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Surveillance for Vertical Safety Rods

at HTLTR

by

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Table of Contents

Introduction	1
Description of Surveillance Tool	2
Quantitative Evaluation	4
Calibration	5
Method of Inspection	7
Frequency of Inspection	8
Limits of Deformation	10

List of Figures

Figure 1	3
Figure 2	6

Introduction

Operation of the High Temperature Lattice Test Reactor (HTLTR) over the temperature range from 20°C to 1000°C has resulted in unpredicted material deformations which occur in the vertical safety rods (VSR). These material deformations⁽¹⁾ have resulted in a malfunction of the VSRs, a potentially hazardous condition. To eliminate the hazard, a new VSR poison plate was designed. A model was constructed and tested under prototypical conditions. The test results showed that eventual deformation of the new design would also occur as the result of normal operation of HTLTR, but at a reduced rate. Therefore, a surveillance tool capable of detecting deformations as small as 0.010-inches in the VSR poison plates has been devised and installed on the VSR system in HTLTR. This report describes the surveillance device, the procedure to follow, and the action to take in the surveillance program, to insure that a hazardous condition is not permitted to develop in the VSR system in HTLTR.

(1) RI Smith, "Modification of HTLTR Vertical Safety Rods - Mark III," BNWL-CC-2643, Revised, Battelle-Northwest, July 29, 1970.

Description of Surveillance Tool

A viewing station has been installed on each of the four VSR housings at HTLTR. Prior to mounting a viewing station on a VSR housing as shown in Figure 1, holes were cut in each of the four VSR support towers, in both the outer housing and the inner liner within which the VSR blade travels. The openings are large enough to view one complete poison plate when positioned within the opening. As seen in Figure 1, the viewing station is an appendage fastened to the side of each VSR outer housing. It includes two quartz glass viewing windows, each six-inches square with the upper window set at an angle of 45° from vertical.

Within the appendage is a flat plate which can be raised or lowered to cover the opening that was made in the inner liner. This internal cover plate will blank the opening during routine operation of the VSR's, to function as a thermal barrier to the radiant energy from a hot VSR as it is raised out of the reactor. This thermal plate will be lowered during times of inspection of the poison plates of a VSR. A lever arm with a weighted disc on its end is used to position the barrier plate. It penetrates the side of a housing, as seen in the figure, through a gas tight gland. Both viewing windows and the entire appendage on each VSR housing have also been made gas tight.

Figure 1

It is possible to visually inspect one side of the upper eleven of the twenty poison plates in each of the four VSR blades. The condition of the other nine plates and the other side of all plates will be inferred from the information gained from the accessible sides of the poison plates.

The inspection can be quite detailed as the view of the poison plates is unimpaired. Any development of consequence to the poison plates should be clearly visible by inspection.

Quantitative Evaluation

The technique developed to provide a quantitative measurement of deformation that may develop in the poison plates uses a standard 3-inch x 4-inch lantern slide projector and a camera. As seen in the figure both are mounted on the same rigid platform which is attached to the VSR appendages.

The inspection procedure is as follows: Open the internal thermal barrier and position a poison plate of a VSR at the opening. A pattern of parallel lines, essentially a grid, will be projected by the slide projector through the quartz glass window and onto the surface of the poison plate. As long as the poison plate remains flat, the projected lines will be straight as viewed by the camera and a photograph will provide a permanent record. If deformation develops in the poison plate, the projected grid lines on the surface of the plate will no longer be straight lines as viewed by the camera. The

curvature seen by the camera and recorded on film for examination (and for the record) measures the deformation occurring in the poison plates. A calibration of the system relates the deviation of a formerly straight grid line to the elevation of deformation in the poison plate.

Calibration

A six-inch square aluminum plate, 1/2-inch thick, was prepared with a ramp two-inches wide in its center section. The ramp rose continuously from zero at one edge to 0.055-inches on the opposite side. A photographic negative of the calibration plate taken when it was installed in the place of a VSR poison plate, was examined on a large optical comparator. A deviation of 0.012-inches (12 mils) was measured on the grid line at the center of the plate where the offset was 0.0275 (27-1/2 mils) for a calibration constant of 2.3 to 1. That is, for each 10 mils of deviation from a straight line as seen at the center of the film, a deformation of about 23 mils on the poison plate has occurred. Similarly, for deformation occurring at the edge of a plate closest to the camera, the 55 mil offset was measured at 26 mils for a calibration constant of 2.1. When the calibration plate was rotated so that the 55 mil offset was furthest from the camera, the 55 mils was measured as 21 mils for a calibration constant 2.6 along this edge.

Figure 2

Assume O deflects $A = OA$

Deflection as seen by
camera = OA_1

After lens on camera is tilted
for maximum focus OA is rotated
to approach OA_2

Then

$OA = OA_2$

Deflection = Image

Figure 2

The variation in the calibration results from the geometry of the set up as well as the optics in the camera. The camera has a tilting objective lens and with this, the entire six-inches of the poison plate is put in to as good a focus as possible. This, in effect, rotates the image plane nearly into the objective plane as shown in Figure 2, so that up to the camera lens, the ratio of actual to observed deformation is approximately one in the center of the photo.

The optics in the camera which reduce the image size on the photo account for most of the calibration constant. For example, by direct measurement, the length of the aluminum piece in the photo was reduced to $2\frac{11}{16}$ -inches from an actual 6-inch length. Assuming that the slight distortion occurring in the upper half of the film compensated for that in the lower half so that the $2\frac{11}{16}$ -inch measurement is a good average, the reduction ratio of 6 to $2\frac{11}{16}$ or 2.2 accounts for essentially the entire calibration constant of 2.3 as measured in the center.⁽²⁾

Method of Inspection

Each plate on a vertical safety rod has been photographed for a record of its pre-operational status and the film placed in a permanent file. Routinely, and at the schedule given below, every accessible plate in each

⁽²⁾ This suggests that the image plane is rotated about 2° away from object plane.

rod will be visually examined and plates 10 and 11 in each rod photographed. The film will be inspected to detect any deformation and when noted, the film negative will be examined on a 30-inch graduated screen of an optical comparator using a magnification lens of 50 power. At the present time, the width of one grid line filmed on a poison plate is 0.006-inches (6 mils) wide on the screen of the optical comparator. A deformation of as little as 0.010-inches (10 mils) should be immediately obvious.

Reproducibility of the filming technique is important and the installation of the equipment has been designed to give the operator an easy procedure to follow. The camera, the projector, and the platform are rigidly supported with no adjustments available except focus and image size. A ground glass image screen is available on the camera. Fiduciary marks on the screen are used to obtain a constant size of photo image and hence the calibration will remain constant.

Frequency of Inspection

The frequency of inspection and photographing is as follows:

Above 250°C:

The poison plates in each rod will be visually inspected following each step change in temperature at which an experiment is to be conducted and prior to conducting the experiment.

Above 600°C:

Poison plates 10 and 11 on each VSR will be photographed after the completion of experiments at a set temperature. And, poison plates 10 and 11 will be photographed no less frequently than every 20 cycles. A cycle is defined as an insertion and a withdrawal of a VSR.

Limits of Deformation

The photographs will be examined for evidence of deformation of the poison plates as they are taken.

The limit of deformation to be permitted for continued operation without further review will be 0.22-inches.

The existing clearance is about 0.33-inches and 0.22-inches is believed to be sufficiently conservative for the rod to still be operational and have the potential for additional service as well.

As soon as is practical a rate of deformation per cycle will be established for the plates inspected, for use in predicting the probable service life of the present VSR plates.