CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TECHNICAL OPERATING PROCEDURE

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Title PROCEDURE FOR ASSEMBLING AND TESTING JOINTED-ROCK TUFF SPECIMENS USING A DYNAMIC SIMULATOR WHICH PRODUCES DYNAMIC SHEAR AND COMPRESSIVE NORMAL LOADS

EFFECTIVITY AND APPROVAL

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Approvals

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PROCEDURE FOR ASSEMBLING AND TESTING JOINTED-ROCK TUFF SPECIMENS USING A DYNAMIC SIMULATOR WHICH PRODUCES DYNAMIC SHEAR AND COMPRESSIVE NORMAL LOADS

1. Purpose

The purpose of this procedure is to outline requirements for assembling field samples into a dynamic simulator and for conducting shear tests to evaluate joint properties of tuff rock in the laboratory.

2. Scope and Applications

This procedure applies to jointed tuff rock specimens tested in a simulator, having controllable normal compressive and dynamic shear loads. It defines procedures for calibrating instrumentation and control equipment, conduct of tests and associated data acquisition, and specifies documentation necessary to substantiate monitored responses of the test sample.

2.1 Applicable Documents and References

The following documents form a part of this procedure to the extent they apply:

2.1.1 Center Technical Operating Procedures, including TOP-006 - Procedure For Obtaining Seismic Rock Mechanics Test Specimens From The Field;

2.1.2 Center Quality Assurance Manual (CQAM);

2.1.3 Center Project Plan for Seismic Rock Mechanics Project (Draft Revision 1, October 1989);

2.1.4 Technical reports and publications relating to items of consequence in this procedure;

2.1.5 Center Report No. CNWRA 90-005, "Development of a Rock Joint Dynamic Shear Test Apparatus," January 1990;

2.1.6 SwRI Nuclear Projects Operating Procedure XII-EE-101-6, "Calibration of Structural Dynamics and Environmental Testing Test Equipment;"

2.1.7 SwRI Nuclear Projects Operating Procedure No. XI-EE-101-3, "Seismic Test of Electrical and Mechanical Equipment."

2.2 Acceptable Specimens

The specimens described in this procedure are to be used to conduct laboratory tests on elements of jointed rock specimens. Acceptable specimens shall be obtained, treated, and handled as outlined in TOP-006.

3. Responsibility

3.1 The Principal Investigator of the project shall be directly responsible for the implementation of this procedure. In cases where the Principal Investigator is not a member of the CNWRA, the Project/Element Manager shall retain this responsibility.

3.2 Test personnel are responsible for performing the test activities in accordance with this procedure.

4. Description Of Equipment To Be Used For Rock Joint Interface Dynamic Shear Tests

4.1 General

A complete description of the dynamic test apparatus to which this procedure applies can be obtained from Center Report No. CNWRA 90-005 (Section 2.1.5). Herein for reference, only a brief description is provided.

A servocontrolled test apparatus with combined normal and direct shear capability designed, fabricated, and assembled specifically to perform direct dynamic shear tests (described in this procedure) on joints in tuff materials shall be used. Figure 1 shows top and side views of the loading apparatus, while Figure 2 schematically depicts the excitation and control system. The apparatus consists of vertical and horizontal servocontrolled loading actuators, reaction frames, and shear box fixtures. A tuff specimen with a naturally occurring joint serves as the test item.

The loading capacity for each of the three vertical actuators is 30,000 lbs and is 20,000 lbs for the horizontal actuator. (An alternate horizontal actuator and associated load cell of 50,000 lbs capacity is available for higher load requirements.) The horizontal actuator can be operated in either load or displacement control mode. Loading patterns such as harmonic load and displacement as well as ground shock and earthquake time histories can be generated through the use of a function generator. Each actuator is equipped with a 25,000 lb capacity load cell for monitoring the applied forces. The set up for monitoring the applied normal load is such that the output is an average value of the three load cells.

The bottom shear box is designed to house a specimen with maximum dimensions of 12 x 8 x 4 in. The top shear box is to house a mating specimen with maximum dimensions of 8 x 8 x 4 in. Both are grouted in their respective specimen boxes. The bottom shear box is bolted to a thick steel plate for base rigidity. Horizontal translation of the top shear box along the direction of shearing is guided by three rollers between the top shear box and top plate. (It can also be guided by side rollers not shown in Figure 1.) A normal load frame is installed in alignment with the horizontal actuator to prevent or limit horizontal translation of the top plate along the direction of shearing. This frame and the action of the side rollers prevent rotation of the vertical actuators (and therefore also the top specimen block) about a vertical axis perpendicular to the direction of shearing. Only translation displacement is input during the test after vertical loads are applied.

4.2 Normal Load System

Normal compression is applied to the specimen by three vertical actuators positioned at 120° about the specimen's vertical centerline. These actuators act through individual load cells whose output is summed and used as the control signal. Thus, the total normal load is controlled at a preselected static or slowly ramped or increasing value. This total load is ultimately applied to the specimen via the normal load frame which acts on the three normal load rollers, and thereby on the upper specimen box. Thus, the normal load frame is constrained to three degrees of freedom:

a) Vertical translation

b) Rotation about the horizontal axis inline with the shear

c) Rotation about the horizontal axis transverse to the shear

These constraints are assured by two double flexures which connect the normal load frame to a fixed reaction brace, and by the two side roller assemblies, which act on the upper specimen box. These degrees of freedom allow for proper alignment of the test specimen prior to application of the horizontal load, and during wear at the interface. Thus, the upper specimen block is constrained to these same three degrees of freedom, plus a fourth, which is translation in the direction of shear.

Response to the applied normal load is measured in terms of vertical relative displacements of the two blocks at three locations of the interface. For this, the transducers are of (noncontacting) proximity type, since horizontal movement of the two surfaces must be allowed, but vertical displacements only are to be sensed. Three relative vertical measurement points are used to resolve the rigid body displacement of the upper block relative to the lower block, according to the three degrees of freedom enumerated above.

4.3 Horizontal Load System

The horizontal actuator produces direct shear to the upper specimen box via the horizontal load cell. Upper block horizontal acceleration is measured by left-side and right-side accelerometers, located on the loading end of the upper block. The displacement control signal (Figure 1) actually is the relative horizontal displacement of the two specimen blocks, as measured at the left and right sides of the block interface. The average is used as the control signal. This signal represents the fourth and final degree of freedom of the upper block, and is compared with a preselected input source, which depends on the dynamic motion desired:

4.3.1 Pseudostatic - A slow (20 to 30 min.) increasing ramp is applied to the relative displacement, while the force required is simultaneously recorded.

4.3.2 Stepped Velocity - A drive signal is generated so that when this signal is applied to the actuator, the relative shear velocity (differentiated shear displacement) simulates a multilevel stepped velocity level.

4.3.3 Steady State Cyclic - A sine wave drive signal is applied. Frequency, amplitude, and duration are based on anticipated performance of the surface.

4.3.4 Earthquake Simulation - A drive signal is generated such that a specified acceleration response spectrum is nominally matched for a given time duration. Compliance is verified by computing the response spectrum from the filtered relative horizontal acceleration signal. Use of a filtered response spectrum is specified since it is anticipated to be most representative of site spectra based on far field data.

4.3.5 Rockburst and Explosive Shock - A procedure similar to that for earthquake simulations is used.

5. Procedure for Assembling and Testing

In order to accomplish the tests, it is necessary to assemble the test specimen properly and then mount it in the dynamic simulator.

5.1 Tuff Test Specimen Assembly Procedure

5.1.1 The prepared tuff specimen package shall be received nominally-trimmed with upper and lower blocks banded together as a mated unit. The unit shall also be banded to a shipping pad as required by TOP-006.

5.1.2 Hoist the specimen package onto a table surface by using attachments to the shipping pad.

5.1.3 Cut the shipping pad bands and specimen unit bands.

5.1.4 Separate the upper and lower specimen blocks at the natural joint and measure the joint roughness coefficient as defined in the Center Project Plan for the Seismic Rock Mechanics Project.

5.1.5 Bolt the lower specimen box together with the three small aluminum spacer blocks in place.

5.1.6 Pour about 3/4-inch of grout into the lower specimen box.

5.1.7 Using hoist and straps, lift the lower specimen block from the shipping pad and settle it into the lower specimen box. Guide settlement of the lower specimen block so that spacing to the inside of the box walls is nominally equal all around. (As the block settles onto the spacers, some grout will extrude upward around the bottom of the block.) Remove the hoisting straps.

5.1.8 Pour grout to the top edge of the lower specimen box and allow it to cure.

5.1.9 Place the upper specimen back onto the lower specimen so that the natural joint interfaces are properly remated.

5.1.10 Install four rubber seals around the edge of the specimen unit interface.

5.1.11 Bolt four sides of the upper specimen box together with the top left off.

5.1.12 Lower this bolted part of the upper specimen box past the sides of the upper specimen until the box sides squeeze the rubber seal between the edges of the upper and lower boxes. Install the two side plates. (This requires compression of the seal down to the spacer and aligns the upper and lower halves of the box so that spacing between the sides of the upper specimen and the upper box walls is nominally equal all around.)

5.1.13 Fill the upper box with grout to the top edge of the upper box.

5.1.14 Bolt the top plate to the top of the upper box. (Note that some excess grout should extrude through upper plate holes.) Wipe away the excess, and allow the grout to cure.

5.1.15 This constitutes one completed Tuff Test Specimen.

5.2 Tuff Test Apparatus Assembly Procedure

5.2.1 Hoist the Tuff Test Specimen onto the test base and align it with the retainer bolt holes.

5.2.2 Install retainer bolts through the lower box.

5.2.3 Attach the horizontal actuator/load-cell assembly to the upper specimen box.

5.2.4 Bolt the roller assembly to the top of the upper specimen box.

5.2.5 Hoist the normal load frame and vertical actuator assembly into position so that the roller guides are centered onto three rollers of the roller assembly. (The bottom attachment holes of the three vertical actuators should match with the clevis holes on the base plate and the normal load frame flexure holes should match with the holes in the normal load frame reaction fixture.)

5.2.6 Attach three vertical actuators by means of pins at clevises on the base plate.

5.2.7 Bolt the two flexures to the normal load frame reaction fixture.

5.2.8 Detach the two side plates from the specimen boxes.

5.2.9 Remove the rubber seals and clean the specimen interface area.

5.2.10 Verify that all instrumentation and equipment is within proper calibration cycles. Perform calibrations according to SwRI Nuclear Projects Operating Procedure XII-EE-101-6, "Calibration of Structural Dynamics and Environmental Testing Test Equipment" (See 2.1.6) and Center Report No. CNWRA 90-005, "Development of a Rock Joint Interface Dynamic Shear Test Apparatus" (See 2.1.5). Calibration of noncontacting displacement detectors is accomplished by a direct comparison of their output with a physical measurement.

5.2.11 Attach all instrumentation to the apparatus and to the data acquisition unit as shown in Figure 1. The following order shall be used for data acquisition.

5.2.11.1 1) Vertical load cell No. 1

5.2.11.2 2) Vertical load cell No. 2

5.2.11.3 3) Vertical load cell No. 3

5.2.11.4 4) Sum of three vertical loads

5.2.11.5 5) Relative vertical displacement detector No. 1

5.2.11.6 6) Relative vertical displacement detector No. 2

5.2.11.7 7) Relative vertical displacement detector No. 3

5.2.11.8 8) Upper specimen block horizontal accelerometer No. 1

5.2.11.9 9) Upper specimen block horizontal accelerometer No. 2

5.2.11.10 10) Horizontal load cell

5.2.11.11 11) Horizontal actuator displacement

5.2.11.12 12) Specimen relative horizontal displacement LVDT No. 1

5.2.11.13 13) Specimen relative horizontal displacement LVDT No. 2

5.2.12 Attach the side guide roller assemblies.

5.2.13 Verify that the appropriate excitation equipment is connected according to Figure 2 and is ready for test.

5.2.14 Proceed with the specified load test.

5.3 Vertical Pseudostatic Load Test Procedure

5.3.1 Prior to the initiation of the test, the Principal Investigator shall determine test parameters; throughput calibration voltages, anticipated channel gain levels, data acquisition sampling levels and rates, vertical load ramp generator limits, and maximum load level.

5.3.2 Program the data acquisition unit for calibration. Apply throughput calibration voltages on all appropriate channels and record the output on the data acquisition unit. Verify the correctness of data on the monitor by comparing it with input values.

5.3.3 Visually verify that all appropriate channel gains are set for the anticipated levels, and make laboratory data log entry.

5.3.4 Program the data acquisition unit for appropriate sampling levels and rates.

5.3.5 Set limits on the vertical load ramp generator.

5.3.6 Start the test and visually monitor results as the test proceeds.

5.3.7 Stop the test at a preselected load level.

5.3.8 Release the vertical load and secure the apparatus and data disk unless further horizontal testing is to be done. Make entries in the laboratory data log.

5.3.9 Remove the Tuff Test Specimen by reversing the apparatus assembly procedure.

5.3.10 Measure joint roughness coefficient as defined in the Center Project Plan for Seismic Rock Mechanics Project. Inspect for any specimen/grout fracturing.

5.4 Combined-Axis Pseudostatic Load Test Procedure

5.4.1 Prior to the initiation of the test, the Principal Investigator shall determine test parameters; throughput calibration voltages, anticipated channel gain levels, data acquisition sampling levels and rates, vertical load ramp generator limits, and maximum load level.

5.4.2 Program the data acquisition unit for calibration. Apply throughput calibration voltages on all channels and record the output on the data acquisition unit. Visually verify correctness of data on the monitor.

5.4.3 Visually verify that all channel gains are set for the anticipated levels, and make the laboratory data log entries.

5.4.4 Program the data acquisition unit for appropriate sampling levels and rate.

5.4.5 Set limits on the vertical load ramp generator and the horizontal displacement ramp generator.

5.4.6 Apply the vertical load to a preselected value and monitor the results. Wait one minute before proceeding while continuing to acquire data.

5.4.7 Start the horizontal displacement ramp and monitor results as the test proceeds.

5.4.8 Stop the test at a preselected relative horizontal displacement level.

5.4.9 Release the vertical load and secure the apparatus and data disk. Make Scientific Notebook entries.

5.4.10 Remove the Tuff Test Specimen by reversing the apparatus assembly procedure.

5.4.11 Measure joint roughness coefficient as defined in the Center Project Plan for Seismic Rock Mechanics Project. Inspect for any specimen/grout fracturing.

5.5 Combined-Axis Dynamic Load Test Procedure

5.5.1 Prior to the initiation of the test, the Principal Investigator shall determine test parameters; horizontal displacement generator programming, horizontal actuator settings, earthquake simulation spectrum (or other shock response spectrum)h, throughput calibration voltages, anticipated channel gain levels, data acquisition sampling levels and rate, vertical load ramp generator limits, and vertical load.

5.5.2 Program the horizontal displacement generator according to the type of motion to be simulated:

5.5.1.1 Generate the stepped-velocity test displacement drive signal with the waveform generator and store the signal on analog tape for input to the horizontal actuator.

5.5.1.2 Set the steady-state cyclic motion amplitude, frequency, and number of cycles on a waveform generator for input to the horizontal actuator.

5.5.1.3 Generate an earthquake simulation drive signal for input to the horizontal actuator. (This displacement signal is designed so that the horizontal shear motion produced on the Tuff Specimen corresponds to a prescribed acceleration response spectrum for motion anticipated to occur at the Yucca Mountain site.) The actuator drive signal shall be developed by means of a digital computer program according to SwRI Nuclear Projects Operating Procedure No. XI-EE-101-3, "Seismic Tests of Electrical and Mechanical Equipment" (See 2.1.7). The actuator drive signal shall first be recorded on analog tape and then input to the horizontal actuator to produce a simulated 30-second earthquake motion on the upper specimen block. Verification of the adequacy of the motion shall be accomplished by computation of the response spectrum for the filtered measured horizontal acceleration and comparison with the prescribed response spectrum.

5.5.1.4 Generate a rockburst simulation drive signal for input to the horizontal actuator by means of a procedure similar to that for the earthquake simulation. A prescribed rockburst acceleration response spectrum and duration shall be used as the basis for the test.

5.5.1.5 Generate an explosive shock simulation drive signal for input to the horizontal actuator by means of a procedure similar to that for the earthquake simulation. A prescribed explosive acceleration response spectrum and duration shall be used as the basis for the test.

5.5.2 Program the data acquisition unit for calibration. Apply throughput calibration voltages on all channels and record the output on the data acquisition unit. Verify correctness of data on monitor by comparing them with input values.

5.5.3 Verify that all channel gains are set for the anticipated levels, and make laboratory data log entries.

5.5.4 Program the data acquisition unit for appropriate sampling levels and rate.

5.5.5 Set appropriate limits on the vertical load ramp generator.

5.5.6 Apply the vertical load to a preselected value and monitor the results. Wait one minute before proceeding while continuing to acquire data.

5.5.7 Start the horizontal dynamic event and monitor results as the test proceeds.

5.5.8 At the end of the dynamic event, compute the test response spectrum, release the vertical load, and secure the apparatus and data disk. Make Scientific Notebook entries.

5.5.9 Remove the Tuff Test Specimen by reversing the apparatus assembly procedure.

5.5.10 Measure joint roughness coefficient as defined in the Center Project Plan for Seismic Rock Mechanics Project. Inspect for any specimen/grout fracturing.

6. Used Sample Storage

6.1 Specimen identification tags given or applied to the test specimen prior to its being assembled into the test apparatus shall be saved while the specimen is being tested.

6.2 After the specimen has been consumed or the test completed, the specimen shall again be stored in a plastic bag and tagged or identified with its original identification tags. Additional tags and information shall include:

6.2.1 Date of Seismic testing

6.2.2 Test parameters and specimen response

7. Deviation from Procedure

During the course of test activities, deviation from this procedure may be necessary. In such cases, no deviation and nonconformance report is required. Prior to a deviation from this procedure, the Principal Investigator or Element Manager shall approve the change. Approval shall be documented in the Scientific Notebook containing the tests performed using the approved deviations. Approval from the other groups approving the base procedure shall be obtained and documented in the Scientific Notebook.

8. Records

8.1 The Scientific Notebook used to record the results of geological characterizations shall contain the following information:

8.1.1 Date

8.1.2 Full name, initials or assigned stamp of individual(s) performing the characterization work

8.1.3 Method of characterization utilized, including any deviation from established procedures

8.1.4 Identification Number of specimen, if applicable (This number should be entered at the top of each page)

8.1.5 Equipment used

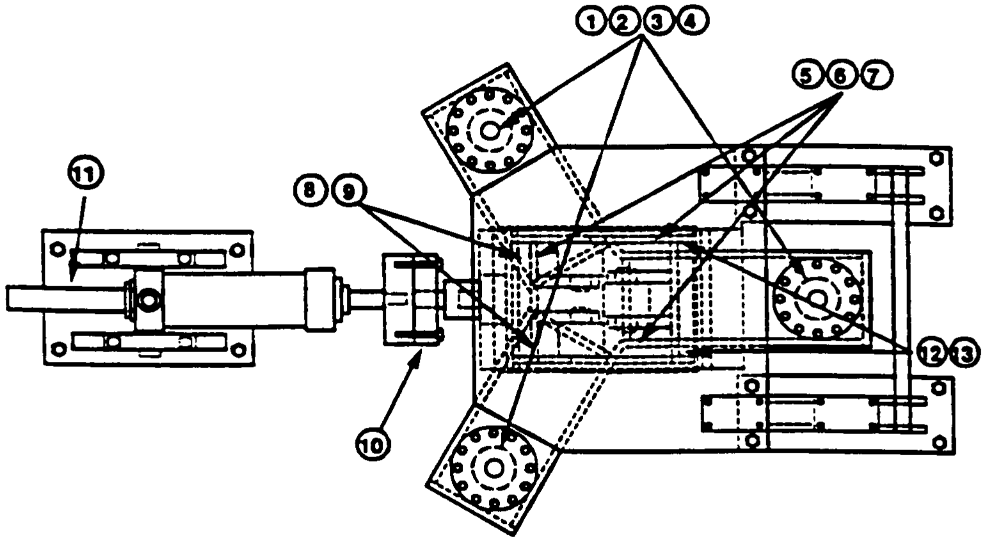
8.1.6 Results

8.2 Each laboratory project task will have its own controlled Scientific Notebook with bound and numbered pages, or another method to capture the results of the work. The notebook is the responsibility of the Principal Investigator until project completion or termination. At that point, the notebook(s) shall be retained, as are other results, in appropriate Center files as primary evidence of work accomplishment. Copies of lab notebook pages may be made, but the lab notebook remains Center property.

8.3 Records generated in the implementation of this procedure shall be maintained in accordance with CQAM Section 17, "QA Records," and retained for three years.

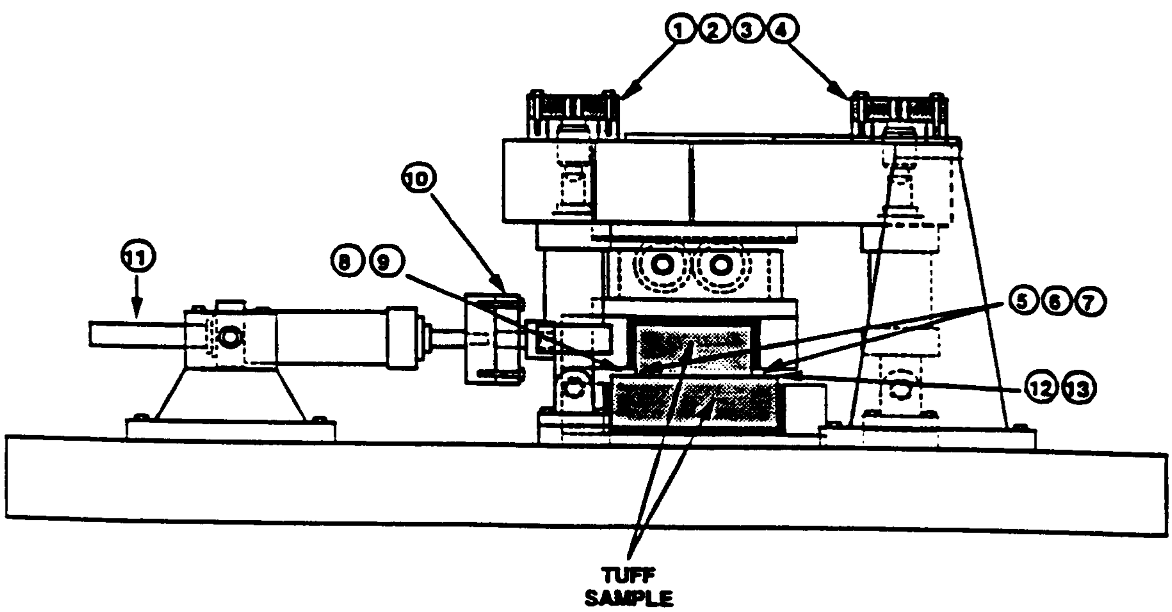
9. Control of Samples

Seismic rock mechanics samples/specimens under the control of the Center shall be kept in a cabinet or equivalent container when not being used in a project test, being prepared for a test, or being characterized. These requirements shall apply to both new and used/tested specimens.



TOP VIEW

Note: Numbers refer to data channels outlined in Section 5.2.11



SIDE VIEW

Figure 1. Instrumentation Position Identification

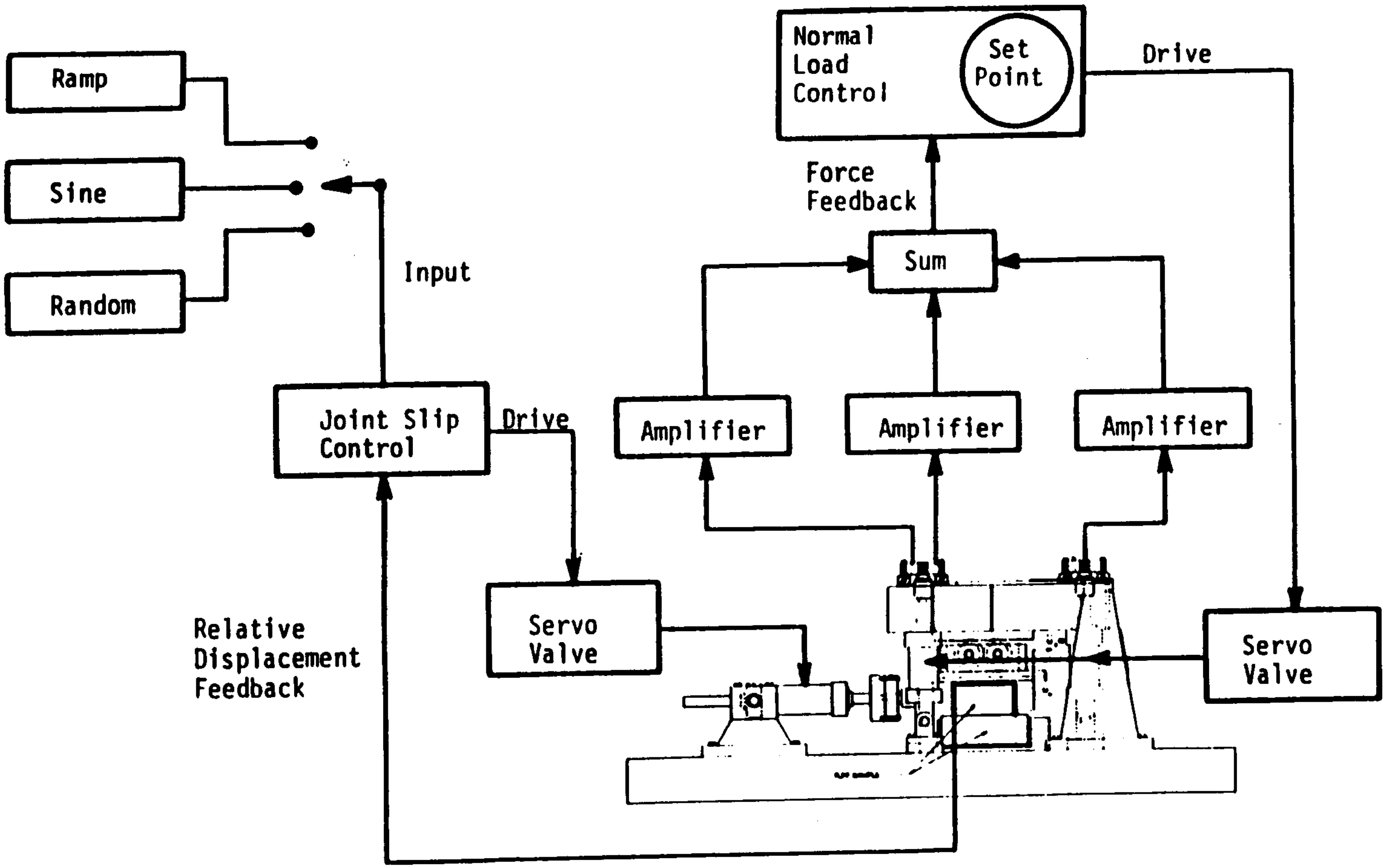


Figure 2. Excitation and Control Block Diagram