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**HAZARDS REPORT FOR
STEP TRANSIENT LOADING TESTS
ON THE SM-1 - TASK XII**

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ABSTRACT

This report evaluates hazards involved with SM-1 plant response and system performance tests (Task XII), to determine the response of the SM-1 plant to step electrical and steam load changes. The report describes the changes in plant equipment and operating procedures for this task and evaluates these changes for possible additional hazards to those described in APAE No. 2, Revision 1, "Hazards Summary Report for the Army Package Power Reactor SM-1."

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1.0 SUMMARY

The Task XII tests are described in general and equipment additions and modifications are discussed. Changes in operating procedures are given and postulated accidents analyzed. Based on this, the following conclusions have been made:

The Task XII tests to be performed do not introduce any hazard over and above those described in the "Hazards Summary Report for the Army Package Power Reactor SM-1," APAE No. 2, Revision 1. (1) The plant is operated according to standard operating procedure, modified where necessary to account for operation of an electrical load bank and a steam bypass system. The maximum heat stored in the primary and secondary systems is not increased; thus, there is no increase in the magnitude of the maximum credible accident hazard, nor is there any significant increase in the probability of its occurrence.

It is therefore recommended that the Task XII tests be conducted, in view of the ability to gain increased understanding of the SM-1 plant.

2.0 INTRODUCTION

The Army Package Power Reactor, now known as SM-1, was designed and constructed by Alco Products, Incorporated under Contract No. AT(11-1)-318 with the Army Reactors Branch of the U S. Atomic Energy Commission.

The SM-1 is a 10 thermal megawatt pressurized water reactor designed to meet the requirements and site conditions of a remote military base and is located at Fort Belvoir, Virginia within the boundaries of the Engineering Research and Development Laboratory. The plant is used for operator training, as a research and development facility, and to supply power to Fort Belvoir.

Task XII is one of a series of research and development projects to be carried on with this reactor. It is the aim of this report to describe the changes in the SM-1 plant equipment and operating procedures for these tests and to evaluate the hazards involved in these changes.

Work on this report was performed as part of Item 7.1 of the FY'61 Program for Engineering Support and Development of Army PWR Power Plants

3.0 TESTS

3.1 TRANSIENT ELECTRICAL LOADING

Step electrical load changes will be imposed on the SM-1 plant to obtain the transient response of both the secondary and primary systems. The response data will be compared to the analytically derived analog computer model transient data. (2), (3) The experimental data will be used to indicate methods of improving plant response and to revise the analytical methods of determining plant transients where necessary.

In order to simulate an isolated plant load condition, the electric generator will be disconnected from the large Fort Belvoir system and a portable resistance reactance electrical load bank will be used to absorb the SM-1 output. The load bank is capable of absorbing the full power output of the SM-1 generator in 200 kw blocks. The load bank connections are shown on the one line diagram, Fig. 1.

The transient response tests will be conducted according to the following schedule:

<u>Base Load %</u>	<u>Step Transient %</u>		
0	+10	+20	+30
10	+10	+20	+30
20	+10	+20	+30
30-70	+10	+20	+30
80	+10	+20	-30
90	+10	-20	-30
100	-10	-20	-30

Approximately 50 system parameters have been instrumented and will be recorded for the tests. Test Procedure A-700 covers the details of these tests which are discussed in detail in AP Note-398. (4)

3.2 TRANSIENT STEAM BYPASS LOADING

Steam bypass tests will be conducted to determine the feasibility of a system which would permit the testing of the reactor and steam generator portions of a nuclear power plant independently of its turbine generator.

The steam bypass system is capable of dumping 100% of the SM-1 rated steam flow directly into the condenser. Two control valves in parallel on the

Figure 1. One Line Diagram with Electrical Load Bank

steam dump line permit base steam loads and step changes in steam demand to be imposed on the steam generating system. The steam bypass line can be seen in Fig. 2.

A transient steam demand test will be made for each of the electrical demand tests previously run. The steam loading changes for the steam demand tests will be the same as the steam loading changes observed during previously conducted electrical demand tests. Base loads will be established with one steam bypass valve. The transient load will be applied by quickly opening the other bypass valve to a predetermined position.

Plant parameters to be recorded and a detailed test procedure may be found in Test Procedure A-701 and AP Note-398. (4)

Figure 2. Steam By-Pass Line

4.0 EQUIPMENT ADDITIONS AND MODIFICATIONS

4.1 TRANSIENT ELECTRICAL LOADING

A portable resistance-reactance electrical load bank has been installed at the SM-1 site. This is an air-cooled assembly of resistance and induction reactance elements which are arranged so that they can be applied to, or removed from, the output of the SM-1 generator in power absorbing blocks of 200 kw each.

A modification of the turbine was necessary because both the electrical and steam tests will be conducted with the main steam line pressure reducing valve blocked open. The turbine throttle pressure will therefore, vary over a range of 190 psia to 425 psia, rather than remain approximately constant at the 200 psia design condition. Modifications were made to the steam turbine throttle valve, turbine steam chest, first stage turbine wheel, valve assembly and nozzle plate and spacer to accommodate the increased steam pressure.

A moisture separator has been installed in the main steam line upstream of the turbine throttle valve to give additional protection to the turbine in the event of excess moisture carryover from the steam generator during load increase transients.

Instrumentation has been added to provide transient data. Each of 50 selected system parameters have been instrumented so that its behavior can be sensed, transmitted and recorded immediately before, during, and immediately following the application of scheduled step load changes on the plant. (4)

Oscillograph recorders have been installed in the control room to record each parameter behavior during the transient loading changes. In addition, the load bank control panel has been installed in the control room.

Additional thermocouples have been installed in the primary and secondary systems. Additional electrical conductors have been installed through the existing vapor container penetrations. These penetrations were helium leak tested after the conductors were installed and determined to be in compliance with the original leak rate specifications.

The safety valve on the steam line outside the vapor container has been removed and the opening blanked off. The turbine pressure rating has been increased so that it no longer needs the protection of this valve. Full steam system protection is now afforded by the safety valve at the steam generator.

4.2 TRANSIENT STEAM BYPASS LOADING

A steam bypass system has been installed to bypass the turbine and dump steam directly into the condenser. This system is designed for applying steady state or transient loadings to the steam generator without the necessity for converting thermal energy to electrical energy through the turbine generator. The steam bypass line contains a flow measuring orifice, two parallel pneumatically operated control valves, a desuperheater and other necessary valves and controls. The control valves are pneumatically closed and "fail open." It is recommended that these valves be redesigned to use "air to open" and "fail close." This would make these valves into fail-safe devices. The steady state and transient steam flow rates are imposed by opening the control valves to pre-calibrated positions. The desuperheater mixes cooling water with the steam after it leaves the control valves to remove the expansion-induced superheat from the steam.

Steam bypass line instrumentation has been installed in the control room to continuously record and control the steady state and transient load tests. A 6-in. steam extraction line has been installed from the steam bypass line at the desuperheater exit to the third stage extraction line from the turbine. This piping addition is to provide feedwater heating during the transient steam loading tests when the turbine is not supplying extraction steam. The basis for this addition is to preclude the possibility of thermal shock at the steam generator feedwater inlet and to insure feedwater temperatures which approximate those occurring when the turbine generator is operating to produce power.

At the higher steam flow rates, pressure drops will occur when the steam passes through the perforated exit headers of the steam bypass line and expands to condenser pressure. The superheat induced by this expansion will be approximately 80°F and a water spray nozzle is installed in the condenser over each of the two perforated headers to knock out this superheat. This precaution is taken to assure that no excessive temperatures are applied to either the condenser tubes or to the turbine exhaust stages.

5.0 CHANGES IN PLANT STANDARD OPERATING PROCEDURES

The plant will be operated in general in accordance with the standard operating procedures. (5) Special operating procedures for the tests have been written in the A-700 and A-701 test procedures. (4) These procedures cover the following:

For the transient electrical load tests:

1. Operation with the main steam pressure reducing valves fully open.
2. The isolation of the electric generator from the Ft. Belvoir tieline and the connecting of the output terminals to the load bank.
3. Starting and operating the plant with station service load supplied from the Ft. Belvoir tieline via the construction pole line.
4. Operation of the load bank.

For the steam bypass load tests:

1. Operation with the main steam pressure reducing valves fully open.
2. The isolation of the electric generator from the Ft. Belvoir tieline and the connecting of the output terminals to the load bank.
3. Starting and operating the plant with station service load supplied from the Ft. Belvoir tieline via the construction pole line.
4. Dumping steam to the main condenser.
5. Operating the turbine at minimum speed under governor control with no load on the generator.
6. Operating both condensate recirculating pumps - one for normal cooling; one for condenser spray and desuperheater cooling.

6.0 OPERATING PRECAUTIONS

6.1 TRANSIENT ELECTRICAL LOADING

The electrical load bank is fenced off with warning signs to preclude inadvertent entrance during operation. A KIRK interlock system prevents entrance to the high voltage compartments until the load bank has been isolated from the 4160-volt ring. ⁽⁴⁾ The 480-volt services to the load bank are not, however, de-energized by the KIRK interlock system. The 480-volt disconnect switch in the electrical equipment room is to be opened before making repairs or adjustments to the load bank.

Personnel performing the tests will coordinate the switchover to construction power with the post engineer.

6.2 TRANSIENT STEAM BYPASS LOADING

The turbine will be warm and rotating at minimum speed under governor control before the steam dump line is operated.

The steam dump line will be drained and slowly warmed to prevent hydraulic and thermal shock.

During steam transients from a zero base load, the feedwater heater extraction line from the desuperheater will be closed. This will prevent any possibility of shock to the feedwater heater.

7.0 POSSIBLE HAZARDS INTRODUCED

7.1 STEAM GENERATOR FAILURE

7.1.1 Operating History

Comparison of the design criteria of SM-1 with the actual operating history since initial startup shows that Task XII will impose less severe stress conditions than those for which the steam generator was designed and those it has already withstood many times without damage.

The SM-1 was designed to the general service lifetime criterion of 20 years. The primary system was designed on the basis of continuous operation over the 20-yr period with only two complete shutdowns each year -- one for scheduled maintenance and refueling, and the other for an inadvertent failure of some critical item of equipment. This criterion is based on normal power plant design practice.

Since startup in the spring of 1957, the SM-1 has been used as an operator's training facility besides its other functions. The training program requires that the plant be started up and shut down many times each training shift. The plant has been started up and shut down thousands of times, many of these involving cooling down to 350°F and several cooldowns to room temperatures have been made. Additional thermal and mechanical shocks were imposed on the steam generator during transient load tests conducted during January and February, 1958. Several of these transient tests imposed more severe conditions of thermal and mechanical shock on the steam generator than those imposed for Task XII. The maximum load transient schedule under Task XII will be + 30% from a base plant output. A maximum of 32 transient tests having this magnitude of load change are contemplated.

On the basis of operating history to date, there appears to be no reason for major concern regarding thermal or mechanical shock to the steam generator during the Task XII testing. In light of concern over a steam generator failure, however, the results of postulated accidents have been considered and are evaluated in the following sections.

7.1.2 Pin Hole Leak

A pin hole leak in a steam generator tube would be detected by the radiation monitor in the blowdown line before two liters of primary coolant had leaked into the secondary system. (6) If such a leak did occur, the plant would be shut down according to standard operating procedures with no resulting hazard to operating or off site personnel.

7.1.3 Tube Failure

A tube failure in the steam generator is considered a remote possibility. The possibility is in no way increased due to the Task XII tests.

In the unlikely event of a tube rupture, several alarms and scrams will operate. These are the pressurizer low level alarm, pressurizer low pressure scram, boiler high pressure alarm, and boiler high pressure scram. The steam generator safety valve opens into the vapor container at 500 psig to protect the steam system from over-pressure. In such an event, the operator will proceed to shut down the plant according to standard operating procedure.

7.1.4 Tube Sheet Failure

A tube sheet failure is considered to be the worst and the least likely steam generator failure. If the tube sheet should fail, the steam generator shell might split and release the contents of both the primary and the secondary systems to the vapor container. This type of accident has been evaluated under the maximum credible accident section of the SM-1 Hazards Summary Report. (1) This summary hazards report states that the containment vessel is designed to contain a release from both the primary and secondary systems.

It should be emphasized that the Task XII tests do not significantly increase the likelihood of this accident over and above that for normal heatup and cooldowns of the system.

7.2 THE LOAD BANK INSTALLATION

The load bank area will be fenced to exclude personnel during periods of operation. If repairs are necessary, an interlock system will be in operation to prevent entrance to the load bank housing before 4160-volt power is shut off. The fenced area around the load bank provides sufficient distance from the hot exhaust air to insure safety of personnel outside the fenced area.

7.3 UNSTABLE VOLTAGE AND FREQUENCY GENERATION

Unstable voltage and frequency control of the main generator will have no effect on the plant operation because the generator is operating isolated from the plant. Reasonable voltage swings and frequency changes will not injure the load bank or connected load system. Extreme voltage swings would indicate the voltage regulator is not operating properly and must be repaired or replaced. Extreme frequency changes indicate that the turbine governor is not operated properly and must be adjusted or repaired before continuing the tests. An analog computer model study as discussed in APAE Memo No. 290(3) revealed that no excessive excursions in plant output voltage and frequency are expected to occur during Task XII tests.

7.4 NEW ELECTRICAL CABLES PENETRATING THE VAPOR CONTAINER

Additional electrical conductors have been installed through the existing vapor container penetrations. These penetrations were helium leak tested after the conductors were installed and determined to be in compliance with the original leak rate specifications. The integrity of the vapor container is therefore guaranteed.

7.5 FAILURE OF NEW THERMOCOUPLE WELLS AND PRESSURE TAPS

Thermocouple wells and pressure taps are welded into secondary and primary system piping. Welds were dye penetrant checked and the system piping, containing the installed welds, has been hydrostatically tested. Thus the integrity of these systems has been maintained.

7.6 INSTALLATION OF NEW THERMOCOUPLE WELLS AND PRESSURE TAPS

The problem of debris entering the piping systems from the installation of new thermocouple wells and pressure caps has been solved. The primary system penetrations are thermocouple wells only and were installed according to special procedures which required careful drilling through the pipe wall and the pressurizing of the internal pipe volume to a pressure sufficient to preclude the possibility of entry of metal chips.

Penetrations of the secondary system were made according to standard installation procedures. Special precautions to exclude debris were not necessary because the plant installation procedures required a thorough cleanout and flushing before closing up and returning to power.

7.7 EXCEEDING CORE SAFE OPERATING LIMITS

An analog study has been made to determine the effects of step load changes on the primary system parameters. ⁽⁷⁾ This study states that power peaking during the Task XII tests, even with the worse combination of hot channel factors, will not exceed safe operating limits.

8.0 TASK XII INFLUENCE ON THE MAXIMUM CREDIBLE ACCIDENT

The Hazards Summary Report for the SM-1 plant (APAE No. 2, Revision 1⁽¹⁾) describes the maximum credible accident. This description defines a sequence of events and postulated failures leading to a maximum energy storage condition in both the primary and secondary plants. It then postulates the instant release of all this energy into the vapor container through a failure in the main coolant piping and a rupture in the steam generator shell. The vapor container is designed to confine this maximum energy release.

The tests to be conducted in the Task XII series in no way increases the maximum credible energy release and therefore, in no way, increases the maximum credible accident hazard.

9.0 CONCLUSIONS

The tests proposed for Task XII do not impose transients that are significantly greater than those imposed during normal training operation. The tests will be conducted with extensive instrumentation and supervision. The operating procedures call for all normal, plus extra, precautions for the additional operations.

The hazards involved in Task XII tests have been reviewed in light of APAE-106, "Criteria for Evaluating Hazards Involved in Proposed Tests on and/or Modifications to the SM-1". (8) Task XII tests in no way violate the principles of APAE-106 except with respect to the steam dump valves, where a design change has been recommended in the body of this report.

The Task XII tests do not increase the magnitude of the maximum credible accident; nor is there any significant increase in the probability of its occurrence.

It is thus recommended that the Task XII testing be conducted in view of the increased understanding of the capabilities of the SM-1 that will result.

10.0 REFERENCES

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