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ULTRASONIC INSPECTION OF A SECTION OF
THE NS SAVANNAH PRIMARY PIPING SYSTEM

October 1963

MA Contract No. 3377
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THE BABCOCK & WILCOX COMPANY

NUCLEAR DEVELOPMENT CENTER

OCT 25 1963

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THE NS SAVANNAH PRIMARY PIPING SYSTEM

October 1963

By
C. R. Johnson
Materials and Processes Section
Nuclear Development Center

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ABSTRACT

A section of NS Savannah primary pipe and part of a primary system gate valve were examined ultrasonically to determine whether a fluctuating flow of low-temperature makeup water entering through a nozzle in the valve had damaged the components during service. Examination was prompted by failure of a Vallecitos Boiling Water Reactor recirculating pipe in which makeup water was introduced under conditions similar to those in the Savannah.

The ultrasonic equipment was calibrated on spare components. The calibration standards, 11-mil-deep chisel marks in the pipe and 25-mil-deep marks in the valve, were more stringent than those used to calibrate equipment for inspection of components at the time of manufacture. The inspections of components conducted aboard ship are therefore thought to be more exacting than those performed on the original equipment.

Ultrasonic inspections of the failed VBWR pipe completely defined the areas of defective material that led to the failure. The VBWR results, together with experience gained by Babcock & Wilcox, indicate that the inspections of Savannah's components were both applicable and definitive. Since no indications of discontinuities were found in the valve or the pipe, both components are considered to be sound and unaffected by service.

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1. INTRODUCTION

A section of NS Savannah primary pipe (PS-12B) and part of a gate valve (PS-6V) were ultrasonically examined for material discontinuities resulting from service. Examination was prompted by failure of a recirculating pipe in the Vallecitos Boiling Water Reactor (VBWR). The VBWR failure was caused by thermal shock of the pipe wall occurring when low-temperature makeup water was introduced intermittently into the recirculating pipe at an area of high stress and excessive mechanical restraint. Low-temperature makeup water is added to the NS Savannah primary system through a nozzle on the reactor side of Valve PS-6V. Pipe PS-12B connects the valve to the reactor vessel as shown in Figure 1. Excepting for the materials in the Savannah piping system not being highly stressed or excessively restrained, the Savannah and VBWR systems are similar in this area.

Ultrasonic examinations of the VBWR pipe in the area of failure revealed numerous indications of discontinuities on the inside pipe surface both upstream and downstream from the inlet water nozzle. Subsequent destructive examinations showed that a fine crazing caused by thermal fatigue during operation produced these discontinuities on the inside pipe surface. The failure occurred after excessive and cyclic stresses associated with reactor startup and shutdown operations prompted the crazed condition to propagate.* Crazing in the VBWR pipe extended downstream approximately 13 inches as shown in Figure 2. Crazing in the upstream portion of the pipe was caused by thermal fatigue during a three-year period of operation under natural circulation which resulted in a net flow of water opposite in direction to that under forced circulation conditions. The VBWR had operated for a total of

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* W. R. Smith and J. B. Violette, The Cause of Failure and the Repair of the VBWR Recirculation Piping, APED 4116, November 1960.

five years at the time of failure (September 1962), three under natural circulation and two under forced circulation conditions.

Operating conditions in the NS Savannah and the VBWR are similar as shown in Table 1. The similarity of operating conditions and the positive indications of discontinuities obtained by the ultrasonic examinations of the VBWR pipe indicated that examinations of the NS Savannah pipe and valve could yield reliable information on the condition of the materials in the area of question.

Table 1. Comparison of NS Savannah and VBWR Systems

	<u>NMSR</u>	<u>VBWR</u>
Primary pipe size, in.	16 OD $\times$ 1.687 wall	10 OD $\times$ 0.650 wall
Pipe material	Seamless Type 304 SS	Welded Type 304 SS
Valve material	Cast Type 304 SS	Not applicable
Primary coolant temperature, F	494 to 521	$\sim$ 550
Primary coolant velocity, fps	30	0 to 30
Makeup-pipe size	1.5-in. Sch 160	1 in. Sch 80
Makeup-pipe material	Type 304 SS	Type 304 SS
Thermal sleeve	Yes	No
Makeup-water temperature, F	115	70 to 130
Makeup-water velocity, fps	0 to 15	0 to 10
Approximate time in service, years	1	3 (Natural circulation) 2 (Forced circulation)

This report describes the methods used in examining the wrought pipe and cast valve in the NS Savannah. The examination of the pipe was made in March 1963, using a Sonoray Model 50A ultrasonic testing unit having a 2-1/4-megacycle crystal (No. ZSL Branson). The valve was examined in September 1963, using a Sonoray Model 50B ultrasonic testing unit having a 1-megacycle crystal (No. Z Branson). The Model 50B unit is particularly suited to examinations of coarse-grained

materials, such as large stainless-steel castings, and was not available at the time of the earlier inspection. Figure 3 is a photograph of the Model 50B unit having a Dumont oscilloscope camera mounted. Some of the photographs of the ultrasonic indications were taken with this camera during the examination of the valve.

There were no indications of discontinuities found by the ultrasonic examinations of either the pipe or the valve. Examination of the pipe was more sensitive than that imposed at the time of manufacture. Examination of the cast valve was definitive and of high sensitivity; however, it was not as sensitive as the pipe examination owing to more background noise being inherent in examinations of coarse-grained materials. In both examinations, full-screen indications were obtained from the calibration standards (see Figures 4 and 5). Expressed as a percentage of the wall thickness of the materials examined, the calibration was 0.63% for the pipe inspection and 1.1% for the valve inspection. Standard inspections at manufacture are calibrated with 5% standard defects; where additional sensitivity is warranted, standard defects equal to 3% of the section thickness are used for calibration.

2. INSPECTION PROCEDURES

A length of spare pipe and a spare valve located in the warehouse at Todd Shipyards were used to calibrate the ultrasonic testing units. The 10-foot-long spare pipe was purchased to the same specifications as the primary piping in NS Savannah reactor service. The spare valve was identical to Valve PS-6V except that the makeup-water nozzle was not bored.

Calibration defects were placed on the outside and inside surfaces of the pipe and on the inside surface of the valve. A chisel was used to make longitudinal and transverse defects. The defects in the pipe were made 0.011 and 0.014 inches deep, while the valve defect was 0.025 inch deep. All calibration defects were about 3/4 inch long. (See Figure 6.)

In calibrating the ultrasonic equipment, attempts were made to obtain full-screen indications from all defects without any noise or other superfluous indications occurring on the oscilloscope screen. Such a calibration was obtained on the pipe; however, a small amount of background noise was unavoidable during calibration for the valve inspection. (See Figures 4 and 5.) After dry calibration for the pipe inspection, the pipe was tilted and filled with water, which covered the standard defect, to simulate conditions in the piping aboard ship. There was no noticeable effect of the water on the calibration or sensitivity of the inspection. (See Figure 7.)

Settings of the controls on the testing equipment were recorded, and the equipment was transported aboard ship without changing the settings. Inspections of the components on the ship were carried out meticulously in both longitudinal and transverse directions using the same equipment, crystals, and contact shoes that were used in calibration. In both cases, plexiglass contact shoes were sanded to coincide with the convexity of the pipe and valve surfaces. Oil was used as a fluid coupling to assure good sonic transmission into the material under inspection.

As an additional verification that the equipment characteristics had not changed between the warehouse and the ship and that the shipboard test was as definitive as the calibration, attenuation patterns were compared. This procedure consisted of projecting a sonic beam normal to the surface of the material under examination and comparing the number of reflections from the inside surface indicated on the oscilloscope. (See Figure 8.) Should the contours or the damping characteristics of the two items compared differ, the oscilloscope pattern would also differ. In the case of the valves and pipes, there was no appreciable difference between the warehouse and shipboard components.

3. RESULTS

There were no indications of discontinuities found in the valve or the pipe inspected aboard the NS Savannah. The materials in these components appeared to be sonically identical with the spare components used as standards. Inspection of the shipboard components covered a much broader area than was required to thoroughly inspect the area under question. While particular physical appurtenances, such as the makeup-water nozzle, were easily located (see Figure 9), there were no unidentifiable variations in the oscilloscope patterns attained.

4. DISCUSSION

Ultrasonic examinations of areas in a section of the primary piping (PS-12B) and the valve (PS-6V) aboard the NS Savannah showed the materials to be sound and free of resolvable defects. The inspection procedures and standards were even more stringent than those used at the time of manufacture of the components. Experience by B&W and others indicates that the inspection procedures used were highly sensitive to the types of discontinuities expected. Direct evidence of the effectiveness of the inspection procedures in locating the type of discontinuity expected in the area examined is contained in APED 4116*.

The inspection of the wrought pipe material was the most sensitive, because a high-frequency sonic energy was employed and a clear oscilloscope indication of a small standard defect was obtained. A full-screen indication was obtained from an 11-mil-deep standard defect in the 1.68-inch-thick pipe wall where essentially no background noise occurred. The area of this standard defect available for reflection of the sonic energy is 0.0083 square inch. Reflecting surfaces of a much smaller area would yield discreet indications of less than full-screen amplitude, while general zones of microscopic discontinuities would produce an increase in the noise level discernible on the oscilloscope.

The inspection of wrought material, using the higher sensitivity discussed in the previous paragraph, was effective to within 9 inches of the centerline of the makeup-water inlet nozzle. In the VBWR piping, operating under similar conditions for approximately three times as long as that of the NS Savannah, crazing extended downstream at least 13 inches. Considering the sensitivity of the Savannah examination and the VBWR experience, it is concluded that if there were any damage in

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* W. R. Smith and J. B. Violette, op cit.

the Savannah system caused by thermal fatigue from the makeup-water inlet, it did not affect the piping as near as 9 inches downstream from the inlet nozzle. Figures 10 through 15 show the inspection of the pipe aboard ship.

The inspection of the cast valve body in the NS Savannah is considered of high sensitivity; however, the valve inspection was not as sensitive as that of the wrought pipe. Nevertheless, a full-screen indication of a standard defect having a reflecting surface of a maximum of 0.0187 square inch was obtained over approximately 5% of the full-screen noise-level. This can be considered a highly sensitive examination of 2-3/8-inch-thick material. Discontinuities of a much smaller reflecting area would produce discreet indications of less than full-screen amplitude on the oscilloscope, while general zones of minor surface discontinuities would produce a decided increase in the noise-level. External surface roughness on the valve body restricted inspection in the transverse direction to an area 3 inches downstream from the edge of the inlet nozzle. Inspection in the longitudinal direction, however, covered the inside surface of the valve right up to the nozzle opening. Since experience in the VBWR shows thermal crazing to be random rather than oriented, any crazing in the NS Savannah valve near the makeup-water nozzle would have been detected by the longitudinal inspection. The absence of discreet indications or increases in the background noise indicates that the valve material downstream from the makeup-water nozzle is sound and has suffered no effects from thermal cycling during service. Figure 16 shows the inspection of the valve aboard ship.

5. CONCLUSIONS

Results of the ultrasonic examinations of a section of the NS Savannah primary pipe and a part of a primary system gate valve lead to the following conclusions:

1. There are no inside surface discontinuities in the inspection area of an integrated reflecting surface area equal or exceeding 0.0083 square inch in the pipe and 0.0187 square inch in the valve. The area inspected extended downstream from the inlet nozzle for a distance in excess of 20 inches and from 90 to 180 degrees around the circumference of the components.

2. Ultrasonic examination for inside surface defects in piping filled with water is feasible and practical, providing suitable calibration standards are used.

3. Ultrasonic examinations of NS Savannah primary piping can be performed aboard ship to a sensitivity at least equal to that originally used during inspection at the time of manufacture. The type of inspections used in both instances are similar except that the shipboard inspection was performed in a manner that would not be practical or necessary during manufacture.

4. Ultrasonic examinations of NS Savannah primary gate valves can be performed even though the cast material in the valve body has a large grain size. The external surface roughness in as-cast areas seriously affects the coupling of the sonic transducer to the valve body and makes detailed inspection impractical from all angles. Where the outside surface of the valve has been machined, a highly definitive ultrasonic examination is possible.

Figure 1. Sketch of NS Savannah Primary Pipe and Valve
in Area of Inspection

Figure 2. Sketch of Inside Surface of Defective VBWR Recirculation Pipe

Information for Sketch From APED 4111 and APED 4116.

Figure 3. Sonoray Model 50B Ultrasonic Testing Unit Having DuMont Oscillograph Record Camera Model 302 Attached

Figure 4. Ultrasonic Indications of Transverse Standard Defect Located on Outside Surface of Pipe

Figure 5. Ultrasonic Indication of Longitudinal Standard Defect Located on Inside Surface of Valve

Figure 6. Photograph of NS Savannah Spare Pipe Containing Chisel Defects

Figure 7. Photograph of Calibration Setup Using Spare Pipe Filled With Water

Figure 8. Attenuation Pattern Obtained From the Spare Pipe and the NS Savannah Pipe Inspected With Identical Instrument Settings

Figure 9. Ultrasonic Indication of Nozzle Opening as Viewed From a Point Approximately 12 Inches Downstream

Figure 10. Ultrasonic Inspection of NS Savannah Pipe

Figure 11. Ultrasonic Inspection of NS Savannah Pipe

Figure 12. Ultrasonic Inspection of NS Savannah Pipe

Figure 13. Ultrasonic Inspection of NS Savannah Pipe

Figure 14. Ultrasonic Inspection of NS Savannah Pipe

Figure 15. Ultrasonic Inspection of NS Savannah Pipe

Figure 16. Ultrasonic Inspection of NS Savannah Gate Valve

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