ANNEX I-3

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EXPERIENCE ON RELIABILITY OF INSERTION OF CONTROL ROD WITH PWRs IN JAPAN

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1. Foreword

There are 47 units of operating light-water type nuclear power plant, currently in Japan. Among them, 25 units are of the BWR type and 22 units are of the PWR type. Either types show good performance and high reliability, and they scarcely had experienced with troubles related to insertion of control rod.

This paper is prepared to introduce, in response to the IAEA Letter dated 1995-02-08, national experience concerning to the reliability of insertion of control rod with PWRs which is relatively similar to WWER 1000.

2. Experience with increase of control rod drop-time, rod sticking, or mispositioning of control rod

1) There was a case in 1985, that the spider vane and spider body of a control rod cluster was separated at the blezed (soldered) joint.

The plant was shut down for annual inspection and planned refueling.

During shutdown operation, any particular behaviour of the control rod movement was not recognized. (Fig-1)

After removing the Reactor Vessel Head, the upper part of the fuel assembly was inspected visualy prior to the refueling operation. Inspection revealed that one of the spider vane was separated from the spider body.

The defective part was investigated, and any dimensional defect was not identified in any part of the vane, and the fracture surface between the spider body and the vane indicated that some exessive force would had been applied to the vane to body joint.

It could be considered that an excessive force which separated the vane to body joint was caused by to the interference between Control Rod and Guide Tube by invasion of some foreign material between them.

The dismounted spider vane with two control rods, found on the top nozzle of the fuel, was stored properly in the fuel control rod guide thimble, and insertion of the control rod cluster was not affected, fortunately.

If the dismounted control rod were not lowered properly in the fuel, the movement of the control cluster might have been interrupted.

From this experience, we learned that even a small particle or debris would cause the mulfunctioning of the control rod.

3. Special operating regimes established(short and lonng term)

Any operation with degraded control rod insertion capability has not been experienced.

Therefore any special operating regimes has not been established, yet.

4. Safety Analyses carried out

Any safety analysis has not been carried out on the assumption that the operation is continued under incomplete capability of control rod insertion.

5. Measures implemented

For Item 2 above, inspection and control of foreign material or loose parts are more strictly implemented. Even though the quality of the joint between the spider vane and spider body was not attributed to the problem, recent manufacture of spider body eliminates the blazed joints by applying precision casting or wire cut from the forging.

For items 3) and 4) above, any measures have not been implemented.

6. Control Rod testing applied during construction

The following tests are conducted during manufacture and construction of the control rod drive line component.

1) Each Control Rod Drive Mechanism is tested on the test loop for operating performance and the current shape of the actuating coil is recorded.

2) After manufacture of the Control Rod Cluster Guide Tube, the cluster gauge is passed through it one by one, and the friction force is measured to confirm that it is within the specified limit.(Fig-2)

3) After assembling of the Control Rod Cluster, each assembly is inserted to pass through the Guide Tube Gauge, and the friction force is measured to confirm that it is within the specified limit.

4) After assembling of the fuel assembly, the control rod cluster gauge (dummy Control Rod Cluster)is inserted to pass through the fuel assembly, and the friction force is measured to confirm that it is within the specified limit.

5) After assembling of the Upper Core Internal Structure, the Control Rod Cluster Gauge is inserted to each Guide Tube, and the friction force is measured to confirm that it is within the specified limit.(Fig-3)

The tests items 2) to 5) above are conducted under dry condition.

6) After the completion of installing Reactor Vessel, Core Internal Structure, Fuel Assemblies, Control Rods, and Control Rod Drive Mechanisms, the control rod drive line test is conducted.
Judgment of the sound operation is made through the current shape and acoustic information on the oscillography, etc.

The test is conducted at both low temperature and hot condition with and without coolant flow.

7) During the test of item 6) above, the control rod drop test is conducted.
The drop-time of the Control Rod is measured to confirm the compliance to the requirements.

8) During the plant operation, the stepping test of Control Rod is conducted to confirm the proper movement.
In this test, the drop-time test is not conducted.

7. Criteria for forces to move Rod

Forces should be predetermined by experiment.
Actual value depends on the gauge and the test aparatus.
As a reference value, forces may be in the order of kilograms.

8. Shape changes of Fuel Assembly

Some deformations of fuel assembly after irradiation have been experienced. Most cases of fuel assembly bow were observed in banana shape, and the amount of deformation was less than 10 mm. However, this amount does not affect to prolonging the drop-time, mispositioning nor sticking of a control rod cluster.
S-shape deformation was rarely observed. Some experiment indicated that the deformation of less than 5 mm in S-shape does not cause any effects on the insertion capability of the control rod, either.

9. Chemical sediments discovered

There was no such a case that clad was deposited whereby drop-time of a control rod became longer or the insertion of control rods was interrupted.

10. Role of friction and wear

1) It can be obtained from analysis that the more a frictional force is increased, the more a drop time is increased. As the result of analysis

and tests, it was indicated that the frictional force was increased to such a degree as the drop-time was affected when the amount of deformation was increased over 15 mm in the banana shape.

2) The wear of control rod by insertion and extraction has not been experienced before.

There were some cases that a control rod were worn during stand still condition at the intersection of the card plate of a Control Rod Cluster Guide Tube caused by fretting. However, any affection on drop-time or insertion problem was not observed.

11. Dependence of rod mispositioning on fuel cycle length

Any mispositioning of control rod was not experienced as mentioned above. Most cases, the deformation of the fuel assembly was observed after the first cycle, but was not increased so much in the second and third cycles.

One of the reasons for this, we suppose, is that the fuels are completely shuffled in each refueling operation, and irradiation of a fuel is not made at the same core location for more than one cycle. This may have some effect on avoiding the accumulation of the deformation due to irradiation.

12. Regulatory requirements to be posed on the operation of an affected plant

The operation has not been conducted with degraded capability of the control rod insertion, so far. Therefore, Safety Analysis of such cases have not been performed.

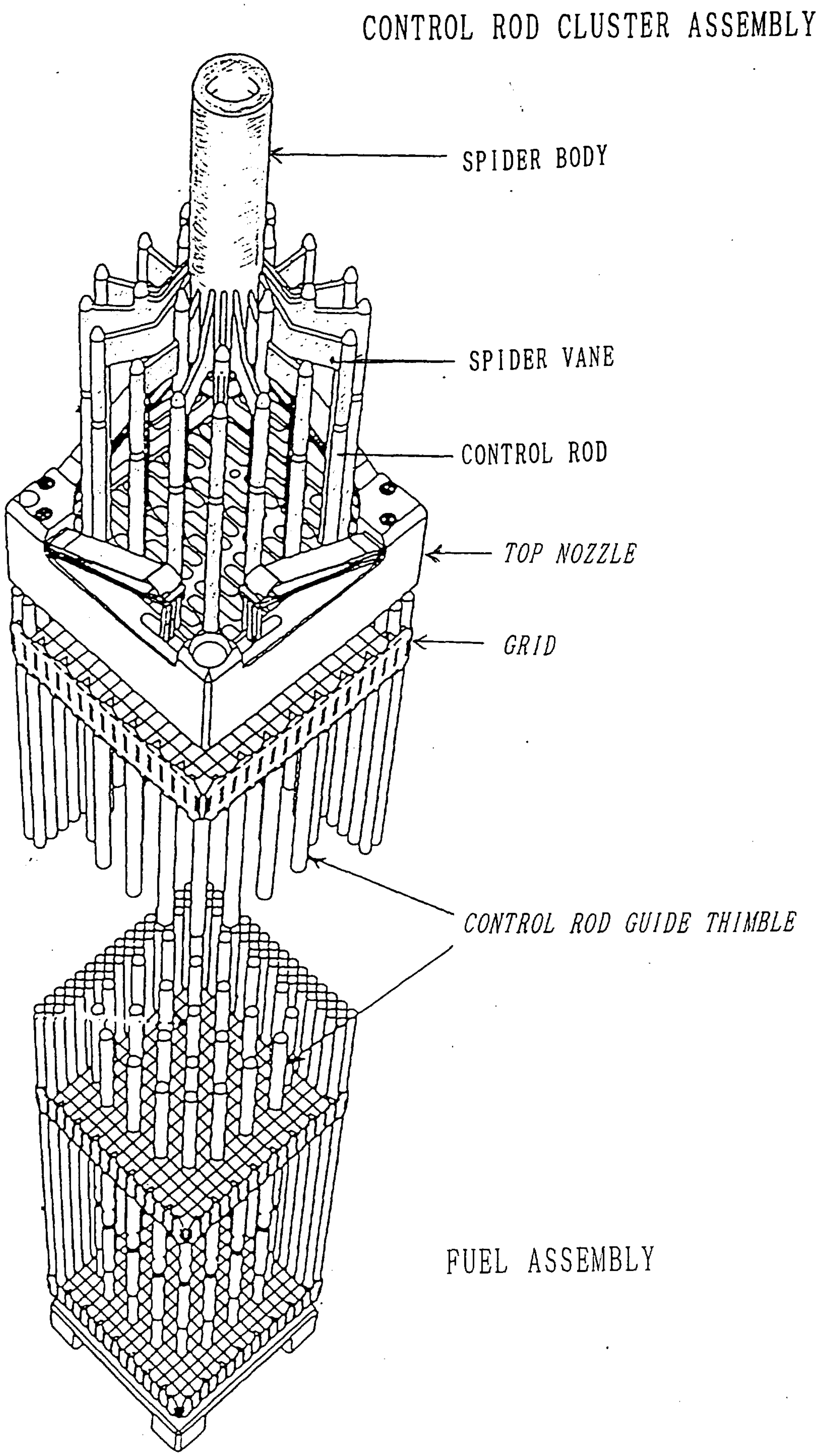

Fig-1 *FUEL ASSEMBLY* AND CONTROL ROD CLUSTER

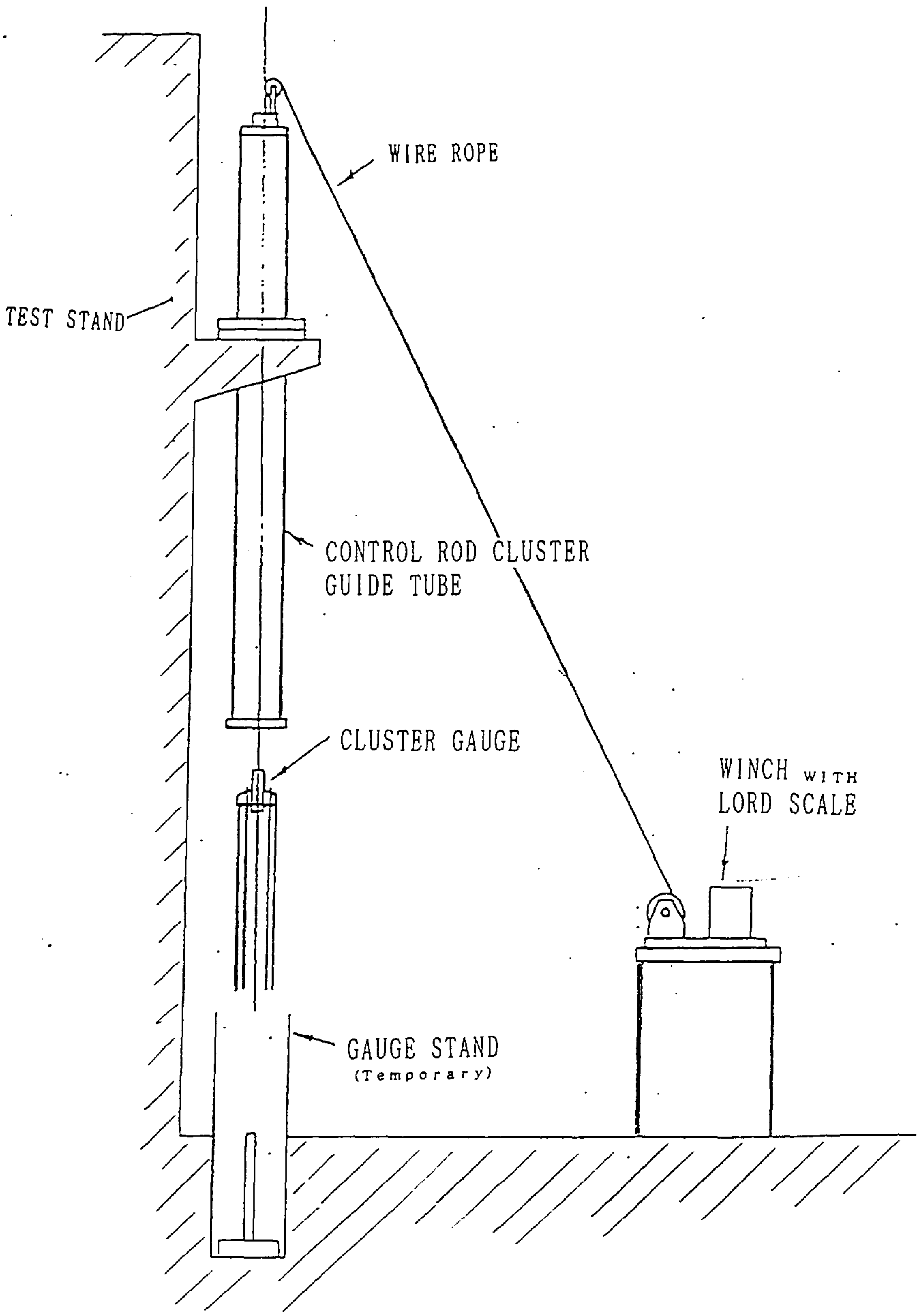

Fig-2 FRICTION TEST FOR
ROD CLUSTER GUIDE TUBE

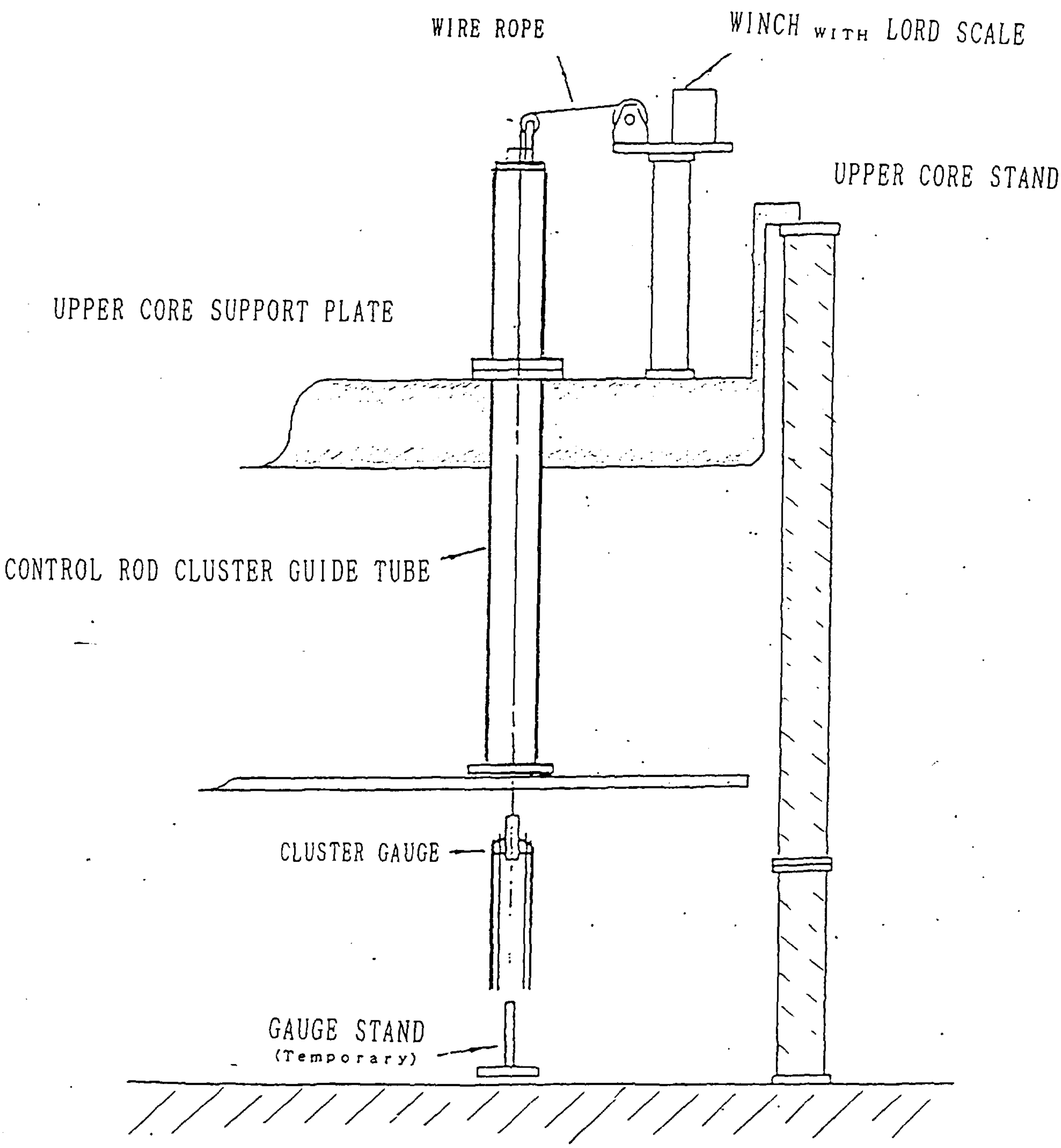

Fig-3 FRICTION TEST ON UPPER
CORE SUPORT STRUCTURE