RECOMMISSIONING THE K-1600 SEISMIC TEST FACILITY*

C. C. Wynn
Central Engineering Division
D. W. Brewer
Applied Technology Division
Martin Marietta Energy Systems, Inc.
Oak Ridge, Tennessee 37831-7294

ABSTRACT

The Center for Natural Phenomena Engineering (CNPE) was established under the technical direction of Dr. James E. Beavers with a mandate to assess, by analyses and testing, the seismic capacity of building structures that house sensitive processes at the Oak Ridge Y-12 Plant. This mandate resulted in a need to recommission the K-1600 Seismic Test Facility (STF) at the Oak Ridge K-25 Site, which had been shutdown for 6 years. This paper documents the history of the facility and gives some salient construction, operation, and performance details of its 8-ton, 20-foot center of gravity payload bi-axial seismic simulator. A log of activities involved in the restart of this valuable resource is included as Table 1.

Some of the problems and solutions associated with recommissioning the facility under a relatively limited budget are included. The unique attributes of the shake table are discussed. The original mission and performance requirements are compared to current expanded mission and performance capabilities.

Potential upgrades to further improve the capabilities of the test facility as an adjunct to the CNPE are considered. Additional uses for the facility are proposed, including seismic qualification testing of devices unique to enrichment technologies and associated hazardous waste treatment and disposal processes.

In summary, the STF restart in conjunction with CNPE has added a vital, and unique facility to the list of current national resources utilized for earthquake engineering research and development.

INTRODUCTION

The K-1600 Seismic Test Facility is located at the K-25 Site on the Oak Ridge Reservation, currently managed by Martin Marietta Energy Systems, Inc., for the Department of Energy (DOE). The conceptual design (Fig. 1) was presented in early 1978 and the Equipment Specification was released in July 1978. Construction was completed in late 1982; operation began in 1983. The facility, formerly designated as the Centrifuge Seismic Test Facility, was designed and built for the purpose of testing gas centrifuge designs for site specific seismological integrity prior to their deployment in DOE's Gas Centrifuge Enrichment Plant (GCEP) near Portsmouth, Ohio.

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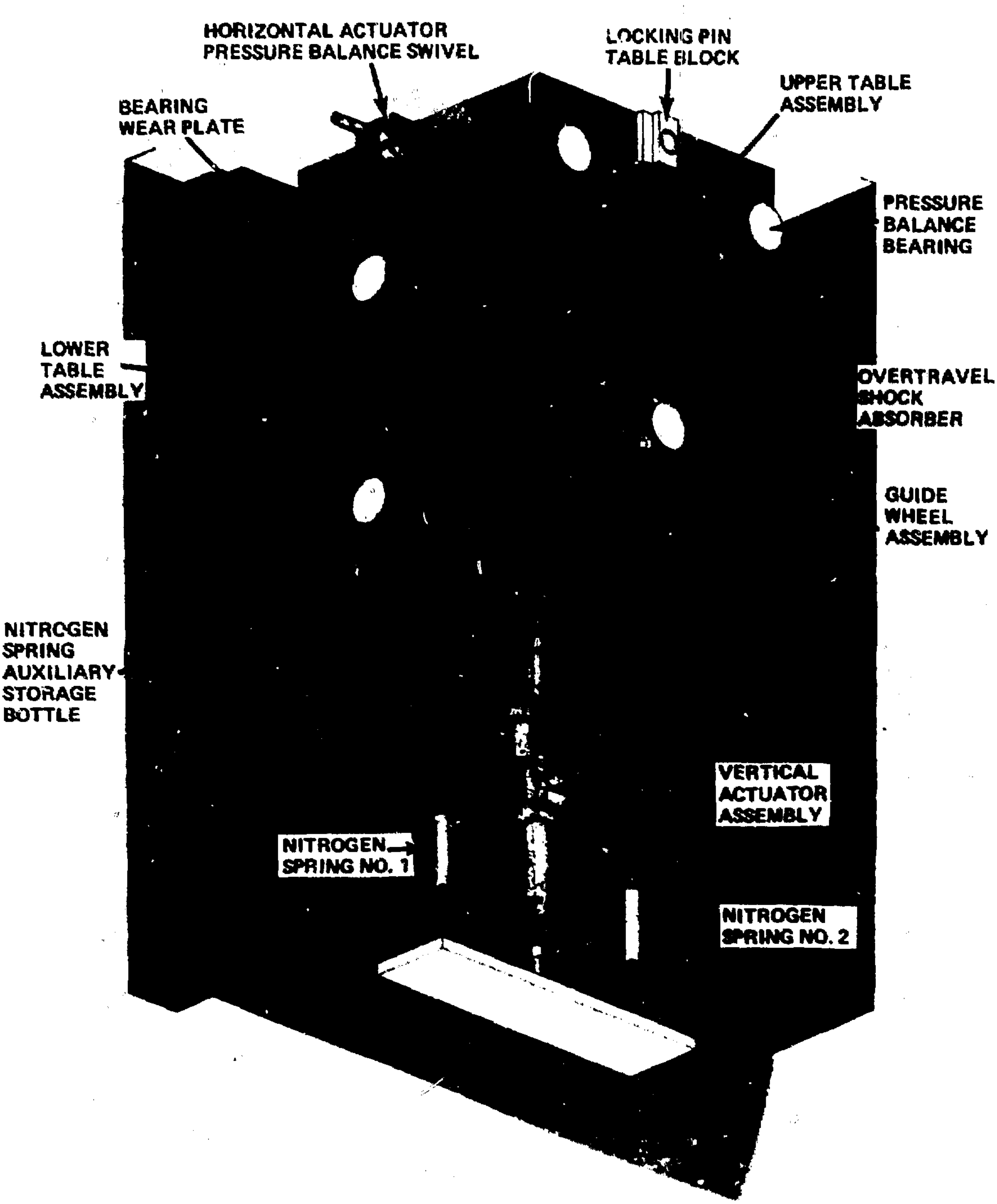

Fig. 1. The conceptual design of the K-1600 Seismic Test Facility.

SYSTEM DESCRIPTION

The 6-ft square steel surface of the shake table is at grade level with the massive 55,000-lb upper table section; the 25,000-lb lower table section; the nitrogen support springs; the vertical actuator; and other support hardware housed in a 20-ft-deep pit. To maintain and assure stability during operation, this pit is centered in a 1,600,000-lb steel- reinforced concrete reaction mass. Pitch and roll axis motions of the table are physically restrained by pairs of pressure balanced bearings that slide on precision bearing plates mounted to the side walls of the pit. Details of the shake table components are shown in Fig. 2.

Power to drive the shake table is supplied by a 125-hp hydraulic power supply and coupled to the table through two electrohydraulic servo-controlled actuators (27-kip vertical and 22-kip horizontal). The static weight of both the table and the specimen is supported by two high-pressure (2500-psi max) nitrogen support springs. Control input signals are supplied to both axes independently by a tunable analog control console that monitors both acceleration and displacement feedback and calculates a pseudovelocity response. The control mode (displacement, velocity, or acceleration) can be selected depending on the most effective or predominant component of the desired table motion. Manual excitation of the table is limited to low-level sine sweep or random noise inputs for determining transfer functions or varying level, fixed frequency (or narrow band sweep) sine wave inputs for modeling specimen response.

Highly accurate closed loop control of the table excitation is attained through a computer system that monitors the acceleration, velocity, and displacement feedback from both axis. These signals are compared to the desired input waveform, and the servo-drive signals are adjusted accordingly. The software is capable of setting soft limits for the protection of both the shaker system and the specimen. Inputs can be from several sources. Prerecorded digitized waveforms can be read into the system for input to the table, or the computer software can generate sinusoidal sweep, dwell, or beat inputs of varying levels. The software can also generate pseudorandom waveforms from any shock spectrum that fits the performance capability envelope as shown in Fig. 3.

The Oak Ridge biaxial shake table is capable of testing hardware with major dimensions of 25 ft in plane; 20 ft out of plane; and 75 ft high, with a total weight of 15,000 lb. The system is capable of independent axis control (vertical and horizontal) with minimal cross-coupling effects. The maximum dynamic performance capabilities are plus or minus 7.6-in. displacement at a velocity of 12 in./s and a peak acceleration of 0.25 g for both axis. Waveform reproduction accuracies are in the order of 25% for acceleration; 10% for velocity; and 5% for displacement, with a maximum table tilt error of 500 μrad. The table has demonstrated maximum errors of less than 5% overall at operating levels of approximately one-half of its capabilities. The maximum envelope errors have never been determined; however, future testing is planned to measure maximum payload controllability.

The system operated with only minor maintenance for 3 years. During this time a number of heavily instrumented gas centrifuges were tested, as well as other critical plant support equipment.

SHUTDOWN

In June 1985, DOE announced the decision to no longer pursue the use of gas centrifuge technology and to shut down all facilities related to the program and place the equipment in a safe condition. In the following months, the Oak Ridge shake table went into "mothball" status. The vertical actuator was removed and replaced by a rigid steel support post. The nitrogen system was fully vented, all the hydraulic fluid was drained from the system, and the steel bearing plates along the walls of the shaker pit were coated with oil to preserve the high quality surface finish. The batteries for the uninterruptible power supply, which supplied power to the control systems, were removed. All electrical power to the facility was turned off. The operating software as well as the earthquake input data were archived on magnetic tape. Test data were archived on microfiche.

RESTART

In the fall of 1989, interest increased in the seismic response and survivability of hollow clay tile (HCT) walls used in the construction of key buildings at the Y-12 Plant and other DOE facilities. This growing interest prompted CNFE to look at the K-1600 shake table as a possible means of modeling and testing HCT walls for earthquake response. MTS Systems, the original designer and manufacturer of the system, was contacted, and a representative was brought on-site to perform an evaluation of the condition of the equipment.

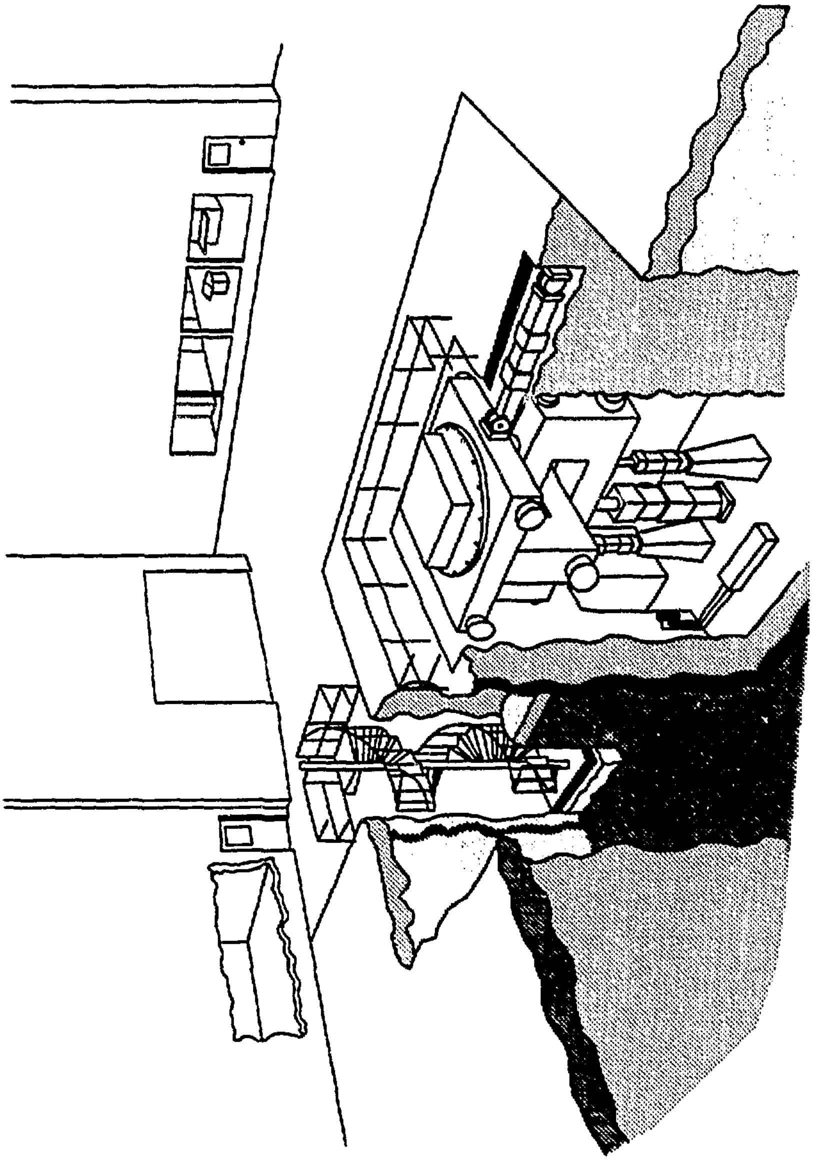

Fig. 2. Details of the shake table components.

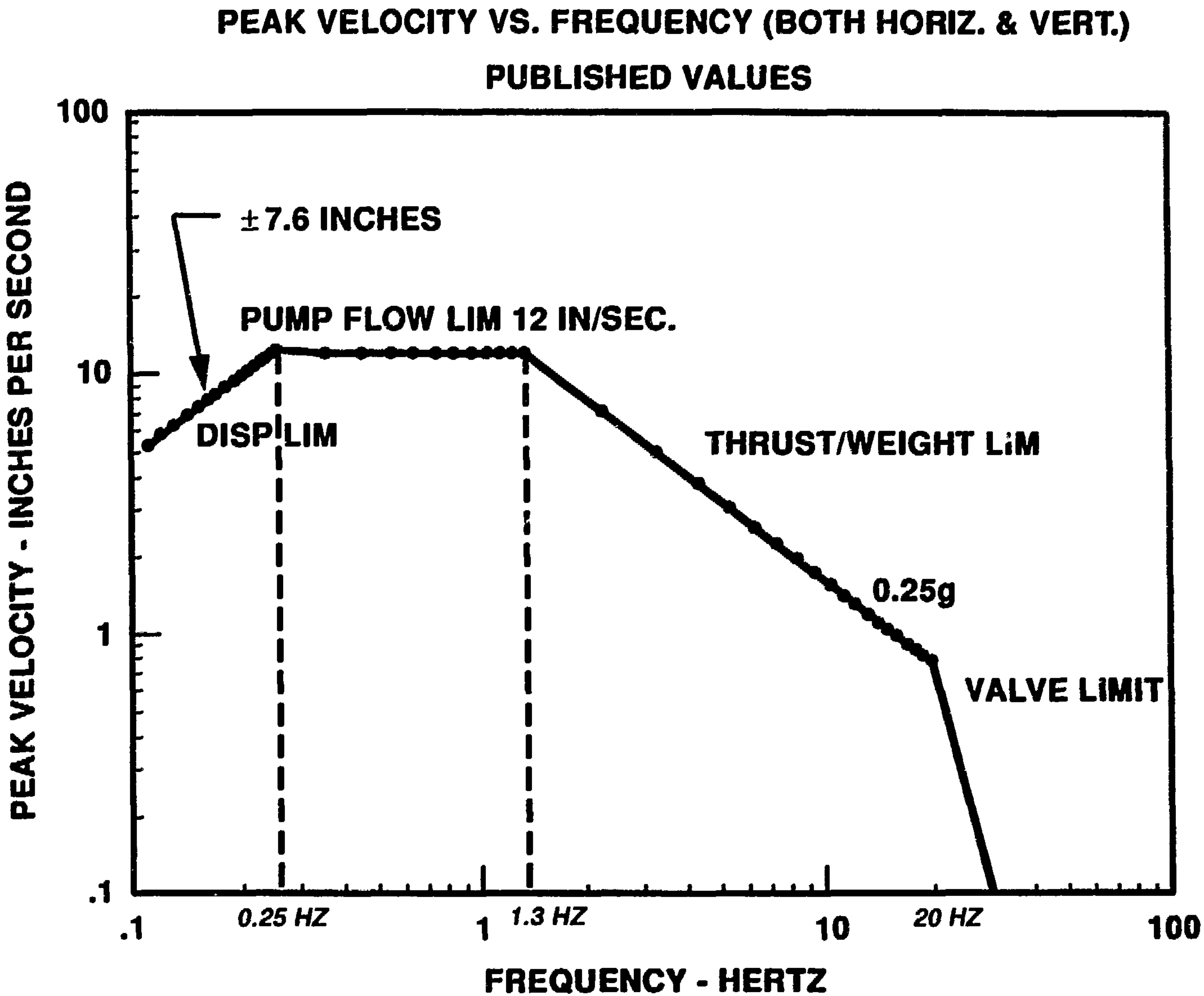

Fig. 3. K-1600 shaker performance.

This evaluation created a list of things that needed attention prior to any attempts to restart the shake table. Althought the equipment had been idle for 4 years, it was in good condition. The most notable finding was a coat of surface rust on the bearing plates, which had been caused by a major water leak in the area. A log of all the problems associated with the restart and the resolution of each is included as Table 1. The major problems were caused by water-filled systems that did not drain well and burst as a result of freezing.

The items that had been identified in the preliminary checkout were corrected, as well as other situations that appeared during this phase of the restart. The shake table restart was accomplished by using the procedures and recommendations in the system operating manuals; all repairs to the equipment were made in accordance with the service manuals and/or direction from the MTS service representative. All systems came back on line with a minimal amount of effort, as indicated in the restart log (Table 1).

No major problems were encountered until an attempt was made to return the archived operating software to service. For unknown reasons, the magnetic tapes were no longer readable, and the manufacturer had maintained only the source files used to generate the operating system. Currently, the available options are under evaluation: generate the old software again (for an outdated DEC PD-11/34 computer system) or replace the computer control system with a new one.

PERFORMANCE VERIFICATION

With the restart activities completed, the controllability and performance of the shake table system will be evaluated by duplicating the majority of the original acceptance test procedure. In conjunction with the acceptance testing, the maximum performance envelope, which has never been determined, will be mapped. Both maximum performance limits and controllability will be determined. This testing will be done by using a "Test Mast" which has a total weight that approaches the table maximum payload and a center of gravity at approximately 9 ft above the table surface. This will be useful in determining what level of testing can be performed for the Hollow Clay Tile Wall Project. A maximum baseline for the current configuration will also be established.

UNIQUE TESTING CAPABILITIES

The K-1600 shake table has certain designed testing capabilities that make it a valuable resource to both the vibration and seismic engineering disciplines. Precision controllability over its entire frequency band, coupled with its wide range of size and weight flexibility, make it ideally suited to vibration testing and seismic simulation at earthquake levels suitable for the majority of the eastern United States. The facility has utilities available that can support testing and qualification under normal and abnormal operating conditions for many active systems: electric motor, switchgear, valves, instrument, control, and safety. This system could also be a very useful tool in scale model evaluation of large structures.

UPGRADING FOR THE FUTURE

Several performance upgrade options have been investigated since the restart activities began. The shake table has proven to be conservatively designed, so some of the upgrades can be implemented with minimal modifications. The upgrade tasks are listed in order of priority, based on current and projected needs.

1. Replace the aging PDP 11/34 test executive computer and software and install an integrated 64 channel dynamic data acquisition system.

2. Improve the maximum horizontal acceleration performance by disabling the vertical motion drive and moving the larger vertical actuator to the horizontal position.

3. Install a lower mass upper table to increase acceleration performance for payloads with weights near the current performance maximum but with a vertical center of gravity that is lower than the current performance maximum.

One goal is to increase the maximum table acceleration performance to achieve the current Paducah Site ground motion design specification. Another goal is to eventually provide a general test facility for use by other projects requiring seismic simulation testing.

Table 1. K-1600 Restart activities log	
Activity	**Action**
Return utilities (electricity, air, water, etc.) to service and relamp facility as needed	The utilities were returned to service, and repairs were made as required.
Recommission the pit air quality system.	The pit exhaust ventilation system was turned on; the oxygen monitor was placed in service and calibrated: the alarm system was tested and the complete system was certified and put on scheduled test and certification recall.
Repair HVAC unit for computer room.	The complete unit was tested. Some piping that had burst due to freezing was replaced; the water to freon heat exchanger and steam coil was tested; and a defective compressor was replaced.
Test/repair water to hydraulic oil heat exchanger for the hydraulic power supply.	The heat exchanger was removed and tested. It had burst and was replaced.
Clean out hydraulic power supply (HPS) reservoir, replace filters, fill with oil, and return to service.	The hatch to the reservoir was removed and the tank cleaned; all filters were replaced; the reservoir was refilled with the proper oil; and the HPS was returned to service in accordance with the manufacturers service manuals.
Clean/inspect table bearing ways, restore rusted surfaces to proper finish, and protect with a coating of oil.	The bearing ways were cleaned following procedure DS-KDE-71600-001, inspected and found to be in specification, and protected with a coating of oil.
Clean drip pans and pit hydraulic oil sump tank.	The drip pans and lines were flushed, and the sump tank was cleaned out.
Retorque all structural table bolts per table assembly schedule listed on drawing 355744-01.	The bolts were checked for tightness.
Inspect and purge nitrogen distribution system.	The nitrogen system was inspected and purged.
Pressurize nitrogen system to maximum operating pressure and check for leaks.	The nitrogen system was pressurized in 250-psi increments. At the first increment, a leaky rupture disc was found and replaced. At the second increment one of the nitrogen spring seals leaked and was replaced. At the third increment the other nitrogen spring seal leaked and was replaced. The system was then taken to 1500-psi and has been maintained there for several months with no sign of a leak. As soon as the gas booster pump is installed the nitrogen system will be taken to the maximum operating pressure (2000 psi) for final leak testing.
Replace all welded hydraulic system accumulators with new ones and charge with dry nitrogen.	All welded accumulators were replaced with new ones supplied by MTS and then pressurized to the correct operating pressure by the Mechanical Testing Organization.
Remove vertical support beam and reinstall vertical actuator.	The support beam was replaced by the actuator. Both the locking pins and the nitrogen support springs were used to support the table for this operation.

(Table 1. continued)	
Acitivity	Action
Flush system per PIE-97714-AX and prepare for normal operations.	Flushing kit was used to flush system as per specifications.
Inspect analog control systems for corrosion, etc.	All connections and circuit cards were cleaned and inspected.
Power up shaker system and perform start-up testing as described in system manuals.	Shake table system was started up, and the checkout was performed. An integrated circuit chip was found defective in the power-up interlock circuitry and replaced. An operational amplifier was found to be defective in the horizontal channel program control circuit and was replaced. Everything else in the analog control systems worked properly.
Refurbish the digital control system.	The digital computer was tested and started up by computer maintenance personnel. The interface power supply had to be replaced along with a memory board and other discrete items. The computer works well considering it is a late seventies DEC PDP-11/34.
Install computer operating software.	The magnetic tapes that the software was stored on during the shutdown period could not be read by the system. Attempts to read the tapes by several groups have been unsuccessful. Currently, the tapes have been sent to an outside contractor for further evaluation.