a range of instruments. In this case a plausible explanation is that a tube to tube plate weld has cracked and opens up each time steam or damp Argon is introduced at pressure, but when low pressure static steam is introduced then something like magnetite blocks up the hole each time. Whatever the explanation opening up and closing the leak are repeatable events. Also there have been no step changes similar to those reported in the increase in size of some micro leaks in rig experiments and the indications are that the relative rate of opening up of the hole has been fairly small. The programme now is to take off the steam header to expose the tube plate and if necessary the whole of the tube bundle can then be taken out. However, the present proposal is to leave sodium in the circuit and only cool the system until people can work on the tube plate (say 100 - 120°C). A system is being designed and equipment is being provided by the Design Office organisation which is based on putting plugs in each end of a U tube and passing gas (hydrogen, nitrogen, Argon or say one of the commercial mixtures of argon with about 10% hydrogen) up to the full pressure of 2500 psi in between the plugs. The installed hydrogen detection equipment or other gas detectors in the gas space will be used to detect when the leaky tube has been found. The problem is that with 500 tubes to examine putting in the plugs, pressurising and waiting for the detecting system to respond is obviously going to be a long and tedious business. A series of alternative methods of detecting the leak have been considered and compare favourably with other suggestions made at the conference. It is hoped that one of these methods which will be quicker than the pressurisation technique will allow the leak to be located without delay.

K.2. Leakage Experiences with 1 MW Steam Generator

A. Kanamori
M. Kawara
A. Sano
Japan

INTRODUCTION

1 MW steam generator was tested from October, 1971 and completed with the first series of experiments by May, 1972 after 3600 hours of operation. During these tests, unextrodinary heat absorption was experienced in the downcomer region, which led to shortage of heat transfer area to attain the rated steam temperature and to one of the reasons of flow instabilities.

The steam generator was disassembled to get test pieces for structure as well as material examinations and then it was reassembled to proceed the second series of tests. Before it was done, a modification was provided to insulate the downcomer region by putting a gas space arround the downcomer tube. The gas space was provided by a dual tube and spacers were welded on the inner tube and an end plate was welded on upper parts between the two to seal the gap by means of fillet welding.

After the modified steam generator was put into operation, water happend to leak into a sodium side two times through these additional welding spots for the gas insulation. This paper presents operating conditions and behaviors of monitors at the time of the leakages, identifications of leaked spots, an evaluation of causes and a treatment or a precaution for them.

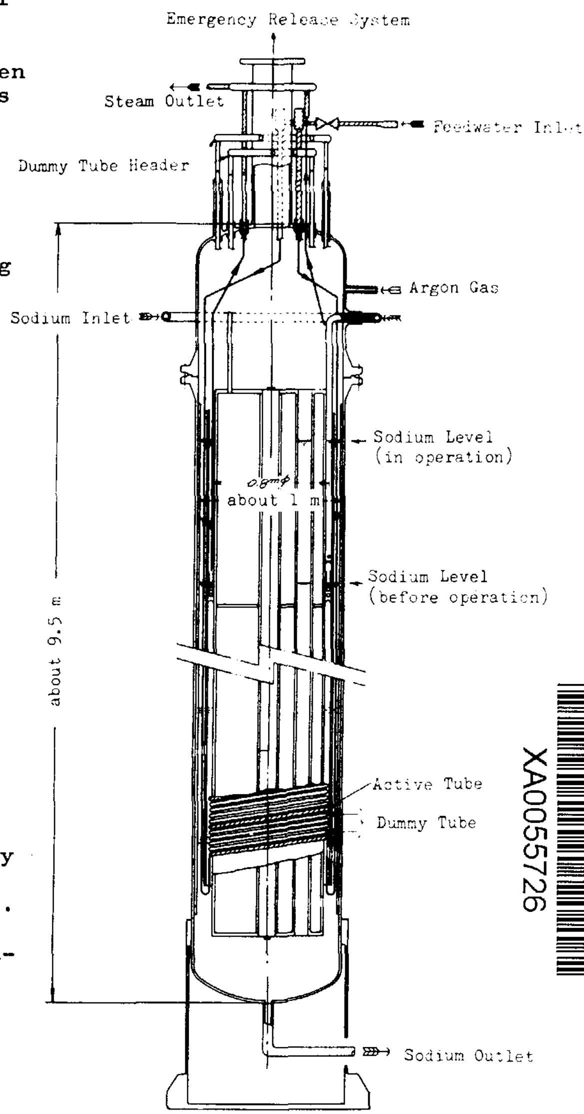


FIG. 1. 1 MWt Steam Generator-Schematic

DESCRIPTION OF STEAM GENERATOR

The modified steam generator is shown in Fig. 1. Two feedwater tubes penetrate the shell by each at the top and go down to the bottom forming straight downcomers. Then, they are turned upward forming herically coiled heat transfer area. The downcomer tube is covered with another tube of bigger diameter so that an argon gas may be filled with tne gap to restrict the excessive heat absorption in the region.

Sodium enters into the steam generator through four distributors, is introduced into the heat transfer area, flows downwards in the annulus region formed by an inner shroud and an outer shroud separating the downcomer region from the heat transfer zone. Sodium would be stagnant in the downcomer region and inside of the inner shroud. The upper portion of shell is provided with a gas space mainly to prevent the flange and penetrants from a thermal shock in case of a rapid temperature change.

In order to detect any water leakage, a gas-chromatograph is provided to monitor hydrogen in the cover gas and a membrane type detector is provided to monitor hydrogen soluted in sodium which is introduced from the discharge of steam generator. The former reads a hydrogen concentration every two minutes and the latter does continiously by a current of an ion pump and mass-spectrometer. A cover gas pressure is monitored continuously by a pressure gauge and a plugging indicator is also provided with the sodium loop.

FIRST LEAKAGE EXPERIENCE

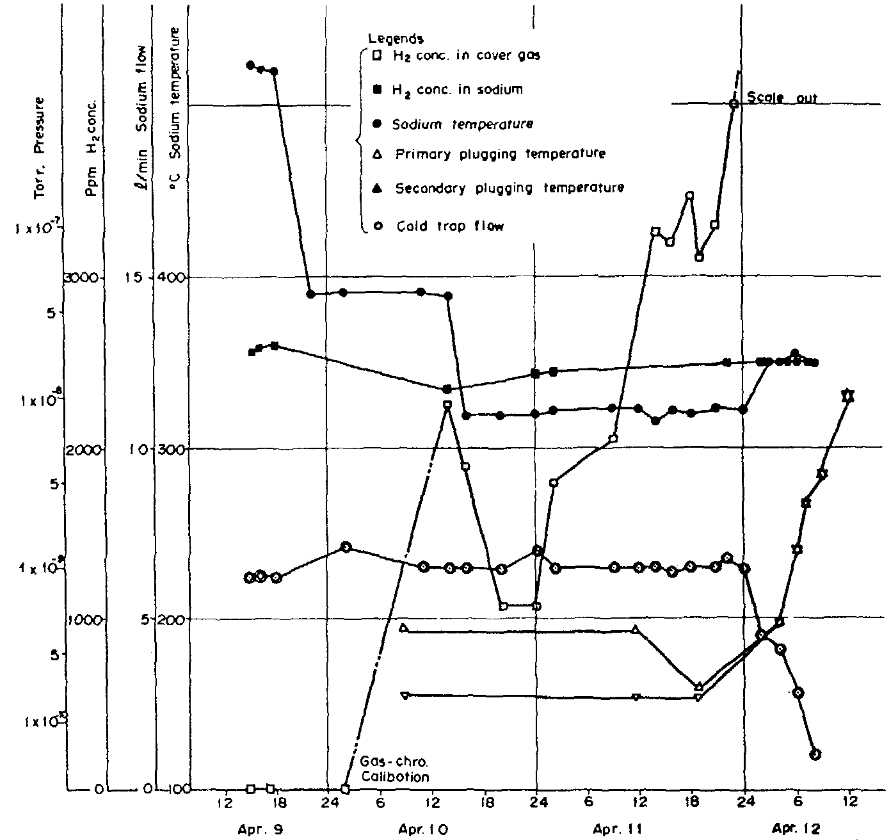
Operation of the modified steam generator started on January, 1973. Following to a flashing operation of water side and adjustment works with hydrogen detectors, sodium was charged into steam generator on early February. Cold trapping operation was followed to clean up sodium and then single phase heat transfer tests were being proceeded which was the first phase of the test schedule.

On April 10, water leakage was experienced for the first time under this situation. Sodium temperature was 350 °C and feedwater pressure was 145 kg/cm^{2}g. It had passed 742 hours since the modified steam generator was put in operation. The first signal of the leakage had come from the cover gas monitor and showed 2250 ppm all of sudden just after it was put back in service finishing calibration and adjustment works on it. Some difficulties were encountered in reducing the amount of hydrogen by breezing with new argon gas.

Hydrogen concentration continued on such a high level of 3200 ppm arround for about 6 hours and went off scale of 4000pppm. The operators, who had previous difficulties in calibrating the instrument, wondered that the calibration was defective because no change in the membrane detector which was used to minitor hydrogen in sodium had been noted. Three or four hours later of the off-scale, an increase of hydrogen with the membrane detector, a going up of plugging temperature and a decrease of sodium flow through cold trap were noticed at almost the same time. Judging with these readings, water leakage was likely definite and it was decided to shut down the operation for inspection. Plots of the above readings under the situation are shown in Fig. 2.

It was imagined that the leakage happened in cover gas region because the gas chromatograph responded first and the membrane detector worked many hours later. Before a tube bundle was lifted up for inspection, the damaged tube was identified by such a way that after evacuating sodium side to vacuum, a helium gas was filled inside of the tubes separately so that a helium detector might identify the leaked one.

The tube bundle was lifted up in an argon atmosphere which was maintained by a vinyl cover. The damaged spot revealed clearly with reaction products and showed the expectations were appropriate. As shown in Fig. 3, the leaked part was recognized along the heat affected zone which had been made with the additional welding as mentioned before. The part were taken off for the further inspection.



Plots of Readings with Detectors

FIG. 2.

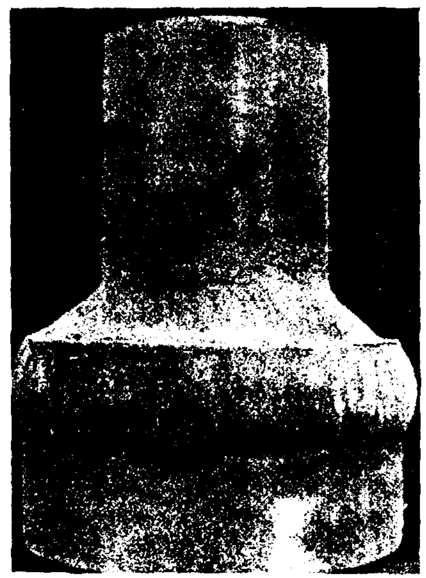


FIG. 3.

Liquid Penetrant Examination on Damaged Spot.

Liquid penetrant examination showed 12.4 mm of cracking on the outer surface and slightly less than 5 mm on the inner surface. Hardness was checked along axial direction which resulted in two or three times harder on the heat affected zone, as shown in Fig. 4.

Stress analysis was made to search for a possibility of cracking due to an excessive stress with restriction or some other reasons but no possibility came out. The microscopic photograph is shown in Fig. 5, which was taken along the cracking. It shows the cracking initiated probably on the sodium side and propagated into the water side. Though it was not so distinctive, the cause of cracking was estimated as a combination of caustic stress corrosion and residual stress due to the welding.

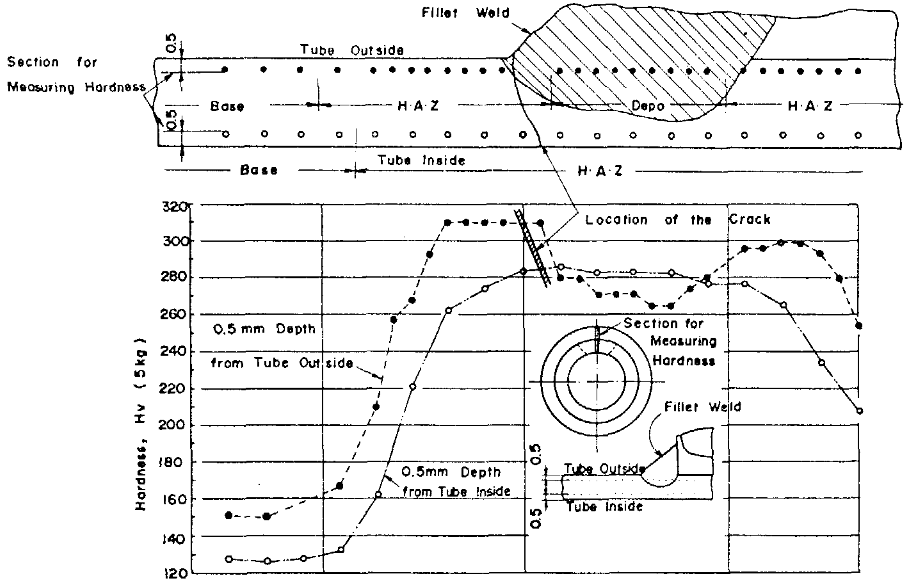


FIG. 4. Hardness of the Tube at the Crack-originated Region

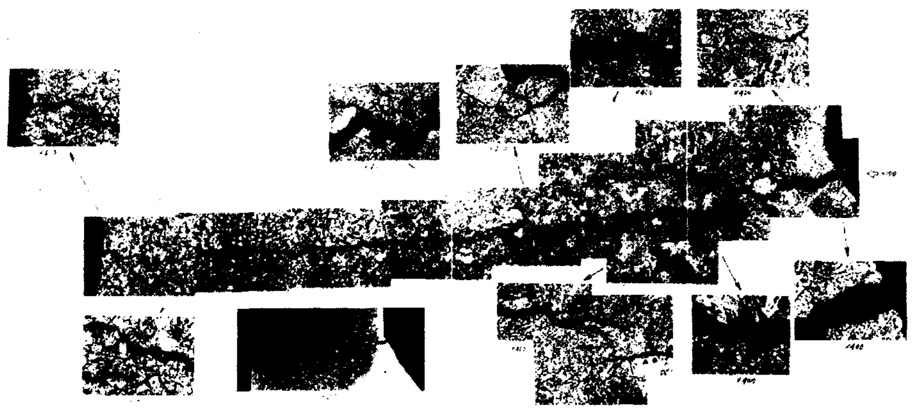
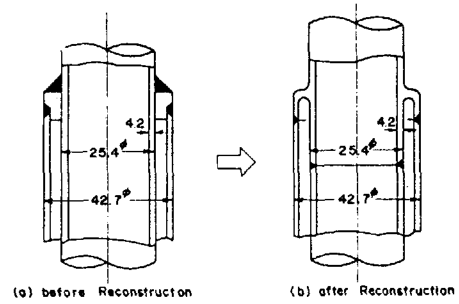


FIG. 5. Microscopic Examination along the Cracks.

The repair was made with using so called "fluid head" which is presented in Fig. 6. It was purposed to adopt a butt-welding instead of a fillet welding and a postweld heat treatment was added to eliminate the residual stress due to the welding. Investigation of the causes, repair works, clean up operation of sodium in the system and washing off caustic products on the surface in the steam generator, which was formed with air during repair works, required so many days until the end of September.



Comparison of Tube-to-Thermal Insulation Pipe

FIG. 6.

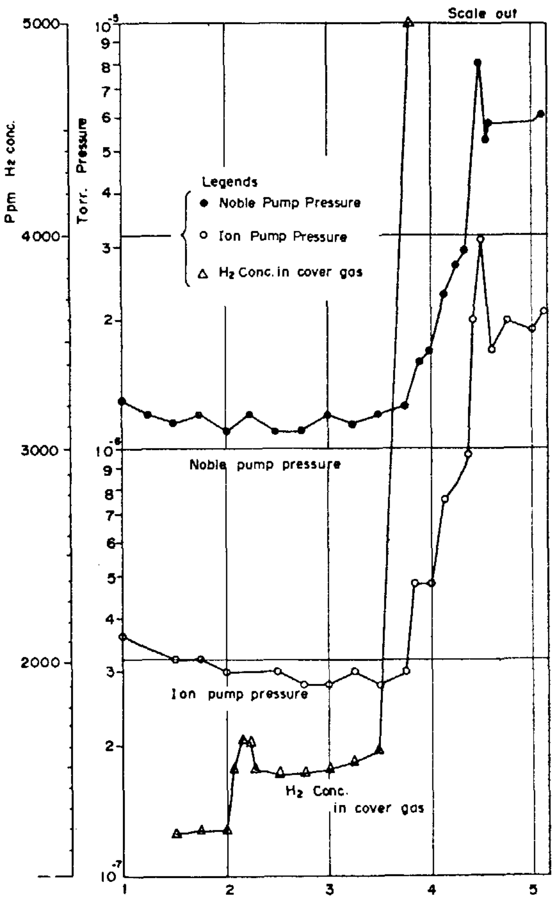
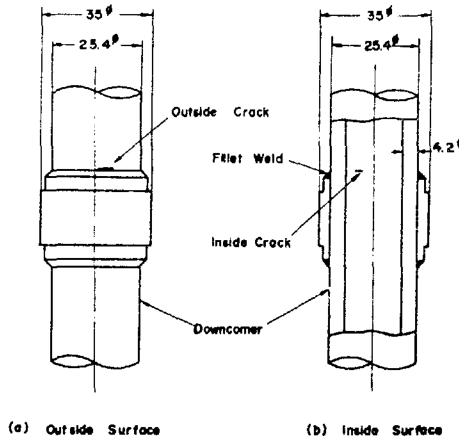


FIG. 7.

Plots of Readings with Detectors



Location of the Tube Crack

FIG. 8.

SECOND LEAKAGE EXPERIENCE

On October, 1973, the steam generator was put back in operation and cold trapping operation was proceeded under the coupled situation of sodium and water. On November 16, water leaked again into sodium side after 542 hours of the operation. Gas-Chromatograph and membrane detectors showed rapid increases almost simultaneously at the second time. Operation was stopped with these signs. Plots of the readings are shown in Fig. 7.

According to the facts that two kinds of detectors responded at almost the same time, the leakage was expected to be in sodium region. To make sure the leakage, the same helium leak test as mentioned before was conducted and succeeded to identify the leaked tube between the two. Next step was to find where it happened, downcomer region or herically coiled heat transfer region.

Sodium was filled to such a level that the open end at the bottom of the downcomer was covered so as to separate two region. Helium leak test indicated the downcomer region was damaged. With the previous experience, the damaged part was expected to be the welded portion of spacers on downcomer tube.

When it was lifted up again for the inspection, some reaction products were found arround the open end of downcomer and then the outer tube was cut away to inspect the downcomer, which showed the expectation was right. The damaged part is shown in Fig. 8. It was a similar cracking along the heat affected zone and the causes was considered to be the same as the previous one. The downcomer tube was replaced to new one and spacers were changed to be fixed with inside of the outer tube with screws.

1 MW steam generator was put back into operation on April. 1974 and it is now successfully on the last stage of test schedule. Experiences obtained through these troubles have been referred and utilized to the design and the fabrication following sodium components.

K.3. KNK-Steam Generator Leakage, Evaluations and Improvements

K. Dumm
W. Ratzel
Fed.Rep.Germany

Abstract:

On September 23rd 1972 the KNK-reactor was shut down due to a sodium-water reaction.
Detection, localisation and possible leak development are described and discussed.
Improvements on the KNK steam generator system due to this leak experience are explained.

1. Introduction

The KNK reactor was manually shut down on September 23rd, 1972 due to indications of a sodium-water reaction in one of its two steam generators. The leak was assumed to be a comparably small one as no rupture disc was actuated. At the time the reactor was running at the 30 % output level and the operating conditions of the failed steam generator were as given below:

sodium temperature inlet	420°C
sodium temperature outlet	276°C
sodium flow rate	180 m^3/h
feed water temperature	200°C
steam temperature	420°C
steam pressure	79 bar
steam flow rate	13 t/h

Fig. 1 shows the geometrical arrangement of the secondary sodium loop with its main components. As explained later the event was partly influenced by this geometrical arrangement. The steam generator with the connected pressure relief system is illustrated in Fig. 2. Steam is produced in 28 parallel tube-in-tube units which are connected to headers. Three additional units are available as spare parts; they are not connected to the headers. Each sodium outlet is equipped with an inductive bubble indicator by which hydrogen bubbles originating from a sodium-water reaction can be detected. At the time when the leak occurred each sodium outlet was additionally equipped with a thermocouple for low load stability measurements. In the case of large sodium-water reaction fast pressure relief is achieved by 4 rupture discs. Previously to the steam generator failure described here all rupture discs were designed having an actuating pressure of 20 bar.

2. Sodium-water reaction

The presence of a sodium water reaction was indicated by several instruments: