3. DESCRIPTION OF SHAKING TABLE SYSTEM COMPONENTS

3.1. INTRODUCTION

The earthquake simulator is a system that consists of several components which must be designed to effectively work together. Each component was designed with the needs of the entire system in mind.

3.2. DESIGN CONCEPT

The design concept of the UPRM Earthquake Simulator was the design of a small uni-directional electro-hydraulic shaking table facility. The initial design concept consisted of a rigid platform sliding over a near frictionless linear bearing system and driven by an actuator attached to a reaction mass. Figure 3.1 illustrates the final design of the uni-directional electro-hydraulic shaking table.

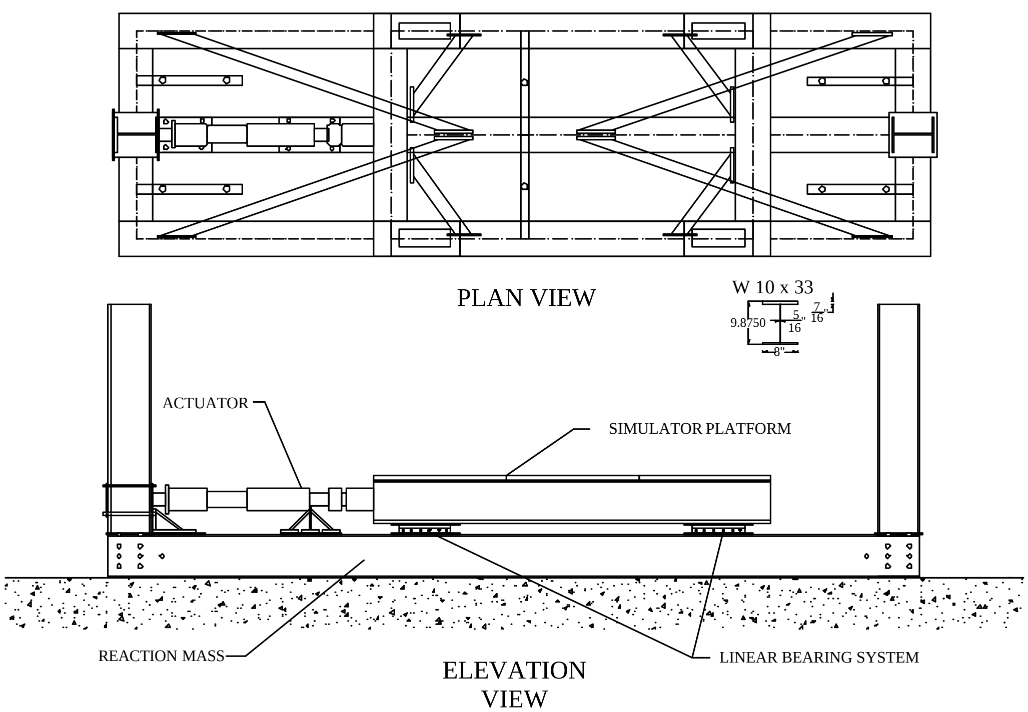


Figure 3.1 Plan and Elevation Views of the Earthquake Simulator.

3.3. SHAKING TABLE COMPONENTS

The components of the UPRM Shaking Table facility can be summarized in the following:

1. Reaction Mass
2. Simulator Rigid Platform
3. Linear Roller Bearings
4. Hydraulic Power Unit
5. Servovalve and Actuator
6. Servo-Controller
7. Control & Data Acquisition
8. Instrumentation for Measurements

Figure 3.2 shows the UPRM earthquake simulator.

a) West Side View. b) East Side View.

Figure 3.2 UPRM Earthquake Simulator.

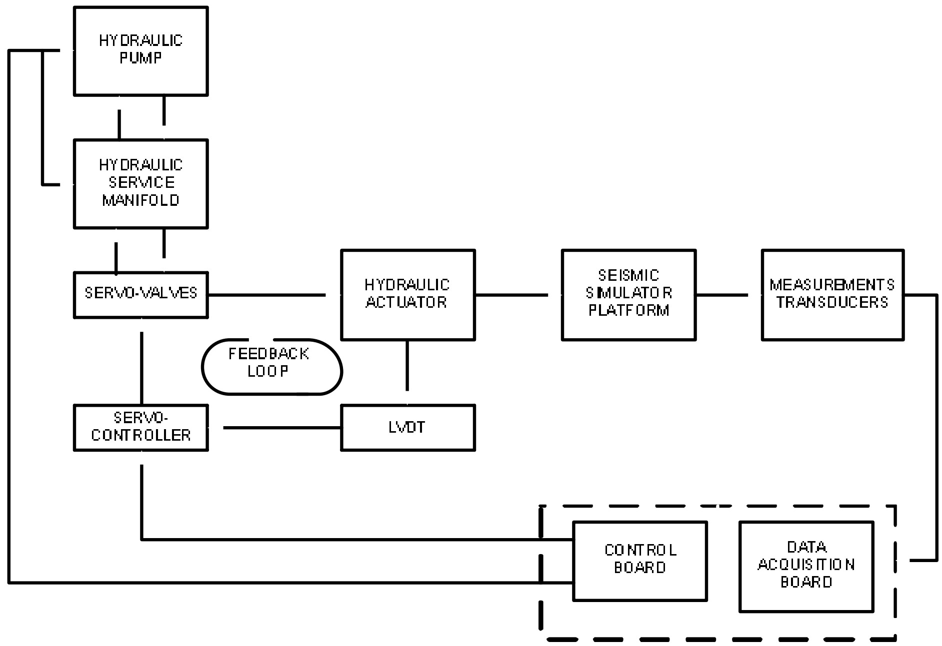


Figure 3.3 Block Diagram of Seismic Simulator [19].

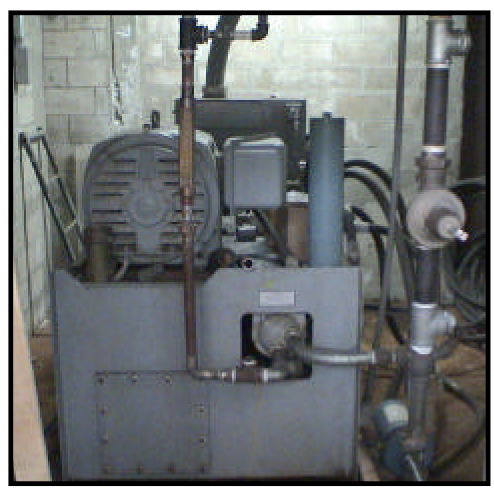
Figure 3.3 illustrates how these components work together. The process is initiated by a signal from the Control Computer to activate the Hydraulic Pump Unit (HPU) and the Hydraulic Service Manifold (HSM). The HPU delivers constant flow of hydraulic fluid. The HSM distributes this hydraulic fluid to the different actuator channels. The HSM houses a pressure accumulator and return accumulator. This helps the system during peak flow demands. The same Control Computer sends a displacement command signal to the Servo-Controller that controls the displacement of the actuator and of the simulator platform. The Servo-Controller uses a closed-loop system that provides continuous correction signals for control of the simulator platform displacement. The closed loop servo-system uses a linear variable differential transformer (LVDT), which is located within the actuator, to make these corrections by comparing the command signal with the LVDT signal. This generates an error signal that is sent to the servo-valves, which controls the amount and direction of the pressurized hydraulic fluid port to the actuator chambers from the HSM, and thus controls the direction of the actuator movement. The measurement transducers measure the motion of the platform and send the measured signals to the Data Acquisition System to be stored.

In the following sections a brief description of the components is provided to give an overview of the function of each component.

3.3.1. HYDRAULIC POWER SYSTEM

Hydraulic power systems typically consist of an arrangement of hydraulic power supplies, remote service manifolds, and accessory equipment. These components integrate into a hydraulic power distribution network to provide hydraulic fluid power to servo-controlled actuators. Figure 3.4 shows the HPU which creates the hydraulic power to move the simulator platform.

a) HPU front view.

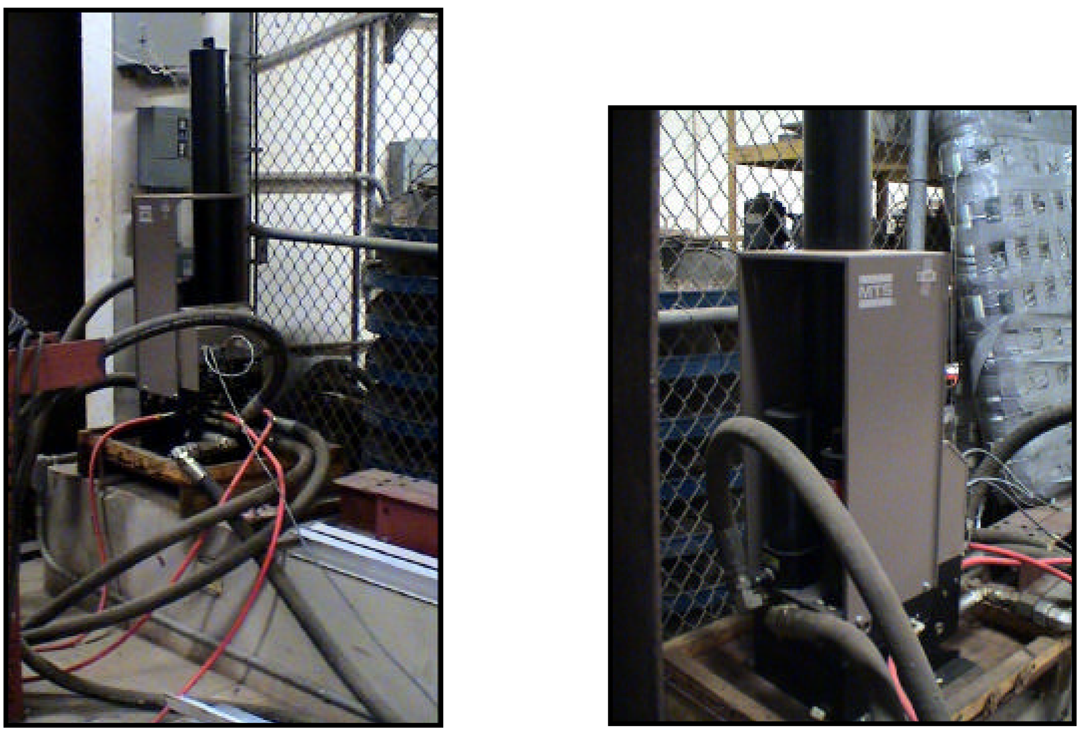


b) HPU back view.

Figure 3.4 Hydraulic Power Unit.

The hydraulic power unit provides the distribution system with constant-pressure, high filtered hydraulic fluid power.

Service Manifolds provide hydraulic accumulation and filtering functions for individual actuators in a system. Hydraulic hoses provide connection of components within the hydraulic power distribution on system. Figure 3.5 shows the HSM which distributes the hydraulic fluid from the HPU to the actuator.



a) HSM front view.

b) HSM back view.

Figure 3.5 Hydraulic Service Manifold.

3.3.2. SERVOVALVE

The servovalve shown in Figure 3.6 provides the final control element in a closed-loop servo-hydraulic system. The servovalve ports the fluid, provided by the hydraulic power system, into the appropriate side of the actuator's chambers. This causes the actuator's piston to move the actuator's arm in the desired direction [5].

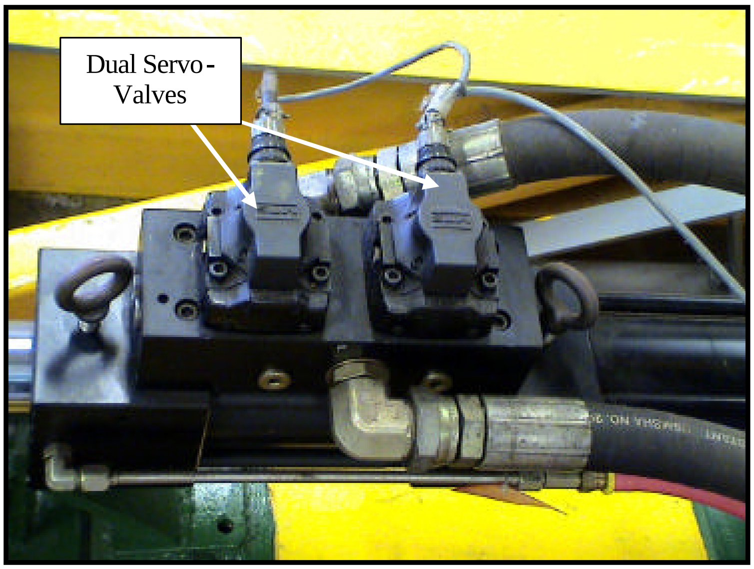


Figure 3.6 Dual Servovalves Mounted on the Actuator

3.3.3. LINEAR ACTUATOR

The linear actuator consists of a cylinder that contains a piston. The LVDT, which measures displacement, is inside the piston rod. The linear actuator system also consists of a load cell transducer, which measures force. Figure 3.7 shows the linear actuator with its components.

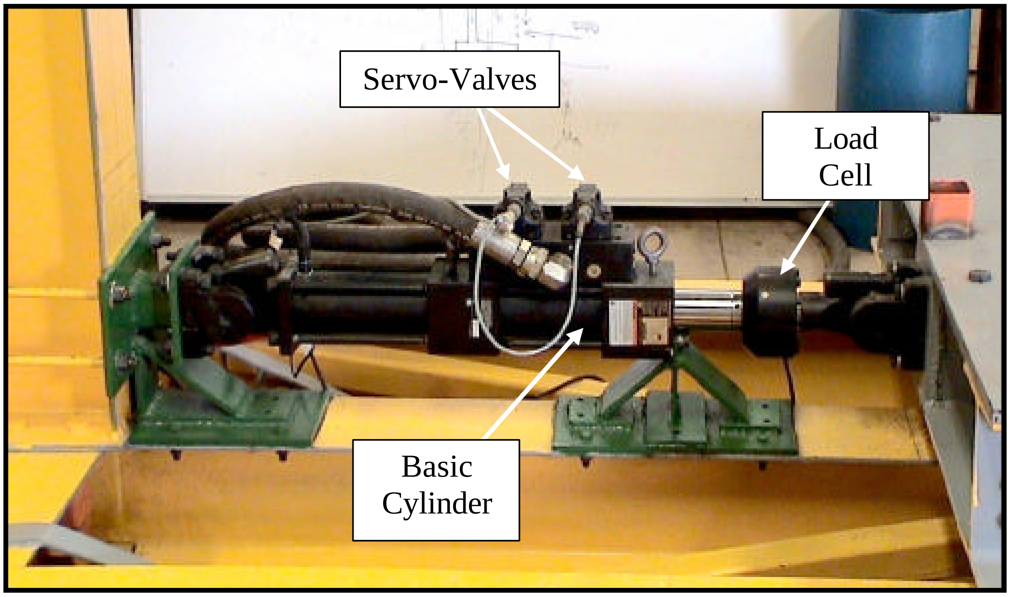


Figure 3.7 Linear Actuator and Components.

Figure 3.8 shows the actuator's cylinder with the LVDT transducer inside. As previously discussed, the movement of the actuator piston rod is accomplished by supplying high pressure hydraulic fluid to one side of the actuator piston (actuator's chamber) and opening the other side to the return line. The force rating of a linear actuator is equal to the effective piston area times the actuating pressure. The maximum flow rate available also determines the maximum simulator platform velocity [5]. The load cell is connected at the end of the actuator's piston rod and in turn to a swivel mounting head. The swivel head connects the actuator-load cell system to the simulator platform, as illustrated in Figure 3.7.

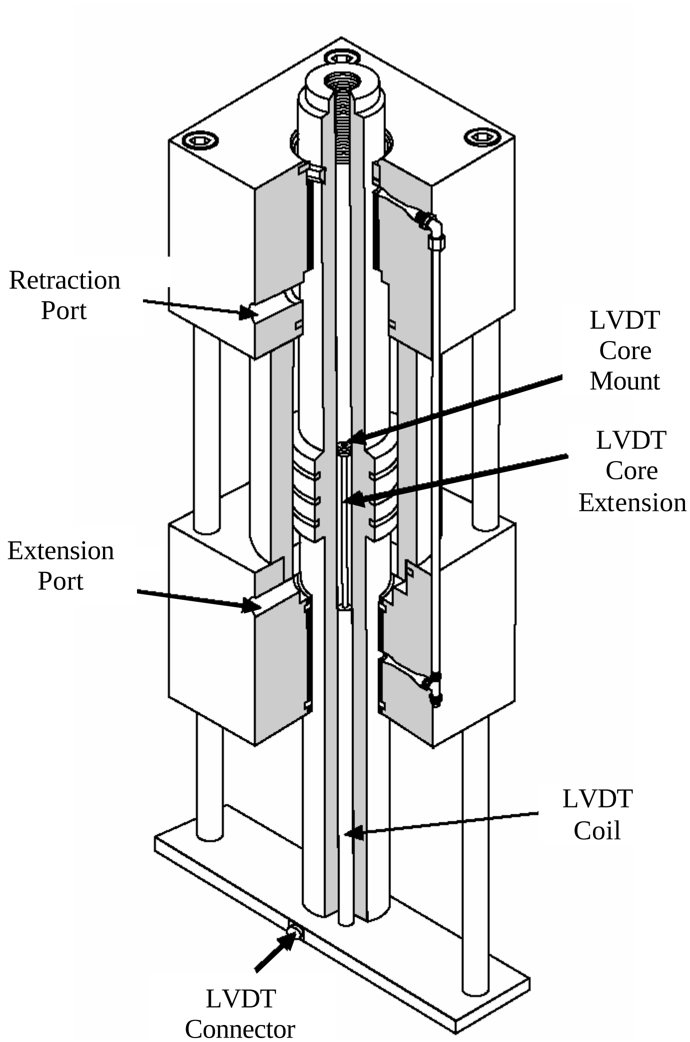


Figure 3.8 Basic Cylinder Components [20].

3.3.4. SIMULATOR PLATFORM

The simulator platform attached to the actuator system is shown in Figure 3.9. The simulator platform provides the surface for model attachment. It is mounted through a system of linear bearings to the reaction mass and its motion is controlled by the movement of the actuator.

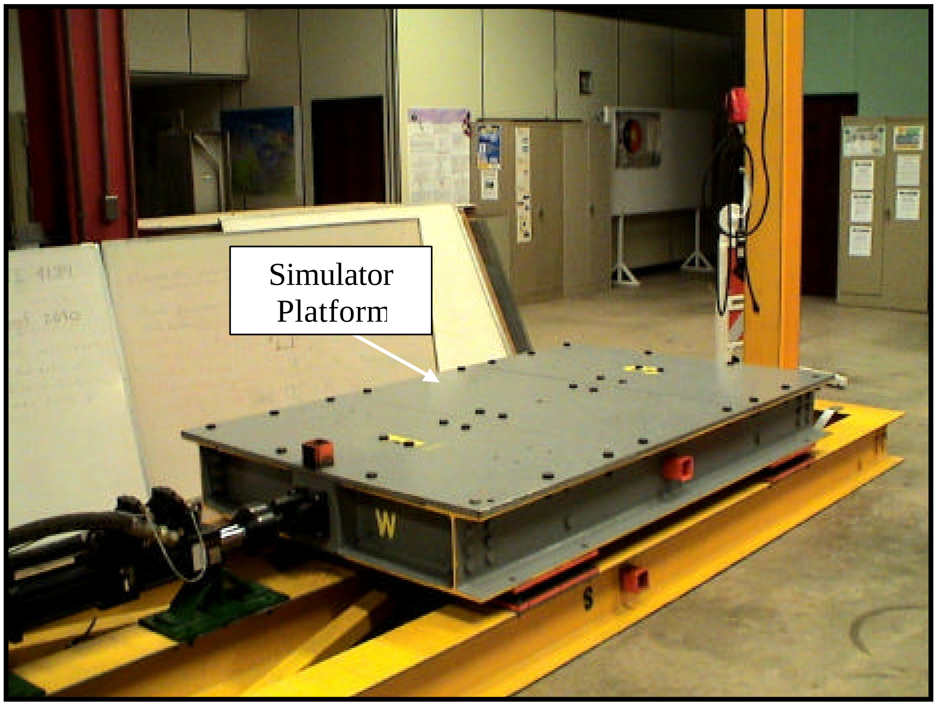
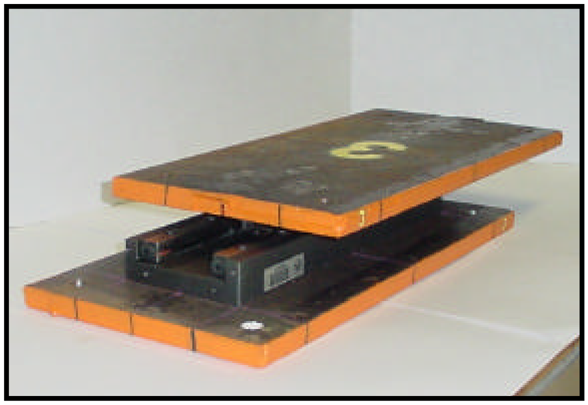


Figure 3.9 Simulator Platform mounted to the Reaction Mass.

3.3.5. LINEAR BEARING SYSTEM

The linear bearing system, shown in Figure 3.10, provides the sliding surface for the simulator platform to move with low friction [5]. Figure 3.10 (a) shows an individual Crossed Roller Table and Figure 3.10 (b) show the Linear Bearing System consisting of four individual Crossed Roller Tables acting as a group. This was accomplished with an efficient leveling procedure.



a) Individual Crossed Roller Table

b) Linear Bearing System mounted on Reaction Mass.

Figure 3.10 Linear Bearing System.

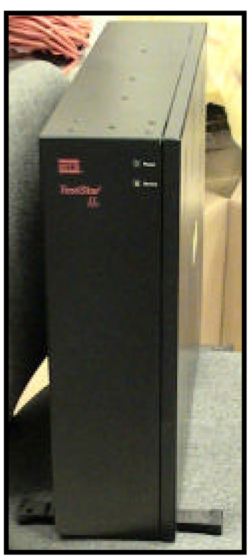
3.3.6. REACTION MASS

For structural or vibration testing, the actuator should be secured to a reaction mass using a swivel or pedestal base. The entire simulator platform system (platform, linear bearing system, actuator and servovalve) are fixed to the reaction mass [5]. The reaction mass provides a place for the actuator's force to react. Figure 3.11, illustrates the reaction mass. The reaction frame is at the same time fixed to the Structural Laboratory's strong floor.

Figure 3.11 Reaction Mass fixed to the Laboratory Strong Floor.

3.3.7. SERVO-CONTROLLER

The MTS Model 493.01 Servo-Controller is the bridge between the command signal sent by the Control computer and the porting of fluid to the actuator's chambers by the servo-valves. Figure 3.12 shows the Servo-Controller. The Servo-Controller utilizes two levels of control to regulate the displacement of the actuator [21]. The first level of control is called the "inner loop" and it regulates the porting of fluid by the servo-valves. This is the lowest level of control. The second level of control, called the "outer loop", utilizes the displacement signal of the LVDT mounted on the actuator and compares it to the command signal sent by the Control computer. The error signal is sent back to the "inner loop" which corrects the error by using the correct valve opening. The "outer loop" is the highest level of control of the Servo-Controller. The controller employs a **P**roportional-**I**ntegral-**D**erivative-**F**eed-**F**orward (**PIDF**) control algorithm to regulate and monitor the state of the system[5].



a) Front view.

b) Back view.

Figure 3.12 Servo-Controller

3.3.8. Control and Data Acquisition

The control of the Servo-Controller is provided by the MTS TestStar IIs AP software in a Compaq personal computer provided by MTS for this purpose. Figure 3.13 shows the MTS TestStar IIs AP Control Computer and the Data Acquisition Computer. The Data Acquisition Computer stores the data of the transducers mounted on the simulator platform and reaction mass. This computer is equipped with an Iotech signal processing board and DasyLab software.

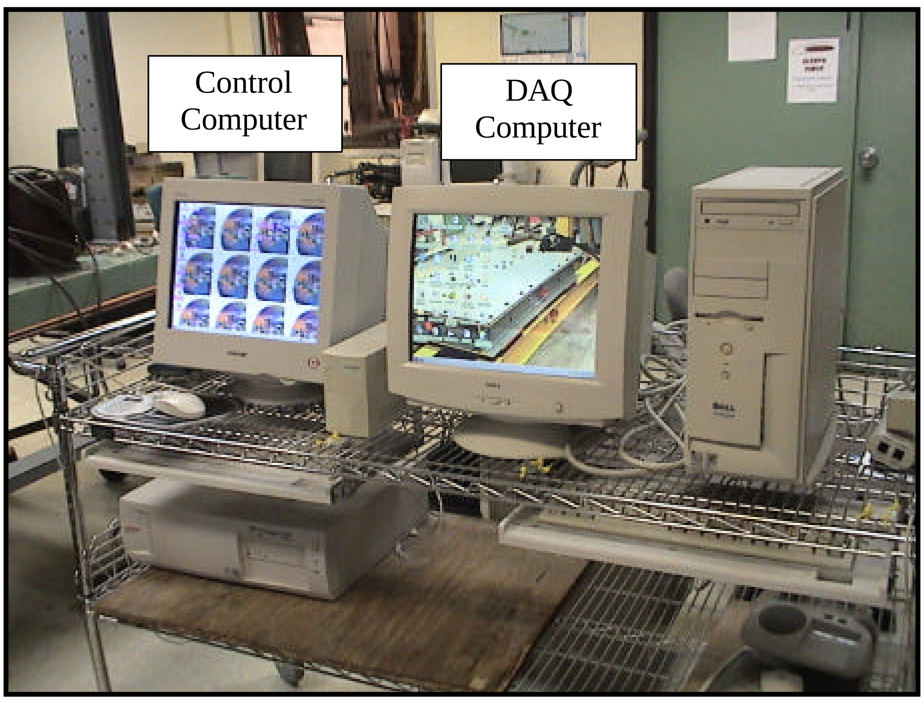


Figure 3.13 MTS TestStar IIs AP Control Computer and Data Acquisition Computer.

3.3.9. Instrumentation for Measurements

Piezoresistive accelerometers were mounted to the reaction mass and simulator platform to measure acceleration. The accelerometers are firmly attached to their locations with screws. Figure 3.14, shows one accelerometer used for measurement of acceleration. The LVDT within the actuator is used to measure the displacement of the actuator piston head and simulator platform displacement. The load cell attached to the end of the actuator utilizes a strain gage to measure force in the actuator.

Figure 3.14 Piezoresistive Accelerometer.