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**REACTOR SHIPPING
DEMONSTRATION PROGRAM**

MASTER

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**Astronuclear Laboratory
Westinghouse Electric Corporation**

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1. Summary

This memo outlines the program for demonstration of the feasibility of assembled NERVA reactor shipment.

The only major unresolved question regarding shipment of assembled NERVA reactors has to do with the ability of the reactor to stand the shock and vibration of shipping. A three part program intended to answer this question has been planned and initiated. The three parts are:

- a. Collection of Information on Past Shipments of Assembled Reactors -
This will establish practices which have been successfully used and take advantage of existing experience.
- b. Analysis and Testing of Reactor Components - This work will be aimed first at evaluating the shock and vibration effects to which the individual reactor parts will be subjected during shipment. A component testing program will then be carried out to determine the ability of the reactor parts to withstand this shock and vibration environment without damage.
- c. Shipments of Simulated Reactor - Actual shipments will be made to measure and record the shock and vibration to which the reactor as a whole is subjected during shipment.

2. Phase I - Collection of Information on Shipment of Naval Reactors

A very substantial body of information and experience exists covering shipment of Naval Reactors by special train. Many of the things which can be learned from this source would otherwise be learned only by actual experience. It is believed that much of this information is pertinent and applicable to our shipping problem. Possession of it will lessen the chance of our making errors and will save effort.

Examples of specific types of information desired are listed below:

- a. Shock and Vibration Data - Actual accelerometer records are desired of the shock and vibration accelerations which were experienced at various points on the rail car and the trailer which were used to ship the Naval Reactors. It is also likely that masses of such data have been summarized for use as a design guide. Such summaries would be of help to us.
- b. Detailed Shipping Procedures
- c. Shipping Crew - Information of the makeup, duties, and training of the crew would be a useful check.
- d. Equipment - Specifications or descriptions of equipment used in shipping Naval Reactors would be useful. Items of interest include rail cars, trailer-trucks, tie-downs, cranes, lifting fixtures, radiation and safety equipment and security equipment.

Information of this sort exists at the Pittsburgh Operations Office of the Atomic Energy Commission and at Bettis Field. We must obtain it through our contract channels. R. Wilke of SNPO-C has agreed to go through channels to the AEC to get permission to meet with AEC personnel and obtain the information desired.

3. Phase II - Analysis and Testing of the Reactor and Its Components

It must be demonstrated that the shock and vibration accelerations transmitted to the entire reactor are below the specified reactor design values. In addition to this it must be shown that the individual reactor components and subassemblies can withstand shipping without damage.

One way to obtain the above demonstration is by a program of analysis and experimentation on individual reactor components. WANL is already engaged in such a program of shock and vibration analysis and test.

This program is being coordinated with other phases of the shipping demonstration in the fashion described in the following paragraphs.

- a. A detailed review of the reactor design is being conducted to select components which might be possible trouble areas in shipment.
- b. The available data on the shock and vibration environment to be encountered during shipping will be reviewed. The purpose of this review is to determine the expected shock and vibration input to the whole reactor. The data which will soon be available from Applied Design tests of the shipping container will be included in this review. An analysis of the shock and vibration environment to be expected is in progress. It will cover the dynamic effects on the container resulting from operation of the special train.
- c. Analysis is being made to determine the attenuation or amplification of vibration and shock within the reactor. It is possible that certain individual reactor parts will be undergoing greater vibration acceleration than the reactor as a unit due to differences in natural frequency and damping.

- d. Experiments will be conducted to verify that the individual reactor parts can withstand the expected vibration and shock. With information from parts a, b, and c above, it will be possible to design experiments which will reasonably duplicate the major influences of shipment on the affected reactor components. Data from these experiments will warn us of possible troubles or eliminate concern.

Tests of the Phase I vibration reactor will of course be more conclusive than experiments with individual components. The results of most of these tests should be available before the shipment of NRX-A2.

4. Phase III - Shipment of Simulated Reactor

This section describes the objectives, plans, and schedules for the first two shipments of a simulated reactor from WANL to NRDS and return. The purpose of these shipments is two-fold. First, they will afford actual shipping experience, and second they will give specific data on the accelerations encountered by the reactor as a unit during shipment.

a. Reactor Shipping Container

The reactor shipping container is presently undergoing tests to verify its shock attenuation characteristics. This shipping container consists of an inner container shock mounted in an outer container. Accelerometers will be mounted on all three axes of both containers. They will record the shock accelerations imposed on the outer container, inner container, and a simulated reactor inside the inner container. The simulated reactor is a rigid solid having the same size, shape, weight, and center of gravity as the actual reactor.

The tests will consist of three major parts: drop tests, rail impact tests, and road tests. The objective of these tests is to verify that the shipping container can attenuate the imposed shock accelerations to amounts safely below reactor design values. The road test will yield data on vibration and shock for the container mounted on a trailer and tested under varying road conditions. More detailed information on the container and its tests can be found in the Applied Design Company report which will be issued after completion of the container testing.

b. Rail Shipment of Simulated Reactor

It is planned to ship the simulated reactor in the instrumented reactor shipping container from WANL to NRDS and return.

This shipment will provide valuable experience for future shipments of actual reactors. It will provide necessary experience to the crew responsible for

b. Cont.

the shipment. It will also serve as a practical test of equipment to expose unforeseen deficiencies.

The shipment will also give us data on the vibration and shock environment imposed on the reactor during rail shipment. Acceleration recordings on all three axes of the inner and outer containers as well as the vertical acceleration of the center of gravity of the simulated reactor will be taken. These records will cover all phases of the trip. The recording equipment will be in operation at all times when accelerations could conceivably be experienced by the container. This includes all periods of motion of rail car or trailer, any coupling or uncoupling of the train, and transfer from trailer to train and vice versa. The records pertaining to the accelerations of the inner container and the simulated reactor can then be compared with the design values of acceleration for the actual reactor. In addition, the records can be compared with the whole reactor accelerations used as the basis for the component test program outlined in Phase II.

A brief outline of the plan for the simulated rail shipment is as follows. The simulated reactor, enclosed in its instrumented shipping container, will be delivered to WANL on a trailer truck. At WANL a rail car will be prepared for the shipment. Upon arrival of the container, it will be transferred by a mobile crane from the trailer to the prepared flat car. The container will then be secured to the car. Instrumentation will be installed on the rail car and carefully checked. The car will then be moved out of WANL and taken by an engine to a convenient point where the train will be made up and prepared for the trip. The special train will consist of an engine, pullman, reactor car, flat car for the tractor-trailer, and train crew caboose.

The special train will travel to the freight yard at Las Vegas, Nevada. Enroute, stops will be made to change crews.

b. Cont.

At Las Vegas, the tractor-trailer will be unloaded and positioned for transfer. A mobile crane will be used to transfer the reactor container from the rail car to the trailer. The container will be secured to the trailer and the trip to the MAD Building will be made. The container will not be unloaded at MAD, since this is not a test of the handling equipment there. The return trip to Las Vegas will then be made and the container will be transferred to the rail car. The tractor-trailer will then be loaded on the train and the return trip to Pittsburgh will be made. Acceleration data will be accumulated on the return trip in the same fashion as on the outbound trip. In this way, more applicable data will be available for examination.

In the Pittsburgh area, the reactor car will be separated from the train and returned to WANL for unloading.

c. Over-the-Road Shipment of the Simulated Reactor

It is planned to ship the simulated reactor in its instrumented container from WANL to the MAD Building and return. This shipment will be made on the special NERVA trailer.

This shipment is intended to accomplish the following:

1. Obtain Experience for the Shipping Crew - It is desirable for the crew to have participated in more than one practice shipment before the first actual reactor is shipped to NRDS. In addition, this shipment will be the first over-the-road shipment to NRDS. Experience will be gained in this type of transport.
2. Test the NERVA Shipping Equipment - The shipment of the simulated reactor by rail must be made without the NERVA trailer because it will not be available at the time this shipment is made. The over-the-

2. Cont.

road shipment will be an excellent test of the equipment under actual conditions. It will demonstrate adequacy of the equipment for the purpose or point out any areas where changes are needed.

3. Pave the Way for Later Truck Shipments - As has been pointed out in the section on evaluation of shipping methods, truck shipment affords significant economies. We wish to make this mode of shipment available.

Shipment of an assembled reactor by truck along this route has no precedent. It has been pointed out that there may be objections by state or local authorities to shipments of this type passing through their area. Shipments approved by the Atomic Energy Commission and meeting the applicable Interstate Commerce Commission requirements are legally permissible. In spite of this, if objections are raised, significant delays might be encountered before matters are straightened out. This shipment will give an indication of any difficulties of this type which might be encountered. It will also serve as an exercise in obtaining the necessary wide load permits.

The sequence of events to be followed in this shipment is given in the paragraphs to follow.

The tractor-trailer unit will be prepared for the shipment and operation of all the equipment will be checked out. Short trips in the Pittsburgh area will be made to gain some assurance that the arrangements are adequate for the trip before we begin it. The shipping container, simulated reactor, and instrumentation will also be prepared for the trip.

The container will be loaded on the trailer and secured. Recording equipment will be connected and checked out.

c. Cont.

As in the case of the rail shipment, the acceleration recording equipment will be in operation at all times during the trip when accelerations might be imposed' on the container.

The tractor-trailer with escort vehicles leading and following it will then travel to the MAD Building. All necessary permits for travel will have been obtained. All state and local regulations will be observed.

On arrival at the MAD Building, preparations will be made for the return trip. The container will not be unloaded at the MAD Building.

The return trip to WANL will be made in the same way as the outbound trip. Acceleration recordings will be maintained in the same way.

5. Evaluation and Selection of Shipping Method

Three methods of shipping the assembled reactor to the test site are available. These are: special train, escorted trailer-truck, and airplane. Each of these methods was investigated with respect to shipment of NRX reactors.

a. Factors Considered in Evaluation

A number of points were considered in the evaluation and comparison of the various method of shipping. Shock and vibration was the first of these.

The evaluation convinced us that the shock attenuation of the shipping container is adequate to protect the reactor from the expected shock and vibration of shipment.

Shock and vibration environment and its probable effects on the reactor is undergoing continuing study. A separate report to be issued later will cover this topic.

Experience in shipment of assembled reactors is an important point to consider. The Snap Reactor Program has plans to ship assembled reactors by truck. The Naval Reactors Program, however, is the only program with extensive experience in shipment of assembled reactors. These reactors were all shipped by special train. Shipments of naval reactors by rail have been taking place since 1953. There is nothing in their experience to date that would indicate any serious problems in shipping NRX reactors by special train.

a. Continued

The handling requirements of the various types of shipments were considered. It was found that the methods and equipment exist for loading, unloading, and transferring the shipping container from a trailer-truck, train or airplane. Handling is minimized by use of a trailer-truck. Delivery to the MAD Building in Nevada must be made by truck, so this is the only method of avoiding intermediate transfers.

Adequate methods for securing the shipping container to the vehicle exist for airplane, truck and train shipment. The "tie-down" arrangements for truck and train will be tested in the acceptance testing program for the shipping container.

The time required for shipment is an important point since the progress of our program is presently paced by shipment as well as other factors. Later on in the program this will probably be much less important, however. The total elapsed time for shipment by special train has been estimated to be between four and five days including the transfers and truck travel at both ends of the trip. The total elapsed time for shipment by truck has been estimated to be between seven and eight days. This comes about because the shipping container constitutes an overwidth load. In most cases, the states along the route will exclude travel after dark and on weekends. Travel by airplane is considerably faster. The time required will be between one and two days including the truck travel and transfers at both ends of the trip.

a. Continued

The cost of shipments is different with each of the methods of shipping considered. The Pennsylvania Railroad has estimated the cost of a one-way trip to Las Vegas by special train to be between \$23,000 and \$26,000 depending on the specific arrangements desired. The return trip for the empty container by trailer truck will cost about \$1,800. The cost a truck shipment to Nevada and returning the empty container via truck is estimated to be about \$3,600. Air shipments would be made via Military Air Transport Service. Costs are not readily available, however one dollar per ton mile should more than cover the costs of MATS. At this figure, the one-way trip would cost \$25,000. None of these estimates include the cost of WANL manpower. They cover only the use of the road or rail equipment and are only for comparison purposes.

The limitations on height, width and weight are different for each method of shipment. None of them appears to cause any serious problems in shipment however. In rail shipment if the load height is held to 17 feet above the rail tops, convenient routing is available. The height of the shipping container mounted on the rail car is 15 ft. 2-1/2 inches.

a. Continued

The height of the container mounted on a special drop center trailer will be less than 13 ft. 6 inches. This will give adequate height clearance for road shipment. The container maximum width is 10 feet. This is in excess of the 8 foot maximum width for unrestricted travel. In most states, it will not be allowed to travel at night or on weekends. Height and width limitations for air shipment come from the dimensions of the cargo door. The C-133 aircraft cargo door is 12 ft, 6 inches high and 12 ft., 2 inches wide. The shipping container is 11 ft., 8 inches high and its maximum width is 10 feet.

b. Conclusions Reached

The most important conclusion reached in the evaluation of shipping methods is that all three methods considered are safe, practical and satisfactory.

The method chosen for the first few shipments is the special train. This method was chosen mainly because it is a means of shipment for which a considerable amount of experience exists. The Reactor Development Division of the Atomic Energy Commission have in the past approved several shipments of assembled reactors by special train. No special permits are required by the states or municipalities. Train shipment will save about three days time compared with truck shipment. It is felt that these advantages outweigh the extra cost of train shipment for the first few reactors.

b. Continued

Later in the program when time of shipment has less of an effect, it is believed that the economy of truck shipment will make it preferable to rail. For reactors on which speed of delivery is important, air shipment will probably be used. Obtaining approval of the Atomic Energy Commission for air shipment will be a more lengthy process than for rail or truck shipment.