground in duct.

16.3.1.11.1. Poles shall be designed to match existing. Fixtures shall be spherical or for pre-arranged locations may be of the "Cobra Head" design similar to State Highway fixtures, except with a painted finish, base coat shall be zinc chromate. Provide conductor for each lighting circuit to facilitate remote control of street light circuits from central automation system in order to override photocell and reduce demand when time-of-day electrical rate is applied.

16.3.1.11.2. Roadway lighting shall be per IES Type II or Type III with distribution obtained by reflectors or in some cases by refractors if approved by the City Engineer.

16.3.1.12. Parking Lots and Will Clayton Parkway and JFK Boulevard – Lighting is supplied by 480/277 volt, 3 phase, distribution system. High mast poles (70 - 100 feet) are supplied with 3 phase, 480 volt, up the pole with 480 volt fixture load balanced between phases. For outside taxiway bridges, lighting is supplied by 480 volt, single phase, distribution system (i.e. 480 volt, 2 wire and ground wire).

16.3.1.13. Apron Lighting -This lighting shall be in accordance with IES Recommended Practice RP-14 "Airport Service Area Lighting" with the following exceptions:

16.3.1.13.1. The Airport design shall provide four (4) to eight (8) fixtures mounted on one (1) or two (2) precast cross members between two standards, sixty (60) feet above the apron, spaced at approximately one hundred (100) feet along the airside face of the Terminal buildings. Currently used fixtures are 1000 watt metal halide and 1000 watt high pressure sodium. New fixtures shall utilize high pressure sodium lamps or other fixture types that provide a wide spectrum range of light and are supported by a life cycle cost analysis. The floodlights are enclosed in spheres with wide and medium horizontal beam spread (up to 100 degrees). Vertical beam spread is minimum with cutoff.

16.3.1.13.2. General lighting near the Terminal buildings is specified at approximately two (2) maintained foot-candles.

16.3.1.13.3. In the service areas, approximately fifty (50) feet to three hundred (300) feet from Terminal buildings, average illumination levels, at five (5) feet above the apron are specified at three (3) to four (4) foot candles horizontal and seven (7) to nine (9) foot candles vertical. The uniformity ratio is in the range of 3:1 (average/minimum) and 6:1 (maximum/minimum). The fixtures have a specified cutoff at four hundred (400) feet from the Terminal building to prevent direct spill onto the taxiways. In addition, internal louvers shall be provided for maximum bare lamp shielding.

16.3.1.13.4. The Designer shall call for submittals of the manufacturer's lighting analysis to include point by point foot-candle calculations to demonstrate the proposal meets the design criteria. In addition, prior to the final acceptance, the Contractor must submit a report, of testing accomplished by an IES certified agency, showing that the installation complies with the specified criteria and the proposal calculated values. These tests shall indicate areas of unacceptable glare as indicated by FAA Air Traffic Controllers or pilots. All testing shall comply with IES recommendations. All adjustments in fixture aiming shall be accomplished by the Contractor at no additional cost to HAS.

16.3.2. Exterior Electrical Systems

16.3.2.1. Standard Lock Out Procedures -Standard electrical circuit lockout procedures are available from Airport Maintenance.

16.3.2.2.1. Redundant services are available and are normally provided for Terminal Buildings, FAA Buildings, Emergency Facilities, Crash/Fire/Rescue Stations, Airport Trains, and other critical use facilities. Other alternate emergency sources may be considered for true uninterruptible power supply.

16.3.2.2.2. All electrical distribution shall be underground.

16.3.2.2.3. Provide all ductwork, equipment pads and metering enclosures in accordance with FAA specifications and standards.

16.3.2.3. Underground Electrical Circuits shall be installed in Schedule 40 PVC. Service entrance conduits shall be encased in concrete.

16.3.2.4. Conductors shall be copper with insulation suitable for wet locations, sized based on NEC recommended maximum allowable voltage drops.

16.3.2.5. Ground Connections shall be bolted (where accessible) or by the exothermic process. Considerations shall be given to local conditions affecting grounding methods. Ground resistance shall not exceed limits as established by IEEE Standard 142. Ground rods shall be ¾” x 10’ stainless steel.

16.3.2.6. Manholes and Handholes shall be provided with heavy duty traffic covers. All circuits shall be labeled with stamped brass tags.

16.4. Airfield Lighting - Runway and taxiway lighting and visual aids shall be designed based on the design standards and requirements of the FAA Advisory Circulars, as appropriately supplemented by the National Electric Code (NEC) as it pertains to vault work and the commercial power side of the vault equipment.

16.4.1. Lighting and Visual Aid Systems and Fixtures -System layout configuration and fixture utilization and design shall be specified by all current applicable FAA Advisory Circulars. Airport operated lighting systems shall be designed for the most critical operational criteria (CAT II/III).

16.4.1.1. In all specifications for lighting and electrical equipment, the item and manufacturer must be listed as approved for use by the FAA. In some instances, requirements above those required for FAA approval will be stipulated. These must be specified precisely; for example "Signs (L-858) - To withstand high wind velocity up to 200 mph regardless of location."

16.4.1.2. Fixtures and lamps shall be specified to match existing equipment whenever possible. Fixtures shall be installed on deep bases (cans) housing the isolation transformers. Inset (shallow) bases shall not be used unless approved by the City Engineer. Runway Distance Remaining Signs and Taxiway Guidance Signs shall be internally lighted to match existing equipment.

16.4.2. Cable and Conduit -Direct burial cable is not permitted. All cables shall be placed in conduit (PVC Schedule 40 as minimum). Bends in underground conduit system are not permitted without a junction box. All cables shall be tagged in manholes with heat sealing tags, Scotch HB-21 or approved equal, imprinted with the circuit number on each side of L823 connectors. 5KV series circuit cables shall be color coded as to circuit type (i.e. Runway CKT, Taxiway CKT, Sign CKT, etc.). Verify color coding with the Airport's Physical Plant Maintenance Section.

16.4.3. Electrical Manholes, Junction Boxes, and Pull Boxes -These structures shall be located outside of runway and taxiway safety areas (as defined in AC 150/5300-13) where HAS maintenance personnel can service them without closing runways or taxiways, if possible. They shall sufficiently be raised, where allowed, above the surrounding grade to prevent ponding water on the structure and the top cover sloped to drain. A concrete apron shall be constructed around all electrical manholes located in turfed areas. Particular attention must be given to storm water drainage plans to prevent placement of electrical structures in areas of channeled for drainage. They shall have all joints and openings completely sealed and vermin proof. Secure covers with bolts. Structures, covers and frames in the runway and taxiway safety areas shall be heavy duty designed for aircraft at 250 psi tire pressures and wheel loads of at least 40,000 pounds. Homerun manholes and pull boxes shall be located at a maximum spacing of six hundred (600) feet.

16.4.4. Saw Kerfs -Saw kerfs are discouraged. However, where saw kerfs are required, only one 1" conduit per saw kerf is allowed.

16.4.5. Circuit Lockouts – No construction or maintenance shall be allowed on Airfield lighting circuits while the circuits are energized. The published circuit "Lock-out and Lock-in" procedures will be required to be followed for all work performed on the airfield. Confirm with Airport's Operations Section the need for temporary circuits for extended outages (more than 1 work period, 8 to 12 hours).

PART 2 - COMMUNICATIONS

16.5. General Information. This section defines general design criteria that apply to the design of communication systems at Houston Airport System's Airports. This design should be prepared by and drawings shall be stamped by a registered RCDD and follow guidelines set forth in the most recent HAS IT Specifications that are applicable. All Communication drawings and specification are to be separate from the electrical drawings and specification following CSI 2004 Master format.

Chapter 1 should be consulted for specific airport regulations and standards that also apply.

16.5.1. Overview. The typical telecommunications infrastructure in a campus environment centers upon telecommunications rooms located throughout the facility. These rooms house wiring cross-connect panels as well as network electronics needed for voice, data, video, etc. Each building has one Main Distribution Frame (MDF) room, and possibly one or more Intermediate Distribution Frame (IDF) rooms located elsewhere in the building. The MDF serves as the connection point between the entrance and riser cabling systems. IDF'S serve as the connection point between the riser and horizontal cabling systems. Each IDF serves as the hub for a particular geographic zone of the building (i.e. floor or wing). In most cases the MDF also serves as an IDF (an originating point of horizontal cabling serving its own geographic zone). Therefore, this section also describes all equipment in the MDF associated with the typical IDF functions. The MDF and/or IDF should be void of drop ceilings. All communications rooms shall have UPS back up with an emergency generator (if required by HAS) for extended outages which shall support HVAC as well (reference 271100).

16.5.2. Current IT Specification. The list below is a list of our current minimum requirements for the IT infrastructure/equipment installation:

Spec 270526 Telecommunications Grounding and Bonding
Spec 270528 Interior Communication Pathways
Spec 270543 Exterior Communication pathways
Spec 270553 Identification and Labeling of Communication Infrastructure
Spec 271100 Communications Cabinets and Equipment Rooms
Spec 271300 Backbone and Riser Media Infrastructure
Spec 271500 Horizontal Media Infrastructure
Spec 272100 Data Communication Network Equipment
Spec 272200 PC, Laptop, and Servers Equipment
Spec 275100 Paging Sound Systems
Spec 281300 Access Control
Spec 282300 Video Surveillance Systems

16.5.3. Plan View. The designer should include a floor plan for each IDF within the project drawings. This floor plan should show type and locations (dimensioned) of equipment cabinets, overhead ladder racks, and all wire ways and conduits that enter the room.

16.5.4. Cabinet Views. The designer should also include an elevation (front) view of each equipment cabinet denoting the equipment to be installed, pertinent termination and numbering information, and labeling instructions. Considerations should be given for a 25% growth when designing the MDF, IDF'S and all associated hardware. See Attachment A - HAS Rack Elevation, for HAS's standard rack elevation configuration for data cabinets.

16.5.5. Cable Tray/Ladder Racks. A system of horizontal and vertical Cable Tray/ladder racks shall be installed in the MDF and each IDF to support and distribute all cabling from where it enters and exits the room or to its appropriate termination location.

16.5.6. Grounding. In order to protect personnel and equipment from hazardous voltages and reduce electro-magnetic interference (EMI), a proper bonding and grounding system is required for the telecommunications infrastructure in campus buildings. The designer should specify this system within the project design for new or completely renovated buildings. This system should comply with the most recent HAS IT Specifications, appropriate codes, industry standards, and these guidelines.

16.5.7. Patching. Installation of patch cords between two cross-connect panels or between network electronics and cross-connect panels in the IDF'S should be performed in accordance with these guidelines. The provision and installation of patch cords will fall within the scope of work for contractors so total channel testing can be performed. Contractor will provide the proper length patch cords and provide 10% spare patch cables for each length. This installation will be accomplished while testing is being performed. However, the designer should position equipment racks such as to allow patch cord installation to be performed with maximum efficiency using the shortest length patch cords possible. When more than one cabinet is needed they will be attached with the adjacent side panels removed.

16.6. Conduit.

16.6.1. Conduit shall be rigid or intermediate galvanized steel when exposed. EMT can be utilized within the building for horizontal distribution.

16.6.2. Electrical Metallic Tubing (EMT) may be used in sizes through two (2) inches where used inside dry locations where not subject to mechanical damage, six (6) feet AFF, if exposed. EMT may not be used outside, in concrete or underground. EMT fittings shall be steel compression type.

16.6.3. Minimum conduit size shall be 1 inch.

16.6.4. Increase conduit one size when flex conduit is used in place of EMT. Must have HAS Technology Division approval prior to installation.

16.6.5. Conduit size and quantity should be designed according to HAS IT Specification fill ratios.

16.7. Cabling and Terminations.

16.7.1. General. All new and reworked cable installations will follow the latest HAS IT Specification installation methods unless specified otherwise within this document or local, state and federal codes supersedes. Each work area outlet (WAO) will consist of four (4) Cat6 cables as defined below. Station wiring, fixtures and patch panel equipment shall be of quality and quantity sufficient to meet current Category 6 standards, and support current and future technology. Renovated areas and new construction independent conduit and/or approved Category 6 cable pathway system shall be provided to organize all data network cables. Routing and coordination of all cable trunks and cable systems shall be approved by HAS Technology Division.

16.7.2. Cable Standards. All horizontal cable shall be Cat-6, must meet applicable HAS IT Specifications Data premise cable jacket shall be green. Life safety premise cable jacket shall be red. Tenant premise cable jacket shall be yellow. Cable shall be labeled per specification 270553. Reference specification 271300 for Backbone & Riser media and 271500 for Horizontal media.

16.7.3. Non-Recommended systems. While a variety of pathway system technologies are commercially available, some are not generally recommended for use. These include under floor duct systems, trench duct systems, cellular floor systems, under-floor conduit systems, multi-drop conduit systems, and access (raised) floor systems. Also, use of floor outlet boxes and "tombstone" is not usually recommended unless certain criteria are met. None of the above systems should be used without approval from the HAS Technology Division.

16.7.4. Horizontal Pathways and Station Cabling. All communication wiring in new or rebuilt walls will be installed in EMT conduit, and shall not be stapled or secured within inaccessible portions of the

wall, floor or overhead. Communications wires installed in existing wall may be run in approved flexible duct. Cables installed in modular furniture raceways do not require conduit; however, conduit or equivalent protection is required between the wall plate or junction box and the raceway. All cables will be run to a standard duplex wall box or modular furniture equivalent, unless minimum bend radius or other requirements require surface-mount or other arrangement acceptable to HAS Technology Division. Surface mounting should be avoided if at all possible. All Wall Area Outlet installations require four (4) 4-Pair Category 6 cables per station or termination point. No electrical power or RF signal sources allowed in the same pathway as communication cables. Horizontal link will not exceed two hundred ninety (290) feet (90 meters), per HAS IT Specifications. Total channel length from a network switch to station equipment will not exceed three hundred thirty (330) feet (100 meters), including patch and drop cables. Ten-foot service loop will be maintained at each end of the station cable. At the cable ends, the length of the untwisted section at the connector or patch panel shall not exceed manufactures specifications. For renovated areas and new construction independent conduit and/or approved Category 6 cable support system shall be provided to organize all network Data cables. Routing, approval and coordination of all cable trunks and cable support systems shall be approved and directed by HAS Technology Division. Reference the specification section listed above.

16.7.5. Station Wall Outlets. Wall plate selection shall accommodate the simultaneous physical installation (not necessarily simultaneous electrical connection) of four (4) 8-position receptacles all green RJ-45 clearly marked for data. Unless otherwise directed all jacks shall be terminated according to 568B wiring scheme.

16.7.6. Data Telecommunications Room Standards. Contractor shall provide patch cable and ipatch panel equipment meeting the same CAT6 specifications as above for the cable. Data patch cables shall be stranded and Green. Data patch panels shall be placed in wall or floor mounted lockable cabinets approved by HAS Technology Division. Cabinet considerations should include: quantity of Wall Area Outlets, electronics, cable management, environment, room security access control. The cabinet shall also comply with applicable HAS IT Specifications regarding grounding, cable routing and accessibility. HAS has gone to VOIP solution for all voice communication and the cabling will be handled as a data circuit. If an analog or digital hand set is required a hybrid patch cable will be used for cross connects to a multi pair cable terminated on a 110 block. Reference specifications listed above.

16.7.8. Copper Testing. Contractor will test all Cat6 cable with certified Cat6 tester and to HAS IT Specification requirements. Reference specification listed above for additional details.

16.8. Fiber Optic Cabling Standards. Fiber optic cable specifications (type and quantity) are dependent on specific project needs. Close coordination needs to be made with the HAS IT Division when designing fiber optic infrastructure.

16.8.1. Fiber Optic Cable Installation.

16.8.1.1. All fiber optic cable shall be installed and terminated in compliance with manufacturer's recommendations regarding maximum pull tension, minimum bend radius, working and resting tension and protection. Splicing should be avoided whenever possible and should only be performed after consulting with HAS Technology Division. Maxcell, Inner-duct and/or approved fiber optic cabling systems shall be incorporated into any plans for any facility requiring fiber optic connections. Building entry shall be considered regarding placement of termination equipment, so to eliminate splice conversion panels and/or patch panels, cable management, environment, security and accessibility. Routing, approval, and coordination of all fiber trunks and cable systems shall be approved and directed by the HAS Technology Division.

16.8.1.2. The Contractor shall perform cable-pulling calculations based on the actual field routing of the cables prior to installation. The calculations shall demonstrate that cable pulling tensions and sidewall pressures are within Manufacturer requirements. The calculations shall be submitted to the HAS Technology Division for approval. Do not exceed maximum allowable pulling tensions. Contractor will be responsible for any damage to the fiber cable prior to acceptance.

16.8.1.3. All fiber optic cable will be installed to have a minimum service loop length of one meter behind the patch panel and ten meters in ceiling or mounted to wall. If fiber optic cable is used as station wiring, bend radius considerations may require surface-mount fixtures; this will be addressed on a case-by-case basis. All fiber optic cable will meet applicable fire and other safety ratings.

16.8.1.4. Cables shall be neatly trained and laced within junction boxes and patch panels. Cable terminations shall be installed in accordance with Manufactures instructions.

16.8.2. Fiber Optic Testing Procedures - Pass / Fail Criteria.

16.8.2.1. Testing will be performed by the Contractor. The Contractor shall provide all tools andequipment required to perform the tests. The tests shall be conducted in the presence of the HAS Technology Division Representative. Contractor shall provide forty-eight (48) hours notice to HAS Technology Division prior to conducting tests). The Contractor shall provide at least one written and one electronic copy of the test results to the HAS Technology Division.

16.8.2.2. Cables shall be tested by OTDR on the spools prior to installation. Cables having attenuation at either wavelength greater than factory specifications shall be rejected and replaced at no cost to HAS.

16.8.2.3. Cables shall be tested bi-directionally at both wave lengths using an OTDR and an Optical Power Loss Meter after installation and termination. Cables having attenuation at either wavelength greater the standard defined in the HAS IT Specifications will be rejected by HAS Technology Division. HAS IT personnel will be present during any re-testing. The tests will be submitted to HAS IT Division for review. A rejected test will be grounds for either replacement or repair at HAS ITS Department's discretion at no additional cost to HAS.

16.8.3. Fiber Optic iPatch Panel.

16.8.3.1. Fiber optic patch panel configurations are dependent on project needs. Close coordination needs to be made with the HAS Technology Division when designing fiber optic infrastructure. HAS has standardized fiber termination of Systimax iPatch 360 panels with LC type connectors. Consult with HAS Technology Division when renovating existing fiber optic cables. All extra fiber cable and iPatch panel connectors will be fitted with a dust/dirt cover sized for the connector rack. This will ensure that the fiber element will not become dirty or contaminated.

The contractor will supply a reasonable amount of extra covers for existing or newly installed panels and cables. These extra covers shall be located at each patch panel in a box, plastic bag or other container selected by the contractor

16.8.3.2. Fiber optic equipment connectors must be of the LC type. The contractor shall be responsible to verify and provide the correct patch cable connection, if necessary, supply adapters to convert the connector type required for existing and newly installed equipment and patch panels.

16.8.3.3. Patch Panels will be labeled following HAS IT Specifications.

16.8.4. Fiber Optic Splicing. It is the intent of HAS that fiber optic cable splicing is not allowed. Exceptions shall be directed in writing to HAS Technology Division for review. In the event of an accidental severed cable, the HAS Technology Division shall direct the method and means for repair or replacement. When fibers are spliced a complete end-to-end testing shall be performed.

Appropriate splice enclosures shall be used depending on the environment. Without exception splice enclosures shall be installed and secured according to the manufactures installation guidelines and to the satisfaction of HAS Technology Division representative.

16.9. Equipment and Cable Labeling. All cables shall be labeled at both ends for identification purposes. All exposed cable trunks (in duct banks, tunnel trays, outside plant trunk cables, etc.) including fiber, shall be identified at major intersections, all penetrations, and at turns greater than 45 degrees, with a water-proof label permanently affixed to the cable as reference in specification 270553. Patch panels and wall receptacles shall also be labeled as appropriate. Materials used for labeling shall be indelible, meet applicable fire codes, and be in compliance with HAS IT Specifications and HAS Technology Division direction. The labeling system for cables and patch cables shall incorporate a clear heat shrinkable tubing covering over the label characters. Cables shall be labeled at both ends. Patch panels and Wall Area Outlet (WAO) labeling shall comply with specification 270553.

16.10. Electrical Power and Electrical Noise. Facilities designed or modified to be data communications areas shall comply with regard to electrical noise and availability of an adequate signal reference ground/grid. Special attention needs to be given to EMI devices. Appropriate distances and/or shields should be maintained in accordance with HAS IT Specifications. Reference specification listed above.

16.11. Telecommunication and Network Systems.

16.11.1. Telephone Riser Cable. The riser cable is to be a riser rate AR Series with 24 AWG Solid Un-tinned Copper Conductors with a dual insulation of semi-rigid PVC over foamed polyethylene. The pairs are assembled into a cable core and wrapped with a polyester film core wrap. They are sheathed with corrugated aluminum tape bonded to a gray PVC Jacket. This product is available in 25-pair to 900-pair sizes for 24 AWG for telephone cabling. Reference specification 271300

16.11.2. Telephone Termination Hardware. All telephone riser cable shall be terminated with 110 style cross connect system wiring blocks using C5 connectors and necessary hardware for cross connect paths. Cross connect system wiring blocks are one-piece units made of fire-retardant molded polycarbonate plastic with horizontal Index strips that secure 25 pairs of 22 through 26 gauge cable conductors. These wiring blocks are designed with legs to mount away from the wall to provide space for cable routing behind the block and are available in 100- and 300-pair sizes. Reference specification 271300 and 270500

16.11.3. Grounding. A bonding and grounding system devoted to the telecommunications system is required and shall be independent of the electrical outlet grounding system. The purpose is to protect personnel, cabling, and equipment from unwanted electrical currents associated with the telecommunications infrastructure and equipment. This system shall be designed according to the standards contained in the appropriate HAS IT Specifications. Building steel, water pipes, or metallic conducts will NOT serve as a substitute for the grounding conductor. Reference specification 270526

16.11.4. Fire Stop. Fire stopping helps limit the spread of fire and smoke through a building by route of the cable or pathway. A HAS approved fire stop method and material shall be used to fire stop or seal the opening in a wall or floor where a riser cable, horizontal cable, conduit, sleeve, or other such objects protrude. The fire stop method and material shall at a minimum meet the fire rating of the material penetrated. Use 3M fire stop or approved equal per NEC/NFPA/HAS Code.

16.12. Paging/Sound Systems. System requirements will be determined by following HAS IT Specifications. Reference specification 275100.

16.12.1. System wiring and components shall be installed per HAS IT Specifications in order not to cause any interference with Airport communication facilities and other tenant facilities.

16.12.2. Ceiling type speakers shall be equipped with properly sized back box and independent support free of the ceiling tile and installed per HAS IT Specifications.

16.13. Radio Communications System.

16.13.1. Coordinate radio system requirements with the HAS Technology Division.

16.13.2. Existing repeater stations are located on the top floor of the hotel and each terminal building.

16.14. mergency Telephones for Installation in Elevators. Viking Electronics, model E1600-02A.

16.15. Documentation.

16.15.1. General. Both electronic and hard copies of required cable test results, As-Built drawings, and warranty information will be submitted to the Owner or Owner's representative at least ten (10) working days before a Notice of Substantial Completion is awarded. CAD files will be submitted in AutoCAD (.dwg) format. When proprietary software is needed to view cable test results, the contractor will provide a licensed copy for HAS Technology Division.

16.15.2. Cable Management Software. The cable management software database is maintained by HAS Technology Division. The Contractor is responsible for providing the installed wiring infrastructure data on a CD in Microsoft Excel (.xls) format. The Contractor shall coordinate the specific document requirements with HAS Technology Division. Systimax database fill is required for all installed and terminated Ipatch panels.

Part 3 - ACCESS CONTROL/ ALARM MONITORING & VIDEO SURVEILLANCE SYSTEMS

16.16 General Information - This section defines general design criteria that apply to the design of security systems at George Bush Intercontinental (IAH) and William P. Hobby (HOU) airports, which are subject to the security requirements for commercial service airports. For Ellington Airport (EFD) the requirements for AOA perimeter security apply.

16.17 Regulatory Compliance – Extension and/or expansion of existing HAS security systems must be consistent with the current Airport Security Plan approved by the Transportation Security Administration.

16.18 System Installation - The Contractor installing the security systems shall be licensed for the installation of such systems by the State of Texas, and shall present proof of such license to the HAS Technology Division and Airport General Manager. The installing contractor shall additionally be a certified Honeywell ProWatch, DVM and MaxPro dealer.

16.19 Access Control / Alarm Monitoring System – Electronic access control and alarm monitoring at all HAS facilities is supported by Honeywell's ProWatch software and hardware components. Access control and alarm monitoring requirements for new construction and/or renovation projects will rely on expansion or extension of the existing Honeywell ProWatch system.

16.19.1 Electronic card readers and credentials shall be from the IClass Elite family of products manufactured by HID.

16.19.2 Electronic card readers and alarm sensors shall communicate to a central ProWatch server via Honeywell intelligent field panels (located in Intermediate Distribution Frame (IDF) rooms) and the HAS corporate data network.

16.19.3 Electric locking hardware shall provide control of ingress and egress at selected portals. Wherever possible, electrified mortise locks shall be utilized. The installing contractor shall provide all permits and inspections required in connection with electric locking hardware.

16.19.4 All circuits that connect field installed alarm sensors to intelligent field panels shall be supervised via end-of-line resistors.

16.20 Video Surveillance System –video surveillance of HAS facilities is supported by Honeywell's DVM and MaxPro video management software. Video surveillance requirements, including video display, recording and retrieval for new construction and/or renovation projects will rely on expansion or extension of the existing Honeywell DVM/MaxPro system.

16.20.1 Fixed and/or motorized digital video cameras shall be strategically located to provide continuous monitoring of specified activities within HAS facilities.

16.20.2 Digital video cameras shall communicate to camera servers and digital video storage arrays (located in Main Distribution Frame (MDF) rooms) via the HAS corporate data network.

16.20.3 Digital video storage capacity necessary to insure a minimum of 30 days of stored video shall be provided for all new cameras.

16.21 Wiring - The security system wiring and pathways shall fully comply with the requirements set forth in Section 16, Part 2 Communications of this design manual.

END OF SECTION 16

Attachment A Network Design Criteria, Policies, and Requirements

Description – This Attachment contains requirements, criteria, and standards for basic design and installation of network infrastructure electronics for the Houston Airport System referred to as **HAS Technology Division Network Design Standards**. Ensure that all network designs meet the requirements of the HAS IT Specifications.

1. Network Infrastructure Electronics.

1.1. The network infrastructure shall be designed so that each end system (computer, printer, etc.) or host will be connected to a switched 100BaseT Ethernet port (Edge switch) at a minimum. Switch ports designated for servers or large storage arrays such as SAN or NAS shall be capable of 1000Mb speeds over either copper or fiber depending on the server. It is the System Integrator's responsibility to insure adequate and correct port types for all hosts, servers, special equipment, etc. connecting to the edge access layer switches. Reference specification 272100

1.2. The HAS Data Network is designed as a large multi-layer hierarchical campus TCP/IP based Ethernet network consisting of Cisco Core, Distribution, and Access layer electronics.

1.2.1. Core Layer switches (MDF) currently consists of Cisco Catalyst 6509 chassis located at four different locations at the airport. These fully meshed devices provide connectivity for distribution layer switches only.

1.2.2. Distribution Layer switches (BDF) when required by the design specifications will consist of a pair of Cisco switches (such as Cisco Catalyst 6509, 4506, 4006, or 3750 models) with multi-layer capabilities connected to two Core layer switches via single-mode fiber if located in a separate location, or multi-mode fiber if located in the same location. It is the responsibility of the System Integrator to obtain written approval from the HAS Technology Division for any exceptions to this standard prior to implementation.

1.2.3. Access Layer switch (IDF) design shall be adequate in numbers of switches so as to provide the correct quantity and type of ports, plus an additional 50% for future expansion. Acceptable access layer switches are the Cisco model3750 switch series. It is the responsibility of the System Integrator to insure that this design criterion is met. Any deviations from this design criterion require written approval from the HAS Technology Division.

1.2.4. External Telecommunication connections to the HAS data network, such as T1, DS3 circuits, originating from an external source other than the HAS network, will be terminated at a minimum to an HAS owned and managed network security appliance. This security appliance shall be capable of performing firewall and security policy duties. The appliance shall also be capable of performing strong-levels of encryption such as 3DES and AES. The device should also support high-availability to provide redundancy. This is a fast changing technology so no specific security appliance is required; however, the specific appliance must be approved in writing by HAS Technology Division prior to implementation. This will ensure that it seamlessly fits into the current security models.

2. Network Infrastructure Connectivity and Topology.

2.1. Gigabit Ether Channel fiber links are currently utilized between Core and Distribution layer switches to provide added reliability and a 4-Gigabit backbone. This provides 'redundant paths' to the rest of the data network yielding reliability and fail-over capabilities for that particular switch or stack of switches.

2.2. A typical Access layer stack consists of three (3) Cisco switches such as the current Cisco 3750 models. The maximum acceptable number of switches in a stack is four (4) with three (3) recommended. Typically, the top Access switch in a stack is connected to Distribution switch number 1 using the 2 Gigabit fiber port (Gi0/2), and the bottom Access switch in the stack is connected to Distribution switch number 2 using the 2 Gigabit fiber port (Gi0/2). The middle switch of that stack (if installed) is connected to the switch above and below it using Gigastack GBIC technology (Gig copper) installed in the first Gigabit port (Gi0/1). Other stacking technology is acceptable if it meets or exceeds the performance of the Gigastack design. It is HAS Technology Division network design standard that every Core, Distribution, and Access layer switch placed in service on the HAS data network will be designed and configured with redundant connectivity (fiber or copper) to the rest of the network. This standard only addresses redundant physical layer connectivity, and not redundant electronics such as Supervisor Modules in the Catalyst 6500 series switches.

2.3. HAS Technology Division network design standard is to design and configure all fiber link connections between backbone switches utilizing routed point-to-point links, not VLAN trunks across the network.

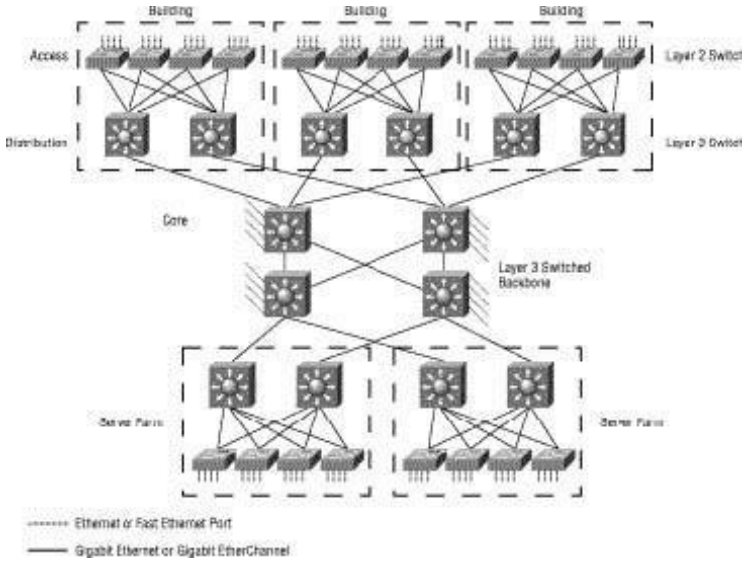
2.4. The HAS IT Division network design standard is to limit or restrict the propagation of any failure or electrical problem associated with a host workstation or server to a single Layer 2 switch or stack of Layer 2 switches in a wiring closet. In order to do this, the deployment of VLANs and VLAN trunking is restricted to one wiring-closet switch or stack of switches. Each wiring-closet or group of wiring-closets installed for the purpose of providing network connectivity to a building, or a section or floor of the building, is assigned to a unique VLAN. Further, a VLAN will not span into multiple wiring-closets from separate geographical locations unless approved in writing by the HAS Technology Division. Restricting one VLAN to a single Layer 2 switch or stack of switches per wiring closet also minimizes the spanning-tree complexity and greatly increases network convergence should an forwarding link fail and the connection fail-over to the backup or redundant link.

2.5. HAS also recommends limiting broadcast traffic on layer 2 networks. Furthermore, in the instance of a bi-directional fiber link failure the port should be automatically disabled. The network design should support these efforts as much as possible.

2.6. Deploying pervasive (geographically diverse) VLANs throughout the campuses adds to the complexity and causes spanning-tree convergence problems and thus is not allowed. HAS Technology Division network design standard is to utilize one IP subnet per VLAN, which then maps to a single switch or stack of switches per wiring closet.

2.7. Figure 1 depicts a typical Layer 3 Switched Campus Backbone which the HAS network design standard is based on.

Figure 1. Large-scale Layer 3 Switched Campus Backbone.



2.8. Determinism is an important design goal of HAS Technology Division network design criteria. For the network to be deterministic, the design must be as simple and highly structured as possible. Recovery mechanisms must be considered as part of the design process. Recovery timing is determined in part by protocol messages such as hellos and keep alives, and these may need to be tuned to achieve recovery goals.

2.9. Quality of service (QoS) for voice over IP (VoIP) consists of providing low-enough packet loss and low-enough delay so that voice quality is not affected by conditions in the network. A reasonable design goal for end-to-end network delay for VoIP is 150 milliseconds. At this level, delay is not noticeable to the speakers. To achieve guaranteed low delay for voice at campus speeds, it is sufficient to provide a separate outbound queue for real-time traffic. The bursty data traffic such as file transfers is placed in a different queue from the real-time traffic. Because of the relative high speed of switched Ethernet trunks in the campus, it does not matter much whether the queue allocation scheme is based on weighted round robin, weighted-fair, or strict-priority.

3. **Remote Access and Internet Standards.**

3.1. Currently HAS has several T1 connections to the data network in several locations. Any additional external network connections, such as T1, frame-relay, etc., will be aggregated into a "Common Demarcation" electronic appliance as defined by the HAS Technology Division Networks section. This will allow for improved security and management of remote access to the HAS network. Any external data or telecommunication connections to the HAS data network will be approved and coordinated through the HAS Technology Division.

4. **Network Management.**

4.1. Any network electronics such as switches, routers, firewalls, VPN concentrators, wireless access points, etc. that are installed on HAS network must be able to be managed by the currently installed network management software. CiscoWorks 2000 is the current network management software in use. These devices must also be able to send SNMP traps to and be able to respond to Secure SNMP queries by the network management server. HAS must be able to limit management access to network devices via built in control mechanisms.

5. **Equipment Specifications.**

5.1. Where specific products are referenced, products that are substituted must be electronically, mechanically, and functionally interchangeable with the product specified. A copy of the specifications of the proposed substitution must be submitted with the vendor's response. Substitutions will only be allowed by written approval by the HAS Technology Division. Any substitutions made without written approval are done at the risk of the vendor. Unacceptable substitutions will be rejected without explanation or appeal. The proposed switches, routers, firewalls, VPN concentrators, network management software, etc. must be approved by the same manufacturer.

5.2. Each electronic network device must have at least a one (1) year, advanced replacement warranty equivalent to the Cisco SMARTnet Maintenance package. Advanced replacement is defined as receiving replacement equipment within one (1) business day after obtaining an TAC case number from Cisco. If the standard warranty does not meet this requirement, the vendor must include a service or maintenance contract that does. The Proposer must also include pricing for providing extended warranty for years two and three.

6. **Physical Security.**

6.1. All network electronics such as switches, routers, firewalls, VPN concentrators, wireless access points, etc. must be physically installed into a cabinet per manufacturer's recommendations, and the cabinet must be able to be physically secured and lockable in order to prevent unauthorized access to that device.

END ATTACHMENT A--16-19

Attachment B

HAS Tenant (Technology) Considerations

- Number of users
- Nearest Telecommunications room
- Cable route
- Cable type:
  - Category 6 UTP
  - Multi mode fiber
  - Single mode fiber
  - Multi pair copper
  - Coax
- Internet service: **(must be ordered 4 to 6 weeks in advance)**
  - T1
  - DSL
- Phones:
  - External provider
  - HAS provided
- Data
- FIDS P.C.
- FIDS (flight information displays)
- Air to ground radio
- Ground Radio
- MATV
- Network printers
- Fax:
  - External provider
  - HAS provided
- Wireless access points
- CCTV
- Access control
- SITA connections
- Equipment location within the space
- Electrical

HAS TIP Submittal (Technology) Requirements

- Provide Engineered "T" drawings following HAS IT Specifications and CSI 2004 Format:
  - Amount and location of work area outlets
  - devices:
    - # Phones:
      - External provider
      - HAS provided
    - # Data
    - # FIDS P.C.

        - FIDS (flight information displays)
        - Air to ground radio
        - Ground Radio
        - MATV
        - Network printers
        - Fax:
            - External provider
            - HAS provided
        - Wireless access points
        - CCTV
        - Access control
        - SITA connections
    - Nearest Telecommunications room
    - Conduit pathways and sizes for the cabling from end to end
    - Cable type
    - Equipment location within the space
    - Internet service: **(must be ordered 4 to 6 weeks in advance)**

- Phone services:
    1. IP

HAS Available Technology Services.

2. Analog (modem and (or) fax)
    - Fiber pathway
        1. Multi mode
        2. Single mode
    - MATV
    - FIDS (flight information displays)
    - Circuit extensions from Service Providers demarcation to the tenant space.
    - Ground Radio
    - Internet Service

<u>Process of Ordering Services from HAS</u>

1. Call the HAS IT helpdesk @ 281-233-1900
2. Request the services you need referencing the TIP #
3. Give as much description as possible (location, date needed, ECT…)
4. Sign agreement for the services
5. Ensure that your cabling / equipment needs are provided by your contactor, to extend the services to your space.
6. The HAS IT help desk must receive the request 20 days prior to the date in which the services are needed
7. Test results must be received prior to the services being extended to your space

END ATTACHMENT B