UPPER ASTRONOMY SHOP
UNIVERSITY OF CALIFORNIA, SANTA CRUZ
SANTA CRUZ, CALIFORNIA 95064

AUTOMATED PLANET FINDER SITEWORK
UCO LICK OBSERVATORY

SPECIFICATIONS

100% SUBMITTAL

MAY 4, 2005

PREPARED BY

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EarthTech
A Tyco International Ltd. Company

SPECIFICATIONS

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SECTION 02300

EARTHWORK

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes the following:

1. Clearing and grubbing of construction areas.

2. Excavating and backfilling for building and structures.

3. Excavating and backfilling for utility trenches.

4. Rock excavation where required.

5. Aggregate base for bedding and backfill in trenches, structure backfill, and for walkway section.

6. Preparing subgrade for crushed rock surfacing.

7. Crushed rock surfacing for walkway surface.

8. Finish grading of site.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. ASTM INTERNATIONAL (ASTM)

ASTM D 1556	Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D 1557	Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/cu. ft. (2,700 kN-m/cu.m.))
ASTM D 2167	Density and Unit Weight of Soil in Place by the Rubber Balloon Method
ASTM D 2487	Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D 2922	Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
ASTM D 2937	Density of Soil in Place by the Drive-Cylinder Method

ASTM D 2940	Graded Aggregate Material for Bases or Subbases for Highways or Airports
ASTM D 3740	Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
ASTM E 329	Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction

B. STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION (CALTRANS)

CSS	Standard Specifications

1.03 DEFINITIONS

A. Excavation: Removal of material encountered above subgrade elevations and to lines and dimensions indicated.

1. Authorized Additional Excavation: Excavation below subgrade elevations or beyond indicated lines and dimensions as directed by the University's Representative. Authorized additional excavation and replacement material will be paid for according to Contract provisions for changes in the Work.

2. Unauthorized Excavation: Excavation below subgrade elevations or beyond indicated lines and dimensions without direction by the University's Representative. Unauthorized excavation, as well as remedial work directed by the University's Representative, shall be without additional compensation.

B. Backfill: Soil material from excavations, or imported, free of organic material and detritus-laden material, used to fill an excavation.

C. Bedding Course: Course placed over the excavated subgrade in a trench before laying conduit.

D. Borrow Soil: Satisfactory soil imported from off-site for use as fill or backfill.

E. Fill: Soil materials from excavations, or imported, free of organic material and detritus-laden material, used to raise existing grades.

F. Structures: Buildings, footings, foundations, retaining walls, slabs, mechanical and electrical appurtenances, or other man-made stationary features constructed above or below the ground surface.

1.04 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Excavation Shoring Plan: If shoring is required, submit an excavation shoring plan prior to excavation.

B. Product Data: For the following:

1. Detectable warning tape.

C. Material Test Reports: From a qualified testing agency indicating and interpreting test results for compliance of the following with requirements indicated:

1. Classification according to ASTM D 2487 of each on-site and borrow soil material proposed for fill and backfill.

2. Laboratory compaction curve according to ASTM D 1557 for each on-site and borrow soil material proposed for fill and backfill.

D. Preexcavation Photographs or Videotape: Show existing conditions of adjoining construction and site improvements, including finish surfaces, that might be misconstrued as damage caused by earthwork operations.

1.05 GEOTECHNICAL DATA

A. Geotechnical data for this project is contained in Report titled Geologic/Geotechnical Study for Proposed Automated Planet Finder Telescope Facility, Lick Observatory at Mt. Hamilton, Santa Clara County, California, Geomatrix Consultants Project No. 8702.000.0, dated August 2004. Refer to Section 00200, GEOTECHNICAL DATA.

1.06 QUALITY ASSURANCE

A. Geotechnical Testing Agency Qualifications: An independent testing agency qualified according to ASTM E 329 to conduct soil materials testing, as documented according to ASTM D 3740.

B. Refer to Section 01400, QUALITY CONTROL, for testing and inspection responsibilities.

1.07 PROJECT CONDITIONS

A. Excavation Conditions: In general, the telescope and building foundation system will extend into sandstone interbedded with weaker layers of shale. The Geologic/Geotechnical Study for this project states that the rock to be excavated for footings and foundations is within the range of rippability for heavy construction equipment. However, at depth the material may become marginally rippable and alternative techniques such as hoe rams and jackhammers may be necessary to excavate the material.

B. Existing Utilities: Do not interrupt utilities serving facilities occupied by the University unless permitted in writing by the University's Representative and then only after arranging to provide temporary utility services according to requirements.

1. Notify the University's Representative not less than two days in advance of proposed utility interruptions.

2. Do not proceed with utility interruptions without the University's Representative's written permission.

3. Contact utility-locator service for area where Project is located before excavating.

PART 2 - PRODUCTS

2.01 SOIL MATERIALS

A. General: Provide borrow soil materials when sufficient satisfactory soil materials are not available from excavations.

B. Satisfactory Soils: ASTM D 2487 Soil Classification Groups GW, GP, GM, SW, SP, and SM, or a combination of these groups; free of rock or gravel larger than 3 inches in any dimension, debris, waste, frozen materials, vegetation, and other deleterious matter.

C. Unsatisfactory Soils: Soil Classification Groups GC, SC, CL, ML, OL, CH, MH, OH, and PT according to ASTM D 2487, or a combination of these groups.

1. Unsatisfactory soils also include satisfactory soils not maintained within 3 percent of optimum moisture content at time of compaction.

D. Engineered Fill: Naturally or artificially graded mixture of natural or crushed gravel, crushed stone, and natural or crushed sand; ASTM D 2940; with at least 90 percent passing a 1-1/2-inch sieve and not more than 12 percent passing a No. 200 sieve.

E. Aggregate Base: As specified in Caltrans Standard Specifications, Section 26, Class 2 Aggregate Base, 3/4 inch maximum particle size.

F. Crushed Rock Surfacing: Crushed rock shall consist of hard, durable, clean processed imported crushed stone, meeting the following:

Percent passing	1-inch sieve	100%
Percent passing	3/4 -inch sieve	90-100
Percent passing	No. 4 sieve	0-10
Percent passing	No. 200 sieve	0-2

2.02 ACCESSORIES

A. Detectable Warning Tape: Acid- and alkali-resistant polyethylene film warning tape, continuously inscribed with a description of the utility, with metallic core encased in a protective jacket for

corrosion protection, detectable by metal detector when tape is buried up to 30 inches deep; colored as follows:

1. Red: Electric.

2. Orange: Telephone and other communications.

PART 3 - EXECUTION

3.01 PREPARATION

A. Protect structures, utilities, pavements, and other facilities from damage caused by settlement, lateral movement, undermining, washout, and other hazards created by earthwork operations.

B. Protect and maintain erosion and sedimentation controls during earthwork operations.

3.02 CLEARING AND GRUBBING

A. All construction areas shall be cleared of objectionable materials including grass, weeds, concrete, asphalt, old construction debris, tree stumps, wood debris, boulders and cobbles, and any other material that might interfere with performance of the work.

B. Any holes created by the grubbing process that are not within the telescope excavation limits shall be backfilled with compacted fill. All objectionable material from clearing and grubbing shall be removed from the site and disposed of at a suitable landfill.

C. In general, after clearing and grubbing, most of the APF facility site will not require stripping. However, if organic-rich or clayey surficial soils are encountered within the excavation and fill area, these soils shall be stripped prior to excavation or filling. These surficial soils, if encountered, shall be stockpiled separately away from the telescope construction area where directed by the University’s Representative.

3.03 EXCAVATION SUPPORT SYSTEM

A. If shoring is required, the Contractor shall submit a shoring plan for approval 15 days prior to starting work. Submit drawings and calculations, certified by a registered State of California professional civil or structural engineer, describing the methods for shoring and sheeting of excavations. Shoring shall be furnished and installed as necessary to protect workmen, banks, adjacent paving, structures, and utilities. Shoring, bracing, and sheeting shall be removed as excavations are backfilled, in a manner to prevent caving.

B. Refer to Section 01060, REGULATORY REQUIREMENTS, paragraph Construction Safety Orders.

3.04 DEWATERING

A. Prevent surface water and ground water from entering excavations, from ponding on prepared subgrades, and from flooding Project site and surrounding area.

B. Protect subgrades from softening, undermining, washout, and damage by rain or water accumulation.

1. Reroute surface water runoff away from excavated areas. Do not allow water to accumulate in excavations. Do not use excavated trenches as temporary drainage ditches.

2. Install a dewatering system to keep subgrades dry and convey ground water away from excavations. Maintain until dewatering is no longer required.

3.05 EXPLOSIVES

A. The use of explosives will not be permitted.

3.06 EXCAVATION, GENERAL

A. Excavate to subgrade elevations regardless of the character of surface and subsurface conditions encountered. Excavated materials may include rock, soil materials, and obstructions. No changes in the Contract Sum or the Contract Time will be authorized for rock excavation or removal of obstructions.

1. If excavated materials intended for fill and backfill include unsatisfactory soil materials, replace with satisfactory soil materials.

2. Earth excavation includes excavating pavements and obstructions visible on surface; underground structures and other items indicated to be removed; together with soil, and other materials not unauthorized excavation.

3.07 EXCAVATION FOR STRUCTURES

A. Excavate to indicated elevations and dimensions within a tolerance of plus or minus 1 inch. If applicable, extend excavations a sufficient distance from structures for placing and removing concrete formwork, for installing services and other construction, and for inspections.

1. Excavations for Footings and Foundations: Do not disturb bottom of excavation. Excavate by hand to final grade just before placing concrete reinforcement. Trim bottoms to required lines and grades to leave solid base to receive other work.

3.08 EXCAVATION FOR UTILITY TRENCHES

A. Excavate trenches to indicated gradients, lines, depths, and elevations.

B. Excavate trenches to uniform widths to provide the following clearance on each side of conduit. Excavate trench walls vertically from trench bottom to 12 inches higher than top of conduit, unless otherwise indicated.

1. Clearance: 12 inches each side of conduit.

C. Trench Bottoms: Excavate and shape trench bottoms to provide uniform bearing and support of conduit. Remove projecting stones and sharp objects along trench subgrade.

3.09 SUBGRADE INSPECTION

A. Notify University's Representative when excavations have reached required subgrade.

B. If the University's Representative determines that unsatisfactory soil is present, continue excavation and replace with compacted backfill or fill material as directed.

C. Proof-roll subgrade below the footings and foundations with heavy pneumatic-tired equipment to identify soft pockets and areas of excess yielding. Do not proof-roll wet or saturated subgrades.

1. Completely proof-roll subgrade in one direction. Limit vehicle speed to 3 mph.

2. Proof-roll with a loaded dump truck or equivalent weighing not less than 15 tons.

3. Excavate soft spots, unsatisfactory soils, and areas of excessive pumping or rutting, as determined by the University's Representative, and replace with compacted backfill or fill as directed.

D. Authorized additional excavation and replacement material will be paid for according to Contract provisions for changes in the Work.

E. Reconstruct subgrades damaged by rain, accumulated water, or construction activities, as directed by the University's Representative, without additional compensation.

3.10 UNAUTHORIZED EXCAVATION

A. Fill unauthorized excavation under foundations or footings by extending bottom elevation of concrete foundation or footing to excavation bottom, without altering top elevation. Lean concrete fill, with 28-day compressive strength of 2500 psi may be used when approved by the University's Representative.

1. Fill unauthorized excavations under other construction or utility conduit as directed by the University's Representative.

3.11 STORAGE OF SOIL MATERIALS

A. Stockpile borrow soil materials and excavated satisfactory soil materials without intermixing. Place, grade, and shape stockpiles to drain surface water. Cover to prevent windblown dust.

1. Stockpile soil materials away from edge of excavations. Do not store within drip line of trees.

3.12 BACKFILL FOR STRUCTURES

A. Place and compact backfill in excavations promptly, but not before completing the following:

1. Construction below finish grade.

2. Surveying locations of underground utilities for Record Documents.
3. Testing and inspecting underground utilities.

4. Removing concrete formwork.

5. Removing trash and debris.

6. Removing temporary shoring and bracing, and sheeting.

B. Place backfill on subgrades free of mud, water or other deleterious materials.

3.13 UTILITY TRENCH BACKFILL

A. Place sand conforming to CALTRANS Standard 19-3.025B and compact to 95 percent of maximum dry density according to ASTM D 1557.

B. Place conduit on supports as indicated and place sand around and over conduit to depth shown. Compact sand to 95 percent.

C. Place a concrete cap, minimum 2,500 psi concrete, over sand backill to depth shown. Sprinkle red iron oxide dye on top of wet concrete.

D. In unpaved areas, place select native soil backfill to grade, and compact to 90 percent according to ASTM D 1557. Install warning tape directly above utility, 12 inches below finished grade.

E. In paved areas, place select native soil backfill as indicated, and compact to 95 percent. Place aggregate base and compact to 95 percent according to ASTM D 1557. Install warning tape directly above utility, below aggregate base. Place asphalt concrete to match existing pavement.

3.14 SOIL FILL

A. Plow, scarify, bench, or break up sloped surfaces steeper than 1 vertical to 4 horizontal so fill material will bond with existing material.

B. Place and compact fill material in layers to required elevations as follows:

1. Under grass and planted areas, use satisfactory soil material.

2. Under walks and pavements, use satisfactory soil material.

3. Under building slabs, use engineered fill.

4. Under footings and foundations, use engineered fill.

C. Place soil fill on subgrades free of mud, water or other deleterious materials.

3.15 SOIL MOISTURE CONTROL

A. Uniformly moisten or aerate subgrade and each subsequent fill or backfill soil layer before compaction to within 3 percent of optimum moisture content.

1. Do not place backfill or fill soil material on surfaces that are muddy.

2. Remove and replace, or scarify and air dry otherwise satisfactory soil material that exceeds optimum moisture content by 3 percent and is too wet to compact to specified dry unit weight.

3.16 COMPACTION OF SOIL BACKFILLS AND FILLS

A. Place backfill and fill soil materials in layers not more than 8 inches in loose depth for material compacted by heavy compaction equipment, and not more than 4 inches in loose depth for material compacted by hand-operated tampers.

B. Place backfill and fill soil materials evenly on all sides of structures to required elevations, and uniformly along the full length of each structure.

C. Compact soil materials to not less than the following percentages of maximum dry density according to ASTM D 1557:

1. Under structures, building slabs, and pavements, scarify and recompact top 12 inches of existing subgrade and each layer of backfill or fill soil material at 95 percent.

2. Under walkways, scarify and recompact top 6 inches below subgrade and compact each layer of backfill or fill soil material at 90 percent.

3. Under lawn or unpaved areas, scarify and recompact top 6 inches below subgrade and compact each layer of backfill or fill soil material at 90 percent.

4. For utility trenches, compact each layer of initial and final backfill soil material at 90 percent.

3.17 GRADING

A. General: Uniformly grade areas to a smooth surface, free of irregular surface changes. Comply with compaction requirements and grade to cross sections, lines, and elevations indicated.

1. Provide a smooth transition between adjacent existing grades and new grades.

2. Cut out soft spots, fill low spots, and trim high spots to comply with required surface tolerances.

B. Site Grading: Slope grades to direct water away from buildings and to prevent ponding. Finish subgrades to required elevations within the following tolerances:

1. Unpaved Areas: Plus or minus 1 inch

2. Walks: Plus or minus 1 inch

C. Grading inside Building Lines: Finish subgrade to a tolerance of 1/2 inch when tested with a 10-foot straightedge.

3.18 BASE COURSES

A. Place base course on subgrades free of mud, water or other deleterious materials. On prepared subgrade, place base course as follows:

1. Place base course 8 inches or less in compacted thickness in a single layer.

2. Compact base course at optimum moisture content to required grades, lines, cross sections, and thickness to not less than 95 percent of maximum dry density according to ASTM D 1557.

3.19 FIELD QUALITY CONTROL

A. Testing Agency: The University will engage a qualified independent geotechnical engineering testing agency to perform field quality-control testing.

B. Allow testing agency to inspect and test subgrades and each fill or backfill layer. Proceed with subsequent earthwork only after test results for previously completed work comply with requirements.

C. Foundation and Footing Subgrades: At least one test of each soil stratum shall be performed to verify design bearing capacities. Subsequent verification and approval of other subgrades may be based on a visual comparison of subgrade with tested subgrade when approved by the University’s Representative.

D. Testing agency shall test compaction of soils in place according to ASTM D 1556, ASTM D 2167, ASTM D 2922, and ASTM D 2937, as applicable. Tests shall be performed at the following locations and frequencies:

1. Building Slab Areas: At subgrade and at each compacted fill and backfill layer, at least 1 test for every 2000 sq. ft. or less of paved area or building slab, but in no case fewer than 3 tests.

2. Foundation Wall Backfill: At each compacted backfill layer, at least 1 test for each 100 feet or less of wall length, but no fewer than 2 tests.

3. Trench Backfill: At each compacted initial and final backfill layer, at least 1 test for each 150 feet or less of trench length, but no fewer than 2 tests.

E. When testing agency reports that subgrades, fills, or backfills have not achieved degree of compaction specified, scarify and moisten or aerate, or remove and replace soil to depth required; recompact and retest until specified compaction is obtained.

3.20 PROTECTION

A. Protecting Graded Areas: Protect newly graded areas from traffic and erosion. Keep free of trash and debris.

B. Repair and reestablish grades to specified tolerances where completed or partially completed surfaces become eroded, rutted, settled, or where they lose compaction due to subsequent construction operations or weather conditions.

1. Scarify or remove and replace soil material to depth as directed by the University’s Representative; reshape and recompact.

C. Where settling occurs before Project correction period elapses, remove finished surfacing, backfill with additional soil material, compact, and reconstruct surfacing.

1. Restore appearance, quality, and condition of finished surfacing to match adjacent work, and eliminate evidence of restoration to greatest extent possible.

3.21 DISPOSAL OF SURPLUS AND WASTE MATERIALS

A. Disposal: Remove surplus satisfactory soil and waste material, including unsatisfactory soil, trash, and debris, and legally dispose of it off University's property.

1. Remove waste material, including unsatisfactory soil, trash, and debris, and legally dispose of it off University's property.

END OF SECTION

SECTION 02490

ROCK ANCHORS

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes furnishing, drilling holes, installing, and testing rock anchors as indicated.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. ACI INTERNATIONAL (ACI)

ACI 301	Specifications for Structural Concrete for Buildings
ACI 318/318R	Building Code Requirements for Structural Concrete and Commentary

B. AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO M 252	Corrugated Polyethylene Drainage Pipe

C. AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 316	ASD Manual of Steel Construction

D. AMERICAN PETROLEUM INSTITUTE (API)

API Spec 5CT	Casing and Tubing (English and Metric Units)

E. ASTM INTERNATIONAL (ASTM)

ASTM A 36/A 36M	Carbon Structural Steel
ASTM A 500	Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A 53/A 53M	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A 536	Ductile Iron Castings
ASTM A 572/A 572M	High-Strength Low-Alloy Columbium-Vanadium Structural Steel

ASTM A 588/A 588M	High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. (100 mm) Thick
ASTM A 709/A 709M	Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges
ASTM A 722/A 722M	Uncoated High-Strength Steel Bar for Prestressing Concrete
ASTM A 775/A 775M	Epoxy-Coated Reinforcing Steel Bars
ASTM C 109/C 109M	Compressive Strength of Hydraulic Cement Mortars (Using 2-in. [50-mm] Cube Specimens)
ASTM C 1107	Packaged Dry, Hydraulic-Cement Grout(Nonshrink)
ASTM C 144	Aggregate for Masonry Mortar
ASTM C 150	Portland Cement
ASTM C 33	Concrete Aggregates
ASTM D 1248	Polyethylene Plastics Extrusion Materials for Wire and Cable
ASTM D 1784	Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
ASTM D 1785	Poly(Vinyl Chloride)(PVC) Plastic Pipe, Schedules 40, 80, and 120
ASTM D 3350	Polyethylene Plastics Pipe and Fittings Materials
ASTM D 4101	Polypropylene Injection and Extrusion Materials

F. POST-TENSIONING INSTITUTE (PTI)

PTI Post Ten Man	Post Tensioning Manual
PTI Rec	Recommendations for Prestressed Rock and Soil Anchors
PTI Spec	Specification for Unbonded Single Strand Tendons

1.03 DEFINITIONS

A. The following definitions are in addition to those given in PTI Rec, Section 2.0:

1. Anchored Structure - The wall, foundation or other structure to which the anchor is to transfer force.

2. Demonstration Test Anchor - An anchor which is performance tested to verify design assumptions and installation practices.

1.04 SYSTEM DESCRIPTION

A. General: The work includes design, fabrication, installation and testing of the rock anchor system. The design of the rock anchor system shall be provided by the Contractor and shall be completely the Contractor's responsibility. General design criteria are shown on the drawings and given in paragraph Design Requirements. The materials, design, stressing, load testing, and acceptance shall be in accordance with PTI Rec and these specifications. Rock anchors should be threaded bar type. The Contractor shall be responsible for the design of the anchor and bearing plate, determining top of rock, determining drilling methods, and determining hole diameter and bond length. The complete design, including design computations, fabrication and installation drawings and installation plan, shall be certified by a Professional Structural or Civil Engineer registered in the State of California and shall be submitted to the University’s Representative for approval. Approval of the design by the University’s Representative shall not relieve the Contractor of responsibility for design and performance of the rock anchors.

B. Anchor Design Requirements

1. The individual rock anchors shall be designed to meet the following criteria:

a. Anchor Location: as shown on the drawings.

b. Horizontal Spacing: four times nominal diameter or 4 feet whichever is greater.

c. Hole Diameter: Diameter of anchor plus minimum 1 inch grout each side.

d. Design Load: 40 kips for anchors in telescope pier footing, 20 kips for anchors in ring footing.

e. Assumed Rock-Grout Bond Strength: 50 psi.

f. Minimum Unbonded Length: Down to elevation 4186.0 feet.

g. Minimum Required Bond Length: A minimum bond length of 10 feet in the rock for ASTM A 722 Type II bar is recommended.

h. Maximum Bond Length: 35 feet.

Corrosion Protection: Class I, Encapsulated anchor with a sheath.

i. Angle of Anchor Inclination: 0 degrees from vertical with a tolerance of 3 degrees.

2. The Design Load shall not exceed 60 percent of the ultimate strength of the bar anchor. The Lock-off Load shall not exceed 70 percent of the ultimate strength of the bar anchor. The maximum Test Load shall not exceed 80 percent of the ultimate strength of the bar anchor. The designer shall include consideration of group effect of closely spaced anchors when determining design load and minimum spacing. The bearing plates shall be designed so that the bending stresses in the plate do not exceed the yield strength of the steel when a load equal to 95 percent of the minimum specified ultimate tensile strength of the bar anchor is applied and so that the average bearing stress on the structure does not exceed 3500 psi. The anchorage assembly connection to the structure shall be designed in accordance with ACI 318/318R.

1.05 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Fabrication and Installation Drawings: The design shall include drawings and detailed installation procedures and sequences showing complete details of the installation procedure and equipment; anchor fabrication; grouting methods; grout mix designs; anchor and casing placement and installation; corrosion protection for bond length, stressing length and anchorage; stressing and testing procedures with lengths, forces, deformations, and elongations for the approval by the University’s Representative. Shop drawings for anchors shall be stamped by a California Registered Engineer and shall include locations and details of the centralizers. If different types of anchors are to be installed, each anchor type shall be readily identifiable. Once reviewed by the University’s Representative, no changes or deviation from shop drawings shall be permitted without further review by the University’s Representative.

B. Equipment Data: Submit catalog cuts, brochures, or other descriptive literature describing the equipment to be used for drilling, grouting, handling, and installing the rock anchors. The Contractor shall also submit sketches, drawings or details showing the access and temporary supports where required for the drilling equipment and stressing frames. Descriptions of stressing jacks, gages, dynamometers, load cells, or other devices for measuring stressing load, certified calibration records for each set of jacking equipment, and current testing curves for stress measurement gages which show that gages have been calibrated for the jacks for which they are used shall be submitted for review 30 days prior to the start of the testing operations.

C. Qualifications of Designer, Fabricator, and Installer: The qualifications and experience records shall be submitted for approval. Experience records shall identify all the individuals responsible for the anchors and shall include a listing of projects of similar scope performed within the specified period along with points of contact. The Contractor shall submit the qualifications prior to the installation of any anchors specified in this section.

D. Installation Plan: Submit a plan for installing the rock anchors. The proposal shall describe the sequence for installation and other restrictions as outlined on the drawings or specified. The anchor and casing installation procedures shall be determined by the Contractor as part of the anchor design. The installation plan shall also include descriptions of methods and equipment to be used by the Contractor for alignment checking of anchor holes and casings.

E. Design Computations: Furnish design computations and data for the rock anchors, bearing plates, and bond zones. The computations shall include drawings, design assumptions, calculations, and other information in sufficient detail to verify the design proposed. The design shall be certified by a California registered Professional Engineer with proven experience in design of rock anchor components as stated in paragraph Qualifications. Calculations shall be included for the stressing frames. The University’s Representative will approve the Contractor's design calculations. Approval of the Contractor's design calculations will not relieve the Contractor of responsibility for unsatisfactory performance of the installed rock anchors. All design computations shall be furnished at least 30 calendar days prior to the proposed commencement of drilling.

F. Anchor Design: Furnish a design schedule for the anchors which includes the following:

1. Anchor number.

2. Anchor design load.

3. Type and size of anchor.

4. Minimum total anchor length.

5. Minimum bond length.

6. Minimum unbonded length.

7. Details of corrosion protection, including details of anchorage and installation.

The design schedule shall be submitted at least 30 days prior to commencement of work on the anchors covered by the schedule.

G. Test Reports

1. Bar Anchors: Submit certified test reports for each heat or lot of bar anchors, with materials delivered to the site.

2. Cement Grout Mixture Proportions: Thirty days prior to installation of anchors, submit the mixture proportions that will produce grout of the quality required. Applicable test reports shall be submitted to verify that the grout mixture proportions selected will produce grout of the quality specified.

H. Certificates

1. Bar Anchors: Furnish five copies of mill reports and five copies of a certificate from the manufacturer stating chemical properties, ultimate strengths, yield strengths, modulus of elasticity, and any other physical properties needed for the required computations, for the type of steel furnished.

I. Driller Logs: Submit the original handwritten log and 3 copies in typed format within two days of the completion of each hole.

J. Anchor Records: Upon completion of installation of each anchor, furnish top of bond zone elevation, bond length, free stressing length of anchor, grout mix, grouting pressure, bags of cement injected, a report of performance test or proof test and extended creep test results, and hole alignment surveys. The performance test, proof test and extended creep test results shall include measured lengths of drill holes and anchors, the loads and elongations recorded during testing, monitoring and stressing of the anchors, and graphs of test results.

1.06 QUALIFICATIONS

A. Anchor designer, fabricator and installer qualifications shall be submitted for approval in accordance with paragraph SUBMITTALS. The submittals shall, where applicable, identify individuals who will be working on this contract and their relevant experience. No changes shall be made in approved personnel without prior approval of the University’s Representative.

B. Designer Qualifications: The anchors shall be designed by Professional Engineers who have designed a minimum three rock anchor projects similar in size and scope to this project within the past ten years. The drawings and calculations shall be signed by a State of California Registered Professional Engineer.

C. Fabricator Qualifications: The anchors shall be fabricated by a manufacturer that has been in the practice of designing and fabricating rock anchors similar in size and scope to this project for at least ten years.

D. Installer Qualifications: The anchors shall be installed by a firm which is regularly engaged in the installation of rock anchors and has at least ten years experience in the installation of similar anchors. The superintendent shall have installed anchors on at least five projects of similar scope and size.

1.07 PREPARATORY MEETING

A. Prior to commencing any work on the anchors, the Contractor, including all field personnel to be involved in drilling and installation of the anchors, shall meet with the University's Representative to review the plans and specifications, work plans, and submittals. Drilling may commence upon approval of the anchor installation plan and procedures described in paragraph SUBMITTALS and after the conduct of the Preparatory Meeting.

1.08 DELIVERY, STORAGE AND HANDLING

A. Materials shall be suitably wrapped, packaged or covered at the factory or shop to prevent being affected by dirt, water, oil, grease, and rust. Materials shall be protected against abrasion or damage during shipment and handling. Materials stored at the site shall be placed above ground on a well supported platform and covered with plastic or other approved material. Materials shall be protected from adjacent construction operations. Grounding of welding leads to bar anchors shall not be permitted. Bar anchors which are damaged by abrasion, cuts, nicks, heavy corrosions, pitting, welds or weld spatter shall be rejected and removed from the site. Anchors shall be inspected prior to insertion into anchor holes for damage to corrosion protection. Any such damage shall be repaired in a manner recommended by the manufacturer and approved by the University's Representative.

1.09 SITE CONDITIONS

A. A foundation investigation has been made at the site by the University and data is presented in the Geologic/Geotechnical Study Report by Geomatrix Consultants. Refer to Section 00200, GEOTECHNICAL DATA. Logs of core borings and subsurface soil data logs are shown in the above report. While the foundation information is representative of subsurface conditions at the respective locations, local variations in the characteristics of the subsurface materials may be anticipated. Local variations which may be encountered include, but are not limited to, classification and thickness of rock strata, fractures, and other discontinuities in the rock structure, and variation in the soil classifications. Such variations will not be considered as differing materially within the purview of the General Conditions, paragraph Concealed or Unknown Conditions. Core from the borings indicated on the drawings are available for inspection as indicated by the University's Representative. The Contractor is responsible for verifying the location of all utilities that may be affected by construction or the installation of the anchors.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Bar Anchors

1. High-Strength Steel Bars: ASTM A 722/A 722M, Type II, meeting all supplementary requirements.

2. Epoxy-Coated Steel Bars: ASTM A 722/A 722M, Type II, conforming to the coating requirements of ASTM A 775/A 775M, 8 mils minimum thickness. Coating at the anchorage end may be omitted over the length provided for threading the nut against the bearing plate.

B. Structural Steel: ASTM A 36/A 36M, ASTM A 572/A 572M, Grade 34550, ASTM A 588/A 588M, or ASTM A 709/A 709M Grade 50.

C. Steel Pipe: ASTM A 53/A 53M, Type E or S, Grade B.

D. Steel Tube: ASTM A 500 or API Spec 5CT, Grade N-80, Oil Field Seconds / Mill Secondary Tubing.

E. Ductile Iron Castings: ASTM A 536.

F. Polyethylene Tubing

1. Smooth Polyethylene Tubing: ASTM D 3350 or ASTM D 1248, Type III.

2. Corrugated Polyethylene Tubing: AASHTO M 252, with average minimum wall thickness of 0.06 inch.

G. Smooth Polypropylene Tubing: ASTM D 4101, designation PP 210 B5542-11.

H. Polyvinyl Chloride (PVC) Pipe: ASTM D 1785, Schedule 40.

I. Polyvinyl Chloride (PVC) Tubing

1. Smooth Polyvinyl Chloride (PVC) Tubing: ASTM D 1784.

2. Corrugated Polyvinyl Chloride (PVC) Tubing: Manufactured from rigid PVC compounds conforming to ASTM D 1784, Class 13464-8 with average minimum wall thickness of 0.04 inch.

J. Heat Shrinkable Sleeve: Radiation crosslinked polyolefin tube internally coated with an adhesive sealant.

K. Corrosion Inhibiting Compound: The corrosion inhibiting compound shall conform to the requirements of Section 3.2.5 of PTI Spec.

2.02 MANUFACTURED ITEMS

A. Anchor Head: Anchor head shall consist of steel bearing plate with nut for bar anchors, and corrosion protection. Anchorage devices shall be capable of developing 95 percent of the guaranteed ultimate strength of bar anchors. The anchorage devices shall conform to the static strength requirements of Section 3.1.6 (1) and Section 3.1.8 (1) and (2) of PTI Post Ten Man. Threaded anchorage items for epoxy coated bars shall be designed to fit over the epoxy coating and maintain the capacity of the bar anchors.

B. Bar Anchor Couplers: Couplers for bars shall be capable of developing 100 percent of the minimum specified ultimate tensile strength of the bar anchor.

C. Centralizers: Centralizers shall be fabricated from plastic, steel or other approved material which is nondetrimental to the bar anchor. Wood shall not be used. The centralizer shall be able to support the bar anchor in the drill hole and position the bar anchor so a minimum of 0.5 inch of grout cover is provided. Centralizers shall permit grout to freely flow up the drill hole.

D. Casing: Casing shall be steel pipe or steel tube selected and sized by the Contractor where required. Casing shall be the necessary type and size to permit proper drilling of anchor holes and placing of anchors as specified herein and shown on the drawings. Straightening of casings and machining of joints may be necessary in order to meet specified alignment tolerances.

E. Anchorage Covers: Anchorage covers shall be fabricated from steel or plastic. The material used shall not be subject to attack by cement, corrosion-inhibiting greases or the environment. If plastic is used, it shall not be susceptible to ultraviolet light degradation. The cover shall be securely attached to the bearing plate. If the cover is to be grease filled, the cover must form a permanent watertight enclosure for the anchorage device.

2.03 GROUT

A. Cement: ASTM C 150, Type I, II, III or V.

B. Water: Water shall be fresh, clean, potable, and free from injurious amounts of sewage, oil, acid, alkali, salts, or organic matter.

C. Aggregates: Fine aggregate for sand-cement grout shall conform to ACI 301 and ASTM C 33 for grout for backfilling holes or ASTM C 144 for grout for pregrouting. Aggregates shall not contain substances which may be deleteriously reactive with alkalies in the cement.

D. Admixtures: Accelerators are not permitted. Admixtures which control bleed, improve flowability, reduce water content and retard set may be used in the grout subject to the approval of the University’s Representative. Any admixtures used shall be compatible with the bar anchors and shall be mixed in accordance with the manufacturer's recommendations.

E. Grout for Anchors

1. Cement Grout: Cement grout mixture proportions shall be the responsibility of the Contractor. Grout for grouting anchors shall consist of a homogenous, pumpable, stable mixture of portland cement and water. The Contractor shall submit his proposed mix design to the University's Representative for approval. The water content shall be the minimum necessary for proper placement but the water-cement ratio shall not exceed 0.45 by weight. Final proportions of materials shall be based on results of tests made on sample mixtures of grout. The minimum compressive strength of two-inch cubes, molded, cured, and tested in accordance with ASTM C 109/C 109M, shall be 3,500 psi at the time of stressing. The Contractor shall be responsible for taking, curing, and breaking of grout test cubes for determining mix design, and all testing shall be done by an independent laboratory approved by the University's Representative. Rock conditions and temperatures shall be replicated in the curing process.

F. Sand-Cement Grout: Grout for waterproofing holes, grouting holes which fail the watertightness test, and for backfilling holes which are abandoned shall consist of a mixture of portland cement, fine aggregate and water. The grout mix proportions shall be the responsibility of the Contractor. The Contractor shall submit his proposed mix design to the University's Representative for approval. The water content shall be the minimum necessary for proper placement. Final proportions of materials shall be based on results of tests made on sample mixtures of grout. The minimum compressive strength of two-inch cubes, molded, cured, and tested in accordance with ASTM C 109/C 109M, shall be 4,000 psi. The Contractor shall be responsible for taking, curing, and breaking of grout test cubes for determining mix design, and all testing shall be done by an independent laboratory approved by the University's Representative. Rock conditions and temperatures shall be replicated in the curing process.

G. Grout for Anchor Pads: Grout for leveling bearing plates shall be nonshrink grout conforming to ASTM C 1107.

2.04 ANCHOR FABRICATION

A. General: Fabrication of the anchors shall be as recommended by the suppliers. Anchors shall be completely assembled with centralizers, grout and vent tubes and corrosion protection prior to insertion into the hole. Fabricated anchors shall be protected, transported and stored in a manner to prevent contamination or damage to any components.

B. Bar Anchors: Anchor material shall be unblemished and free of pitting, nicks, grease, or injurious defects. When required to maintain the anchor location within the hole, centralizers shall be provided at a maximum of 10 foot intervals center-to-center throughout the bond length. The entire bond length of the bar anchor

shall be free of dirt, lubricants, loose rust, corrosion-inhibiting coatings and other contaminants.

C. Bond Breaker: Bond breaker for free stressing length of unbonded anchors shall consist of smooth polyethylene tubing, minimum wall thickness 0.04 in., or smooth PVC tubing, minimum wall thickness 0.04 in.

D. Vent Tubes: Vent tubes used during grouting operations, if necessary, shall be any appropriate type for the job, as recommended by the supplier of the anchors.

E. Grout Tubes: Grout tubes shall be polyethylene tubing or as recommended by the anchor manufacturer and approved by the University’s Representative. Inside diameter of grout tubes shall be adequate to fully grout the entire hole.

F. Corrosion Protection: Double corrosion protection (Class I protection) is required. Corrosion protection shall be provided for the entire anchor and shall include anchorages covers filled with corrosion inhibiting compound or grout and encapsulation of the free stressing length and bond length.

1. Free Stressing Length Encapsulation: Encapsulation for free stressing length shall consist of a sheath of smooth polyethylene tubing, minimum wall thickness 0.06 inch; smooth polypropylene tubing, minimum wall thickness 0.06 inch; smooth PVC tubing, minimum wall thickness 0.04 inch; steel pipe or tube with minimum wall thickness 0.20 inch, or corrugated tubing conforming to paragraph Bond Length Encapsulation. Sheath for bars may be heat shrinkable sleeve with a minimum thickness of 0.024 inch. Where corrugated tubing is used for sheath for unbonded anchors, a separate bond breaker shall be provided.

2. Bond Length Encapsulation: Bond length encapsulation shall consist of corrugated polyethylene tubing, minimum wall thickness 0.060 inch or corrugated PVC tubing, minimum wall thickness 0.040 inch.

2.05 TESTS, INSPECTIONS, AND VERIFICATIONS

A. The Contractor shall have required material tests performed on bar anchors and accessories by an approved laboratory to demonstrate that the materials are in conformance with the specifications. Grout shall be tested in accordance with ASTM C 109/C 109M. These tests shall be at the Contractor's expense. Prestressing steel test results shall be furnished prior to beginning fabrication of any anchors. Grout test results shall be provided to the University’s Representative within 24 hours of testing.

PART 3 - EXECUTION

3.01 EQUIPMENT

A. The Contractor's Quality Control manager shall verify that the equipment used on site is the same as the equipment submitted for approval.

B. Drilling Equipment: Drilling equipment shall be suitable for advancing the drill tools to the depths and at the alignment indicated.

C. Grouting Equipment

1. Grout Mixer: The grout mixer shall be a high-speed, high-shear, colloidal type grout mixer capable of continuous mechanical mixing that will produce uniform and thoroughly mixed grout which is free of lumps and undispersed cement. The mixer shall be equipped with suitable water and admixture measuring devices calibrated to read in cubic feet and tenths and so designed that after each delivery the hands can be conveniently set back to zero.

2. Grout Pump: The grout pump shall be of the positive displacement type, and shall be capable of pumping at all flow rates below 20 gallons per minute, and shall be capable of pumping at the pressure of at least 50 psi at zero flow rate. For neat cement grout, the pump shall have a screen with 0.125 inch maximum clearance to sieve the grout before being introduced into the pump. Screens are not required for shear type mixers. A pump shall also be available which is capable of pumping both neat cement grout mixes and sanded grout mixes. The pumping equipment shall have a pressure gage capable of measuring pressures of at least 150 psi or twice the required grout pressure, whichever is greater.

D. Stressing Equipment: Stressing equipment shall be hydraulically operated and shall have a capacity sufficient to stress the anchors to the required Test Loads within the rated capacity in one stroke. Pumps shall be capable of applying each load increment in less than 60 seconds and shall be capable of maintaining the hydraulic pressure within 50 psi. The equipment shall permit stressing of the anchor in increments and raising or lowering the load in the anchor. The equipment shall be calibrated with an accuracy of +2% and the calibration certificate and graphs shall be available at the site. The production gage shall have graduations of 100 psi or less. A second certified gage shall be maintained for periodic verification of the production gage. A dial gage or approved device shall be provided to measure total bar anchor elongation at each load increment to the nearest 0.001 inch. The dial gage shall be capable of measuring the entire anchor movement without being reset. Calibration of gages shall be verified no more than 30 calendar days prior to commencing work under this contract and at six-month intervals throughout the period of use.

E. Testing Equipment: Testing equipment shall consist of a hydraulic jack with calibrated pressure gage for applying the load and a dial gage or vernier scale to measure anchor movement. The ram travel of the stressing equipment shall be not less than the theoretical elastic elongation of the total anchor length at the maximum Test Load. The pressure gage shall be graduated in 100 psi increments. The stressing equipment and pressure gage must have been calibrated as a unit no more than 30 calendar days prior to commencing work under this contract and at six-month intervals throughout the period of use. The movement measuring device shall have a minimum travel equal to the theoretical elastic elongation of the total anchor length at the maximum Test Load without resetting the device. An approved dial gage or vernier scale and stand shall be provided to measure movement of the structure.

3.02 DRILLING HOLES

A. General: The top of bond zone elevations and other physical conditions are the result of soil sampling and core borings. (See also paragraph "SITE CONDITIONS"). Holes shall be drilled at the locations and inclinations shown and to the depths and diameters determined by the Contractor to provide the design bond length and capacity indicated on the drawings. The locations of the holes may be changed only as approved by the University’s Representative. Any redesign of the anchored structure due to relocation of anchor holes will be performed by the University. Unless otherwise specified, the Contractor shall determine the drilling method to be used. No holes shall be drilled within 50 feet of a grouted hole until the grout has set at least 24 hours. Pressure grouting and drilling shall not be simultaneously performed within a distance of 50 feet. Care shall be taken while drilling to avoid damage of any kind to the existing structures. Damages of any nature will be evaluated by the University’s Representative and repairs or replacements shall be made at his discretion. Holes shall be drilled a maximum of 3 feet beyond the required anchor bond length. A temporary plug shall be provided for all holes drilled more than 10 days prior to installation of the anchor. Waste water from drilling operations shall be collected and recycled or treated; it shall not be discharged directly into a sewer or on the ground.

B. Drilling In Soil: Holes in soil may be drilled by rotary drilling, rotary percussive, or vibratory driven casing. Holes in soil shall be provided with steel casing where required for support of the surrounding material. Casing shall be removed during anchor grouting. Where soil is susceptible to caving, holes through soil shall be drilled by the duplex method using an inner and outer casing with return water flow between the casings.

C. Casing: Casing shall be utilized for drilling through unstable soil formations. The casing shall be advanced by rotary drilling or driving.

D. Drilling in Rock: Unless otherwise specified, holes in rock may be drilled by core drilling, rotary drilling, percussion drilling or down-the-hole hammer using equipment suitable for the intended purpose. The drilling method shall not cause structural damage to

existing structures. If damage is observed, the drilling method shall be modified. Core drilling shall be performed with rotary drilling equipment using diamond-matrix coring bits. Core from holes shall be furnished to the University's Representative in core boxes at the site for information. Additional drilling may be required based on the quality of the rock encountered. Rock core from demonstration test anchor holes only shall be retained by the Contractor for the duration of the contract as specified in paragraph "Retention of Core". Retention of core from other holes, after evaluation and release by the University's Representative, is not required. Overdrilling of holes by a maximum of three feet beyond the required elevation will be permitted if complete removal of cuttings and other material cannot be accomplished.

E. Records: The Contractor shall submit driller logs and records as specified in paragraph Driller Logs. The presence of a University's Inspector or the keeping of separate drilling records by the University's Representative shall not relieve the Contractor of the responsibility for the work specified in this paragraph. Payment will not be made for any work for which the required records have not been furnished by the Contractor.

F. Alignment

1. Tolerances: The anchor hole shall be located within 2 inches of the plan location. The entry angle shall be within 3 degrees of the specified inclination. The alignment of the drilled hole shall be within 3 degrees of the theoretical alignment. If the hole alignment is not within these tolerances, the hole shall be backfilled with cement or sand-cement grout and a new hole drilled adjacent to the rejected hole.

2. Alignment Check: Each drilled hole shall be checked for alignment as specified herein upon completion of drilling and before commencement of any other work. Direction and inclination of all anchor holes shall be checked by the Contractor for each 10-foot interval throughout the hole. Checking the alignment of each anchor hole shall be done by measuring the inclination of the actual drilled anchor hole center line in place with respect to the specified anchor center line. The specified anchor center line shall consist of a single, straight, continuous line extending from the top of the hole to the required bottom elevation of the hole. Specified anchor centerlines shall slope at the inclinations shown on the drawings. The University's Representative shall have access to holes for alignment surveys that may include, but not be limited to, slope indicators or other down-the-hole equipment. Drill rods may be required to be removed from the hole or left in place as directed by the University's Representative. Holes, or portions of holes, which are out of alignment shall be corrected or filled with cement grout having a water-cement ratio of 0.40 or sand-cement grout, and a new hole drilled as directed by the University's Representative. Slight adjustments to inclinations indicated on the drawings may be required, as directed by the

University's Representative. The Contractor shall be responsible for all drilled holes until accepted by the University's Representative. Holes to replace incorrectly drilled holes shall be drilled at no additional cost to the University. All equipment for checking alignment of anchor holes shall be operated by personnel experienced in the operation of such equipment.

3. Alignment Checking Equipment: Alignment of holes shall be checked by means of a magnetic single shot survey instrument, or equal equipment. The camera and plumb-bob assembly shall be selected based on the maximum expected range of angle deviation to be measured. If embedded metal within the structure is reasonably believed to have affected the standard magnetic compass, then a down-hole gyrocompass may be required. Payment for use of the gyrocompass will be made at the contract unit price per day.

3.03 INSTALLATION OF ANCHORS

A. General: The Contractor shall be responsible for each drilled hole until the anchor has been installed, grouted, stressed and accepted. Holes in rock and casings shall be cleaned by pressurized air and/or water to remove drill cuttings and mud. The anchors designated as demonstration test anchors shall be installed and tested prior to drilling the bond zone for other anchors within the area represented by the demonstration test anchor.

B. Placing: Equipment used in handling and placing the anchors shall be such that it does not damage or deteriorate the bar anchors, corrosion protection, or the anchorages. Each anchor shall be inspected prior to insertion into the hole. Any damage to corrosion protection shall be repaired prior to insertion or, if determined by the University's Representative to be not repairable, the anchor shall be replaced. Insertion of anchors shall be in accordance with PTI Rec.

C. Cement Grouted Rock Anchors: Grouting equipment shall be of type and capacity required for successful installation of the rock anchors. All anchors shall use single stage grouting to encase the anchor. Grouting shall be performed by a method in accordance with PTI Rec, paragraph 7.6. Grouting shall commence at the bottom of the grout zone and proceed to the top of the zone. Grouting shall be gravity flow. The casing shall be withdrawn as the grouting proceeds.

D. Anchorage Installation: The bearing plate and anchor nut shall be installed perpendicular to the anchor, within 3 degrees, and centered on the anchor without bending of the bar anchor. Wedges, wedge holes and anchor shall be free of dirt, grout or other contaminants. Corrosion protection shall be maintained intact at the anchorage and any damage shall be repaired prior to stressing.

3.04 STRESSING

A. After the anchor grout in the bond zone has reached sufficient strength in accordance with the Contractor's design, as verified by grout cube break, the anchors shall be stressed. Prior to stressing, surfaces upon which the stressing equipment is resting must be clean and the stressing equipment shall be aligned as nearly with the center of the hole as possible. An Alignment Load of 10 percent of the Design Load shall be applied to the anchor prior to setting dial gauges. The Contractor shall stress the anchor in accordance with the anchor manufacturer's recommendation, subject to the approval of the University's Representative. Design and Lock-off loads are given on the drawings. The Contractor shall determine the lock-off procedure so that the lift-off results meet the acceptance criteria specified in paragraph Acceptance. The maximum stress shall never exceed 80 percent of the guaranteed ultimate strength of anchor steel. The process of stressing the anchors shall be so conducted that accurate elongation of the anchor steel can at all times be recorded and compared with the computations submitted to, and accepted by the University's Representative. Safety precautions shall be taken to prevent workers from being behind or in front of the stressing equipment during stressing. Stressing of the anchors shall be performed in a sequence submitted by the Contractor for review by the University's Representative. All stressing shall be done in the presence of the University's Representative. At no time during the stressing and testing of an anchor shall the stressing equipment be disconnected from the temporary stressing head or anchor. Each anchor to be performance tested shall be declared acceptable before proceeding with drilling for other anchors within the section type represented by that anchor.

B. Lock-off: After completion of all required tests, the load shall be returned to the Alignment Load and the specified Lock-off Load shall be applied to the anchor. A lift-off test shall be made to verify the load in the anchor before the anchor is locked-off and the stressing equipment is removed. The lift-off reading shall be within five percent of the specified lock-off load. If the lift-off reading is not within five percent of the specified lock-off load, the anchorage shall be reset and another lift-off reading shall be made. This procedure shall be repeated until a satisfactory lift-off reading is obtained. After lock-off, the anchorage recess shall be fully grouted flush with the adjacent surfaces.

3.05 FIELD QUALITY CONTROL

A. General: All testing shall be performed by Contractor's Testing Laboratory. The first three anchors and a minimum of 2 percent of the remaining anchors shall be designated as demonstration test anchors. The designated demonstration test anchors shall be used to verify top of rock elevation, rock quality and the adequacy of the Contractor's anchor design and installation procedures. Demonstration test anchors shall pass the performance test prior to placing other anchors within the section represented by the respective demonstration test anchor. All other anchors shall be proof tested.

During the stressing of each anchor, a record shall be kept of gage pressure and of anchor elongation at each stage of stressing to the specified test or Lock-off Load, as applicable. The Test Load shall not be exceeded. The Contractor shall provide a qualified engineer to evaluate the anchor test results and determine the acceptability of the anchors in accordance with the criteria indicated hereunder. Final acceptance of each anchor will be made by the University's Representative. All tests shall be run in the presence of the University's Representative.

B. Performance Test: At least three of the anchors for telescope footing and one for building footing shall be performance tested. Performance test shall consist of cyclically and incrementally loading and unloading the anchor, and shall be conducted in accordance with PTI Rec, Paragraph 8.3.2. During the testing of each anchor, a record shall be kept of gage pressure and of anchor elongation at each stage of stressing to each Test Load required by PTI Rec. Measurements of the elongation of prestressing steel shall be made in accordance with PTI Rec. If the total movement at the end of 10 minutes at the Test Load exceeds 0.040 inch, the Test Load shall be held an additional 50 minutes and the movement readings shall be taken at the interval specified in PTI Rec, Paragraph 8.3.2. Test records, including plots and graphical analysis of test data, shall be furnished upon acceptance of each performance tested anchor in accordance with paragraph SUBMITTALS.

C. Proof Test: Each anchor shall be proof tested to at least 1.33 times the design load. Proof test shall consist of incrementally loading the anchor and shall be conducted in accordance with PTI Rec, Paragraph 8.3.3. During the testing of each anchor, a record shall be kept of gage pressure and of anchor elongation at each stage of stressing to the Test Load required by PTI Rec. Measurements of the elongation of prestressing steel shall be made in accordance with PTI Rec. If the total movement at the end of 10 minutes at the Test Load exceeds 0.040 inch, the Test Load shall be held an additional 50 minutes and the movement readings shall be taken at the interval specified in PTI Rec, Paragraph 8.3.3. Test records, including plots and graphical analysis of test data, shall be furnished upon acceptance of each proof tested anchor in accordance with paragraph SUBMITTALS. The proof test results shall be compared with similar anchors in which performance tests have been performed. If any significant variation from the proof tests occurs, the University's Representative may require additional performance tests.

D. Supplementary Extended Creep Tests: At least two extended creep tests shall be performed on anchors in telescope footing (not ring wall footing). Creep test shall consist of cyclically and incrementally loading and unloading the anchor, and shall be conducted in accordance with PTI Rec, Paragraph 8.3.4. Each maximum load shall be held in accordance with PTI Post Ten Man, Table 8.3.4. A plot of each family of creep curves shall be submitted along with the recorded readings taken at time of the test.

E. Driller Logs: The Contractor shall keep accurate driller logs and records of all work accomplished under this contract and shall deliver complete, legible copies of these logs and records to the

University's Representative upon completion of the work or at such other time or times as he may be directed. All such records shall be preserved in good condition and order by the Contractor until they are delivered and accepted, and the University's Representative shall have the right to examine such records at any time prior to their delivery. Separate logs shall be made for each hole. The Contractor shall use a DRILLING LOG form which provides the required information for his logs. The following information shall be included on the logs or in the records for each hole:

1. Hole number or designation and elevation of top of hole.

2. Inclination of the hole.

3. Make and manufacturer's model designation of drilling equipment.

4. Dates and time when drilling operations were performed.

5. Time required for drilling each run.

6. Elevation of top of rock.

7. Steel casing seat elevation.

8. Depths and elevations at which core was recovered or attempts made to core including top and bottom depth of each run.

9. Geologic classification or description by depths of each stratigraphic unit cored. This classification or description shall be made immediately following the taking of the core.

10. Percentage of core recovered and rock quality designation per run.

11. Depth and elevation of rod drops and other unusual occurrences.

12. Depth and elevation at which groundwater is encountered.

13. Depths and elevations at which drill water is lost and regained and amounts.

14. Depth and elevation of bottom of hole, determined by measuring the drill steel length.

F. Anchor Records: Upon completion of installation of each anchor, the anchor records shall be furnished to the University's Representative as specified in paragraph SUBMITTALS. In addition, as-built drawings showing the completed installation of the anchors shall be furnished upon completion of installation of all anchors.

3.06 ACCEPTANCE

A. General: Acceptance of anchors shall be determined by the University's Representative. The following criteria will be used in determination of the acceptability of each anchor:

1. Creep: Creep movement shall not exceed 0.040 inch at maximum Test Load during the first 10 minutes of the performance or proof test. If the creep movement exceeds this limit, it shall not exceed 0.080 inch at the maximum Test Load at the end of 60 minutes. If the creep movement exceeds 0.080 inch at the maximum Test Load at the end of 60 minutes, the anchor shall be rejected.

2. Movement: Apparent free length shall be calculated from the observed elastic movement in accordance with PTI Rec, Section 8.3.2.

    a. Minimum Apparent Free Length: The calculated free length shall be not less than 80% of the designed free anchor length plus the jack length. If the anchor does not meet this criteria, the anchor shall be restressed from the Alignment Load to the Test Load and the apparent free length shall be recalculated. If the anchor does not meet this criteria after 3 attempts (original plus 2 restresses), the anchor shall be rejected.

    b. Maximum Apparent Free Length: The calculated free length shall be not more than 100% of the designed free anchor length plus 50% of the bond length plus the jack length. If the anchor does not meet this criteria, and the cause of the behavior is not investigated and explained to the satisfaction of the University’s Representative, the anchor shall be rejected.

3. Initial Lift-Off Reading: The initial lift-off reading shall be within 5% of the specified Lock-off Load. If the anchor does not meet this criteria, the anchor shall be adjusted as necessary and the lift-off reading shall be repeated.

B. Replacement of Rejected Anchors: Any anchor that fails the performance or proof test or is rejected by the University’s Representative shall be replaced. A replacement anchor, including a new anchor hole, shall be provided by the Contractor at no expense to the University. The location of the replacement anchor shall be as directed by the University’s Representative. The Contractor shall provide all materials, supplies, equipment, and labor necessary to provide a new anchor assembly to the satisfaction of the University’s Representative. No drilling shall be performed for a replacement anchor until the grouting of all rock anchors within 50 feet of the replacement anchor location has been allowed to set for at least 24 hours. Payment will not be made for rejected or failed anchors. The Contractor shall either remove failed anchors and thoroughly ream and clear the anchor hole or remove the load and cut the anchor and casing flush.

- END OF SECTION -

SECTION 03100

STRUCTURAL CONCRETE FORMWORK

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes the following:

1. Furnishing form materials

2. Constructing formwork

3. Removing forms

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. AMERICAN HARDBOARD ASSOCIATION (AHA)

AHA A135.4	Basic Hardboard

B. U.S. DEPARTMENT OF COMMERCE (DOC)

PS1	Construction and Industrial Plywood (APA V995)

1.03 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Shop Drawings: Submit drawings showing details of formwork, including dimensions of joints, supports, studding and shoring, and sequence of form and shoring removal.

B. Product Data: Submit manufacturer's data including literature describing form materials, accessories, and form releasing agents.

PART 2 - PRODUCTS

2.01 FORM MATERIALS

A. Forms For Class C Finish: Forms for Class C finished surfaces shall be plywood conforming to PS1, Grade B-B concrete form panels, Class I or II; tempered concrete form hardboard conforming to AHA A135.4; other approved concrete form material; or steel, except that steel lining on wood sheathing shall not be used.

B. Forms For Class D Finish: Forms for Class D finished surfaces, except where concrete is placed against earth, shall be wood or steel or other approved concrete form material.

C. Form Ties: Form ties shall be factory-fabricated metal ties, shall be of the removable or internal disconnecting or snap-off type, and shall be of a design that will not permit form deflection and will not spall concrete upon removal. Solid backing shall be provided for each tie. Except where removable tie rods are used, ties shall not leave holes in the concrete surface less than 1/4 inch nor more than 1 inch deep and not more than 1 inch in diameter. Removable tie rods shall be not more than 1-1/2 inches in diameter.

D. Form Releasing Agents: Form releasing agents shall be commercial formulations that will not bond with, stain or adversely affect concrete surfaces. Agents shall not impair subsequent treatment of concrete surfaces depending upon bond or adhesion nor impede the wetting of surfaces to be cured with water or curing compounds.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Formwork: Forms shall be mortar tight, properly aligned and adequately supported to produce concrete surfaces meeting the surface requirements specified in Section 03300 CAST-IN-PLACE STRUCTURAL CONCRETE and conforming to construction tolerance given in TABLE 1. Where forms for continuous surfaces are placed in successive units, the forms shall fit over the completed surface to obtain accurate alignment of the surface and to prevent leakage of mortar. Forms shall not be reused if there is any evidence of surface wear and tear or defects which would impair the quality of the surface. Surfaces of forms to be reused shall be cleaned of mortar from previous concreting and of all other foreign material before reuse. Form ties that are to be completely withdrawn shall be coated with a nonstaining bond breaker.

3.02 CHAMFERING

A. Except as otherwise shown, external corners that will be exposed shall be chamfered, beveled, or rounded by moldings placed in the forms.

3.03 COATING

A. Forms for Class C and D finished surfaces may be wet with water in lieu of coating immediately before placing concrete, except that in cold weather with probable freezing temperatures, coating shall be mandatory. Surplus coating on form surfaces and coating on reinforcing steel and construction joints shall be removed before placing concrete.

3.04 REMOVAL OF FORMS

A. Forms shall be removed preventing injury to the concrete and ensuring the complete safety of the structure. Formwork may be removed when the concrete has attained sufficient strength to resist damage from the removal operation but not before at least 24 hours has elapsed since concrete placement.

TABLE 1

TOLERANCES FOR FORMED SURFACES

1.	Variations from the plumb:	In any 10 feet of length ---------- 1/4 inch
	a. In the lines and surfaces of walls	Maximum for entire length ---------- 1 inch
	b. For exposed control-joint grooves, and other conspicuous lines	In any 20 feet of length ---------- ---- 1/4 inch Maximum for entire length---------- 1/2 inch
2.	Variation from the level or from the grades indicated on the drawings:	In any 10 feet of length ----------1/4 inch In any bay or in any 20 feet of length---------- 3/8 inch
	a. In exposed sills, horizontal grooves, and other conspicuous lines	In any bay or in any 20 feet of length ---------- ----- 1/4 inch Maximum for entire length---------- 1/2 inch
3.	Variation of the linear building lines from established position in plan	In any 20 feet --------- 1/2 inch Maximum ----------1 inch
4.	Variation in the sizes and locations of sleeves, floor openings, and wall opening	Minus ---------- 1/4 inch Plus ---------- 1/2 inch
5.	Variation in cross-sectional dimensions in the thickness of slabs and wall	Minus ---------- 1/4 inch Plus ---------- 1/2 inch
6.	Footings:	
	a. Variation of dimensions in plan	Minus ---------- 1/2 inch Plus ---------- 2 inches when formed or plus 3 inches when placed against unformed excavation

TABLE 1 (Cont.)

TOLERANCES FOR FORMED SURFACES

b.	Misplacement of eccentricity	2 percent of the footing width in the direction of misplacement but not more than 2 inches
c.	Reduction in thickness of specified thickness	Minus ---------- 5 percent

END OF SECTION

SECTION 03200

CONCRETE REINFORCEMENT

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes furnishing and installing reinforcement for cast-in-place concrete construction.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. ACI INTERNATIONAL (ACI)

ACI 318/318R	Building Code Requirements for Structural Concrete and Commentary

B. ASTM INTERNATIONAL (ASTM)

ASTM A 615/A 615M	Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

C. CONCRETE REINFORCING STEEL INSTITUTE (CRSI)

CRSI 1MSP	Manual of Standard Practice

1.03 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Shop Drawings: Submit detail drawings showing reinforcing steel placement, schedules, sizes, grades, and splicing and bending details. Drawings shall show support details including types, sizes and spacing.

B. Certificates: Submit certified copies of mill reports attesting that the reinforcing steel furnished contains no less than 25 percent recycled scrap steel and meets the requirements specified herein, prior to the installation of reinforcing steel. Reinforcing steel shall also meet the requirements for use in resisting earthquake-induced forces as set forth in ACI 318/318R, paragraph 21.2.5.

1.04 DELIVERY AND STORAGE

A. Reinforcement and accessories shall be stored off the ground on platforms, skids, or other supports.

PART 2 – PRODUCTS

2.01 DOWELS

A. Dowels shall conform to ASTM A 675/A 675M, Grade 80.

2.02 REINFORCING STEEL

A. Reinforcing steel shall be deformed bars conforming to ASTM A 615/A 615M, grades and sizes as indicated.

2.03 WIRE TIES

A. Wire ties shall be 16 gauge or heavier black annealed steel wire.

2.04 SUPPORTS

A. Bar supports for formed surfaces shall be designed and fabricated in accordance with CRSI 1MSP and shall be steel or precast concrete blocks. Precast concrete blocks shall have wire ties and shall be not less than 4 inches square when supporting reinforcement on ground. Precast concrete block shall have compressive strength equal to that of the surrounding concrete. Where concrete formed surfaces will be exposed to weather, steel supports within 1/2 inch of concrete surface shall be galvanized, plastic protected or of stainless steel. Concrete supports used in concrete exposed to view shall have the same color and texture as the finish surface. For slabs on grade, supports shall be precast concrete blocks, plastic coated steel fabricated with bearing plates, or specifically designed wire-fabric supports fabricated of plastic.

PART 3 – EXECUTION

3.01 REINFORCEMENT

A. Reinforcement shall be fabricated to shapes and dimensions shown and shall conform to the requirements of ACI 318/318R. Reinforcement shall be cold bent unless otherwise authorized. Bending may be accomplished in the field or at the mill. Bars shall not be bent after embedment in concrete. Safety caps shall be placed on all exposed ends of vertical concrete reinforcement bars that pose a danger to life safety. Wire tie ends shall face away from the forms.

B. Placement: Reinforcement shall be free from loose rust and scale, dirt, oil, or other deleterious coating that could reduce bond with the concrete. Reinforcement shall be placed in accordance with ACI 318/318R at locations shown plus or minus one bar diameter. Reinforcement shall not be continuous through expansion joints and shall be as indicated through construction or contraction joints. Concrete coverage shall be as indicated or as required by ACI 318/318R. If bars are moved more than one bar diameter to avoid interference with other reinforcement, conduits or embedded items, the resulting arrangement of bars, including additional bars required

to meet structural requirements, shall be approved before concrete is placed.

C. Splicing: Splices of reinforcement shall conform to ACI 318/318R and shall be made only as required or indicated. Splicing shall be by lapping or by mechanical connection; except that lap splices shall not be used for bars larger than No. 11 unless otherwise indicated. Lapped bars shall be placed in contact and securely tied or spaced transversely apart to permit the embedment of the entire surface of each bar in concrete. Lapped bars shall not be spaced farther apart than one-fifth the required length of lap or 6 inches. Mechanical butt splices shall be in accordance with the recommendation of the manufacturer of the mechanical splicing device. Butt splices shall develop 125 percent of the specified minimum yield tensile strength of the spliced bars or of the smaller bar in transition splices. Bars shall be flame dried before butt splicing. Adequate jigs and clamps or other devices shall be provided to support, align, and hold the longitudinal centerline of the bars to be butt spliced in a straight line.

3.02 DOWEL INSTALLATION

A. Dowels shall be installed in slabs on grade where construction joints are required by the concrete placement schedule and at right angles to joint being doweled. Dowels shall be accurately positioned and aligned parallel to the finished concrete surface before concrete placement. Dowels shall be rigidly supported during concrete placement. One end of dowels shall be coated with a bond breaker.

END OF SECTION

SECTION 03300

CAST-IN-PLACE STRUCTURAL CONCRETE

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes the following:

1. Furnish concrete materials

2. Place, finish, cure, and protect concrete

3. Perform testing and inspection of concrete construction

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. ACI INTERNATIONAL (ACI)

ACI 117	Standard Tolerances for Concrete Construction and Materials & Commentary
ACI 211.1	Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 214.3R	Simplified Version of the Recommended Practice for Evaluation of Strength Test Results of Concrete
ACI 305R	Hot Weather Concreting
ACI 318/318R	Building Code Requirements for Structural Concrete and Commentary

B. ASTM INTERNATIONAL (ASTM)

ASTM C 1017/C 1017M	Chemical Admixtures for Use in Producing Flowing Concrete
ASTM C 1059	Latex Agents for Bonding Fresh to Hardened Concrete
ASTM C 1064/C 1064M	Temperature of Freshly Mixed Portland Cement Concrete
ASTM C 1077	Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

ASTM C 1107	Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
ASTM C 136	Sieve Analysis of Fine and Coarse Aggregates
ASTM C 143/C 143M	Slump of Hydraulic Cement Concrete
ASTM C 150	Portland Cement
ASTM C 171	Sheet Materials for Curing Concrete
ASTM C 172	Sampling Freshly Mixed Concrete
ASTM C 173/C 173M	Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C 192/C 192M	Making and Curing Concrete Test Specimens in the Laboratory
ASTM C 203	Breaking Load and Flexural Properties of Block-Type Thermal Insulation
ASTM C 231	Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 260	Air-Entraining Admixtures for Concrete
ASTM C 309	Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C 31/C 31M	Making and Curing Concrete Test Specimens in the Field
ASTM C 33	Concrete Aggregates
ASTM C 39/C 39M	Compressive Strength of Cylindrical Concrete Specimens
ASTM C 42/C 42M	Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C 494/C 494M	Chemical Admixtures for Concrete
ASTM C 618	Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete
ASTM C 78	Flexural Strength of Concrete (Using Simple Beam With Third-Point Loading)
ASTM C 881	Epoxy-Resin-Base Bonding Systems for Concrete

ASTM C 94/C 94M	Ready-Mixed Concrete
ASTM D 75	Sampling Aggregates
ASTM E 1155	Determining Floor Flatness and Floor Levelness Numbers
ASTM E 96	Water Vapor Transmission of Materials

1.03 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Product Data: Submit concrete mixture Proportions. Include the results of trial mixture design studies along with a statement giving the maximum nominal coarse aggregate size and the proportions of ingredients that will be used in the manufacture of each strength or class of concrete, at least 14 days prior to commencing concrete placing operations. Aggregate weights shall be based on the saturated surface dry condition. The statement shall be accompanied by test results from an approved independent commercial testing laboratory, showing that mixture design studies have been made with materials proposed for the project and that the proportions selected will produce concrete of the qualities indicated. No substitutions shall be made in the materials used in the mixture design studies without additional tests to show that the quality of the concrete is satisfactory.

B. Test Reports: Submit certified copies of laboratory test reports, including mill tests and all other test data, for portland cement, blended cement, pozzolan, aggregate, admixtures, and curing compound proposed for use on this project.

C. Certificates: Submit written documentation for Contractor Quality Control personnel qualifications.

1.04 QUALIFICATIONS

A. Contractor Quality Control personnel assigned to concrete construction shall be American Concrete Institute (ACI) Certified Workmen in one of the following grades or shall have written evidence of having completed similar qualification programs:

Concrete Field Testing Technician, Grade I
Concrete Laboratory Testing Technician, Grade I or II
Concrete Construction Inspector, Level II
Concrete Transportation Construction Inspector or
Reinforced Concrete Special Inspector, Jointly certified by American Concrete Institute (ACI), Building Official and Code Administrators International (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International (SBCCI).

1.05 GENERAL REQUIREMENTS

A. Tolerances: Except as otherwise specified herein, tolerances for concrete batching, mixture properties, and construction as well as definition of terms and application practices shall be in accordance with ACI 117. Level and grade tolerance measurements of slabs shall be made as soon as possible after finishing; when forms or shoring are used, the measurements shall be made prior to removal.

B. Strength Requirements: Specified compressive strength (f'c) shall be as follows:

COMPRESSIVE STRENGTH	STRUCTURE OR PORTION OF STRUCTURE
4000 psi at 28 days	Foundations
3000 psi at 28 days	Slab on grade
4000 psi at 28 days	Piers/Pedestals
3000 psi at 28 days	Walls

Concrete slabs on-grade shall have a 28-day flexural strength of 650 psi. Concrete made with high-early strength cement shall have a 7-day strength equal to the specified 28-day strength for concrete made with Type I or II portland cement. Compressive strength shall be determined in accordance with ASTM C 39/C 39M. Flexural strength shall be determined in accordance with ASTM C 78.

1. Evaluation of Concrete Compressive Strength: Compressive strength specimens (6 by 12 inch cylinders) shall be fabricated by the Contractor and laboratory cured in accordance with ASTM C 31/C 31M and tested in accordance with ASTM C 39/C 39M. The strength of the concrete will be considered satisfactory so long as the average of all sets of three consecutive test results equals or exceeds the specified compressive strength f'c and no individual test result falls below the specified strength f'c by more than 500 psi. A "test" is defined as the average of two companion cylinders, or if only one cylinder is tested, the results of the single cylinder test. Additional analysis or testing, including taking cores and/or load tests may be required at the Contractor's expense when the strength of the concrete in the structure is considered potentially deficient.

2. Investigation of Low-Strength Compressive Test Results: When any strength test of standard-cured test cylinders falls below the specified strength requirement by more than 500 psi or if tests of field-cured cylinders indicate deficiencies in protection and curing, steps shall be taken to assure that the load-carrying capacity of the structure is not jeopardized. When the strength of concrete in place is considered potentially deficient, cores shall be obtained and tested in accordance with ASTM C 42/C 42M. At least three representative cores shall be taken from each member or area of concrete in place that is considered potentially deficient. The location of cores will be determined by the University's Representative to least impair the strength of the structure. Concrete in the area represented by the core

testing will be considered adequate if the average strength of the cores is equal to at least 85 percent of the specified strength requirement and if no single core is less than 75 percent of the specified strength requirement. Nondestructive tests (tests other than test cylinders or cores) shall not be used as a basis for acceptance or rejection. The Contractor shall perform the coring and repair the holes. Cores will be tested by the University's Representative.

3. Load Tests: If the core tests are inconclusive or impractical to obtain or if structural analysis does not confirm the safety of the structure, load tests may be directed by the University's Representative in accordance with the requirements of ACI 318/318RACI 318/318R. Concrete work evaluated by structural analysis or by results of a load test as being understrength shall be corrected in a manner satisfactory to the University's Representative. All investigations, testing, load tests, and correction of deficiencies shall be performed by and at the expense of the Contractor and must be approved by the University's Representative, except that if all concrete is found to be in compliance with the drawings and specifications, the cost of investigations, testing, and load tests will be at the expense of the University's Representative.

4. Evaluation of Concrete Flexural Strength: Flexural strength specimens (beams) shall be fabricated by the Contractor and laboratory cured in accordance with ASTM C 31/C 31M and tested in accordance with ASTM C 78. The strength of the concrete will be considered satisfactory so long as the average of all sets of three consecutive test results equals or exceeds the specified flexural strength and no individual test result falls below the specified flexural strength by more than 50 psi. A "test" is defined as the average of two companion beams. Additional analysis or testing, including taking cores and/or load tests may be required at the Contractor's expense when the strength of the concrete in the slab is considered potentially deficient.

C. Water-Cement Ratio: Maximum water-cement ratio (w/c) for normal weight concrete shall be as follows:

WATER-CEMENT RATIO, BY WEIGHT	STRUCTURE OR PORTION OF STRUCTURE
0.40	All concrete in contact with soil

These w/c's may cause higher strengths than that required above for compressive or flexural strength. The maximum w/c required will be the equivalent w/c as determined by conversion from the weight ratio of water to cement plus pozzolan, by the weight equivalency method as described in ACI 211.1.

D. Air Entrainment: All normal weight concrete shall be air entrained to contain between 4 and 7 percent total air, except that when the nominal maximum size coarse aggregate is 3/4 inch or smaller it shall be between 4.5 and 7.5 percent. Specified air content shall be

attained at point of placement into the forms. Air content for normal weight concrete shall be determined in accordance with ASTM C 231.

E. Slump: Slump of the concrete, as delivered to the point of placement into the forms, shall be within the following limits. Slump shall be determined in accordance with ASTM C 143/C 143M.

Structural Element	Slump Minimum	Slump Maximum
Foundation walls, substructure walls, footings, slabs	1 in.	3 in.
Any structural concrete approved for placement by pumping:		
At pumps	2 in.	6 in.
At discharge of line	1 in.	4 in.

When use of a plasticizing admixture conforming to ASTM C 1017/C 1017M is permitted to increase the slump of concrete, concrete shall have a slump of 2 to 4 inches before the admixture is added and a maximum slump of 8 inches at the point of delivery after the admixture is added.

F. Concrete Temperature: The temperature of the concrete as delivered shall not exceed 90 degrees F. When the ambient temperature during placing is 40 degrees F or less, or is expected to be at any time within 6 hours after placing, the temperature of the concrete as delivered shall be between 55 and 75 degrees F.

G. Size of Coarse Aggregate: The largest feasible nominal maximum size aggregate (NMSA) specified in paragraph AGGREGATES shall be used in each placement. However, nominal maximum size of aggregate shall not exceed any of the following: three-fourths of the minimum cover for reinforcing bars, three-fourths of the minimum clear spacing between reinforcing bars, one-fifth of the narrowest dimension between sides of forms, or one-third of the thickness of slabs or toppings.

H. Special Properties and Products: Concrete may contain admixtures other than air entraining agents, such as water reducers, superplasticizers, or set retarding agents to provide special properties to the concrete, if specified or approved. Any of these materials to be used on the project shall be used in the mix design studies.

1.06 MIXTURE PROPORTIONS

A. Concrete shall be composed of portland cement, other cementitious and pozzolanic materials as specified, aggregates, water and admixtures as specified.

B. Proportioning Studies for Normal Weight Concrete: Trial design batches, mixture proportioning studies, and testing requirements for various classes and types of concrete specified shall be the responsibility of the Contractor. Except as specified for flexural strength concrete, mixture proportions shall be based on compressive strength as determined by test specimens fabricated in accordance with ASTM C 192/C 192M and tested in accordance with ASTM C 39/C 39M. Samples of all materials used in mixture proportioning studies shall be representative of those proposed for use in the project and shall be accompanied by the manufacturer's or producer's test reports indicating compliance with these specifications. Trial mixtures having proportions, consistencies, and air content suitable for the work shall be made based on methodology described in ACI 211.1, using at least three different water-cement ratios for each type of mixture, which will produce a range of strength encompassing those required for each class and type of concrete required on the project. The maximum water-cement ratios required in subparagraph Water-Cement Ratio will be the equivalent water-cement ratio as determined by conversion from the weight ratio of water to cement plus pozzolan, by the weight equivalency method as described in ACI 211.1. If pozzolan is used in the concrete mixture, the minimum pozzolan content shall be 15 percent by weight of the total cementitious material, and the maximum shall be 35 percent. Laboratory trial mixtures shall be designed for maximum permitted slump and air content. Separate sets of trial mixture studies shall be made for each combination of cementitious materials and each combination of admixtures proposed for use. No combination of either shall be used until proven by such studies, except that, if approved in writing and otherwise permitted by these specifications, an accelerator or a retarder may be used without separate trial mixture study. Separate trial mixture studies shall also be made for concrete for any conveying or placing method proposed which requires special properties and for concrete to be placed in unusually difficult placing locations. The temperature of concrete in each trial batch shall be reported. For each water-cement ratio, at least three test cylinders for each test age shall be made and cured in accordance with ASTM C 192/C 192M. They shall be tested at 7 and 28 days in accordance with ASTM C 39/C 39M. From these test results, a curve shall be plotted showing the relationship between water-cement ratio and strength for each set of trial mix studies. In addition, a curve shall be plotted showing the relationship between 7 day and 28 day strengths. Each mixture shall be designed to promote easy and suitable concrete placement, consolidation and finishing, and to prevent segregation and excessive bleeding.

C. Proportioning Studies for Flexural Strength Concrete: Trial design batches, mixture proportioning studies, and testing requirements shall conform to the requirements specified in paragraph Proportioning Studies for Normal Weight Concrete, except that proportions shall be based on flexural strength as determined by test specimens (beams) fabricated in accordance with ASTM C 192/C 192M and tested in accordance with ASTM C 78. Procedures given in ACI 211.1 shall be modified as necessary to accommodate flexural strength.

D. Average Compressive Strength Required for Mixtures: The mixture proportions selected during mixture design studies shall produce a required average compressive strength (f'cr) exceeding the specified compressive strength (f'c) by the amount indicated below. This required average compressive strength, f'cr, will not be a required acceptance criteria during concrete production. However, whenever the daily average compressive strength at 28 days drops below f'cr during concrete production, or daily average 7-day strength drops below a strength correlated with the 28-day f'cr, the mixture shall be adjusted, as approved, to bring the daily average back up to f'cr. During production, the required f'cr shall be adjusted, as appropriate, based on the standard deviation being attained on the job.

1. Computations from Test Records: Where a concrete production facility has test records, a standard deviation shall be established in accordance with the applicable provisions of ACI 214.3R. Test records from which a standard deviation is calculated shall represent materials, quality control procedures, and conditions similar to those expected; shall represent concrete produced to meet a specified strength or strengths (f'c) within 1,000 psi of that specified for proposed work; and shall consist of at least 30 consecutive tests. A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days. Required average compressive strength f'cr used as the basis for selection of concrete proportions shall be the larger of the equations that follow using the standard deviation as determined above:

   (f'cr = f'c + 1.34S where units are in psi)

   (f'cr = f'c + 2.33S - 500 where units are in psi)

   Where S = standard deviation

   Where a concrete production facility does not have test records meeting the requirements above but does have a record based on 15 to 29 consecutive tests, a standard deviation shall be established as the product of the calculated standard deviation and a modification factor from the following table:

NUMBER OF TESTS	MODIFICATION FACTOR FOR STANDARD DEVIATION
15	1.16
20	1.08
25	1.03
30 or more	1.00

2. Computations without Previous Test Records: When a concrete production facility does not have sufficient field strength test records for calculation of the standard deviation, the required average strength f'cr shall be determined as follows:

a. If the specified compressive strength f'c is less than 3,000 psi,

f'cr = f'c + 1000 psi

b. If the specified compressive strength f'c is 3,000 to 5,000 psi,

f'cr = f'c + 1,200 psi

c. If the specified compressive strength f'c is over 5,000 psi,

f'cr = f'c + 1,400 psi

E. Average Flexural Strength Required for Mixtures: The mixture proportions selected during mixture design studies for flexural strength mixtures and the mixture used during concrete production shall be designed and adjusted during concrete production as approved, except that the overdesign for average flexural strength shall simply be 15 percent greater than the specified flexural strength at all times.

1.07 STORAGE OF MATERIALS

A. Cement and other cementitious materials shall be stored in weathertight buildings, bins, or silos which will exclude moisture and contaminants and keep each material completely separated. Aggregate stockpiles shall be arranged and used in a manner to avoid excessive segregation and to prevent contamination with other materials or with other sizes of aggregates. Aggregate shall not be stored directly on ground unless a sacrificial layer is left undisturbed. Reinforcing bars and accessories shall be stored above the ground on platforms, skids or other supports. Other materials shall be stored in such a manner as to avoid contamination and deterioration. Admixtures which have been in storage at the project site for longer than 6 months or which have been subjected to freezing shall not be used unless retested and proven to meet the specified requirements. Materials shall be capable of being accurately identified after bundles or containers are opened.

1.08 UNIVERSITY'S REPRESENTATIVE ASSURANCE INSPECTION AND TESTING

A. Day-to day inspection and testing shall be the responsibility of the Contractor Quality Control (CQC) staff. However, the University's Representative may inspect construction as considered appropriate and will monitor operations of the Contractor's CQC staff. University's Representative inspection or testing will not relieve the Contractor of any of his CQC responsibilities.

B. Materials: The University's Representative may sample and test aggregates, cementitious materials, other materials, and concrete to determine compliance with the specifications as considered appropriate. The Contractor shall provide facilities and labor as may be necessary for procurement of representative test samples.

Samples of aggregates will be obtained at the point of batching in accordance with ASTM D 75. Other materials will be sampled from storage at the jobsite or from other locations as considered appropriate. Samples may be placed in storage for later testing when appropriate.

C. Fresh Concrete: Fresh concrete will be sampled as delivered in accordance with ASTM C 172 and tested in accordance with these specifications, as considered necessary.

D. Hardened Concrete: Tests on hardened concrete will be performed by the University's Representative when such tests are considered necessary.

E. Inspection: Concrete operations may be tested and inspected by the University's Representative as the project progresses. Failure to detect defective work or material will not prevent rejection later when a defect is discovered nor will it obligate the University's Representative for final acceptance.

PART 2 - PRODUCTS

2.01 CEMENTITIOUS MATERIALS

A. Cementitious materials shall be portland cement, or portland cement in combination with pozzolan and shall conform to appropriate specifications listed below. Use of cementitious materials in concrete which will have surfaces exposed in the completed structure shall be restricted so there is no change in color, source, or type of cementitious material.

B. Portland Cement: ASTM C 150, Type I low alkali with a maximum 15 percent amount of tricalcium aluminate, or Type V.

C. Pozzolan (Fly Ash): ASTM C 618, Class C or F with the optional requirements for multiple factor, drying shrinkage, and uniformity from Table 2A of ASTM C 618. Requirement for maximum alkalies from Table 1A of ASTM C 618 shall apply. If pozzolan is used, it shall never be less than 15 percent nor more than 35 percent by weight of the total cementitious material.

2.02 AGGREGATES

A. Aggregates shall conform to the following:

1. Fine aggregate shall conform to the quality and gradation requirements of ASTM C 33.

2. Coarse aggregate shall conform to ASTM C 33, Class 5S, size designation 3/4 inch for slab on grade; size designation 1-1/2 inches for foundations.

2.03 CHEMICAL ADMIXTURES

A. Chemical admixtures, when required or permitted, shall conform to the appropriate specification listed. Admixtures shall be furnished in liquid form and of suitable concentration for easy, accurate control of dispensing.

B. Air-Entraining Admixture: ASTM C 260 and shall consistently entrain the air content in the specified ranges under field conditions.

C. Accelerating Admixture: ASTM C 494/C 494M, Type C or E, except that calcium chloride or admixtures containing calcium chloride shall not be used.

D. Water-Reducing or Retarding Admixture: ASTM C 494/C 494M, Type A, B, or D, except that the 6-month and 1-year compressive and flexural strength tests are waived.

E. Surface Retarder: COE CRD-C 94.

F. Other Chemical Admixtures: Chemical admixtures for use in producing flowing concrete shall comply with ASTM C 1017/C 1017M, Type I or II. These admixtures shall be used only when approved in writing, such approval being contingent upon particular mixture control as described in the Contractor's Quality Control Plan and upon performance of separate mixture design studies.

2.04 CURING MATERIALS

A. Impervious-sheet materials shall conform to ASTM C 171, type optional, except that polyethylene sheet shall not be used.

B. Membrane-Forming curing compound shall conform to ASTM C 309, Type 1-D or 2. Nonpigmented compound shall contain a fugitive dye, and shall have the reflective requirements in ASTM C 309 waived.

C. Burlap and cotton mat used for curing shall conform to AASHTO M 182.

2.05 WATER

A. Water for mixing and curing shall be fresh, clean, potable, and free of injurious amounts of oil, acid, salt, or alkali.

2.06 NONSHRINK GROUT

A. Nonshrink grout shall conform to ASTM C 1107, Grade A, B, or C, and shall be a commercial formulation suitable for the proposed application.

2.07 LATEX BONDING AGENT

A. Latex agents for bonding fresh to hardened concrete shall conform to ASTM C 1059.

2.08 EPOXY RESIN

A. Epoxy resin for use in repairs shall conform to ASTM C 881, Type V, Grade 2 or 3, Class as appropriate to the existing ambient and surface temperatures.

2.09 EPOXY GROUT

A. ASTM C 881. Provide Type I or Type II for grouting bolts, dowels, and rebars into concrete. Provide Grade 1 or 2 for horizontal surfaces and Grade 3 for vertical surfaces. Provide Class A if placement temperature is below 40 degrees F; Class B if placement temperature is between 40 and 60 degrees F or Class C if placement temperature is above 60 degrees F.

2.10 EMBEDDED ITEMS

A. Embedded items shall be of the size and type indicated or as needed for the application.

2.11 VAPOR BARRIER

A. Vapor barrier shall be polyethylene sheeting with a minimum thickness of 6 mils or other equivalent material having a vapor permeance rating not exceeding 30 nanograms per Pascal per second per square meter (0.5 perms) as determined in accordance with ASTM E 96.

2.12 EXPANDED POLYSTYRENE JOINT FILLER

A. Expanded polystyrene shall be a commercially available polystyrene board of thickness indicated. Expanded polystyrene shall have a flexural strength of 35 psi, minimum, determined in conformance with ASTM C 203, and a compressive yield strength of between 16 and 40 psi, at 5 percent compression.

2.13 RED DYE FOR DUCT BANK CONCRETE CAP

A. Red dye shall be commercial red iron oxide.

PART 3 – EXECUTION

3.01 PREPARATION FOR PLACING

A. Before commencing concrete placement, the following shall be performed. Surfaces to receive concrete shall be clean and free from frost, ice, mud, and water. Forms shall be in place, cleaned, coated, and adequately supported, in accordance with Section 03100 STRUCTURAL CONCRETE FORMWORK. Reinforcing steel shall be in place, cleaned, tied, and adequately supported, in accordance with Section 03200 CONCRETE REINFORCEMENT. Transporting and conveying equipment shall be in-place, ready for use, clean, and free of hardened concrete and foreign material. Equipment for consolidating concrete shall be at the placing site and in proper working order. Equipment and material for curing and for protecting concrete from weather or

mechanical damage shall be at the placing site, in proper working condition and in sufficient amount for the entire placement. When hot, windy conditions during concreting appear probable, equipment and material shall be at the placing site to provide windbreaks, shading, fogging, or other action to prevent plastic shrinkage cracking or other damaging drying of the concrete.

B. Foundations

1. Concrete on Earth Foundations: Earth (subgrade or base course) surfaces upon which concrete is to be placed shall be clean, damp, and free from debris, frost, and standing or running water. Prior to placement of concrete, the foundation shall be well drained and shall be satisfactorily graded and uniformly compacted.

2. Excavated Surfaces in Lieu of Forms: Concrete for footings may be placed directly against the soil provided the earth or rock has been carefully trimmed, is uniform and stable, and meets the compaction requirements of Section 02300 EARTHWORK. The concrete shall be placed without becoming contaminated by loose material, and the outline of the concrete shall be within the specified tolerances.

C. Preparation of Previously Placed Concrete: Concrete surfaces to which other concrete is to be bonded shall be abraded in an approved manner that will expose sound aggregate uniformly without damaging the concrete. Laitance and loose particles shall be removed. Surfaces shall be thoroughly washed and shall be moist but without free water when concrete is placed.

D. Vapor Barrier: Vapor barrier shall be provided beneath the interior on-grade concrete floor slabs. The greatest widths and lengths practicable shall be used to eliminate joints wherever possible. Joints shall be lapped a minimum of 12 inches. Torn, punctured, or damaged vapor barrier material shall be removed and new vapor barrier shall be provided prior to placing concrete. For minor repairs, patches may be made using laps of at least 12 inches. Lapped joints shall be sealed and edges patched with pressure-sensitive adhesive or tape not less than 2 inches wide and compatible with the membrane. Vapor barrier shall be placed directly on underlying base course, or capillary water barrier, unless it consists of crushed material or large granular material which could puncture the vapor barrier. In this case, the surface shall be choked with a light layer of sand, as approved, before placing the vapor barrier. A 2 inch layer of compacted, clean concrete sand (fine aggregate) shall be placed on top of the vapor barrier before placing concrete. Concrete placement shall be controlled so as to prevent damage to the vapor barrier, or any covering sand.

E. Embedded Items: Before placement of concrete, care shall be taken to determine that all embedded items are firmly and securely fastened in place as indicated on the drawings, or required. Conduit and other embedded items shall be clean and free of oil and other foreign

matter such as loose coatings or rust, paint, and scale. The embedding of wood in concrete will be permitted only when specifically authorized or directed. Voids in sleeves, inserts, and anchor slots shall be filled temporarily with readily removable materials to prevent the entry of concrete into voids. Welding shall not be performed on embedded metals within 1 foot of the surface of the concrete. Tack welding shall not be performed on or to embedded items.

3.02 TRANSPORTING CONCRETE TO PROJECT SITE

A. Concrete shall be transported to the placing site in truck mixers.

3.03 CONVEYING CONCRETE ON SITE

A. Concrete shall be conveyed from mixer or transporting unit to forms as rapidly as possible and within the time interval specified by methods which will prevent segregation or loss of ingredients, as approved by the University’s Representative. Conveying equipment shall be cleaned before each placement.

3.04 PLACING CONCRETE

A. Mixed concrete shall be discharged within 1-1/2 hours or before the mixer drum has revolved 300 revolutions, whichever comes first after the introduction of the mixing water to the cement and aggregates. When the concrete temperature exceeds 85 degrees F, the time shall be reduced to 45 minutes. Concrete shall be placed within 15 minutes after it has been discharged from the transporting unit. Concrete shall be handled from mixer or transporting unit to forms in a continuous manner until the approved unit of operation is completed. Adequate scaffolding, ramps and walkways shall be provided so that personnel and equipment are not supported by in-place reinforcement. Placing will not be permitted when the sun, heat, wind, or limitations of facilities furnished by the Contractor prevent proper consolidation, finishing and curing. Sufficient placing capacity shall be provided so that concrete can be kept free of cold joints.

B. Depositing Concrete: Concrete shall be deposited as close as possible to its final position in the forms, and there shall be no vertical drop greater than 5 feet except where suitable equipment is provided to prevent segregation and where specifically authorized. Depositing of the concrete shall be so regulated that it will be effectively consolidated in horizontal layers not more than 12 inches thick, except that all slabs shall be placed in a single layer. Concrete to receive other construction shall be screeded to the proper level. Concrete shall be deposited continuously in one layer or in layers so that fresh concrete is deposited on in-place concrete that is still plastic. Fresh concrete shall not be deposited on concrete that has hardened sufficiently to cause formation of seams or planes of weakness within the section. Concrete that has surface dried, partially hardened, or contains foreign material shall not be used. When temporary spreaders are used in the forms, the spreaders shall be removed as their service becomes unnecessary. Concrete shall not

be placed in slabs over columns and walls until concrete in columns and walls has been in-place at least two hours or until the concrete begins to lose its plasticity. Concrete for beams, girders, brackets, column capitals, haunches, and drop panels shall be placed at the same time as concrete for adjoining slabs.

C. Consolidation: Immediately after placing, each layer of concrete shall be consolidated by internal vibrators, except for slabs 4 inches thick or less. The vibrators shall at all times be adequate in effectiveness and number to properly consolidate the concrete; a spare vibrator shall be kept at the jobsite during all concrete placing operations. The vibrators shall have a frequency of not less than 10,000 vibrations per minute, an amplitude of at least 0.025 inch, and the head diameter shall be appropriate for the structural member and the concrete mixture being placed. Vibrators shall be inserted vertically at uniform spacing over the area of placement. The distance between insertions shall be approximately 1-1/2 times the radius of action of the vibrator so that the area being vibrated will overlap the adjacent just-vibrated area by a reasonable amount. The vibrator shall penetrate rapidly to the bottom of the layer and at least 6 inches into the preceding layer if there is such. Vibrator shall be held stationary until the concrete is consolidated and then vertically withdrawn slowly while operating. Form vibrators shall not be used unless specifically approved and unless forms are constructed to withstand their use. Vibrators shall not be used to move concrete within the forms. Slabs 4 inches and less in thickness shall be consolidated by properly designed vibrating screeds or other approved technique. Grate tampers (“jitterbugs”) shall not be used.

D. Cold Weather Requirements: Special protection measures, approved by the University's Representative, shall be used if freezing temperatures are anticipated before the expiration of the specified curing period. The ambient temperature of the air where concrete is to be placed and the temperature of surfaces to receive concrete shall be not less than 40 degrees F. The temperature of the concrete when placed shall be not less than 50 degrees F nor more than 75 degrees F. Heating of the mixing water or aggregates will be required to regulate the concrete placing temperature. Materials entering the mixer shall be free from ice, snow, or frozen lumps. Salt, chemicals or other materials shall not be incorporated in the concrete to prevent freezing. Upon written approval, an accelerating admixture conforming to ASTM C 494/C 494M, Type C or E may be used, provided it contains no calcium chloride. Calcium chloride shall not be used.

E. Hot Weather Requirements: When the ambient temperature during concrete placing is expected to exceed 85 degrees F, the concrete shall be placed and finished with procedures previously submitted and as specified herein. The concrete temperature at time of delivery to the forms shall not exceed the temperature shown in the table below when measured in accordance with ASTM C 1064/C 1064 M. Cooling of the mixing water or aggregates or placing concrete in the cooler part of the day may be required to obtain an adequate placing temperature. A retarder may be used, as approved, to facilitate placing and

finishing. Steel forms and reinforcements shall be cooled as approved prior to concrete placement when steel temperatures are greater than 120 degrees F. Conveying and placing equipment shall be cooled if necessary to maintain proper concrete-placing temperature.

Maximum Allowable Concrete Placing Temperature

Relative Humidity, Percent, During Time of Concrete Placement	Maximum Allowable Concrete Temperature Degrees
Greater than 60	90 F
40-60	85 F
Less than 40	80 F

F. Prevention of Plastic Shrinkage Cracking: During hot weather with low humidity, and particularly with appreciable wind, as well as interior placements when space heaters produce low humidity, the Contractor shall be alert to the tendency for plastic shrinkage cracks to develop and shall institute measures to prevent this. Particular care shall be taken if plastic shrinkage cracking is potentially imminent and especially if it has developed during a previous placement. Periods of high potential for plastic shrinkage cracking can be anticipated by use of Fig. 2.1.5 of ACI 305R. In addition the concrete placement shall be further protected by erecting shades and windbreaks and by applying fog sprays of water, sprinkling, ponding or wet covering. Plastic shrinkage cracks that occur shall be filled by injection of epoxy resin as directed, after the concrete hardens. Plastic shrinkage cracks shall never be troweled over or filled with slurry.

G. Placing Concrete in Congested Areas: Special care shall be used to ensure complete filling of the forms, elimination of all voids, and complete consolidation of the concrete when placing concrete in areas congested with reinforcing bars, embedded items, and other tight spacing. An appropriate concrete mixture shall be used, and the nominal maximum size of aggregate (NMSA) shall meet the specified criteria when evaluated for the congested area. Vibrators with heads of a size appropriate for the clearances available shall be used, and the consolidation operation shall be closely supervised to ensure complete and thorough consolidation at all points. Where necessary, splices of reinforcing bars shall be alternated to reduce congestion. Where two mats of closely spaced reinforcing are required, the bars in each mat shall be placed in matching alignment to reduce congestion. Reinforcing bars may be temporarily crowded to one side during concrete placement provided they are returned to exact required location before concrete placement and consolidation are completed.

H. Placing Flowable Concrete: If a plasticizing admixture conforming to ASTM C 1017/C 1017M is used or if a Type F or G high range water reducing admixture is permitted to increase the slump, the concrete

shall meet all requirements of paragraph GENERAL REQUIREMENTS in PART 1. Extreme care shall be used in conveying and placing the concrete to avoid segregation. Consolidation and finishing shall meet all requirements of paragraphs Placing Concrete, Finishing Formed Surfaces, and Finishing Unformed Surfaces. No relaxation of requirements to accommodate flowable concrete will be permitted.

3.05 JOINTS

A. Joints shall be located and constructed as indicated or approved. Joints not indicated on the drawings shall be located and constructed to minimize the impact on the strength of the structure. In general, such joints shall be located near the middle of the spans of grade beams. Joints shall be perpendicular to the main reinforcement. Reinforcement shall be continued across joints, except where shown otherwise. Reinforcement or other fixed metal items shall not be continuous through expansion joints, or through construction or contraction joints in slabs on grade. Reinforcement shall be 2 inches clear from each joint. Except where otherwise indicated, construction joints between interior slabs on grade and vertical surfaces shall consist of 30 pound asphalt-saturated felt, extending for the full depth of the slab. The perimeters of the slabs shall be free of fins, rough edges, spalling, or other unsightly appearance.

B. Construction Joints: For concrete other than slabs on grade, construction joints shall be located so that the unit of operation does not exceed 100 feet. Concrete shall be placed continuously so that each unit is monolithic in construction. Fresh concrete shall not be placed against adjacent hardened concrete until it is at least 24 hours old. Construction joints shall be located as indicated or approved. Where concrete work is interrupted by weather, end of work shift or other similar type of delay, location and type of construction joint shall be subject to approval of the University's Representative. Unless otherwise indicated and except for slabs on grade, reinforcing steel shall extend through construction joints. Construction joints in slabs on grade shall be keyed or doweled as shown. Other lifts shall terminate at such levels as to conform to structural requirements or architectural details. Prior to placing additional concrete, horizontal construction joints shall be prepared as specified in paragraph Previously Placed Concrete.

C. Contraction Joints in Slabs on Grade: Contraction joints shall be located as shown on the drawings. Contraction Joints shall be produced by sawing a continuous slot with a concrete saw. The joint shall be 1/4 the depth of the slab thickness and 1/8 inch wide. Cutting shall be timed properly with the set of the concrete. Cutting shall be started as soon as the concrete has hardened sufficiently to prevent ravelling of the edges of the saw cut. Cutting shall be completed before shrinkage stresses become sufficient to produce cracking. Sludge and cutting debris shall be removed.

D. Expanded Polystyrene Joint Filler: Where expanded polystyrene joint filler is shown, the filler shall be placed in correct position before concrete is placed against the filler. Holes and joints in the

filler shall be filled with mastic to prevent the passage of mortar or concrete from one side of the joint to the other. The edges of the concrete, at the joints, shall be edger finished.

E. Dowels and Tie Bars: Dowels and tie bars shall be installed at the locations shown on the drawings and to the details shown, using materials and procedures specified in Section 03200 CONCRETE REINFORCEMENT and epoxy grout specified herein. Conventional smooth "paving" dowels shall be installed in slabs using approved methods to hold the dowel in place during concreting within a maximum alignment tolerance of 1/8 inch in 12 inches. "Structural" type deformed bar dowels, or tie bars, shall be installed to meet the specified tolerances. Care shall be taken during placing adjacent to and around dowels and tie bars to ensure there is no displacement of the dowel or tie bar and that the concrete completely embeds the dowel or tie bar and is thoroughly consolidated.

3.06 FINISHING FORMED SURFACES

A. Forms, form materials, and form construction are specified in Section 03100 STRUCTURAL CONCRETE FORMWORK. Finishing of formed surfaces shall be as specified herein. Unless another type of architectural or special finish is specified, surfaces shall be left with the texture imparted by the forms except that defective surfaces shall be repaired. Except for major defects, as defined hereinafter, surface defects shall be repaired as specified herein within 24 hours after forms are removed. Repairs of the so-called "plaster-type" will not be permitted in any location. Tolerances of formed surfaces shall conform to the requirements of ACI 117. These tolerances apply to the finished concrete surface, not to the forms themselves; forms shall be set true to line and grade. Form tie holes requiring repair and other defects whose depth is at least as great as their surface diameter shall be repaired as specified in paragraph Damp-Pack Mortar Repair. Defects whose surface diameter is greater than their depth shall be repaired as specified in paragraph Repair of Major Defects. Repairs shall be finished flush with adjacent surfaces and with the same surface texture. The cement used for all repairs shall be a blend of job cement with white cement proportioned so that the final color after curing and aging will be the same as the adjacent concrete. Concrete with excessive honeycomb, or other defects which affect the strength of the member, will be rejected. Repairs shall be demonstrated to be acceptable and free from cracks or loose or drummy areas at the completion of the contract. Repairs not meeting these requirements will be rejected and shall be replaced.

B. Class C and Class D Finishes: Class C finish is required in the following areas: all formed surfaces of walls, except below grade. Class D finish is required in the following areas: foundations not usually exposed. Fins, ravelings, and loose material shall be removed, and, except as otherwise indicated or as specified in Section 03100 STRUCTURAL CONCRETE FORMWORK, holes left by removal of form ties shall be reamed and filled. Honeycomb and other defects more than 1/2 inch deep or more than 2 inches in diameter shall be repaired. Defects more than 2 inches in diameter shall be cut back to sound concrete, but in all cases at least 1 inch deep.

3.07 REPAIRS

A. Damp-Pack Mortar Repair: Form tie holes requiring repair and other defects whose depth is at least as great as their surface diameter but not over 4 inches shall be repaired by the damp-pack mortar method. Form tie holes shall be reamed and other similar defects shall be cut out to sound concrete. The void shall then be thoroughly cleaned, thoroughly wetted, brush-coated with a thin coat of neat cement grout and filled with mortar. Mortar shall be a stiff mix of 1 part portland cement to 2 parts fine aggregate passing the No. 16 mesh sieve, and minimum amount of water. Only sufficient water shall be used to produce a mortar which, when used, will stick together on being molded into a ball by a slight pressure of the hands and will not exude water but will leave the hands damp. Mortar shall be mixed and allowed to stand for 30 to 45 minutes before use with remixing performed immediately prior to use. Mortar shall be thoroughly tamped in place in thin layers using a hammer and hardwood block. Holes passing entirely through walls shall be completely filled from the inside face by forcing mortar through to the outside face. All holes shall be packed full. Damp-pack repairs shall be moist cured for at least 48 hours.

B. Repair of Major Defects: Major defects will be considered to be those more than 1/2 inch deep and, for Class C and D finishes, more than 2 inches in diameter. Also included are any defects of any kind whose depth is over 4 inches or whose surface diameter is greater than their depth. Major defects shall be repaired as specified below.

1. Surface Application of Mortar Repair: Defective concrete shall be removed, and removal shall extend into completely sound concrete. Approved equipment and procedures which will not cause cracking or microcracking of the sound concrete shall be used. If reinforcement is encountered, concrete shall be removed so as to expose the reinforcement for at least 2 inches on all sides. All such defective areas greater than 12 square inches shall be outlined by saw cuts at least 1 inch deep. Defective areas less than 12 square inches shall be outlined by a 1 inch deep cut with a core drill in lieu of sawing. All saw cuts shall be straight lines in a rectangular pattern in line with the formwork panels. After concrete removal, the surface shall be thoroughly cleaned by high pressure washing to remove all loose material. Surfaces shall be kept continually saturated for the first 12 of the 24 hours immediately before placing mortar and shall be damp but not wet at the time of commencing mortar placement. The Contractor, at his option, may use either hand-placed mortar or mortar placed with a mortar gun. If hand-placed mortar is used, the edges of the cut shall be perpendicular to the surface of the concrete. The prepared area shall be brush-coated with a thin coat of neat cement grout. The repair shall then be made using a stiff mortar, preshrunk by allowing the mixed mortar to stand for 30 to 45 minutes and then remixed, thoroughly tamped into place in thin layers. If hand-placed mortar is used, the Contractor shall test each repair area for drumminess by firm tapping with a

hammer and shall inspect for cracks, both in the presence of the University's Representative, immediately before completion of the contract, and shall replace any showing drumminess or cracking. If mortar placed with a mortar gun is used, the gun shall be a small compressed air-operated gun to which the mortar is slowly hand fed and which applies the mortar to the surface as a high-pressure stream, as approved. Repairs made using shotcrete equipment will not be accepted. The mortar used shall be the same mortar as specified for damp-pack mortar repair. If gun-placed mortar is used, the edges of the cut shall be beveled toward the center at a slope of 1:1. All surface applied mortar repairs shall be continuously moist cured for at least 7 days. Moist curing shall consist of several layers of saturated burlap applied to the surface immediately after placement is complete and covered with polyethylene sheeting, all held closely in place by a sheet of plywood or similar material rigidly braced against it. Burlap shall be kept continually wet.

2. Repair of Deep and Large Defects: Deep and large defects will be those that are more than 6 inches deep and also have an average diameter at the surface more than 18 inches or that are otherwise so identified by the University's Representative. Such defects shall not be repaired and that portion of the structure shall be completely removed and replaced.

3.08 FINISHING UNFORMED SURFACES

A. The finish of all unformed surfaces shall meet the requirements of paragraph Tolerances in PART 1, when tested as specified herein.

B. The ambient temperature of spaces adjacent to unformed surfaces being finished and of the base on which concrete will be placed shall be not less than 50 degrees F. In hot weather all requirements of paragraphs Hot Weather Requirements and Prevention of Plastic Shrinkage Cracking shall be met. Unformed surfaces that are not to be covered by additional concrete or backfill shall have a float finish, with additional finishing as specified below, and shall be true to the elevation shown on the drawings. Surfaces to receive additional concrete or backfill shall be brought to the elevation shown on the drawings, properly consolidated, and left true and regular. Unless otherwise shown on the drawings, exterior surfaces shall be sloped for drainage, as directed. Where drains are provided, interior floors shall be evenly sloped to the drains. Joints shall be carefully made with a jointing or edging tool. The finished surfaces shall be protected from stains or abrasions. Grate tampers or "jitterbugs" shall not be used for any surfaces. The dusting of surfaces with dry cement or other materials or the addition of any water during finishing shall not be permitted. If bleedwater is present prior to finishing, the excess water shall be carefully dragged off or removed by absorption with porous materials such as burlap. During finishing operations, extreme care shall be taken to prevent over finishing or working water into the surface; this can cause "crazing" (surface shrinkage cracks which appear after hardening) of the surface. Any slabs with surfaces which exhibit

significant crazing shall be removed and replaced. During finishing operations, surfaces shall be checked with a 10 foot straightedge, applied in both directions at regular intervals while the concrete is still plastic, to detect high or low areas.

C. Floated Finish: Slabs to receive more than a rough slab finish shall next be given a wood float finish. The screeding shall be followed immediately by darbying or bull floating before bleeding water is present, to bring the surface to a true, even plane. Then, after the concrete has stiffened so that it will withstand a man's weight without imprint of more than 1/4 inch and the water sheen has disappeared, it shall be floated to a true and even plane free of ridges. Floating shall be performed by use of suitable hand floats or power driven equipment. Sufficient pressure shall be used on the floats to bring a film of moisture to the surface. Hand floats shall be made of wood, magnesium, or aluminum. Lightweight concrete or concrete that exhibits stickiness shall be floated with a magnesium float. Care shall be taken to prevent over-finishing or incorporating water into the surface.

D. Non-Slip Finish: Non-slip floors shall be constructed in accordance with the following:

1. Broomed or Brushed: Areas as indicated on the drawings shall be given a broomed or brushed finish. After floating, the surface shall be lightly steel troweled, and then carefully scored by pulling a coarse fiber push-type broom across the surface. Brooming shall be transverse to traffic or at right angles to the slope of the slab. After the end of the curing period, the surface shall be vigorously broomed with a coarse fiber broom to remove all loose or semi-detached particles.

3.09 CURING AND PROTECTION

A. General: Concrete shall be cured by an approved method for the period of time given below:

Concrete with Type III cement	3 days
All other concrete	7 days

Immediately after placement, concrete shall be protected from premature drying, extremes in temperatures, rapid temperature change, mechanical injury and damage from rain and flowing water for the duration of the curing period. Air and forms in contact with concrete shall be maintained at a temperature above 50 degrees F for the first 3 days and at a temperature above 32 degrees F for the remainder of the specified curing period. Exhaust fumes from combustion heating units shall be vented to the outside of the enclosure, and heaters and ducts shall be placed and directed so as not to cause areas of overheating and drying of concrete surfaces or to create fire hazards. Materials and equipment needed for adequate curing and protection shall be available and at the site prior to placing concrete. No fire or excessive heat, including welding, shall be permitted near or in direct contact with the concrete at any

time. Except as otherwise permitted by paragraph Membrane Forming Curing Compounds, moist curing shall be provided for any areas to which other concrete is to be bonded. Except for plastic coated burlap, impervious sheeting alone shall not be used for curing.

B. Moist Curing: Concrete to be moist-cured shall be maintained continuously wet for the entire curing period, commencing immediately after finishing. If water or curing materials used stain or discolor concrete surfaces which are to be permanently exposed, the concrete surfaces shall be cleaned as approved. When wooden forms are left in place during curing, they shall be kept wet at all times. If steel forms are used in hot weather, nonsupporting vertical forms shall be broken loose from the concrete soon after the concrete hardens and curing water continually applied in this void. If the forms are removed before the end of the curing period, curing shall be carried out as on unformed surfaces, using suitable materials. Surfaces shall be cured by ponding, by continuous sprinkling, by continuously saturated burlap or cotton mats, or by continuously saturated plastic coated burlap. Burlap and mats shall be clean and free from any contamination and shall be completely saturated before being placed on the concrete. The Contractor shall have an approved work system to ensure that moist curing is continuous 24 hours per day.

C. Membrane Forming Curing Compounds: Membrane forming curing compounds shall be used only on formed surfaces. Concrete in the following areas may be cured with a nonpigmented curing compound containing a fugitive dye in lieu of moist curing. Membrane curing shall not be used on surfaces that are to receive any subsequent treatment depending on adhesion or bonding to the concrete, including surfaces to which a smooth finish is to be applied or other concrete to be bonded. Curing compound shall be applied to formed surfaces immediately after the forms are removed and prior to any patching or other surface treatment except the cleaning of loose sand, mortar, and debris from the surface. All surfaces shall be thoroughly moistened with water. Curing compound shall be applied to slab surfaces as soon as the bleeding water has disappeared, with the tops of joints being temporarily sealed to prevent entry of the compound and to prevent moisture loss during the curing period. The curing compound shall be applied in a two-coat continuous operation by approved motorized power-spraying equipment operating at a minimum pressure of 75 psi, at a uniform coverage of not more than 400 square feet per gallon for each coat, and the second coat shall be applied perpendicular to the first coat. Concrete surfaces which have been subjected to rainfall within 3 hours after curing compound has been applied shall be resprayed by the method and at the coverage specified. Surfaces on which clear compound is used shall be shaded from direct rays of the sun for the first 3 days. Surfaces coated with curing compound shall be kept free of foot and vehicular traffic, and from other sources of abrasion and contamination during the curing period.

D. Impervious Sheeting: The following concrete surfaces may be cured using impervious sheets: foundations. However, except for plastic coated burlap, impervious sheeting alone shall not be used for

curing. Impervious-sheet curing shall only be used on horizontal or nearly horizontal surfaces. Surfaces shall be thoroughly wetted and be completely covered with the sheeting. Sheeting shall be at least 18 inches wider than the concrete surface to be covered. Covering shall be laid with light-colored side up. Covering shall be lapped not less than 12 inches and securely weighted down or shall be lapped not less than 4 inches and taped to form a continuous cover with completely closed joints. The sheet shall be weighted to prevent displacement so that it remains in contact with the concrete during the specified length of curing. Coverings shall be folded down over exposed edges of slabs and secured by approved means. Sheets shall be immediately repaired or replaced if tears or holes appear during the curing period.

E. Ponding or Immersion: Concrete shall be continually immersed throughout the curing period. Water shall not be more than 20 degrees F less than the temperature of the concrete.

F. Cold Weather Curing and Protection: When the daily ambient low temperature is less than 32 degrees F the temperature of the concrete shall be maintained above 40 degrees F for the first seven days after placing. During the period of protection removal, the air temperature adjacent to the concrete surfaces shall be controlled so that concrete near the surface will not be subjected to a temperature differential of more than 25 degrees F as determined by suitable temperature measuring devices furnished by the Contractor, as required, and installed adjacent to the concrete surface and 2 inches inside the surface of the concrete. The installation of the thermometers shall be made by the Contractor as directed.

3.10 SETTING BASE PLATES AND BEARING PLATES

A. After being properly positioned, column base plates, bearing plates for beams and similar structural members, and machinery and equipment base plates shall be set to the proper line and elevation with damp-pack bedding mortar, except where nonshrink grout is indicated. The thickness of the mortar or grout shall be approximately 1/24 the width of the plate, but not less than 3/4 inch. Concrete and metal surfaces in contact with grout shall be clean and free of oil and grease, and concrete surfaces in contact with grout shall be damp and free of laitance when grout is placed.

B. Damp-Pack Bedding Mortar: Damp-pack bedding mortar shall consist of 1 part cement and 2-1/2 parts fine aggregate having water content such that a mass of mortar tightly squeezed in the hand will retain its shape but will crumble when disturbed. The space between the top of the concrete and bottom of the bearing plate or base shall be packed with the bedding mortar by tamping or ramming with a bar or rod until it is completely filled.

C. Nonshrink Grout: Mix, place and finish nonshrink grout in accordance with manufacturer's instructions.

3.11 TESTING AND INSPECTION FOR CONTRACTOR QUALITY CONTROL

A. The Contractor shall perform the inspection and tests described below and, based upon the results of these inspections and tests, shall take the action required and shall submit specified reports. When, in the opinion of the University's Representative, the concreting operation is out of control, concrete placement shall cease and the operation shall be corrected. The laboratory performing the tests shall be onsite and shall conform with ASTM C 1077. Materials may be subjected to check testing by the University's Representative from samples obtained at the manufacturer, at transfer points, or at the project site. The University's Representative will inspect the laboratory, equipment, and test procedures prior to start of concreting operations for conformance with ASTM C 1077.

B. Grading and Corrective Action

1. Fine Aggregate: At least once during each shift when the concrete plant is operating, there shall be one sieve analysis and fineness modulus determination in accordance with ASTM C 136 for the fine aggregate or for each fine aggregate if it is batched in more than one size or classification. The location at which samples are taken may be selected by the Contractor as the most advantageous for control. However, the Contractor is responsible for delivering fine aggregate to the mixer within specification limits. When the amount passing on any sieve is outside the specification limits, the fine aggregate shall be immediately resampled and retested. If there is another failure on any sieve, the fact shall immediately be reported to the University's Representative, concreting shall be stopped, and immediate steps taken to correct the grading.

2. Coarse Aggregate: At least once during each shift in which the concrete plant is operating, there shall be a sieve analysis in accordance with ASTM C 136 for each size of coarse aggregate. The location at which samples are taken may be selected by the Contractor as the most advantageous for production control. However, the Contractor shall be responsible for delivering the aggregate to the mixer within specification limits. A test record of samples of aggregate taken at the same locations shall show the results of the current test as well as the average results of the five most recent tests including the current test. The Contractor may adopt limits for control coarser than the specification limits for samples taken other than as delivered to the mixer to allow for degradation during handling. When the amount passing any sieve is outside the specification limits, the coarse aggregate shall be immediately resampled and retested. If the second sample fails on any sieve, that fact shall be reported to the University's Representative. Where two consecutive averages of 5 tests are outside specification limits, the operation shall be considered out of control and shall be reported to the University's Representative. Concreting shall be stopped and immediate steps shall be taken to correct the grading.

C. Quality of Aggregates: Thirty days prior to the start of concrete placement, the Contractor shall perform all tests for aggregate quality required by ASTM C 33. In addition, after the start of concrete placement, the Contractor shall perform tests for aggregate quality at least every three months, and when the source of aggregate or aggregate quality changes. Samples tested after the start of concrete placement shall be taken immediately prior to entering the concrete mixer.

D. Scales, Batching and Recording: The accuracy of the scales shall be checked by test weights prior to start of concrete operations and at least once every three months. Such tests shall also be made as directed whenever there are variations in properties of the fresh concrete that could result from batching errors. Once a week the accuracy of each batching and recording device shall be checked during a weighing operation by noting and recording the required weight, recorded weight, and the actual weight batched. At the same time, the Contractor shall test and ensure that the devices for dispensing admixtures are operating properly and accurately. When either the weighing accuracy or batching accuracy does not comply with specification requirements, the plant shall not be operated until necessary adjustments or repairs have been made. Discrepancies in recording accuracies shall be corrected immediately.

E. Concrete Mixture

1. Air Content Testing: Air content tests shall be made when test specimens are fabricated. In addition, at least two tests for air content shall be made on randomly selected batches of each separate concrete mixture produced during each 8-hour period of concrete production. Additional tests shall be made when excessive variation in workability is reported by the placing foreman or University's Inspector. Tests shall be made in accordance with ASTM C 231 for normal weight concrete. Test results shall be plotted on control charts which shall at all times be readily available to the University's Representative and shall be submitted weekly. Copies of the current control charts shall be kept in the field by testing crews and results plotted as tests are made. When a single test result reaches either the upper or lower action limit, a second test shall immediately be made. The results of the two tests shall be averaged and this average used as the air content of the batch to plot on both the air content and the control chart for range, and for determining need for any remedial action. The result of each test, or average as noted in the previous sentence, shall be plotted on a separate control chart for each mixture on which an "average line" is set at the midpoint of the specified air content range from paragraph Air Entrainment. An upper warning limit and a lower warning limit line shall be set 1.0 percentage point above and below the average line, respectively. An upper action limit and a lower action limit line shall be set 1.5 percentage points above and below the average line, respectively. The range between each two consecutive tests shall be plotted on a secondary control chart for range where an

upper warning limit is set at 2.0 percentage points and an upper action limit is set at 3.0 percentage points. Samples for air content may be taken at the mixer, however, the Contractor is responsible for delivering the concrete to the placement site at the stipulated air content. If the Contractor's materials or transportation methods cause air content loss between the mixer and the placement, correlation samples shall be taken at the placement site as required by the University's Representative, and the air content at the mixer controlled as directed.

2. Air Content Corrective Action: Whenever points on the control chart for percent air reach either warning limit, an adjustment shall immediately be made in the amount of air-entraining admixture batched. As soon as practical after each adjustment, another test shall be made to verify the result of the adjustment. Whenever a point on the secondary control chart for range reaches the warning limit, the admixture dispenser shall be recalibrated to ensure that it is operating accurately and with good reproducibility. Whenever a point on either control chart reaches an action limit line, the air content shall be considered out of control and the concreting operation shall immediately be halted until the air content is under control. Additional air content tests shall be made when concreting is restarted.

3. Slump Testing: In addition to slump tests which shall be made when test specimens are fabricated, at least four slump tests shall be made on randomly selected batches in accordance with ASTM C 143/C 143M for each separate concrete mixture produced during each 8-hour or less period of concrete production each day. Also, additional tests shall be made when excessive variation in workability is reported by the placing foreman or University's Inspector. Test results shall be plotted on control charts which shall at all times be readily available to the University's Representative and shall be submitted weekly. Copies of the current control charts shall be kept in the field by testing crews and results plotted as tests are made. When a single slump test reaches or goes beyond either the upper or lower action limit, a second test shall immediately be made. The results of the two tests shall be averaged and this average used as the slump of the batch to plot on both the control charts for slump and the chart for range, and for determining need for any remedial action. Limits shall be set on separate control charts for slump for each type of mixture. The upper warning limit shall be set at 1/2 inch below the maximum allowable slump specified in paragraph Slump in PART 1 for each type of concrete and an upper action limit line and lower action limit line shall be set at the maximum and minimum allowable slumps, respectively, as specified in the same paragraph. The range between each consecutive slump test for each type of mixture shall be plotted on a single control chart for range on which an upper action limit is set at 2 inches. Samples for slump shall be taken at the mixer. However, the Contractor is responsible for delivering the concrete to the placement site at

the stipulated slump. If the Contractor's materials or transportation methods cause slump loss between the mixer and the placement, correlation samples shall be taken at the placement site as required by the University's Representative, and the slump at the mixer controlled as directed.

4. Slump Corrective Action: Whenever points on the control charts for slump reach the upper warning limit, an adjustment shall immediately be made in the batch weights of water and fine aggregate. The adjustments are to be made so that the total water content does not exceed that amount allowed by the maximum w/c ratio specified, based on aggregates which are in a saturated surface dry condition. When a single slump reaches the upper or lower action limit, no further concrete shall be delivered to the placing site until proper adjustments have been made. Immediately after each adjustment, another test shall be made to verify the correctness of the adjustment. Whenever two consecutive individual slump tests, made during a period when there was no adjustment of batch weights, produce a point on the control chart for range at or above the upper action limit, the concreting operation shall immediately be halted, and the Contractor shall take appropriate steps to bring the slump under control. Additional slump tests shall be made as directed.

5. Temperature: The temperature of the concrete shall be measured when compressive strength specimens are fabricated. Measurement shall be in accordance with ASTM C 1064/C 1064M. The temperature shall be reported along with the compressive strength data.

6. Strength Specimens: At least one set of test specimens shall be made, for compressive or flexural strength as appropriate, on each different concrete mixture placed during the day for each 500 cubic yards or portion thereof of that concrete mixture placed each day. Additional sets of test specimens shall be made, as directed by the University's Representative, when the mixture proportions are changed or when low strengths have been detected. A truly random (not haphazard) sampling plan shall be developed by the Contractor and approved by the University's Representative prior to the start of construction. The plan shall assure that sampling is done in a completely random and unbiased manner. A set of test specimens for concrete with a 28-day specified strength per paragraph Strength Requirements in PART 1 shall consist of four specimens, two to be tested at 7 days and two at 28 days. Test specimens shall be molded and cured in accordance with ASTM C 31/C 31M and tested in accordance with ASTM C 39/C 39M for test cylinders and ASTM C 78 for test beams. Results of all strength tests shall be reported immediately to the University's Representative. Quality control charts shall be kept for individual strength "tests", ("test" as defined in paragraph Strength Requirements in PART 1) moving average of last 3 "tests" for strength, and moving average for range for the last 3 "tests" for each mixture. The charts shall be similar to those found in ACI 214.3R.

F. Inspection Before Placing: Foundations, construction joints, forms, and embedded items shall be inspected by the Contractor in sufficient time prior to each concrete placement in order to certify to the University's Representative that they are ready to receive concrete. The results of each inspection shall be reported in writing.

G. Placing: The placing foreman shall supervise placing operations, shall determine that the correct quality of concrete or grout is placed in each location as specified and as directed by the University's Representative, and shall be responsible for measuring and recording concrete temperatures and ambient temperature hourly during placing operations, weather conditions, time of placement, volume placed, and method of placement. The placing foreman shall not permit batching and placing to begin until it has been verified that an adequate number of vibrators in working order and with competent operators are available. Placing shall not be continued if any pile of concrete is inadequately consolidated. If any batch of concrete fails to meet the temperature requirements, immediate steps shall be taken to improve temperature controls.

H. Vibrators: The frequency and amplitude of each vibrator shall be determined in accordance with COE CRD-C 521 prior to initial use and at least once a month when concrete is being placed. Additional tests shall be made as directed when a vibrator does not appear to be adequately consolidating the concrete. The frequency shall be determined while the vibrator is operating in concrete with the tachometer being held against the upper end of the vibrator head while almost submerged and just before the vibrator is withdrawn from the concrete. The amplitude shall be determined with the head vibrating in air. Two measurements shall be taken, one near the tip and another near the upper end of the vibrator head, and these results averaged. The make, model, type, and size of the vibrator and frequency and amplitude results shall be reported in writing. Any vibrator not meeting the requirements of paragraph Consolidation, shall be immediately removed from service and repaired or replaced.

I. Curing Inspection

1. Moist Curing Inspections: At least once each shift, and not less than twice per day on both work and non-work days, an inspection shall be made of all areas subject to moist curing. The surface moisture condition shall be noted and recorded.

2. Moist Curing Corrective Action: When a daily inspection report lists an area of inadequate curing, immediate corrective action shall be taken, and the required curing period for those areas shall be extended by 1 day.

3. Membrane Curing Inspection: No curing compound shall be applied until the Contractor has verified that the compound is properly mixed and ready for spraying. At the end of each operation, the Contractor shall estimate the quantity of compound used by measurement of the container and the area of concrete surface covered, shall compute the rate of coverage in square feet per gallon, and shall note whether or not coverage is uniform.

4. Membrane Curing Corrective Action: When the coverage rate of the curing compound is less than that specified or when the coverage is not uniform, the entire surface shall be sprayed again.

5. Sheet Curing Inspection: At least once each shift and once per day on non-work days, an inspection shall be made of all areas being cured using impervious sheets. The condition of the covering and the tightness of the laps and tapes shall be noted and recorded.

6. Sheet Curing Corrective Action: When a daily inspection report lists any tears, holes, or laps or joints that are not completely closed, the tears and holes shall promptly be repaired or the sheets replaced, the joints closed, and the required curing period for those areas shall be extended by 1 day.

J. Cold-Weather Protection: At least once each shift and once per day on non-work days, an inspection shall be made of all areas subject to cold-weather protection. Any deficiencies shall be noted, corrected, and reported.

K. Mixer Uniformity

1. Stationary Mixers: Prior to the start of concrete placing and once every 6 months when concrete is being placed, or once for every 75,000 cubic yards of concrete placed, whichever results in the shortest time interval, uniformity of concrete mixing shall be determined in accordance with ASTM C 94/C 94M.

2. Truck Mixers: Prior to the start of concrete placing and at least once every 6 months when concrete is being placed, uniformity of concrete mixing shall be determined in accordance with ASTM C 94/C 94M. The truck mixers shall be selected randomly for testing. When satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of the blades may be regarded as satisfactory.

3. Mixer Uniformity Corrective Action: When a mixer fails to meet mixer uniformity requirements, either the mixing time shall be increased, batching sequence changed, batch size reduced, or adjustments shall be made to the mixer until compliance is achieved.

L. Reports: All results of tests or inspections conducted shall be reported informally as they are completed and in writing daily. A weekly report shall be prepared for the updating of control charts covering the entire period from the start of the construction season through the current week. During periods of cold-weather protection, reports of pertinent temperatures shall be made daily. These requirements do not relieve the Contractor of the obligation to report certain failures immediately as required in preceding paragraphs. Such reports of failures and the action taken shall be

confirmed in writing in the routine reports. The University's Representative has the right to examine all Contractor Quality Control records.

END OF SECTION

SECTION 05500

MISCELLANEOUS METAL

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes furnishing, fabricating, galvanizing, and installing the following:

1. Rod anchor assemblies
2. Machine anchor bolt assemblies
3. High strength anchor bolt assemblies
4. Expansion anchors
5. Fabricated pipe supports
6. Guardrail
7. Miscellaneous metal fabrications indicated

B. Rock anchors are specified in Section 02490, ROCK ANCHORS.

C. Pipe support devices are specified in Section 15185, PIPING AND VALVES.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M	Structural Welding Code - Steel
AWS D1.3	Structural Welding Code - Sheet Steel

B. ASTM INTERNATIONAL (ASTM)

ASTM A 123/A 123M	Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A 153/A 153M	Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A 307	Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength

ASTM A 325	Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
ASTM A 36/A 36M	Carbon Structural Steel
ASTM A 500	Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A 53/A 53M	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A 563	Carbon and Alloy Steel Nuts
ASTM A 780	Repair of Damaged and Uncoated Areas of Hot-Dipped Galvanized Coatings
ASTM F 436	Hardened Steel Washers

C. SHEET METAL AND AIR-CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA Seismic Restraint Manual	Seismic Restraint Manual: Guidelines for Mechanical Systems

1.03 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Shop Drawings: Submit detail drawings indicating material thickness, type, grade, and class; dimensions; finish coatings; and construction details. Drawings shall include catalog cuts, erection details, manufacturer's descriptive data and installation instructions, and templates.

B. Product Data: Submit for the following:

1. Guardrail

2. Expansion anchors

1.04 QUALITY ASSURANCE

A. Welding and Qualification of Welders: Perform shop and field welding in accordance with AWS D1.1/D1.1M and AWS D1.3. Use only welders who have been certified by AWS D1.1/D1.1M testing within one year of contract date.

1.05 GENERAL REQUIREMENTS

A. The Contractor shall verify all measurements and shall take all field measurements necessary before fabrication. Items specified to be galvanized, when practicable and not indicated otherwise, shall be hot-dip galvanized after fabrication. Galvanizing shall be in

accordance with ASTM A 123/A 123M, ASTM A 153/A 153M or ASTM A 653/A 653M, G 60, as applicable. Materials and parts necessary to complete each item, even though such work is not definitely shown or specified, shall be included. Poor matching of holes for fasteners shall be cause for rejection. Thickness of metal and details of assembly and supports shall provide strength and stiffness. Joints exposed to the weather shall be formed to exclude water.

1.06 DISSIMILAR MATERIALS

A. Where dissimilar metals are in contact, the surfaces shall be protected with a coat of bituminous paint or asphalt varnish.

1.07 WORKMANSHIP

A. Miscellaneous metalwork shall be well formed to shape and size, with sharp lines and angles and true curves. Drilling and punching shall produce clean true lines and surfaces. Welding shall be continuous along the entire area of contact except where tack welding is permitted. Exposed connections of work in place shall not be tack welded. Exposed welds shall be ground smooth. Exposed surfaces of work in place shall have a smooth finish. Where tight fits are required, joints shall be milled. Corner joints shall be coped or mitered, well formed, and in true alignment. Work shall be accurately set to established lines and elevations and securely fastened in place. Installation shall be in accordance with manufacturer's installation instructions and approved drawings, cuts, and details.

PART 2 - PRODUCTS

2.01 MISCELLANEOUS METAL ITEMS

A. Rod Anchor Assemblies

1. Rods: ASTM A 325 Type 1, galvanized.

2. Anchor Plates: ASTM A 36/A 36M, galvanized.

3. Nuts: Heavy hexagonal, ASTM A 563 Grade DH, galvanized.

B. Machine Anchor Bolt Assemblies

1. Bolts: ASTM A 307, Grade A, galvanized.

2. Nuts: Hexagonal, ASTM A 563, Grade A, galvanized.

3. Washers: ASTM F 436, Type 1, galvanized.

C. High Strength Anchor Bolt Assemblies

1. Bolts: ASTM A 325 Type 1, galvanized.

2. Nuts: Heavy Hexagonal, ASTM A 563 Grade DH, galvanized.

3. Washers: ASTM F 436, Type 1, galvanized.

D. Expansion Anchors: Stainless steel wedge anchors; Rawl-Stud Anchor by the Rawlplug Company, Wedge Anchor by ITT Phillips Drill Division, Kwik-bolt by Hilti Fastening Systems, or approved equal.

E. Fabricated Pipe Supports: Pipe supports shall be designed in accordance with SMACNA Restraint Manual: Guidelines for Mechanical Systems. Pipe support devices are specified in Section 15185, PIPING AND VALVES.

1. Structural Carbon Steel: ASTM A 36/A 36 M.

2. Structural Tubing: ASTM A 500.

3. Steel Pipe: ASTM A 53, Type E or S, Grade B.

4. Hardware: As indicated.

5. Hot dipped galvanized after fabrication.

2.02 GUARDRAIL

A. Steel guardrail, including inserts in concrete, shall be steel pipe conforming to ASTM A 53/A 53M or structural tubing conforming to ASTM A 500, Grade A or B of equivalent strength. Steel guardrail shall be nominal sizes indicated.

B. Galvanized wire rope, 7 x 19 strand core, 1/4 inch diameter, clear vinyl coated, with compression sleeves at wire rope ends shall be provided as indicated.

C. Posts and rails shall be welded and ground smooth. Holes shall be provided for wire rope passage where shown. Railing splices shall be fitted with interior bar not less than 6 inches long welded in place. Blank eyebolts shall be provided where indicated.

D. Rails and posts shall be hot dipped galvanized.

E. Pipe sleeve inserts in concrete shall be provided as indicated.

2.03 MISCELLANEOUS

A. Miscellaneous plates and shapes for other items indicated, such as sill angles, miscellaneous mountings, and frames, shall be provided to complete the work. Miscellaneous items shall be hot-dip galvanized.

2.04 GALVANIZING REPAIR

A. Repair damaged surfaces with galvanizing repair paint conforming to ASTM A 780 or by application of stick or thick paste material specifically designed for repair of galvanizing. Clean area to be repaired and remove slag from welds. Heat surfaces to which stick or

paste material is applied, with a torch to a temperature sufficient to melt the metallics in stick or paste; spread molten material uniformly over surfaces to be coated and wipe off excess material.

PART 3 - EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. All items shall be installed at the locations shown and according to the manufacturer's recommendations.

3.02 ANCHORAGE, FASTENINGS, AND CONNECTIONS

A. Provide anchorage where necessary for fastening miscellaneous metal items securely in place. Include for anchorage not otherwise specified or indicated slotted inserts, expansion shields, and powder-driven fasteners, when approved for concrete, and machine and carriage bolts for steel. Provide non-ferrous attachments for non-ferrous metal.

3.03 BUILT-IN WORK

A. Form for anchorage metal work embedded in concrete, or provide with suitable anchoring devices as indicated or as required. Furnish metal work in ample time for securing in place as the work progresses.

3.04 GUARDRAIL

A. Install guardrail in pipe sleeves embedded in concrete and filled with non-shrink grout or quick setting anchoring cement.

B. After installation and grouting of posts and rails, install vinyl-coated wire rope. Attach compression sleeve on one end of wire rope, apply nominal 20 pounds tension on wire rope, and attach compression sleeve on opposite end of wire rope. Wire rope shall be free of twist and kinks.

- END OF SECTION -

SECTION 13125

INSTALLATION OF APF DOME AND EQUIPMENT

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes assembling, erecting and installing a pre-manufactured, University-furnished, APF dome and equipment to co-function with a University-furnished 2.4 meter telescope. Refer to Appendix A, EOS Icestorm Assembly Manual, and Section 01010, Summary of Work.

B. Furnish staffing, equipment, and tools as specified in Appendix A, except those items and services specified as University-furnished elsewhere in these Specifications.

- END OF SECTION -

SECTION 13851

FIRE DETECTION AND ALARM SYSTEM

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section covers the requirements for a fire alarm and detection system.

B. The system shall connect to and be compatible with the existing fire alarm system.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C2	National Electrical Safety Code

B. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	National Electrical Code (NEC)
NFPA 72	National Fire Alarm Code

C. UNDERWRITERS LABORATORIES INC. (UL)

UL	Fire Protection Equipment Directory

1.03 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Shop Drawings and Data: Submit shop drawings and manufacturer's operating and maintenance instructions of all equipment to be incorporated in the system, including wiring diagrams, equipment data and testing laboratory's report, before proceeding with the Work.

B. Spare Parts Data: As soon as practicable after approval of the schedule, furnish spare parts data for each different item of equipment. Data shall include a complete list of parts with current unit prices and source of supply, normally furnished at no extra cost with the equipment or as part of the contract; and a list of additional items recommended by the manufacturer to assure efficient operation for a minimum period of 120 days.

C. As-Built Diagrams and Manuals

1. Upon completion of the Work and prior to final inspection, furnish as-built diagrams of the fire alarm and detection system, showing alarm signals and initiating devices in the exact sequence in which they are installed in the circuits.

2. Furnish four copies of an instruction manual for the operation, inspection, testing and maintenance of the system, complete with wiring diagrams.

1.04 EXISTING FIRE ALARM SYSTEM

A. The existing fire detection and alarm system is Siemens MXL fire protection system.

B. The new fire detection and alarm system shall be an extension of and completely compatible with the existing system.

1.05 PERFORMANCE

A. Fire detection and alarm system shall meet applicable requirements of NFPA 72, and the operational requirements specified herein.

B. Equipment and components shall be of standard quality, products of the manufacturer's latest design, UL-listed and suitable to perform the functions intended. Where two or more pieces of equipment must perform the same functions, they shall be duplicated products of one manufacturer. Name of the manufacturer and the serial number shall appear on each major component. Locks for cabinets shall be keyed alike.

PART 2 - PRODUCTS

2.01 MATERIALS AND ACCESSORIES

A. Control Panel: Control panel (for 120 V, 60 Hz power input) shall be a multi-zone fire alarm and detection panel with 24 V dc power supply, common control circuitry; Siemens MXL enclosure with the following:

1. Battery pack assembly consisting of two 12 V, 4.5 ampere-hour gelled electrolyte batteries, connecting cable and bracket for 24 V dc standby power operation

2. Motherboard for accommodating function circuit boards

3. Power supply circuit card for receiving low-voltage ac power from transformer and converting to dc; card shall include battery charger and four additional circuits for horns and strobes; Siemens PAD-2

4. Common control circuit card to provide common alarm and trouble outputs for proper operation of control panel

5. Four-zone detector circuit card for device loops which operate on a contact closure (heat detectors, and four-wire smoke detectors)

6. Horn/strobe module; Siemens CSM-4

7. Supervisory circuit card to supervise remote annunciators

8. Control panel shall be connected to the existing site Fire Alarm System.

B. Alarm Horns: Alarm horns shall be Siemens providing parallel (polarized) signals. Siemens backbox is required for surface mounting.

C. Visual Alarm Units: Siemens 24 V dc with strobe flasher and backbox, required for surface mounting.

D. Heat Detectors: Detectors shall be Siemens fixed temperature rate-of-rise combination type, each with a temperature rating of 135°F.

E. Smoke Detectors: Detectors shall be Siemens dual chamber ionization type, with initiating alarm signal and light indicator, and field-adjustable sensitivity.

F. End-of-Line Resistors: Siemens standard design.

2.02 OPERATION

A. General: Operation of any automatic fire-detection device shall result in continuous sounding of alarm horns in the system. Supervisory, alarm and trouble modes of operation of the electrically supervised fire detection system shall be provided.

B. Supervisory Mode (Normal Operating Condition): When the system is turned on, the "POWER-ON" lamp shall illuminate; no alarm shall be in progress; trouble signal shall be silent, and common "TROUBLE" lamp shall be off. Trouble lamps on all zone-receiving and signal modules shall be off.

C. Alarm Mode (Operation of any Initiating Device): When the system is on alarm mode:

1. Alarm signal shall sound

2. Alarm buzzer shall sound (pulse) at panel

3. Red "zone" lamp and common "alarm" lamp shall flash at panel

4. Flashing zone lamp shall indicate location from which the alarm originated

5. Individual zone and common alarm contacts shall operate.

D. Faulty Circuits: When fault, such as open in initiating circuit or open or short in signaling circuit develops, system trouble buzzer shall sound steadily and "ZONE" and common "TROUBLE" lamps shall illuminate at panel. Zone lamp shall indicate faulty circuit. Common trouble contacts shall also operate. When ground occurs in any alarm initiating or signaling circuit, system shall operate as described above, except zone lamp shall remain off and "GROUND" lamp shall illuminate.

E. Power Failure: When main power fails, system shall transfer to standby battery power. Common "TROUBLE" lamp shall turn on, buzzer shall sound and "POWER-ON" lamp shall turn off.

F. Heat Detectors: Rate-of-rise feature shall close contacts when temperature increases more than 15°F per minute and automatically restore itself. Fixed temperature feature (non-restoring) shall close contacts when temperature reaches rating of detector.

G. Smoke Detectors: Each detector shall operate on the ionization principle. Detectors shall sense the change in conductivity of ionized air caused by the presence of combustion products and respond quickly to both fast burning "clean" fire and slow smoldering fire. Detector shall initiate an alarm signal and also light an indicator on the unit to give a visual on-the-spot indication or alarm.

2.03 TOOLS AND ACCESSORIES

A. Special tools necessary for the maintenance of the equipment shall be furnished. One spare set of fuses of each type and size required, and 2 percent of the total number of each type of detector, but not less than two thereof, shall be furnished.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Fire detection and alarm system shall be installed by an experienced crew regularly engaged in the installation of automatic fire detection and alarm systems, in accordance with NFPA 70 and 72, and applicable requirements of Section 16050, BASIC ELECTRICAL MATERIALS AND METHODS. The University may reject any Contractor's personnel who cannot show evidence of such qualification.

B. System components shall be securely fastened to their supports, independently from the wiring. Installation of wiring and equipment shall conform to Article 760 of NFPA 70.

C. Installation work shall be carefully laid out in advance. Cutting, channeling, chasing or drilling of floor, wall, partition, ceiling or other surfaces, if necessary for the proper installation of the fire detection and alarm system, shall be carefully and properly done. Damage to building or equipment shall be repaired and refinished by skilled mechanics of the Contractor.

3.02 TESTS AND INSPECTIONS

A. Work shall be tested by the Contractor in the presence of the University's Representative and shall be approved by the University's Representative.

B. System shall be tested in accordance with NFPA 72 and as set forth by the University's Fire Department.

C. System components shall be adjusted to their normal working condition.

D. Contractor shall furnish all labor and materials required for making the tests.

- END OF SECTION -

SECTION 15000

MECHANICAL – GENERAL

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The work covered under Division 15, MECHANICAL, includes furnishing and installation of an air cooled chiller, pumps and piping and shall include furnishing all equipment, material and labor necessary for complete and operable systems.

1.02 QUALITY ASSURANCE

A. Material and Equipment Qualifications: Provide materials and equipment that are standard products of manufacturers regularly engaged in the manufacture of such products, which are of a similar material, design and workmanship. Standard products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2 year period.

B. Alternative Qualifications: Products having less than a two-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturer's factory or laboratory tests, can be shown.

C. Service Support: The equipment items shall be supported by service organizations. Submit a certified list of qualified permanent service organizations for support of the equipment which includes their addresses and qualifications. These service organizations shall be reasonably convenient to the equipment installation and able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

D. Manufacturer's Nameplate: Each item of equipment shall have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

1.03 ELECTRICAL REQUIREMENTS

A. Furnish motors, controllers, disconnects and contactors with their respective pieces of equipment. Motors, controllers, disconnects and contactors shall conform to and have electrical connections provided under Section 16402 INTERIOR DISTRIBUTION SYSTEM. Furnish internal wiring for components of packaged equipment as an integral part of the equipment.

B. Extended voltage range motors will not be permitted. Controllers and contactors shall have a maximum of 120 volt control circuits, and shall have auxiliary contacts for use with the controls furnished. When motors and equipment furnished are larger than sizes indicated, the cost of additional electrical service and related work shall be included under the section that specified that motor or equipment. Power wiring and conduit for field installed equipment shall be provided under and conform to the requirements of Section 16402 INTERIOR DISTRIBUTION SYSTEM.

1.04 ACCESSIBILITY

A. Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves, expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

PART 2 – PRODUCTS

Not used.

PART 3 - EXECUTION

3.01 STENCILING AND IDENTIFICATION

A. Each piece of equipment including the chiller, pumps etc., shall be stenciled. Conform to tag numbers shown on the drawings. Use minimum 2 inch high stencil lettering. Label shall be engraved plastic, with black background and 1/2-inch tall white lettering. Attach to equipment with stainless steel screws. Stick-on type labels are not acceptable.

B. A typewritten schedule of all stencils and markers used, with identification, shall be framed and posted where directed.

C. Identify all pipes using pipe markers by Gemco, Brady, Kolby, or equal, minimum 7 inches long secured to piping. Show flow direction. Secure in place with adhesive every 20 feet on mains, at sectionalizing or isolating valve, at all branch take-offs and adjacent to valves or cocks. Protect from damage with an additional protective coating of varnish. Apply after pipes are insulated and covered. Labels shall be visible from normal point of reference. Where pipes are located above normal line of vision, the label(s) shall be placed below the horizontal centerline of the pipe; where pipes are below normal line of vision, place labels above the horizontal centerline of the pipe. Designation shall be as directed by the University's Representative.

D. Warning signs shall be placed on all machines driven by electric motors which are controlled by automatic starters. See General Industry Safety Orders, Title 8, Section 3320, Article 7. Subchapter 7, California Administrative Code.

3.02 LUBRICATION

A. All lubrication points shall be accessible. Where this is impossible, provision shall be made for lubrication at an accessible location. Where oil is used, an oil level indicator and capped, vented filling connection shall be provided and firmly mounted in an accessible space and shall be connected to the bearing with pipe(s) as required. Where grease is used for lubricant, the pipe shall have a suitable lubricating fitting installed at the accessible end. All equipment shall be thoroughly lubricated before operation and at the time work is accepted. Provide a typed list of all lubricants required for all installed equipment, local dealer, and lubrication schedule.

3.03 PAINTING

A. Equipment shall be primed and finish painted in factory and touch-up painted in the field. Touch-up paint shall match factory-applied paint.

3.04 TESTING AND ADJUSTING

A. Furnish all labor and test equipment required for the testing and adjusting work.

B. Clean and purge equipment and piping before each test. Test piping systems as specified in Section 15185, PIPING AND VALVES.

C. Test mechanical systems in sections as work progresses. Systems or sections previously tested shall become parts of any repeated test when it becomes part of distribution or collection system.

D. Repair leaks by remaking with approved new material.

E. Should any equipment or material fail during testing, immediately remove and replace the defective material or equipment with new; retest system.

F. Perform all tests in presence of the University’ Representative.

G. After completion of testing and adjustment, operate systems and equipment under normal working conditions for 7 continuous days, to verify specified performance. If performance of equipment or system is not in conformance with specifications or submitted data, alter or replace equipment at no increase in contract price. Contractor at his option may order tests by an independent approved laboratory to determine compliance with the requirements of the Contract Documents. All such tests shall be at no increase of contract price.

H. At completion of work, provide written certification that the system has been installed in accordance with contract requirements, and is functioning satisfactorily and without defects.

I. Isolate from the system all equipment which may be damaged by test pressure.

END OF SECTION

SECTION 15080

THERMAL INSULATION

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes furnishing and installing thermal insulation and jackets for pipes, provided under Division 15, except insulation specified in other Sections.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. ASTM INTERNATIONAL (ASTM)

ASTM C547	Mineral Fiber Pipe Insulation
ASTM C585	Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System)
ASTM C1136	Flexible, Low Permeance Vapor Retarders for Thermal Insulation
ASTM E84	Surface Burning Characteristics of Building Materials

B. CALIFORNIA CODE OF REGULATIONS (CCR)

CCR Title 24	California Building Standards

C. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 255	Surface Burning Characteristics of Building Materials

D. UNDERWRITERS LABORATORIES (UL)

UL 723	Test for Surface Burning Characteristics of Building Materials

1.03 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Product Data: Submit for the following:

1. Piping insulation

2. Insulation jacket

3. Cements and finishes

4. Application procedures

1.04 REGULATIONS

A. Conform to the following:

1. Underwriters Laboratories Test Method No. 723: Fire Hazard Classification.

2. CCR Title 24, Part 6, California Energy Code.

PART 2 - PRODUCTS

2.01 GENERAL

A. Manufacturers: Owens-Corning Fiberglas Corp., Johns Manville, Certain-Teed, or equal.

B. Fire Hazard Classifications: Provide insulation, jackets, facings adhesives and accessories acceptable to the California State Fire Marshal, and meeting the requirements of CCR Title 24, Part 4, California Mechanical Code. Meet the following fire hazard classifications when tested in accordance with ASTM E84 or NFPA 255:

1. Flame Spread: Maximum 25.

2. Fuel Contributed: Maximum 50.

3. Smoke Developed: Maximum 50.

2.02 PIPING INSULATION

A. Insulation for Refrigerant Piping: Armstrong Armaflex, or equal, fire retardant flexible foamed plastic in formed sections.

B. Insulation for 50% Propylene Glycol Supply and Return Piping: Piping shall be insulated with O.C. Fiberglas SSL-211 or equal, two-piece, 4.2 pounds per cubic foot sectional pipe insulation conforming to ASTM C547 and ASTM C585, with ASJ self-sealing jacket of laminated white kraft aluminum foil reinforced with glass yarns and flame snuffing adhesive.

C. Aluminum Jacket: Cover pipe insulation exposed outdoors with aluminum jacket. Jacket shall be 0.01 inch aluminum with longitudinal seams and butt joint strips pre-coated with mastic. Cover joints with aluminum bands. Valves and fittings shall be covered with preformed aluminum covers secured with straps. The jackets shall be weatherproof with integral mastic sealed joints and seams.

D. Insulation Thickness, inches:

Service	Fluid Temperature Range, °F	Pipe Sizes		
		1 1/4" & Less	1-1/2" to 3"	
50% Propylene Glycol supply and return lines	-5	1″	1.5″	
Refrigerant pipes suction liquid lines		1″	--	

2.03 CEMENTS AND FINISHES

A. Lagging Adhesive: Arabol E1658E, Foster 30-36, or equal, thinned per manufacturer's instructions.

B. Vapor Barrier Coating: Non-flammable, fire-resistant, polymeric resin, compatible with insulation.

C. Spray Mastic: Insulcoustic 551, Foster 35-01, or equal.

D. Glass Cloth: Twinberg-Miller "Glasfab" No. 2020-X, Foster "Mast-A-Fab", or equal.

E. Bonding Adhesive: Foster 85-17, 3M, or equal.

F. Vapor Retarder: Conforming to ASTM C1136.

PART 3 - EXECUTION

3.01 GENERAL

A. Use whatever means are necessary to protect insulation materials before, during and after installation. No insulation material shall be installed that has become wet or damaged.

B. Apply insulation in a neat and workmanlike fashion, in maximum continuous lengths, with all butt and lap joints and seams secured.

3.02 PIPE INSULATION

A. Apply pipe insulation over clean and dry surfaces butting adjoining sections firmly together. Seal insulation smoothly and secure with self-sealing longitudinal lap using nylon sealing tool. Adhere factory furnished 3 inch wide pressure sealing strips to all butt joints and end joints.

B. Insulate fittings, flanges, valves, and strainers with polyvinyl chloride (PVC) plastic factory preformed jackets with factory pre-cut insulation. In all cases where the one-piece factory molded PVC insulated fitting jackets are used, apply two layers of the proper

factory supplied, precut fiber glass insulation. Tuck the ends of the fiber glass insulation snugly into the throat of the fitting, and tuck in the edges of the adjacent pipe covering. Hold the fiber glass in place by wrappings of twine. Cover the circumferential edges of the jacket with glass cloth soaked in lagging adhesive, overlapping the joint 2 inches on either side. Fitting shall not deform permanently under pressure. Any fitting not packed or sealed completely will not be accepted. Insulation material thickness shall be equal to the thickness of adjoining insulation.

C. All insulation shall be continuous including fittings, flanges, valves, strainers, and piping specialties. All insulation joints shall be sealed.

D. Extend piping insulation without interruption through walls, floors, and similar piping penetrations, except where otherwise specified.

3.03 FINISHES

A. Vapor Barrier: Insulation on chilled propylene glycol and refrigerant piping, pipe support inserts, valves and specialties shall be continuously covered with an approved vapor barrier. Apply two coats of the approved vapor barrier coating over all surfaces and lagging not covered with continuous vapor barrier jackets. Fill all joints, cracks, seams and depressions, and apply additional lagging as necessary to form smooth continuous surfaces.

B. Jacket: Apply aluminum jacket over pipe insulation after the insulation is completely vapor sealed. Lap joints 2 inches minimum. Attach with aluminum bands 18 inches o.c. Apply vapor barrier sealant to all joints and seams. Install seam on bottom of horizontal piping.

END OF SECTION

SECTION 15185

PIPING AND VALVES

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes furnishing, fabricating, installing and testing the following:

1. Pipe

2. Fittings

3. Valves

4. Pipe support devices

B. Fabricated pipe supports are specified in Section 05500, MISCELLANEOUS METAL.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. ASTM INTERNATIONAL (ASTM)

ASTM B 32	Solder Metal
ASTM B 62	Composition Bronze or Ounce Metal Castings
ASTM B 88	Seamless Copper Water Tube

B. ASME INTERNATIONAL (ASME)

ASME B16.18	Cast Copper Alloy Solder Joint Pressure Fittings
ASME B16.22	Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B31.3	Process Piping

C. SHEET METAL AND AIR-CONDITIONING CONTRACTORS NATIONAL ASSOCIATION (SMACNA)

SMACNA Seismic Restraint Manual	Seismic Restraint Manual: Guidelines for Mechanical Systems

1.03 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Product Data: Submit for the following:

1. Pipe

2. Fittings

3. Valves

4. Pipe support devices

B. Operation and Maintenance Data: Submit service instructions for valves.

PART 2 - PRODUCTS

2.01 PIPE

A. Copper Tubing: ASTM B 88, type "K", hard drawn deoxidized copper tubing.

2.02 FITTINGS

A. Soldered Fittings, for Copper Tubing: Wrought copper, ASME B16.22.

B. Unions for Copper Tubing: Solder joint ends, cast bronze, ASTM B 62 and ASME B16.18.

C. Copper to Ferrous Connections: Epco, Vallet, Ecoff, or equal, dielectric pipe unions, threaded or flanged as required, with gaskets rated 210°F at 250 psig.

D. Threaded to Solder Adapters: As specified for soldered fittings.

E. Thread Lubricant: Armite Joint Seal Compound 250, Enterprise Commercial "Thread-Seal", or equal, or Teflon thread sealing tape as specified.

F. Solder for Copper Tubing:

1. Lead-free tin-silver solder conforming to ASTM B 32 for 50% propylene glycol piping, with non-corrosive flux.

2. Pipe and fittings charred or collapsed due to excessive heating will not be permitted and shall be removed from the jobsite.

2.03 VALVES

A. Materials: In the following valve descriptions, bronze means ASTM B 62.

B. Manufacturers: Crane, and Stockham or equal, except where another manufacturer is specifically named. In the following valve description the first model number is Crane, the second is Stockham unless another manufacturer is named.

C. 50% Propylene Glycol Service:

1. Gate Valves 2 inch and Smaller: No. 431UB, threaded; union bonnet, rising stem, bronze gate valves Class 150.

2. Ball Valves 2 inch and Smaller: No. 9302, S216BR-R-T, 600 psi, bronze body ball valve, threaded ends.

3. Check Valve 2 inch and Smaller: 137, B321, threaded ends, bronze swing check valves.

2.04 PIPE SUPPORT DEVICES

A. Pipe supports shall be designed in accordance with SMACNA Restraint Manual: Guidelines for Mechanical Systems.

B. Pipe Support: Unistrut, Superstrut, Grinnell Power-strut or equal, 12 gauge channel complete with pipe clamps, nuts, bolts, and end caps.

C. Riser Clamps: Grinnell Figure 261, Unistrut, Superstrut, or equal.

D. Pipe Insulation Protection Shields: Grinnell Figure 167 or equal.

E. Miscellaneous Steel, Bolts, Nuts, and Washers: See Section 05500, MISCELLANEOUS METAL.

F. Attachments to Structure: Expansion anchors, lag bolts, steel brackets, mechanical bolts with washer and nuts as required.

PART 3 - EXECUTION

3.01 PIPE

A. Pressure piping material, fabrication and supports shall comply with ASME B31.3.

B. Use American Standard pipe threads for IPS threaded work. Ream out burrs formed by cutting tools and, before installing, examine each section of pipe to see that it is clean and clear. Pipes shall be free of tool marks. In making up threaded joints, apply specified thread lubricant or thread sealing tape to male threads only.

C. Slope pressure piping minimum 1 inch in 40 feet, except where space conditions will not permit this slope. Slope piping up in the direction of flow to high points and provide manual air vents as indicated or as required at all high points. Provide 3/4 inch ball valve bibb connections at low points for system drainage. Use eccentric reducing fittings wherever necessary to provide free drainage or venting of lines.

D. Wherever changes in sizes of piping occur, use reducing fittings. The use of bushings will not be permitted.

E. Bullhead tee connection in either mixing or diverging flow will not be permitted.

F. Install dielectric unions at all connections of ferrous to non-ferrous systems.

G. Run piping to maintain proper clearance for maintenance and to clear openings in exposed areas. Run piping in coordination with electrical conduit and equipment, structural and architectural conditions, and work of other trades. Verify inverts and pitched lines before starting work.

H. Install exposed piping parallel to or at right angles with building walls and tight to walls, ceilings, or structure wherever possible, unless otherwise shown on the drawings. Install exposed overhead piping as high, and as tight to structure, as possible.

I. No valve, piece of equipment, or trim shall support the weight of any pipe.

J. Install piping free from traps and air pockets and true to line and grade.

K. Place piping without spring or forcing unless specifically indicated. Provide flexibility, anchors, and support to prevent strain from thermal movement or weight from being imposed on equipment.

L. Provide 3/4 inch valved drain at the bottom of each riser.

3.02 VALVES

A. Valves, unless specifically sized, shall be the same sizes as the pipelines in which they are installed. No valve shall be installed with its stem pointing below the horizontal unless specifically shown otherwise. Install a union adjacent to every threaded valve, where required for disassembly, and where shown.

3.03 PIPE SUPPORTS

A. Support Schedule: See drawings for pipe support details.

B. Support pipes at intervals indicated and at each change in direction.

C. Every branch of piping over 3 feet long shall have a separate hanger.

D. Use specified pipe shields at pipe supports.

3.04 PIPE BRACING

A. Bracing: See Section 05500.

3.05 TESTING

A. Clean and hydrostatically test piping system in accordance with ASME B31.3. Repair leaks and re-test until proven leak-free.

END OF SECTION

SECTION 15620

PACKAGED AIR-COOLED CHILLER SYSTEM

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section includes furnishing, installing and testing an outdoor factory assembled packaged fully automatic air-cooled liquid chilling system of proven performance for the capacity as scheduled.

B. The package shall include compressors, evaporators, condensers, pumps, motors, purge unit, and components and accessories necessary for safe and satisfactory operation, including integral piping, unit mounted controls, electrical wiring, thermometer, pressure gauge, and instrumentation.

C. The chiller shall be capable of providing full capacity performance at 9^{o}F above the design ambient temperatures specified below:

Summer	94^{o}F
Winter	0^{o}F.

1.02 REFERENCES

A. AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 15	Safety Standard for Refrigeration Systems

B. ASME INTERNATIONAL (ASME)

ASME B31.5	Refrigeration Piping and Heat Transfer Components
ASME BPVC SEC VIII	Boiler and Pressure Vessel Code: Section VIII, Rules for Construction of Pressure Vessels, Division 1

C. AIR-CONDITIONING AND REFRIGERATION INSTITUTE (ARI)

ARI 210/240	Unitary Air-Conditioning and Air-Source Heat Pump Equipment
ARI 270	Sound Rating of Outdoor Unitary Equipment
ARI 550/590	Water Chilling Packages Using the Vapor Compression Cycle

D. UNDERWRITERS LABORATORIES (UL)

UL 984	Hermetic Refrigerant Motor-Compressors

1.03 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Product Data: Submit data on air cooled chiller, including dimensions, features, wiring diagrams, certified performance, accessories, weight, and mounting recommendations. Indicate equipment, piping and connections, valves, strainers and thermostatic valves required for complete system.

B. Factory certified test report indicating the chiller's rating in accordance with ARI 550/590.

C. Installation Instructions: Submit manufacturer's installation Instructions.

D. Operation and Maintenance Data: Submit for all equipment furnished under this Section.

E. Shop Tests: Furnish a Test Report for shop tests to verify that design conditions have been met.

F. Field (Acceptance) Test: Following field performance test, furnish a Test Report to University's Representative to demonstrate the satisfactory operation and performance of the chiller system and its components.

1.04 REGULATIONS

A. The packaged air-cooled chiller system shall conform to the following:

1. Air-Conditioning and Refrigeration Institute:

a. ARI 210/240: Unitary Air Conditioning and Air-Source Heat Pump Equipment

b. ARI 270: Sound Rating of Outdoor Unitary Equipment

2. California Energy Commission: Efficiency certification.

3. Underwriters Laboratories or E.T.L. Label.

1.05 WARRANTY

A. Warrant the chiller unit's performance for capacity, efficiency, vibration, operating control, and safety cutouts in accordance with the requirements of ARI 550/590.

B. Provide 4-year manufacturer's warranty for parts and labor.

C. Provide 5-year warranty on compressors.

1.06 EQUIPMENT SCHEDULES

A. Air-Cooled Liquid Chiller Unit

Equipment No.	Type	Capacity kW/BTUH	Chilled 50% Propylene Glycol		
			Temp °F		Flow gpm
			Enter	Leave	
CH-1	Air-Cooled Scroll	25/85,330 (8.2 Ton)	33	24	25

B. Pumps

Equipment No.	Service	Media	Flow gpm	Pump Head* Feet	Motor Hp/rpm	Elect. V/Ph/Hz
P-1	Chilled Liquid Circulation	50% Propylene Glycol	25	90	Vendor	240 V, 3-phase, 60 Hz
P-2	Chilled Liquid Circulation	50% Propylene Glycol	25	90	Vendor	240 V, 3-phase, 60 Hz

*Pump head does not include pressure drop across chiller.

PART 2 - PRODUCTS

2.01 OUTDOOR PACKAGED AIR COOLED LIQUID CHILLER CH-1

A. Manufacturer: Airstack Model ASP or approved equal. Contact for Airstack: Kurt Wessel, 510-433-8953.

B. System Description: The chiller shall be complete with an accessible full hermetic direct drive scroll compressor and shall consist of two completely independent circuits. Each refrigerant circuit shall consist of an individual compressor set, condenser, evaporator, microprocessor-based control panel and unit mount motor starter. Each circuit shall be capable of working independently of the other circuit from a refrigeration and electrical standpoint. The chiller shall be designed to operate with R407c, or other approved less-ozone-depleting rated refrigerant. R-22 will not be acceptable.

C. Performance and Rating: As shown in Equipment Schedule herein. Ratings shall be in accordance with ARI Standards 550/590 and ARI 270.

D. Cabinet and Chassis: Heavy duty painted galvanized steel, internally insulated and designed for curb mounting.

E. The chiller shall be shop wired and charged with the refrigerant specified in paragraph 2.01B.

F. Compressors: The chiller shall contain two fully hermetic scroll compressors with suitable vibration isolators. Each system shall also include high discharge pressure and low suction pressure safety cut-outs.

G. Evaporator: Each evaporator shall be shell and tube or plate design, tested and stamped in accordance with ASME BPVC SEC VIII for 115 psi minimum. Insulate the evaporator with closed cell PVC nitrile rubber sponge or with metal-sheathed 2-inch polystyrene with aluminum foil vapor barrier. Provide insulated drain pan.

H. Condenser: The condenser of each circuit shall consist of passivated aluminum fins bonded to seamless copper tubes integral with subcooling circuit. The condenser air fan shall be of the propeller type, directly driven by a motor and discharging upward. Fan motor shall be weather proof, pressure controlled and have built-in thermal overload protection.

I. Refrigeration System: The refrigeration system shall be self-contained with evaporator and condenser sections factory piped and sealed with an operating charge. Include filter dryer, refrigerant line sight glass and moisture indicator. Provide reversing valve for heat pump.

J. Central Control System:

1. Provide all necessary control interfaces with the building automatic controls system to provide control, monitoring and alarm functions.

2. Provide a unit mounted starter panel with motor starter and protection factory mounted and completely prewired to the motor and control panel. Provide an ammeter on the starter panel door.

3. Provide continuous automatic capacity control from 20% to 100%, achieved by use of a side valve.

4. Control Panel: Provide a microprocessor based control panel with the following functions:

a. Monitoring of time between motor starters.

b. Leaving chilled 50% propylene glycol temperature control.

c. Automatic shut down protection with manual reset of low evaporator refrigerant pressure and temperature, high condenser refrigerant pressure, high compressor discharge temperature, high motor temperature, motor current overload, phase reversal, low oil flow, high oil temperature and low chilled 50% propylene glycol temperature.

d. Evaporator free protection and low limit control.

e. Diagnostic function to detect refrigerant charge loss.

f. Automatic shut down protection and automatic reset for loss of evaporator water flows, power loss, low chilled liquid temperature and anti-cycle.

g. Motor protection against phase loss, phase imbalance, phase reversal, under/over voltage and motor overload.

h. Menu drive display of control parameters and diagnostic codes.

i. Compressor service switches.

j. Periodic pump down.

5. Display: Control panel shall display at least the following:

a. Entering and leaving evaporator liquid temperatures.

b. Evaporator and condenser refrigerant pressures.

c. Current draw and current limit and percentage of LRA set point.

d. Compressor number of starts and elapsed time.

e. Chilled 50% propylene glycol set point.

f. Evaporator inlet temperature gauge.

g. Evaporator outlet temperature gauge.

h. Refrigerant discharge pressure gauge.

i. Refrigerant suction pressure gauge.

j. Oil pressure gauge.

k. Chiller shall be designed to operate on 240 V, 3 phase, 60 Hertz.

2.02 PUMPS P-1 and P-2

A. The chiller package shall include two pumps as an integral part of the chiller system. The pumps shall be centrifugal pumps in a Primary/Standby pumping arrangement. The pump capacity and head shall be as indicated in the Equipment Schedule herein. Pump starters and controls shall be provided to enable manual selection of lead pump. The pumping system shall be completely factory assembled and tested prior to shipment.

B. The pumps and their related piping shall be insulated with fiberglass insulation with vapor barrier as specified in Section 15080, THERMAL INSULATION.

2.03 EXPANSION TANK

A. Expansion tank shall be welded steel with butyl rubber diaphragm and capable of maximum operating temperature of 240°F and maximum working pressure of 100 psig. Tank shall be interconnected through the

common chiller header system and require no additional water connection.

2.04 SHOP TESTS

A. Shop tests shall be performed on the liquid chiller system prior to shipment to the project site. The University’s Representative may elect to witness any or all of these tests. Contractor shall give at least 7 days advance notice of shop tests to the University’s Representative.

B. System test shall be performed in accordance with ARI 550/590. If a system item fails to meet the performance requirements, that item shall be rectified, and the system shall be retested until the tests show that all design conditions have been met.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Set the chiller in place on concrete pad at grade using manufacturer's recommended attachments.

B. Support shall be dead level.

C. Install and connect all piping. Connect condensate drain minimum 6 inches above grade.

D. Wire all interlock controls. Install and connect power wiring.

3.02 FIELD TEST

A. After the chiller has been put in operation, conduct a performance test of the system to verify performance requirements and operation of all controls and displays. Refer to Section 15000, Paragraph “Testing and Adjusting” for requirements. Submit test report to the University’s Representative.

END OF SECTION

SECTION 16050

BASIC ELECTRICAL MATERIALS AND METHODS

PART 1 – GENERAL

1.01 SECTION INCLUDES

A. This Section describes the requirements for furnishing and installing basic electrical materials and equipment.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C2	National Electrical Safety Code
ANSI C80.1	Specification for Zinc-Coated Rigid Steel Conduit

B. AMERICAN SOCIETY FOR TESTING AND MATERIAL (ASTM)

ASTM B3	Soft or Annealed Copper Wire

C. NATIONAL ELECTRICAL MANUFACTURER'S ASSOCIATION (NEMA)

NEMA ICS 6	Enclosures for Industrial Controls and Systems
NEMA MG 1	Motors and Generators
NEMA PB 1	Panelboards
NEMA TC 8	PVC Plastic Utilities Duct for Underground Installation
NEMA TC 9	Fittings for ABS and PVC Plastic Utilities Duct for Underground Installation
NEMA VE 1	Metallic Cable Tray Systems
NEMA WC 5	Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
NEMA WC 7	Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
NEMA WD 1	General-Purpose Wiring Devices

D. INSULATED CABLE ENGINEERS ASSOCIATION (ICEA)

S-61-402	Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
S-66-524	Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

E. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	National Electrical Code (NEC)

F. UNDERWRITERS LABORATORIES, INC. (UL)

UL 1	Flexible Metal Conduit
UL 6	Rigid Metal Conduit
UL 20	General-Use Snap Switches
UL 67	Panelboards
UL 498	Attachment Plugs and Receptacles
UL 514A	Metallic Outlet Boxes
UL 514B	Fittings for Conduit and Outlet Boxes
UL 797	Electrical Metallic Tubing

1.03 QUALITY ASSURANCE

A. Electrical equipment, material and wiring devices shall conform to cited standards of NEMA and ANSI, and where UL provide a listing, shall bear the UL label.

1.04 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Manufacturer's Data: Submit manufacturer's literature for proposed equipment and materials to be furnished. A single, complete submittal is required for all products covered by this Section.

B. Shop Drawings: Prior to fabrication, submit shop drawings on fabricated work being furnished and installed under this Specification. Shop drawings shall be completely dimensioned, giving plans and elevations together with such sections as shall be necessary to clearly and adequately show construction.

C. Test Reports: Submit test results, as indicated and as required.

D. As-Built Drawings: Furnish as-built drawings prior to acceptance of the Work. The as-built drawings shall show the complete layout of the electrical systems as installed, with sufficient dimensions and information to facilitate troubleshooting and future expansions of the systems.

1.05 UNIVERSITY-FURNISHED EQUIPMENT

A. Unloading and Handling of University-Furnished Equipment: Equipment and materials furnished by the University will be delivered to the Contractor at the plant site. Contractor shall receive, unload, and properly store and protect and be responsible for any loss or damage to University-furnished items until acceptance of the completed work by the University.

B. Inspection of University-Furnished Equipment

1. The Contractor shall check all equipment furnished by the University to ensure that the proper components and wiring are provided to operate, control and protect the equipment as shown on the drawings and specified.

2. Where an item of equipment furnished by the University is deficient in any respect, the Contractor shall advise the University’s Representative in writing, within 7 calendar days of receipt of equipment.

C. Storing University-Furnished Equipment

1. During the period that University-furnished equipment and materials are in the possession of the Contractor, the Contractor shall be responsible for the storing and protecting of the equipment against damage or loss. The Contractor shall promptly notify the University’s Representative of any damage or loss of University-furnished materials and equipment in order that the University’s Representative may expeditiously replace such equipment. All expenses incurred in replacing damaged or lost University-furnished equipment, after acceptance of such equipment by the Contractor, will be at the expense of the Contractor.

2. Contractor shall ensure that manufacturers' recommendations for the storing and heating of equipment to maintain electrical insulation quality are strictly enforced.

3. Contractor shall store small items and subassemblies in original containers to minimize possibility of damage or loss.

4. Equipment received with openings without adequate cover shall be covered to prevent entrance of water, dust or vermin during storage period.

5. Contractor shall protect all finished surfaces, not otherwise protected, from damage, corrosion, and oxidation. Machined surfaces shall be protected by films of corrosion-retarding oil, grease or other rust preventatives, and coatings shall be renewed or repaired when necessary to maintain the film intact. Protective coatings shall conform to manufacturer's specifications. Equipment and material shall not be stacked or piled on any machined surfaces unless the finished surfaces are positively protected by means of substantial covers rigidly secured in place.

6. Contractor shall comply with special instructions furnished by equipment suppliers for outdoor storage of their respective equipment.

D. Field Assembly of Equipment: Certain University-furnished equipment will require field assembly prior to installation. Such equipment will have been shop assembled to the greatest extent practical prior to shipment. The Contractor shall field assemble such equipment as required, in accordance with the drawings and manufacturer's instructions.

PART 2 - PRODUCTS

2.01 GENERAL

A. Materials and equipment shall be suitable for use in the ambient conditions that will exist at the particular location. In dry location use NEMA 1 enclosures. In wet areas NEMA 4 enclosures or hermetically-sealed devices shall be used. These requirements apply unless modified herein. All material shall be inherently rust-resistant or shall be suitably protected from rust by plating processes or by the application of suitable rust-resistant coatings.

2.02 CABLE TRAYS

A. Cable trays 24 inches wide or less and accessories shall be ladder type, with a minimum uniform loading capacity of 50 pounds per linear foot on a 16'-0" simple span having a maximum deflection not to exceed 1 inch. Cable trays wider than 24 inches and accessories shall be ladder type, with minimum uniform loading capacity of 75 pounds per linear foot on a 20'-0" simple span having a maximum deflection also not to exceed 1 inch. Trays shall be galvanized steel and shall have a maximum rung spacing of 9 inches. Trays and accessories shall be hot-dip or electrolytic galvanized after fabrication. Vertical and horizontal changes in direction shall be made with an adequate radius tray fitting that will accommodate the cable(s) installed therein. This radius shall be not less than that recommended by the cable manufacturer. Minimum depth of tray shall be 6 inches. Covers where required, shall be solid galvanized steel with spacers to provide a 1/2-inch gap between the cover and tray for ventilation. Trays shall have a minimum design safety factor of 1.5, and shall conform to NEMA VE 1.

B. Depth and width of trays and type of supports shall be as indicated. Trays, covers, supports and accessories shall be by the same manufacturer.

C. Full depth barrier strips shall be furnished and installed in trays as indicated on the drawings.

2.03 CONDUIT AND FITTINGS

A. Rigid Conduit

1. Conduit shall be rigid galvanized steel (RGS), or electrical metallic tubing (EMT). Only couplings and fittings designed specifically for the type of conduit specified shall be used. Each length of conduit, nipple, and elbow shall bear the label of the Underwriters' Laboratories, Inc. Conduit shall be supported by corrosion-resistant straps and clamps. Minimum size shall be 3/4-inch in general and 1/2 inch for exposed lighting and exposed runs to individual devices or instruments. Aluminum conduit shall not be used.

2. RGS conduit and fittings shall conform to UL 6 and UL 514B, and shall be zinc coated.

3. EMT tubing and fittings shall conform to UL 797 and UL 514B, and shall be zinc coated.

4. Rigid nonmetallic conduit for underground application shall be PVC and shall conform to NEMA TC 8, Type DB. Fittings shall conform to NEMA TC 9.

B. Flexible Conduit: Flexible conduit shall be liquid-tight with a grounding conductor built-in conforming to UL 1, and shall be jacketed with a plastic extrusion. Such conduit may be non-liquid-tight in enclosed walls, plenums and connections to lighting fixtures above ceilings.

C. Steel Conduit Fittings, Outlet Boxes, Junction Boxes and Pull Boxes

1. Cast iron alloy conduit fittings with threaded conduit hubs shall be used unless otherwise approved. Fittings shall be of a UL listed type.

2. Flush mounted outlet boxes shall be code gauge pressed steel, shall comply with the requirements of UL 514A and UL 514B for fittings, shall accommodate the conduit and wire, and shall have a grounding terminal. All device boxes shall be surface mounted.

3. Standard size pull boxes or junction boxes located in dry or noncorrosive areas shall be made from galvanized sheet steel, or cast metal. Pull or junction boxes shall be sized in accordance with NEC requirements, and the conduit penetrations shall be located so that the cable can be installed without bending it to a radius less than that recommended as a minimum by the cable manufacturer. Non-standard pull boxes shall be fabricated from 12 gage sheet steel, minimum. After fabrication, boxes shall be thoroughly cleaned and painted with one coat of manufacturer's standard rust preventive paint and a finish coat of color to match surrounding equipment or building.

4. Standard size NEMA 4 weatherproof type pull boxes or junction boxes shall be made of galvanized sheet steel or cast metal and shall have taper-threaded conduit hubs. Alternatively, connections may be made with zinc conduit hub fittings, or by means of a weatherproof sealing locknut on the outside and regular locknut on the inside, properly tightened. Non-standard NEMA 4 weatherproof type pull boxes or junction boxes shall be fabricated from 12 gage sheet steel. After fabrication, boxes shall be cleaned and painted as indicated in the preceding paragraph.

5. Metallic insulated bushings and locknuts shall be used on all conduit terminations.

2.04 Panelboards

A. Panelboards shall be dead-front, totally enclosed in NEMA type 1 enclosures. Enclosures shall be formed construction, code-gauge, cold-rolled steel and shall conform to UL 67. Finish shall be suitable for the location intended, and unless otherwise indicated, ferrous metal parts shall be hot-dip galvanized after fabrication and fronts shall be finished to resist corrosion with not less than one priming coat and one specified finishing coat of paint. Exposed parts of trim and doors shall be finished after erection as directed. Each panelboard shall have a door over the switches or circuit breakers in the panel. A directory holder six inches wide by eight inches high, minimum, shall be welded to the back of the door. Each door shall have one or more catches and shall be lockable. Three keys shall be furnished, each of which shall operate all panelboard cabinet locks included in the Work. Panelboards shall be floor standing, wall mounted, surface mounted or flush mounted, as indicated. Manufacturer's standard panelboards shall have code-size

gutters and standard knockouts.

B. Circuit breakers shall be a bolt-on type. The RMS symmetrical interrupting rating shall be not less than that specified for the panel. Circuit breakers shall trip on overload and short-circuit and the handle positions shall indicate ON, OFF and TRIPPED. Circuit breakers shall be thermal magnetic type. Handle tie bars to make multi-pole breakers will not be permitted. Circuit breakers for motor circuits shall have provisions for padlocking the handle in OFF position.

C. Panelboards shall be equipped with main lugs or main breaker as indicated. Panelboards shall have insulated neutral bus and bonded ground bus. Bus bars shall be copper with joints silver plated. Connection straps, interconnectors, neutral bus bars and internal wiring shall be copper. Solid neutral bar connectors shall be numbered to correspond to branch circuits. Bus bars and straps shall be rigidly supported on insulators and shall be rated for maximum branch circuit load and short-circuit capacities. Bus bars shall be located behind the switches and circuit breakers. Panelboards shall conform to NEMA PB 1 and UL 67.

2.05 STARTERS

Magnetic starters shall be as follows:

A. Across-the-line, full voltage, combination circuit breaker magnetic starters designed to work in series with a motor circuit breaker shall be furnished in individual enclosures. Thermal overload relays on starters shall be non-compensated bimetallic type with selector for either auto or manual reset. Overload heater units shall be provided in each starter unit.

B. Each motor starter shall be provided with a minimum of two-N.O. and two-N.C. additional contacts. Auxiliary contacts shall be wired to terminal blocks.

C. All motor starters shall be equipped with three overload elements.

D. Starter overload reset button shall be operable with the compartment door closed.

E. Each motor starter shall be equipped with an individual 120 volt control circuit transformer, with two primary fuses and one leg of the secondary fused and the other grounded.

F. Each motor starter shall be provided with two indicating lights (red and green lens) in the door of the compartment.

2.06 WIRE AND CABLE, COPPER, 600 VOLT FOR POWER, LIGHTING AND CONTROL

A. Wire and cable size 10 AWG and smaller shall be solid and color coded per the NEC. Wire and cable size 8 AWG and larger shall be stranded copper and shall be color coded with tapes. Applicable provisions of the following standards shall apply to electrical conductors and cables unless otherwise specified:

ICEA NO.	NEMA NO.	
S-61-402	WC 5	Thermoplastic-Insulated Wire and Cable
S-66-524	WC 7	Cross-Linked-Thermosetting-Polyethylene

B. 600 volt wire and cable for power, lighting and control shall be copper. Wire and cable shall bear the UL label and shall be brought to the job in unbroken packages, or on reels, and shall consist of annealed, uncoated wire conforming to ASTM B3. Wire and cable delivered to the site shall be of current manufacture, having a shelf life of less than one year from date of manufacture to delivery at site.

2.07 FRACTIONAL HORSEPOWER MOTORS

A. Motors supplied with equipment shall be adequately rated for the accelerating and full load duty requirements of the driven equipment. All motors shall be suitable for continuous, full load operation at 10% above or below the rated supply voltage, or at 5% above or below the rated supply frequency without exceeding a safe temperature rise.

B. Motors shall be suitable for full voltage (across the line) starting. Torque and current characteristics shall be in accordance with NEMA design B unless drive requirements dictate higher values.

C. Characteristics shall be:

1. Motors shall be squirrel cage induction motors.

2. Motors less than 1/2 horsepower shall be rated for 120 volt, 60 Hz, single-phase power.

3. Motors rated 1/2 horsepower and larger shall be rated for three-phase, 240 volt, 60 Hz power, unless otherwise specified.

4. Service factor at rated voltage shall be 1.0.

D. Technical requirements are:

1. Enclosures shall be TEFC with threaded drain hole with plug.

2. Terminal box shall have solderless compression type lugs with terminal for power supply ground wire.

3. Bearings shall be grease lubricated ball type.

4. Insulation shall be Class F with Class B temperature rise.

5. Provide stainless steel nameplate with standard NEMA information.

6. Provide eyebolt lifting lugs.

2.08 RECEPTACLES

A. 120 volt, 20 ampere receptacles shall be "U" slot, three-wire grounding type.

B. Configuration and requirements for connector and outlet receptacles shall be in accordance with UL 498 and NEMA WD 1 for heavy-duty, general use type.

C. Receptacles shall have fire-resistant nonabsorptive hot-molded phenolic composition bodies and bases with metal plaster ears integral with supporting member.

D. Receptacles and plugs (caps) shall be provided with white-colored terminal for neutral connections, amber or brass-colored for phase

conductor connections and green-colored hexagonal machine screws for the equipment grounding conductor or connections.

E. Special receptacles for computer equipment shall be provided in accordance with computer system manufacturer's instructions.

2.09 COVER PLATES

A. Cover plates shall be one piece, with rounded or beveled edges, or stainless steel. Mounting screws shall be of metal and have countersunk heads finished to match cover plate.

2.10 NAMEPLATES

A. Nameplates shall be provided for every separately installed control switch, breaker, fuse, meter, relay, instrument, or similar device. Nameplates shall be laminated plastic engraved with motor number and name as indicated on the one-line diagrams to show lettering on a white background. The size shall be one inch by two inches with 3/8 inch lettering and numbers.

2.11 LUGS AND WIRE CONNECTORS

A. Lighting conductors shall be spliced by means of Ideal set screw connectors or approved equal. Power cable terminations shall be copper terminal lugs, long barrel, two-bolt hole, compression type as manufactured by T&B.

2.12 CONDUIT SYSTEMS AND EQUIPMENT SUPPORT CHANNELS AND HARDWARE

A. Conduit systems and equipment support channels and hardware shall be hot-dipped galvanized steel.

2.13 LUBRICANT FOR PULLING WIRES AND CABLE

A. Lubricant for pulling wire and cable shall be a type approved by the wire and cable manufacturer for the conduit used.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General: Manufactured articles, materials and equipment shall be applied, installed, connected, erected, tested, used, cleaned and conditioned as recommended by the manufacturer, and in accordance with ANSI C2.

B. Cable Trays

1. Support trays at intervals in a manner recommended by the tray manufacturer, pertinent drawings, and for the specified tray loading conditions.

2. Cables shall not be placed in cable trays more than two layers deep. Cables shall be arranged in trays so as to provide a minimum of cable crossovers.

3. Cable tray covers shall be solid, and shall be adequately secured.

4. Cables shall be secured to the cable tray rungs by means of nylon cable ties of the self-locking type. As a minimum, power cables shall be tied every other rung and control cables shall be tied every fourth rung.

5. Electrical continuity of the cable tray system shall be assured.

C. Utility Trenches: Utility trenches shall be excavated and backfilled as specified in Section 02300, EARTHWORK. Conduit shall be buried in compacted sand and covered by a concrete cap with red dye and warning tape as indicated and specified.

D. Rigid Conduit: Conduit buried underground or embedded in concrete shall be as indicated. EMT conduit shall be used for interior wiring in the building for power, control, lighting, and fire alarm.

1. Where underground connections enter a building above the ground floor, a suitable pull box shall be installed. Where a conduit enters through a concrete floor, the curved portion shall not be visible above the finished floor. Metallic conduit and fittings which are direct-burial shall be coated with bituminous material to prevent corrosion from the soil.

2. Conduit stub-ups into floor standing equipment (switchgear, control panels) shall be of sufficient height to accommodate grounding bushings and shall not interfere with equipment wireways and terminals. Conduit stub-ups shall be close to walls, and column footings, and shall not interfere with traffic and other equipment.

3. Conduit shall be installed parallel with or at right angles to the building walls and shall be supported adequately by pipe straps or by other approved methods. Conduit at suspended ceilings shall be located, when practicable, above the ceiling. In slabs, conduit shall be located so as not to affect the structural strength of the slabs.

4. Conduit shall be installed in accordance with the NEC, and shall present a neat and accurately aligned appearance when completed.

5. Conduit joints shall be made with approved couplings and unions. Right angle bends, offsets and change-in-direction bends shall be made with standard elbows, conduit fittings, pull boxes, or formed with a hickey or power bender. Conduit runs shall be straight and true; elbows, off-sets and bends shall be uniform and symmetrical. Bends shall be made without kinking or deforming the cross-sectional contour of the conduit. Conduit ends shall be cut square, properly reamed to remove burrs and sharp edges and threaded to engage not less than five threads. Joints shall be made up tight.

6. Each conduit raceway shall contain only those conductors constituting a single feeder circuit.

7. Conduit terminations at outlets, boxes and cabinets shall be provided with locknuts and bushings unless otherwise indicated. Where applicable, conduit shall be provided with grounding bushings for connecting a jumper to the box ground point.

8. Straight runs of rigid conduit made up with approved threaded couplings and uninterrupted by outlet boxes, junction boxes or cabinets shall be supported at intervals as required by the NEC.

9. Fastening of conduit clamps and straps shall be as follows: to wood by means of screws; to concrete by means of threaded metal inserts, or metal expansion screws; and to steel by means of machine screws or bolts.

10. Conduit runs shall be cleaned and swabbed to remove foreign matter and moisture prior to pulling in wire and cable.

E. Flexible Conduit: Motors and movable devices shall be connected to the conduit with a short length of flexible conduit. A grounding bond wire shall be installed to ensure electrical continuity across the flexible conduit unless the material used and its fittings are specifically designed to make the use of such bond unnecessary. Sufficient flexible conduit shall be installed to allow maximum movement of motors on bases.

F. Conduit Fittings, Outlet Boxes, Junction Boxes and Pull Boxes

1. Ganged boxes shall be used whenever two or more outlet boxes for switches or receptacles are adjacent and identical in size. Boxes and fittings shall conform to UL 514A and 514B.

2. Conduit sleeves or block-outs shall be provided for penetrations. Penetrations through the walls and ceilings shall be sealed and made watertight and dusttight. Penetrations in exterior or underground walls shall be watertight. Penetrations through fire-rated interior walls shall be sealed with a material having a fire rating equal to the wall.

G. General Purpose Electrical Equipment

1. The installation of panelboards shall be in accordance with code regulations, equipment manufacturer's recommended practices and shall be performed by craftsmen experienced or trained in the installation of the specified materials and equipment.

2. Each panelboard and other miscellaneous general purpose equipment and apparatus used for the operation or control of circuits, appliances or equipment shall be provided with a permanent identification nameplate.

3. Panelboards shall be installed as specified in the preceding paragraph, except that the top of the panel shall be not higher than 6 feet from the floor. For flush-mounted boxes, the wall opening shall be completely covered by the trim, which shall fit tightly to the flush surface without forcing or warping. Hinged covers shall close smoothly, and locks and catches shall operate easily.

H. Wire and Cable, Copper

1. Conduit fills shall be calculated in accordance with NEC requirements, based on cable O.D.'s corresponding to specified cables. Should substitutes be approved, it shall be the Contractor's responsibility to check that conduit fills do not exceed NEC requirements.

2. Conductor Identification: All wires and multiconductor cables shall be marked with wire numbers at all terminations and in terminal boxes using engraved split plastic sleeve markers. Conductors of power and lighting feeder circuits shall be adequately identified at intermediate pull boxes by fireproof tags or other approved means.

3. Multiconductor cables shall be marked with circuit or cable numbers at each end and, if accessible, once every fifty feet and at least once in each room through which they pass. Marking shall be done by use of plastic or metal tags with nylon ties.

4. Control and circuit wiring in cabinets, panels, pull boxes and junction boxes shall be neatly trained and held with nylon cable ties.
5. Instrumentation circuits shall be installed in splice-free continuous runs.

6. Multiple-conductor feeder circuits shall consist of multiple conductors in parallel and shall be installed such that each phase conductor is grouped together with conductors of the other two phases, and the neutral where one is used.

7. Feeder conductors, where practicable, shall be continuous from origin to termination without splices in intermediate pull boxes or splicing chambers. Sufficient slack shall be left at terminations to make proper connections.

8. Circuits passing through pull boxes shall have conductors of each circuit banded together with cabling twine, cable ties or clamps, and adequately identified by fireproof tags or other accepted means.

9. Hangers, racks, clamps and supports shall be provided as required for proper wire and cable installation. All cables shall be rigidly supported by insulated cross bracing in large pull and terminal boxes.

10. In general, cable installation shall be in compliance with the cable manufacturer's recommendations.

11. Minimum installed bending radii of the cable shall be ten times the cable diameter or as required by NEC. Minimum radii of sheaves used for cable pulling shall be twelve times the cable diameter.

12. Pulling tensions shall be calculated and shall not exceed those allowable by the manufacturer.

13. When cutting cables, enough length shall be left for training, splicing and discarding the pulling end. Immediately after the cable is cut, ends shall be resealed per manufacturer's recommendation, until such time as the cable is terminated or spliced.

14. Ample slack wire shall be left at all terminal connections so that stress is not placed on terminals.

15. After wire and cable are installed in conduits entering junction and pull boxes, the ends shall be sealed with duct-seal or other easily removable material to prevent the entrance of moisture into the boxes.

16. Power feeders shall be marked at termination points with the following colors by means of precolored adhesive tape:

L1 Hot – red	Neutral - white
L2 Hot – black	Ground - green

17. Splices and Terminations, 600 Volt Class Conductors: Splices in wires and cables shall joint the conductors securely both mechanically and electrically.

a. Splices in conductors No. 10 AWG and smaller may be made by means of Ideal set screw connectors, or accepted equal. Splices in conductors No. 8 AWG and larger shall be made with accepted solderless connectors and shall be covered with insulating tape or hot-molded composition covers having an insulating value equal to the conductor insulations.

b. Terminations shall be made with accepted solderless, copper two-bolt, long barrel compression-type connectors except where suitable accepted termination means are furnished as an integral part of equipment.

c. Compression type connectors shall be of correct size for each application and shall be applied with proper methods and tools in accordance with manufacturer's instructions.

d. Conductors terminating at each wired outlet shall be left not less than eight inches long at their outlet fitting to facilitate the installation of devices or fixtures.

I. General Purpose Wiring Devices

1. Locations of Outlets and Switches: The edges of outlet boxes for concealed work shall be not more than 1/4 inch from the plane of the finished surface, except that boxes having flush plates shall not project beyond finished walls. The distance from the finished floor to the bottom of wiring devices shall be as indicated on the drawings.

2. Mounting of Devices:

a. Conduit shall not be used as mounting support for any device.

b. Devices shall be located and mounted in such positions as not to be subject to vibration or accidental bumping.

c. Nameplates shall be provided for every separately installed pushbutton, disconnect switch, control switch, breaker, fuse, meter, relay, instrument, or similar device. Nameplates shall be laminated plastic engraved to show black lettering on a white background.

J. Painting

1. Distribution panels and similar equipment provided with enameled or lacquered finish by the manufacturer, which are scratched or defaced during construction, shall be refinished and restored to the original finish. Structural steel, equipment, ducts, or other surfaces defaced by the installation of electrical work shall be touched up.

2. Where required, field fabricated items shall be painted inside and outside with one coat of primer, rust-inhibitive type paint. Dry mil thickness shall be 1-2 mils. One finish coat of rust-inhibitive type paint shall be applied to the outside, having a dry film thickness of 1-2 mils.

3.02 SEISMIC RESTRAINTS

Seismic restraints shall be in accordance with the following as a minimum:

A. Wall and column-mounted equipment such as transformers, panelboards, and the like, shall be securely mounted with through-bolts, preformed framing channels, clamps and hangers in a manner to prevent dislodgement.

B. Racks for panelboards and similar equipment shall be attached securely to walls or columns, with legs resting on the floor or platform.

C. Earthquake-resistant devices designed to resist strong horizontal and vertical movements and bolted to the equipment and to the floor, or movement-restraining field-fabricated devices covered with resilient materials to minimize impact loads, shall be provided for equipment mounted on vibration dampers.

D. Switchgear and other free-standing equipment shall be bolted or welded to the floor.

E. Transformers shall be anchored to their foundation by suitable bolts and clamping hardware.

F. Control panels and other structures shall be adequately braced and their components firmly attached to avoid dislodgement.

3.03 FIELD QUALITY CONTROL/INSPECTION

A. Materials and devices shall be inspected prior to and after installation to assure that they are of the quality and type as specified herein, free of manufacturer's defects and possible shipping damage, and that they have been installed in the proper manner.

B. At any stage of construction and when observed, any electrical equipment or system determined to be damaged, faulty, or requiring repairs shall be reported to the University’s Representative.

C. Prior to checkout and testing, the Contractor shall ensure that equipment and wiring is properly and permanently identified with nameplates and other identification. The Contractor shall also check and tighten all terminals and connections, repair damaged or scratched finishes, inspect for broken and missing parts and review and collect manufacturer's drawings and instructions for delivery to the University’s Representative. The Contractor shall also make routine checks and tests as the job progresses and as necessary to ensure that wiring and equipment is properly installed and wired.

D. Perform checkout and testing of electrical systems in accordance with the NEC, requirements of the University’s Representative, and in accordance with recommendations of the manufacturer of the University-furnished APF dome and equipment.

- END OF SECTION -

SECTION 16060

GROUNDING

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section describes the requirements for grounding.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM B228 Concentric-Lay-Stranded Copper-Clad Steel Conductors

B. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 National Electrical Code (NEC)

C. UNDERWRITERS LABORATORIES, INC. (UL)

UL Electrical Construction Materials Directory

1.03 QUALITY ASSURANCE

A. Materials shall be listed by UL.

PART 2 - PRODUCTS

2.01 CONDUCTORS

A. Ground conductors shall be No. 6 AWG minimum, bare stranded, soft-drawn or medium-hard-drawn copper, except where noted otherwise, and shall be sized as required by the NEC.

2.02 GROUND RODS

A. Ground rods shall be cone pointed copper clad steel or copper, 3/4 inch diameter by 10 feet long. The manufacturer's trade-mark shall be die stamped near the top. Copper clad steel rods shall be Grade 40 HS conforming to ASTM B228.

2.03 GROUND CONNECTORS

A. Ground connectors and fittings shall be suitable for the location as recommended by the manufacturer.

PART 3 - EXECUTION

3.01 GROUNDING

A. General: The grounding of equipment for which a ground connection is required by the NEC shall be included.

B. Ground Wires

1. Ground wires penetrating concrete walls and floors shall be waterproofed by leading the length of cable from three inches to one side through the wall to three inches on the other side of the wall.

2. A separate ground wire shall be included in all power feeder and receptacle circuits.

C. Lighting Fixtures: Lighting fixtures shall be grounded in accordance with the NEC.

D. Structural Steel: Structural steel for building shall be effectively connected to ground system.

E. Metal Enclosures: Metal enclosures of electrical equipment (switches, motors, panels, etc.) shall be grounded at two places.

F. Cable Tray: Cable tray shall have electrical continuity from section to section, and shall be grounded in at least two places.

3.02 FIELD QUALITY CONTROL/INSPECTION

A. Equipment required and tests conducted shall demonstrate the following:

1. The grounding materials and systems are in the proper condition and configuration for such interface.

2. The continuity and resistance of grounding systems meet the requirements of the NEC. Signed and initiated forms for each equipment ground conductor shall be turned over to the University prior to energization.

3. Record all values and furnish a test report with completed data.

- END OF SECTION -

SECTION 16500

LIGHTING

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. This Section describes the requirements for furnishing and installing lighting systems, complete and operable, as indicated, including fixtures; fixture mounting hardware including brackets, canopies, and hangers; lamps; auxiliary lighting equipment; and lighting control equipment.

B. The work shall be in accordance with applicable provisions of Section 16050, BASIC ELECTRICAL MATERIALS AND METHODS.

1.02 REFERENCES

The latest edition or supplement thereto in effect at the time of invitation to bid shall be considered to be the issue in effect.

A. AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C82.1	Ballasts for Fluorescent Lamps
ANSI C82.2	Methods of Measurement of Fluorescent Lamp Ballasts
ANSI C82.3	Reference Ballasts for Fluorescent Lamps

B. ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA (IES)

IES	Lighting Handbook

C. CERTIFIED BALLAST MANUFACTURERS ASSOCIATION (CBM)

CBM	Ballast Standards

D. ELECTRICAL TESTING LABORATORIES (ETL)

ETL	Testing Standards

E. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	National Electrical Code (NEC)

F. UNDERWRITERS' LABORATORIES, INC. (UL)

UL 924	Emergency Lighting and Power Equipment
UL	Electrical Construction Materials Directory

1.03 QUALITY ASSURANCE

The following specifies the documentation required and the factory tests to be conducted on the specified luminaires.

A. Luminaire to be tested shall be typical of the units it represents, clean and free of mechanical defects, equipped with the proper fittings, and with the lamp of the size and type in the position recommended for service operation.

B. Material, equipment and components shall be tested in accordance with UL standards, and shall be UL listed. Material, equipment and components not covered by UL standards shall be tested in accordance with other nationally recognized standards approved by the University, or shall be of the kind whose production is periodically inspected by a nationally recognized testing laboratory, and shall bear a label, tag, or certification of such inspection.

C. Tests for photometric performance shall be made and reported in accordance with the approved methods outlined by the IES for photometric testing, and shall include data on candlepower distribution, zonal lumens, maximum luminance values and luminaire efficiency including complete coefficients of utilization tables to indicate compliance with performance requirements.

D. Lamps which fail within 90 days after acceptance shall be replaced at no additional cost to the University.

1.04 SUBMITTALS

Make submittals as specified in Sections 01300 and 01340.

A. Manufacturer’s Data: Submit manufacturers' literature and descriptive information for materials and equipment proposed to be furnished, including hardware, photometric curves for proposed lighting installations, and evidence of UL listing of the equipment.

B. Samples: Submit a complete operable sample of each luminaire for inspection, when requested by the University. Such samples will be returned and, if approved, may be incorporated into the permanent work.

1.05 PACKAGING AND HANDLING

A. Products shall be packaged, handled, and transported in a manner that prevents damage.

B. Each package shall be indelibly marked with the following information:

1. Fixture, Lamp or Component Type

2. Quantity

3. Manufacturer's Name and Product Number.

PART 2 – PRODUCTS

2.01 REMOTE CONTROL LOW VOLTAGE SWITCHING SYSTEM

A. Furnish complete remote control system for control of lighting and other equipment as indicated on the drawings and schedules.

B. System shall be complete with modular relay panels including enclosures, transformers, and relays, as well as switches, pilot lights, wall plates, and wiring. Remote control equipment shall be as manufactured by GE Total Lighting Control, or equal quality as approved by the University.

1. Modular Relay Panels: Preassembled panels shall be UL listed and consist of an enclosure with cover, interior relays, and power supply.

2. Switches: Specification grade momentary contact, 3-wire pushbutton switches in standard, pilot and locator light options.

3. Wiring: Low voltage wiring from the switches to relay panel shall be Class 2 or Class 2P as required by National Electrical Code and local standards.

4. Wiring Color Code: Wiring shall be color coded to match relays and switches:

a. Red – ON
b. Black – OFF
c. Blue – 24 V AC rectified
d. Yellow – Pilot
e. White - Common

2.02 MODULAR RELAY

A. Enclosure: NEMA 1, capable of mounting 12, 24 or 48-relay interior. Enclosure shall have surface or flush cover with captive screws in a hinged, lockable configuration.

B. Interior: Enclosure interior shall include a bracket and circuit board backplane with connector for plug-in relays, and a barrier separating low voltage (24 V AC) from line voltage.

C. Relays: Mechanically-held, momentary pulsed contactors rated at 20 A, 120/277 V AC. Electrically held relays are not acceptable. Each relay shall be capable of direct ON/OFF control by a low voltage switch.

D. Power Supply: Power supply shall be one 40 VA transformer in one power assembly, connecting to the circuit board. Transformer shall power relays and associated low voltage switches. Transformer shall include internal overcurrent protection with automatic reset and metal oxide varistor protection against power line spikes.

2.03 LUMINAIRES

A. Luminaires shall comply with the IES Lighting Handbook; shall be UL classified, and labeled for the intended use; and shall be of the type, size and quality shown on the Luminaire Schedule on the drawings.

B. Lamps shall be of the quality, type, size and color as shown on the Luminaire Schedule, and shall have maximum service life within the particular lamp category.

C. Substitutions will not be considered unless the quality distribution curve of the proposed luminaire indicates that the proposed luminaire is equal to or better than the specified luminaire.

D. Luminaire wire, and the current-carrying capacity thereof, shall be in accordance with the NEC.

E. Luminaires and lighting equipment shall be delivered to the project site complete, with suspension accessories, canopies, castings, sockets, holders, reflectors, ballasts, diffusing materials, louvers, frames, recessing boxes, and related items.

2.04 BALLASTS

A. Fluorescent luminaries shall be provided with electronic ballasts suitable for the line voltage and for the type, size, and number of lamps required by the luminaire. Ballasts shall have a high power factor, and shall be manufactured in accordance with ANSI C82.1, C82.2, and C82.3.

B. Ballasts for thermally-protected fluorescent luminaires shall be indoor type, UL Class P, with automatic reset integral protector device set to limit case temperature to a maximum of 110°C under abnormal conditions.

C. Ballasts in luminaires for exterior use shall provide reliable starting of the lamps at 90 percent nominal line voltage. All locations except in totally enclosed rooms shall be considered as exterior locations.

D. Ballasts having UL ratings for which the Certified Ballast Manufacturers Association (CBM) has issued specifications, and for those ballasts which have been tested by Electrical Testing Laboratories, Inc. (ETL) for compliance with such specifications, shall have CBM/ETL label attached.

E. Ballasts which produce excessive noise (above 80 dB) or vibration will be rejected.

PART 3 - EXECUTION

3.01 REMOTE CONTROL LOW VOLTAGE SWITCHING SYSTEM

A. Install panels, components and wiring in accordance with manufacturer’s instructions.

3.02 LUMINAIRES

Luminaires shall be installed in accordance with the manufacturer's instructions, complete with lamps, hangers, brackets, poles, fittings, and accessories, ready for operation as indicated.

A. Align, mount and level the luminaires uniformly.

B. Avoid interference with and provide clearance for equipment. Where the indicated locations for the luminaires conflict with the locations for equipment, change the locations for the luminaires by the minimum distances necessary.

C. For suspended luminaires, the mounting heights shall provide the clearances between the bottoms of the luminaires and the finished floors as indicated. Mounting heights to bottom of fixtures shown on drawings are given as accurately as possible. Stem lengths shall be adjusted to suit actual field conditions.

D. Luminaire supports shall be anchored to the structural slab or to structural members as indicated. Supports shall maintain the luminaire positions after cleaning and relamping. Typical details are shown on the drawings to illustrate methods of mounting; determine actual methods of fastening and installation in accordance with field conditions.

E. Surface-mounted luminaires shall be bracketed rigidly from the mounting surfaces. A 1/4-inch clearance between surfaces shall be provided when the fixture is flat mounted against concrete surfaces. Luminaires shall be installed with a noncumulative dimensional alignment tolerance of 1/16 inch and when mounted in continuous runs shall be mounted with one inch spacing between individual luminaires. Nipples carrying wires between luminaires shall be watertight.

F. Where aluminum is placed in contact with dissimilar materials, except galvanized steel, zinc or stainless steel, contact surfaces shall be treated as follows:

1. When in contact with dissimilar metals, apply a prime coat of zinc chromate primer followed by two coats of aluminum and masonry paint.

2. When in contact with concrete, masonry or plaster surfaces, apply zinc chromate primer, bituminous paint, aluminum metal and masonry paint, or pressure tape to aluminum contact surfaces.

3. When in contact with wood or other absorptive materials, apply two coats of aluminum paint to such materials, and protect aluminum contact surfaces with bituminous paint.

G. Pendant luminaires shall be provided with swivel hangers to assure a plumb installation and have a minimum 25-degree swing from horizontal in all directions. Single unit suspended fluorescent luminaires shall have twin stem hangers. Multiple units or continuous units shall have a tubing or stem for wiring at one point and tubing provided for each unit length of chassis including one at each end. Tubing shall be not less than 3/16 inch in diameter. Motion of swivels or hinged joints shall not cause sharp bends in conductors or damage to insulation. For heavy pendant-mounted luminaires, where support independent of box is required and where conduit and outlet boxes are installed on surface, safety swivel hangers with fixture studs shall be provided.

H. Required lamps shall be provided in each luminaire as soon as luminaires are installed.

I. Locations of fixtures may be adjusted to make optimum use of supports.

J. Pendant fixtures shall be securely attached through their support systems to building structures. Chains shall be of the solid link type, and hooks shall be of the safety latch type. The suspension shall be adequate for resisting seismic loads.

K. Verify the locations of exit signs shown on the drawings with actual conditions, and adjust locations as necessary to ensure maximum visibility of the signs.

3.03 BALLASTS

A. Ballasts, other than those mounted integrally within luminaires, shall be installed as indicated, and in such a manner that the ballast is protected from weather, moisture, and other atmospheric conditions, and so that the ambient temperature surrounding the ballast will not cause the temperature of the ballast housing hot spot to exceed UL requirements.

B. Voltage drop to lamp, due to remote mounting, shall not exceed one percent of the nominal lamp voltage. Secondary ballast conductors shall have 1000-volt insulation.

C. When more than one ballast is mounted at one location, the minimum spacing between ballasts shall be 6 inches in a horizontal direction and 12 inches in a vertical direction.

3.04 FIELD QUALITY CONTROL AND INSPECTION

A. Luminaires, lamps and associated hardware shall be inspected prior to and after installation to ensure that they are of the quality and type as specified herein and as shown on the Luminaire Schedule, and are free of defects and damage.

B. Whenever practicable, lighting systems shall be tested at the same time that the distribution panelboard or switchboard is tested.

- END OF SECTION -