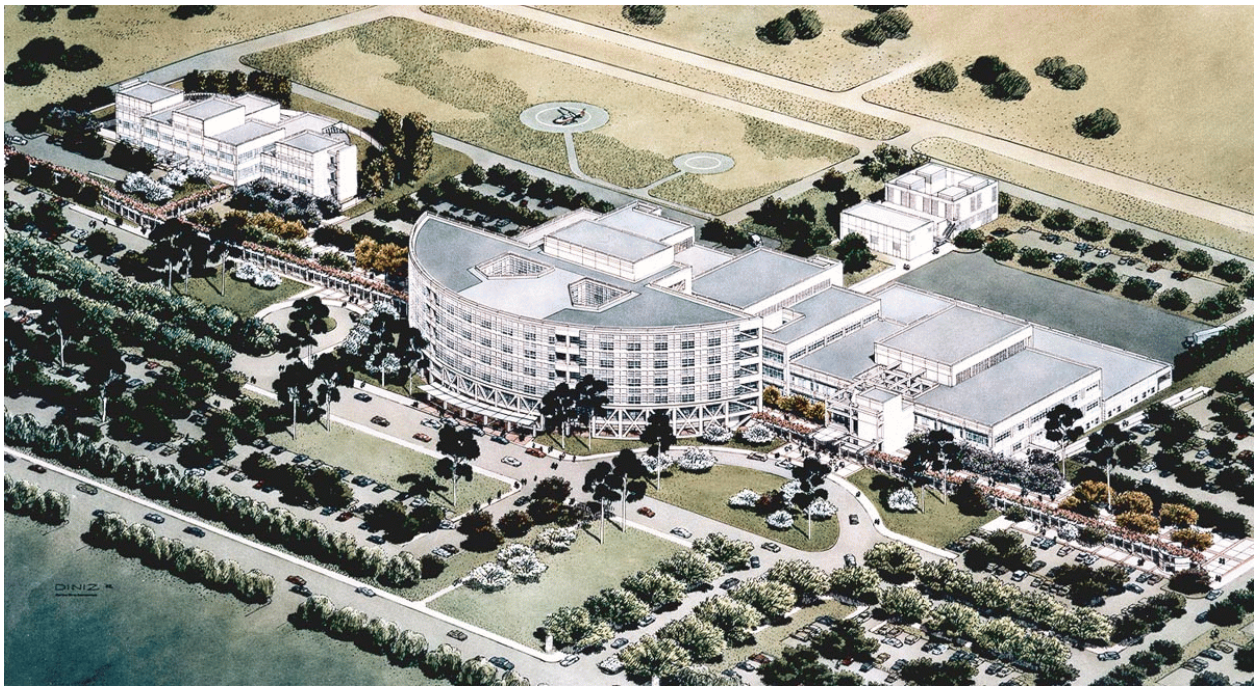
SAN BERNARDINO COUNTY MEDICAL CENTER REPLACEMENT PROJECT TECHNICAL SPECIFICATIONS

Section 13085
Viscous Damping Devices



SPECIFICATION CONTROL DOCUMENT
FLUID VISCOUS DAMPERS

SECTION 13085
VISCOUS DAMPING DEVICES

PART 1 - GENERAL

1.01 DESCRIPTION: Provide viscous fluid damping devices complete.

A. WORK IN THIS SECTION: Principal items include:

1. Preparation of shop drawings, test reports, designing, fabrication, testing, handling and shipping to the site.

2. Extent of fabrication of Viscous Damping Devices (VDD) work of this Section is indicated by the requirements of this Section.

3. Production Dampers: Provide Viscous Damping Devices/Dampers (VDD), referred to herein as "Production Dampers" in accordance with the specifications.

4. Prototype Dampers: Provide VDD Dampers (referred to herein as "Prototype Test Dampers") of each type required, in accordance with these specifications. Prototype Test Dampers shall not be used for construction.

B. RELATED WORK NOT IN THIS SECTION: Installation of dampers shall be by others.

1.02 REFERENCES

A. STANDARDS: Conform to the applicable provisions of the current editions of the following standards, except as indicated otherwise on the drawings or the specifications:

1. Title 24, Part 2, CCR, 1989 Amendments
2. ASTM E4 - Load Verification of Testing Machines
3. ASTM A36 - Specification for Structural Steel
4. ASTM A325 - Specification for High Strength Steel Bolts
5. ASTM A570 - Specification for Structural Sheet Steel
6. AWS Dl.1 - Structural Welding Code of the American Welding Society

7. MIL-W-6858 - Welding, Resistance: Spot and Seam
8. MIL-B-7883 - Brazing of Steels, Copper, Copper Alloys, Nickel Alloys, Aluminum and Aluminum Alloys
9. MIL-W-45223 - Welding, Spot, Hardenable
10. MIL-STD-248 - Qualification Testers for Welders (Other Than Aircraft Weldments)
11. MIL-STD-889 - Dissimilar Metals
12. MIL-STD-970 - Standards and Specifications, Order of Preference for the Section of
13. MIL-STD-2175 - Casting, Classification and Inspection of
14. MIL-Q-9858A - Quality Program Requirements
15. MIL-I-4520A - Inspection System Requirements
16. ISO 9001 - Model for Quality Assurance
17. AISC "Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings," by the American Institute of Steel Construction
18. AISC "Code of Standard Practice for Steel Buildings and Bridges"
19. SSPC "Steel Structures Painting Council"
20. Design and Testing Criteria for VDDs for the San Bernardino County Medical Center Replacement Project

NOTE: Proposed alternate standards shall be submitted to the Architect/Engineer for review and approval.

1.03 SUBMITTALS: Refer to Section 01340 for procedures:

A. GENERAL: All submittals shall be made as directed by the County.

B. SHOP DRAWINGS: Shop Drawings shall include, but shall not be limited to: fabrication drawings, installation drawings, setting diagrams, bolting templates and schedules. Submit Shop Drawings for:

1. Each and every VDD type including all prototypes indicating dimensions, weights, component material types and method of assembly. Submit prior to manufacture: of item, allowing adequate time for review/revision/approval.

2. All steel mounting and connecting hardware which is integral with the VDD.

C. PRODUCT DATA:

1. VDD: Product Data shall include, but shall not be limited to manufacturer's product specifications and installation instructions.

2. All materials and components used in manufacture: Submit Product Data for review and approval.

3. Paint: Submit manufacturer's literature and data, including evidence of conformance to the requirements of regulatory agencies, printed preparation and application instructions for each substrate and certified laboratory tests showing compliance with the property and test requirements specified.

D. CERTIFICATIONS: Submit the following documents, written and signed by an independent testing agency, approved by the County.

1. Certification that all testing equipment has been checked for accuracy by appropriate standards for the purpose of this Purchase Agreement.

2. Certified mill test reports for all steel to be used.

E. INSPECTION AND TEST REPORTS: Submit the following test reports, written and signed by testing agency approved by the County:

1. Prototype VDD Test Reports: Prototype VDD test data shall be submitted and approved by the County and Architect/Engineer prior to commencement of fabrication of the Production VDDs.

2. Production VDD Test Reports: Submit Prototype VDD test data for each Production VDD within seven (7) calendar days after the completion of testing of the subject VDD.

3. Final VDD Test Report: Submit the Final VDD Report, as described in this Section, within fourteen (14) calendar days after the completion of all Production VDD testing.

F. PROPOSED TEST PROCEDURES: Submit annotated and drafted illustrations of all proposed test apparatus and procedures for tests required by this Section. Such illustrations shall be submitted and approved by the County and Architect/Engineer prior to the commencement of any testing.

1.04 DELIVERY, STORAGE AND HANDLING

A. DELIVERY: Deliver Production VDD to the job site in protective packaging for freight and handling purposes.

B. HANDLING: Handling VDDs and components carefully to prevent damage, breaking, denting or scoring. Do not deliver damaged VDDs or components; replace with new.

C. STORAGE: Store VDDs in a clean place. Protect from dirt, fumes, construction debris and physical damage.

1.05 WARRANTIES AND GUARANTEES

Specific warranties and guarantees shall be jointly developed by the Vendor and the County in conformance with this Section, the General Conditions, the Supplemental Conditions and the Division 1 - General Requirements, Section 01740.

PART 2 - PRODUCTS

2.01 VDD MATERIALS AND PARTS

A. Except as specified herein, the materials, parts and processes used in the design and manufacture of the unit shall conform to specifications and standards selected in the order of precedence established by MIL-STD-970. All materials and processes used shall be identified in Vendor drawings by specifications or standards.

B. MATERIALS - All materials used in the manufacture of the unit shall be subject to County approval. The Vendor may be required to substantiate suitability of the material by furnishing samples or certified test data, or both.

1. Materials - Materials shall have allowable stress values taken from MIL-HDBK-5. Unless suitably protected against electrolytic corrosion, dissimilar materials as defined in MIL-STD-889 shall not be used in contact with each other. Dissimilar metal joints shall not be permitted without a non-metallic separator or gasket of at least .06 inch thickness. The use of aluminum, aluminum alloys, magnesium, magnesium alloys, beryllium and beryllium alloys is prohibited. The use of non-stainless steel internally exposed to internal pockets of air or gas (as could occur in an internal reservoir) is prohibited.

2. Fungus Resistant Materials - Only non-nutrient materials shall be used in the unit.

3. Castings - All castings shall be Class 1A as established by MIL-STD-2175 except for parts such as covers, handles, etc., whose failure would not affect the structural integrity or performance characteristics of the unit. Such casting may be Class 2B, subject to County approval.

C. PARTS

1. Age Sensitive Parts - All non-metallic packings, seals, wipers or gaskets shall be of non-age control materials.

2. No plating will be permitted on piston rods or any other metal part that slides relative to a seal. Spherical end attach bearing shall be fabricated only with stainless steel, and may be of the lined type with non-metallic liners.

3. Any working fluid used in the dampers shall be both non-toxic and non-flammable, using current OSHA standards for guidance. Petro-chemical fluids shall not be used.

4. Parts List Approval - The Vendor shall submit the equipment parts list for review and approval by the County. Approval will be based on an evaluation of the following documentation as applicable to each part.

    a. Vendor part number and nomenclature
    b. Military or other applicable specifications
    c. Source name and part number
    d. Tests and inspection requirements

PART 3 - QUALITY ASSURANCE

3.01 QUALITY CONTROL PROVISIONS

A. PRODUCT QUALITY CONTROL - To ensure effective control over product quality, the contractor shall, in accordance with Section 01400, establish and maintain a manufacturing/processing control system including written process specifications and procedures to insure that manufacturing, processing inspection and testing are accomplished in accordance with at least one of the following:

1. Control of Quality MIL-Q-9858A
   The seller shall provide and maintain a system that complies with U.S. Specification MIL-Q-9858A, “Quality Program Requirements.”

2. Control of Quality MIL-I-45208A
   The seller shall provide and maintain a system that complies with U.S. Specification MIL-I-45208A, “Inspection System Requirements.”

3. Control of Quality ISO 9001
   The seller shall provide and maintain a system that complies with U.S. requirements of the International Standard Organization (ISO) 9001 model for quality assurance in design, development, production, installation and servicing. Certification to ISO 9001 by an individual or firm located outside the United States of America is prohibited.

B. MANUFACTURING PROCESS CONTROL - In addition to compliance with one of the three quality assurance systems, the Contractor must maintain a system for manufacturing process control of this project which includes as a minimum the following:

1. Raw Material Traceability

2. Specific Raw Material Traceability

3. Special Process Certification Traceability

4. Detailed manufacturing instructions that identify by operation and machine the work performed

5. Inspection instructions

6. In process and final detail component inspection instruction with actual dimensions

C. PART INFORMATION - Specific instructions for detail part marking providing for one way backward traceability to the information listed in paragraph 3.01.B (above) shall be provided by the contractor. This information shall be readily retrievable and shall be combined into one inclusive document that is controlled and approved by quality assurance personnel at the contractor's facility.

D. CALIBRATION SYSTEM REQUIREMENTS - All devices used to measure, gage, test, inspect or otherwise examine items to determine compliance with specification and/or contractual requirements shall be calibrated in compliance with MIL-STD-120 and MIL-STD-45662A, to a calibrated measurement standard which has known valid relationships traceable to the National Institute of Standards and Technology (NIST).

PART 4 - FABRICATION

4.01 FABRICATION

A. PROCESSES: All processes used in the manufacture of the unit shall be subject to County approval.

1. Protective Treatment - Materials subject to deterioration when exposed to environmental conditions likely to occur during service usage, shall be protected against such deterioration in a manner that will in no way prevent compliance with the requirements of this specification. The use of any protective coating that will crack, chip or scale with age or extremes of climate and environmental conditions shall be avoided. Corrosion control shall be used as a guide for minimizing corrosion damage to the assembly.

2. Fusion Welding - Fusion welding shall be in accordance with approved standards. Weld design shall be based on the function and strength of the assemblies. Fillet welds on plate above 0.125 inch thickness will not be used on primary structure without specific approval of the County. Weld quality shall be specified on Vendor drawings with proper acceptance standards and inspection methods.

3. Resistance Welding - Resistance welding shall be in accordance with MIL-W-6858 and MIL-W-45223, as applicable.

4. Welders Certification - Certification tests for welders shall be in accordance with MIL-STD-248.

5. Brazing - The brazing of steels, copper, copper alloys and nickel alloys shall conform to MIL-B-7883.

6. Soldering - Soldering shall be in accordance with approved standards. Whenever insulation material is subject to heating during soldering, the material shall be undamaged and parts fastened thereto shall not be loosened. No mechanical assembly shall depend on soft-solder for mechanical strength.

7. Finish - The exterior finish of the unit shall be in accordance as approved by the County. The color and finish type required shall be recommended by the Vendor and submitted to the County for approval.

B. WORKMANSHIP - The unit, including all parts and accessories, shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be given to neatness and thoroughness of soldering, wiring, making of parts and assemblies, welding and brazing, plating, finishes, riveting, machining and screw assemblies. All parts shall be free of burrs and sharp edges and any damage, defect or foreign material which might detract from the intended operation, function or appearance of the unit.

4.02 SAFETY

A. SAFETY - The design of the unit shall be such that all possible sources of danger to personnel or equipment during assembly, disassembly, testing operation and maintenance are minimized. Where required, precautionary measures shall be prominently and clearly indicated on the equipment.

4.03 MAINTAINABILITY

A. MAINTAINABILITY - The unit shall be constructed to be essentially maintenance free. Each VDD unit shall be designed and constructed such that installation, removal and replacement, if necessary, shall be a simple process not requiring any special tools or methods.

4.04 INTERCHANGEABILITY

A. INTERCHANGEABILITY - All parts having the same manufacturer's part number shall be functionally and physically interchangeable. The Vendor shall assign new part numbers when change numbers cause any of the following conditions:

1. Performance or durability is affected to such an extent that superseded items must be discarded for reasons of safety or malfunctioning.

2. Parts, subassemblies of complete units are changed to such an extent that the superseded and superseding items are not interchangeable.

3. Superseded parts are limited to use in specific articles or models of articles and the superseding parts are not so limited to use.

When interchangeable repairable assemblies contain a noninterchangeable part, the part number re-identification of the noninterchangeable part, of its next assembly and all the progressive higher assemblies shall be changed up to and including the assembly where the interchangeability is re-established.

4.05 CHANGE CONTROL

A. CHANGE CONTROL - After initial design completion and approval or initial hardware delivery, whichever occurs first, any change or substitution of material, dimensions, processes or other characteristics must be approved by the County prior to incorporation. The Vendor shall exercise the same configuration control over his suppliers.

4.06 IDENTIFICATION MARKING

A. IDENTIFICATION MARKING - Units, subassemblies and parts shall be marked for identification in accordance with MIL-STD-130.

4.07 SERIAL NUMBER ASSIGNMENT

A. SERIAL NUMBER ASSIGNMENT - Sequential serial number shall be assigned to all units in accordance with Architect/Structural Engineers' requirements. The individual number shall be assigned according to the Vendor's standard practice unless otherwise specified in the purchase order or contract.

PART 5 - DETAIL AND TECHNICAL REQUIREMENTS

5.01 FUNCTION

A. FUNCTION - Each VDD shall be part of a supplemental viscous damping system for each of the five base isolated buildings on this project. The units shall be installed in pairs of orthogonal units or individual units typically at column/isolator locations as schematically shown in Appendix A. The units shall be attached to a fixed concrete element at one end and to the base of the steel superstructure above the isolator level at the other end as schematically shown in Appendix A. The VDDs shall thus be utilized as a damping system in response to seismic excitation for each of the base isolated buildings.

B. FLUID MEDIUM - The unit shall use inert silicone fluid as the operating fluid medium which shall comply with U.S. Federal Standard VV-D-1078.

C. FLUID EXPANSION COMPENSATION - The unit shall contain provisions to allow for thermal expansion and contraction of the fluid medium to prevent excessive buildup of internal high pressure or vacuum pressure.

D. SERVICING PROVISIONS - The VDD unit shall be designed and constructed to be essentially maintenance free.

E. ADJUSTMENT - The unit shall be designed to provide for a length adjustment of plus or minus 0.25 inch.

F. DIMENSIONS - The overall dimensions of the unit shall be held to a minimum consistent with the requirements of this specifications, but in no case shall they exceed the dimensions specified in Figure 1.

5.02 CONSTRUCTION

A. GENERAL - The VDD unit shall be of corrosion protected construction with stainless steel piston rod internally mounted.

B. DESIGN LOADS

1. Axial Design Load - The maximum axial design load shall be 325 kips tension or compression with the rod fully extended, retracted or at any intermediate point.

2. Lateral Design Loads - The unit shall be designed to withstand lateral acceleration of 1 g in any direction in any position of rod extension/retraction.

3. Fluid Pressure - The unit shall be designed to withstand the following internal pressure.

   a. Proof: 200 percent of maximum operating pressure
   b. Burst: 400 percent of maximum operating pressure

4. Factors of Safety - Minimum factors of safety for the unit shall be 2.0 limit and 3.0 ultimate. The unit shall be such that no yielding will result from the application of limit loads and no failure will result from application of ultimate loads. Limit and ultimate loads shall include the effects of load factors included herein.

5.03 PERFORMANCE

A. DAMPING COEFFICIENT - The unit shall operate with a damping coefficient in both directions of travel as shown in Figure 2.

B. FORCE AND VELOCITY LIMIT - The unit shall be equipped with pressure relief such that the maximum force developed shall not exceed 325 kips up to a maximum input velocity of 75 ips in both direction of travel. The normal operating force developed by the unit over the design range of velocity shall always fall within the envelope shown in Figure 2, or as indicated on Table 1.

C. DUTY CYCLES - The unit shall be designed to the amplitude, frequency and time requirements of the following wind load and seismic loading duty cycles.

1. Wind Loading Duty Cycle - 0.5 in. amplitude at 1 cps for 300,000 cycles per year.

2. Seismic Loading Duty Cycle - 15 in.. mean amplitude (22 ins. peak amplitude) at 0.75 cps for 5 cycles (avg.) per year.

D. MAXIMUM/MINIMUM OPERATING TEMPERATURES - The unit shall be capable of operating at the energy levels, time and the environmental conditions specified herein, without degradation of performance or life as a result of maximum/minimum operating temperature.

E. LEAKAGE - The unit shall be designed to allow a dynamic leakage level that will have no effect on performance over the life of the building (75 years). This leakage quantified in a way that is easily measurable. Under non-operating conditions, static seals shall not leak externally. When subjected to proof pressure for five (5) minutes, the unit shall show no visible evidence of external leakage.

F. STROKE - The unit shall be capable of meeting the performance requirements of 4.03 A, B and D when cycled about any point with plus or minus 22 inches of the mid-point of the total stroke.

5.04 LIFE

A. LIFE - The unit shall be designed to guarantee a minimum reuse of one maximum credible seismic event before requiring refurbishment.

5.05 ENVIRONMENTAL CONDITIONS

A. AMBIENT OPERATING TEMPERATURE - When installed, the unit shall be capable of operating in an ambient air temperature from +20˚F to +130˚F.

B. ATMOSPHERIC PRESSURE - The unit shall operate at essentially sea level pressure (760 plus or minus 50mm mercury).

C. HUMIDITY - The unit shall be designed to withstand relative humidity up to 100 percent, including condensation due to temperature change.

D. OTHER ATMOSPHERIC ELEMENTS - The unit shall be designed to withstand any of the probable combinations of the following atmospheric elements: rain, snow, sleet, hail, ice, fog, smoke, wind, ozone, sunshine, sand and dust, and salt atmosphere.

PART 6 - TESTING

6.01 TESTING OF VISCOUS DAMPING DEVICE UNITS:

A. PHASES OF TESTING:

There are three distinct phases for testing VDDs. The first is the testing of small scale prototype VDDs which will provide data on the force-velocity characteristics of the small scale VDD which is manufactured with the same sub-scale orifice design as the full scale VDDs and will also verify correlation between drop testing and dynamic cyclic testing. The small scale prototype testing will also provide data on the variation of VDD properties in response to temperature changes. The second phase is the testing of full-scale prototype VDDs to confirm the force-velocity relationship used in the design of the isolation system and to validate the design and construction of the units under maximum proof loads and displacements. The third phase is a program of quality control testing implemented during the manufacture of the VDDs. A special inspector shall be present during all tests on the VDDs.

B. SMALL SCALE PROTOTYPE VDD TESTS:

1. Two 1/6 scale VDDs for each of the different types of VDDs utilized on this project shall be tested as below. The cyclic testing (1.a.(1), (2)) and the drop testing (1.b.(1)) shall be performed for 3 different temperature conditions of the small scale VDDs. The first series of tests shall be performed with the VDDs at room ambient temperature. Immediately prior to commencing the second series of tests, the VDDs shall be conditioned at an ambient temperature of 32F for a minimum of 4 hours. Immediately prior to commencing the third series of tests, the VDDs shall be conditioned at an ambient temperature of 120F for a minimum of 4 hours. Each test sequence shall be performed within 2 hours after removing the VDD from the temperature conditioned environment. Furthermore, all practically feasible methods of attempting to maintain the conditioned temperature of the VDD shall be employed during testing.

    a. Cyclic Testing:

        (1) Each small scale VDD shall be subjected to dynamic cyclic testing at the following displacements and cyclic rates (peak velocities):

Number	Stroke [1.] (Ins)	Peak Velocities [2.] (Ins/Sec)					
1	0.5	0.17	1	3	5	–	--
2	2.0	0.17	1	3	5	10	20
3	4.5	0.17	1	3	5	10	20

1. Neutral position to extreme displacement.
2. 0.17 in/s is quasi static (saw tooth), all others sinusoidal.

(2) Plots of force vs. velocity shall be made for 20 cycles of fully reversed loading at each of the displacement levels and cycling rates noted above.

b. Drop Testing:

(1) The same small scale VDDs shall be tested using a heavyweight drop hammer at peak velocities / velocity increments similar to those given above.

(2) Plots of force vs. velocity and resultant damping function shall be obtained from this test.

c. Test Reports and Acceptance Criteria:

(1) The supplier responsible for the manufacture and testing of the VDDs shall submit engineering drawings of the small scale VDDs along with drawings and descriptions of the proposed testing apparatus and procedure to the Structural Engineer prior to manufacturing/testing the small scale VDDs.

(2) The VDD supplier shall submit a test report for this phase of the testing that shall include all raw data in addition to force-velocity relationships including temperature dependent variations and comparisons from both types of tests.

(3) The test results shall be used to provide a preliminary indication of the properties of the full scale VDDs, their variation with temperature and number of stroke cycles and to provide a basis for correlating dynamic cyclic testing with drop testing. A variation of 10% between the measured results of the cyclic testing and the drop testing shall be deemed acceptable.

C. FULL SCALE PROTOTYPE VDD TESTS (CONFIRMATORY):

1. Introduction:

a. General:

Two full-scale prototype VDDs shall be manufactured and tested for each frequently used type and size of VDD as agreed to by the Structural Engineer and OSHPD.

The purpose of the confirmatory prototype testing is:

(1) To provide confirmed values of the force-velocity characteristics of each type of VDD in order to verify and validate the previously completed final design of the base isolated buildings in the project.

(2) To verify symmetry of VDD output in both compression and tension plus verify that damping output is not sensitive to initial position of rod stroke position.

(3) To verify soundness and leak proof nature of construction of the VDD under proof loading and life cycle testing.

(4) To verify consistency of response between two units of the same type.

b. Acceptance Criteria:

(1) The test units shall be identical to the proposed production units in every way, including all details, parts, components and methods of manufacture and shall comply with the project specifications for the production VDDs in every respect.

(2) No visible leakage or signs of physical deterioration or degradation in performance shall be observed during and after the series of tests. There shall be no signs of yielding or permanent deformation.

(3) The force-velocity results from the drop tests both in tension and in compression, adjusted for expected variations due to temperature and number of stroke cycles (ref. 6.01.B.1.c(3)), shall fall entirely within the upper and lower bound curves (Figure 2) used for the final design of each of the base isolated buildings in the project.

2. Sequence of Testing:

a. Proof Load Test:

An internal pressure shall be applied to the test unit that shall be equivalent to 125% of the maximum damper load. This pressure shall be maintained for 120 seconds.

b. Life Cycle Test:

The unit shall be cycled through its full end to end displacement (minimum of two times Design Displacement + 4" over travel) a total of 120 cycles. The cyclic velocity is expected to be much slower than the design maximum velocity and shall depend on the capacity of the approved testing apparatus.

c. Drop Tests:

(1) Compression Testing: Utilizing a heavy weight drop hammer set-up, the unit shall be tested in compression at velocities from 1 in/s to maximum analytical velocity response (from dynamic analysis) in 5 in/s increments. The force, displacement and time-measurements shall be accurately obtained and recorded. Force-velocity plots shall be constructed from this data. At each velocity increment (hammer weight and/or height of drop) there shall be two hammer drops, each at a different piston stroke position.

(2) Tension Testing: The same sequence of tests as for compression testing shall be conducted with the unit responding in tension (extension). The data shall be recorded and plotted as above.

D. PRODUCTION UNIT TESTING:

1. Purpose: Production unit testing shall be conducted in order to verify the following:

   a. The general quality and manufacturing consistency of each of the production units.

   b. The general consistency of the production units in terms of their performance characteristics with the tested performance of the prototype units.

2. Acceptance Criteria:

   As in Section l.b above.

3. Sequence of Testing:

   a. Quality Assurance Tests: Production units shall be subjected to and pass the following sequence of quality assurance tests:

      (1) Proof load test per Section 2.a above (each production unit).

      (2) Life cycle test per Section 2.b above (one out of every twenty production units as selected by the Inspector of Record).

   b. Performance Verification Tests:

      Each production unit shall be tested for performance verification as follows:

      (1) Drop tests per Section 2.c.1 above.

E. INSPECTION:

An OSHPD approved Independent Inspector, hired by the County, shall be responsible for observing and verifying the manufacture and testing of all VDD units.

TABLE 1

Force - Velocity Relationship for 300 kip Viscous Damping Device

NOTE: The output force of the damper shall fall between upper and lower bounds throughout the entire stroke regardless of stroking direction.

Equations:

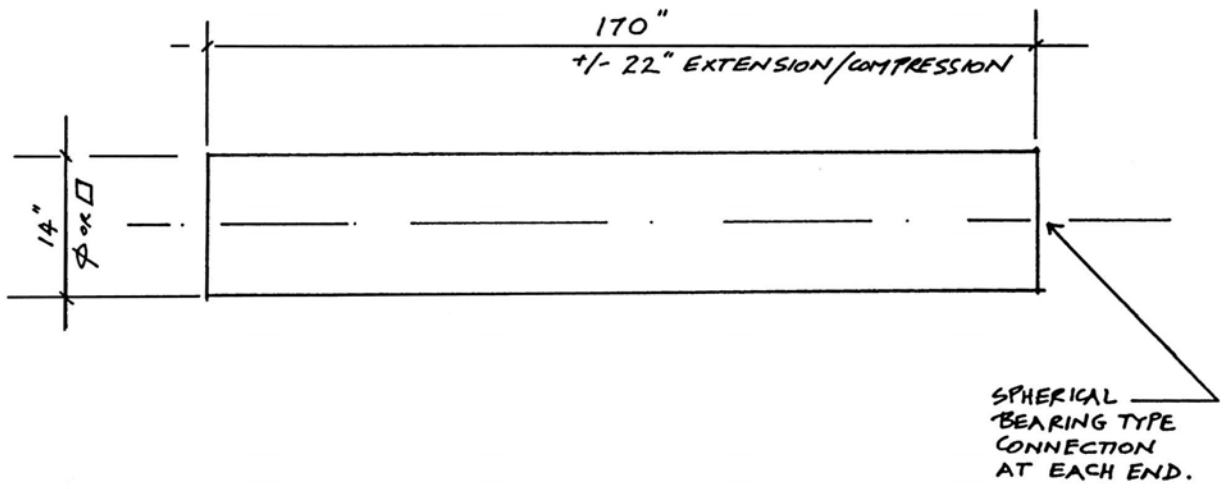
Lower Bound Values	
Velocity (In/Sec)	**Force (kips)**
0-3	21, 243 V
3-60	36, 794 $V^{0.5}$

Upper Bound Values	
Velocity (In/Sec)	**Force (kips)**
0-0.04	274, 013 V + 800
0.04-60	68, 711 $V^{0.4}$

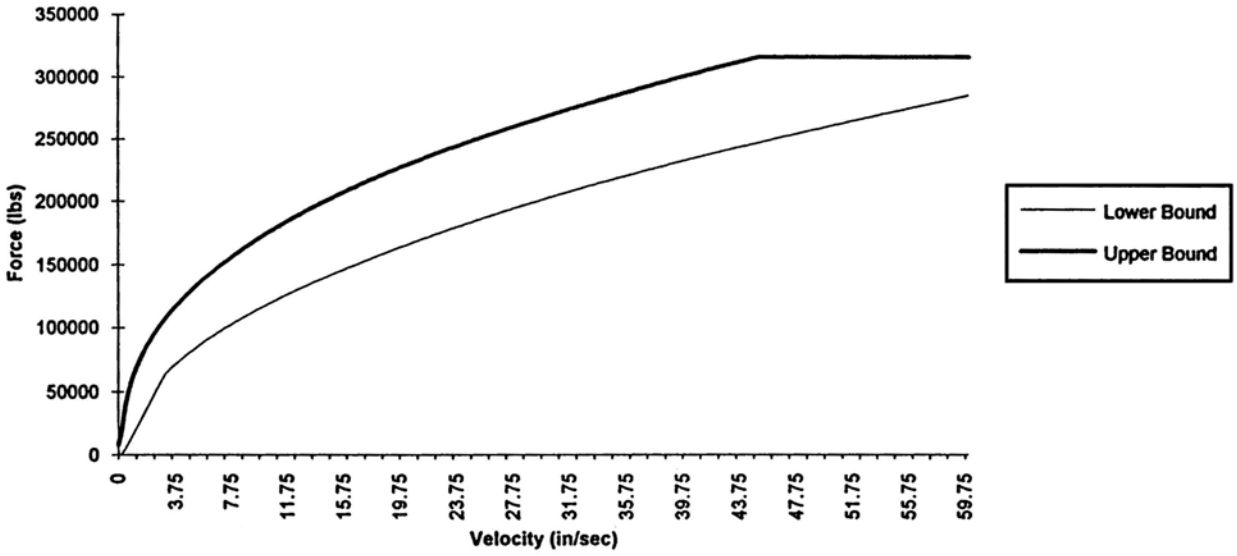
Tables:

Lower Bound Values	
Velocity (In/Sec)	**Force (kips)**
0.5	10622
1	21243
1.5	31865
2	42486
2.5	53108
3	63729
3	63729
4	73588
8	104069
12	127458
16	147176
20	164548
24	180253
28	194696
32	208138
36	220764
40	232706
44	244064
48	254916
52	265325
56	275341
60	285005

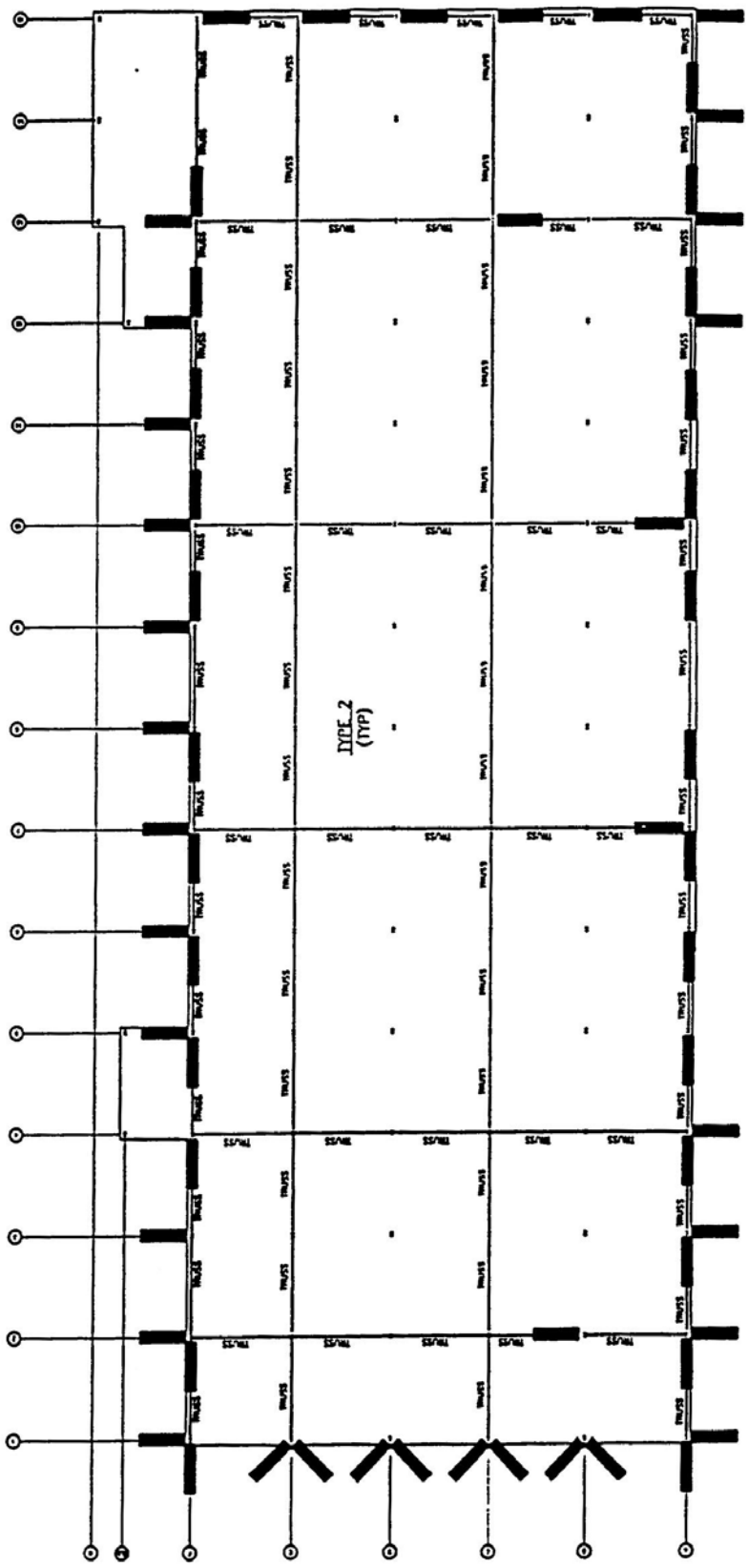
Upper Bound Values	
Velocity (In/Sec)	**Force (kips)**
0.04	18961
0.5	52073
1	68711
1.5	80810
2	90665
2.5	99129
3	106629
4	119633
8	157856
12	185652
16	208293
20	227739
24	244969
28	260549
32	274844
36	288103
40	300504
44	312182
45	315000
-	-
-	-
60	315000



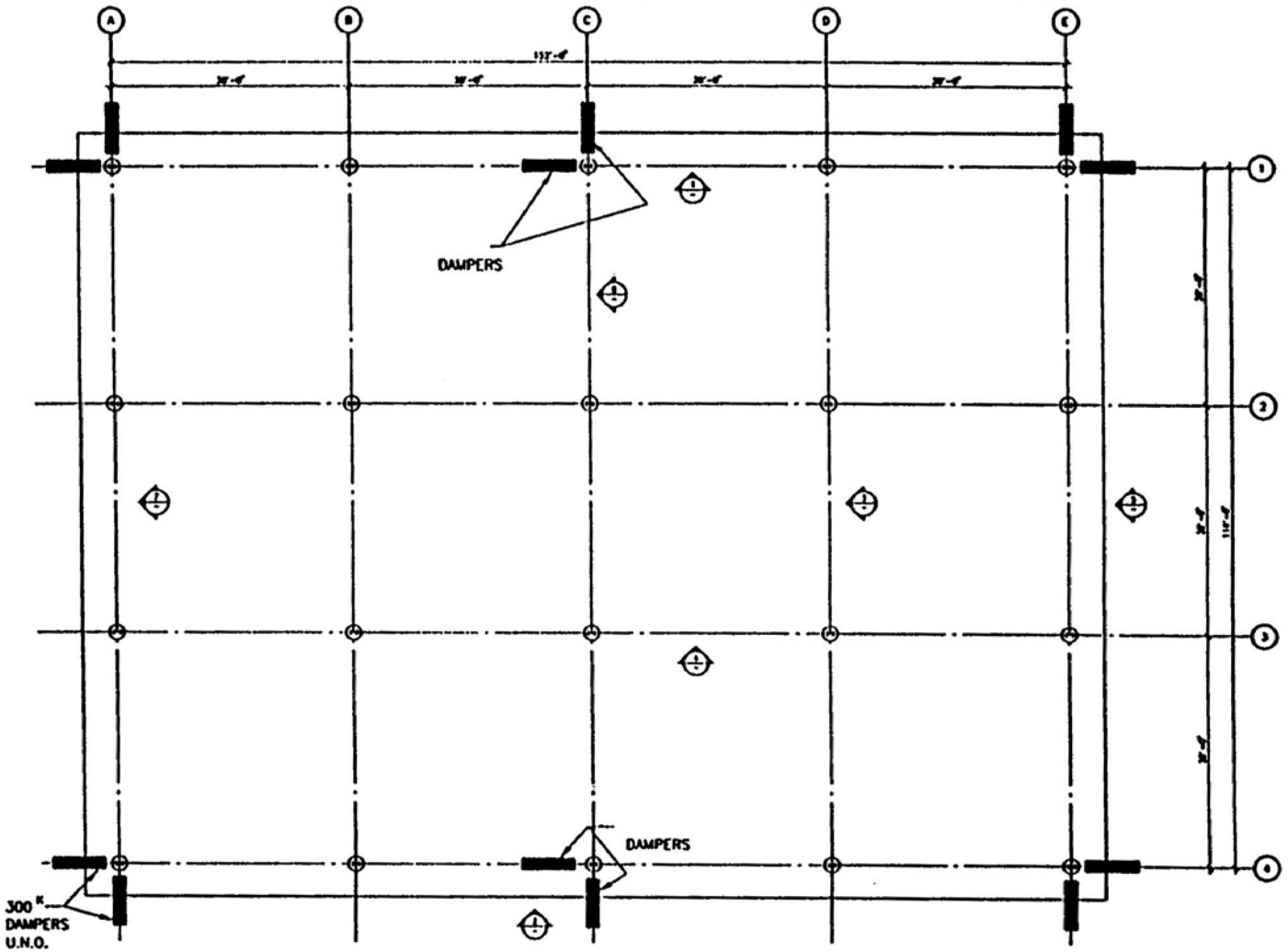
Maximum Envelope of VDD
Figure 1



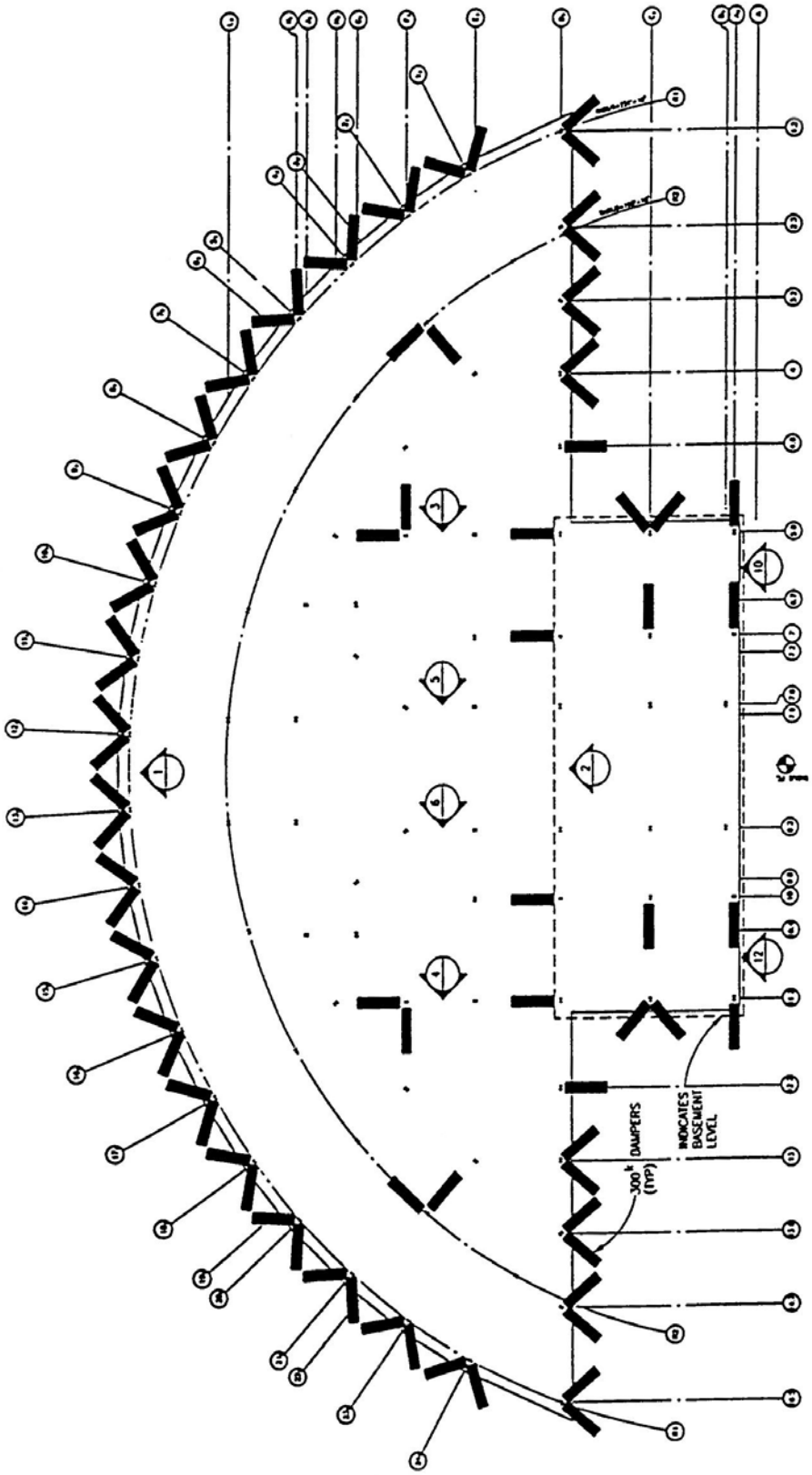
300 kip VDD Output Envelope
Figure 2



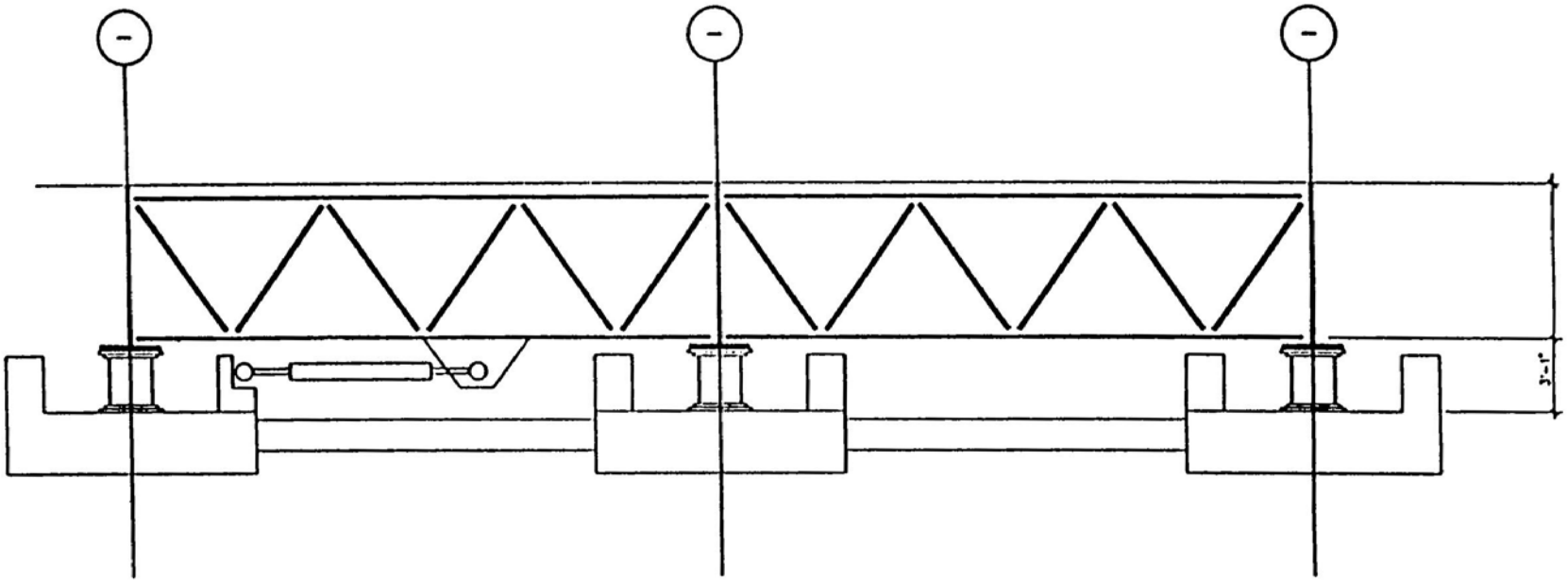
D & T Building
Truss Locations with Dampers



Central Plant Building
Damper Locations



Nursing Tower with Dampers



Typical Building
Truss Type 4 with Dampers