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DEVELOPMENT AND DESIGN OF AN
ULTRASONIC INSPECTION SYSTEM FOR
RADIOACTIVE WASTE CONTAINERS

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Under Contract AT(45-1)-1830

DEVELOPMENT AND DESIGN OF AN
ULTRASONIC INSPECTION SYSTEM FOR
RADIOACTIVE WASTE CONTAINERS

to

Atlantic Richfield Hanford Company (ARHCO)
Richland, Washington

June 8, 1971

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Battelle Memorial Institute
Pacific Northwest Laboratories
Richland, Washington 99352

DEVELOPMENT AND DESIGN OF AN
ULTRASONIC INSPECTION SYSTEM FOR
RADIOACTIVE WASTE CONTAINERS

J. C. Crowe

INTRODUCTION

The solid radioactive waste storage program presently being undertaken by the Atlantic Richfield Hanford Company (ARHCO) involves the encapsulation and subsequent storage of radioactive cesium and strontium. The waste storage containers used in this program must exhibit a high degree of structural integrity. This report presents the results of a project performed by Battelle-Northwest to develop and define a nondestructive test system capable of performing ultrasonic inspection of the waste containers to assure container integrity. The basic design of the inspection system is outlined including detailed circuit drawings, functional specification design drawings for the inspection tanks, and appropriate interconnection diagrams. In addition, some examples of the results obtained with a laboratory prototype inspection system are presented which illustrate the performance of the system design.

GENERAL DESCRIPTION

The ultrasonic test system design provides for a very versatile system capable of performing inspection on the as-fabricated capsule components and the critical end cap welds. The inspection system consists of three major components: a remote inspection tank (to be located inside a radioactive containment cell), a component inspection tank, and a central control console common to both inspection tanks. Capsule components to be inspected include the raw tubing sections and the end cap materials. These materials can be tested at the component inspection tank. The "cold" or bottom end cap weld also will be inspected at this tank. The final closure weld inspection will be performed remotely by the "remote" inspection tank.

The design of the inspection system can be separated into two major parts: (1) ultrasonic and electronic circuitry design, including signal generation, signal processing, and data readout functions and (2) mechanical design of remote and local inspection tanks including transducer positioning mechanisms, test piece positioning mechanisms, and associated mechanical functions. The inspection tanks are required to perform the mechanics of transducer positioning, water temperature control (when required), test piece rotation and positioning, and other similar functions. The ultrasonic pulse generation and signal preamplification electronics will be located at the inspection tanks. The control console provides the signal processing, data readout, system control and other operator controlled functions. A general system outline is shown in Fig. 1. The following paragraphs describe the detailed electronic circuitry design and the functional specification design for the remote and component inspection tanks.

REMOTE INSPECTION TANK

The basic functions to be performed at the remote inspection tank are listed in Figure 2. Since this tank is to be located in a "hot" cell, the operation of this tank is to be controlled by a control console, located outside of the cell. Figure 3 is the functional specification drawing for the remote inspection tank. Positioning of the capsule to be inspected is performed by the air-operated collet chuck shown in the drawing. A mechanical stop is provided to assure proper location of the capsules as they are placed in the chuck. The chuck is rotated by the SCR controlled motor located under the tank, directly beneath the chuck assembly. The transducer positioning mechanisms are electrically driven by SCR controlled motors located at the inspection tank. A viewing window on the side of the tank will allow the operator full view of the collet holder and test head assembly.

The internally generated heat associated with the waste capsules requires that provisions be made to cool the capsules and to maintain the ambient water temperature in the inspection tank. A heat exchanger, pump, and motor are located beneath the inspection tank to provide the necessary water cooling. The piping diagram shown on the specification drawing indicates the water flow path and valving arrangement. The water path between the transducer face and the capsule end cap must be maintained at a relatively constant temperature. To accomplish this result a cooling chamber is provided which will force a continuous stream of cooling water across the face of the transducer and maintain a relatively constant temperature between the transducer and the end cap.

The electronic functions to be performed at the remote inspection tank are listed in Figure 2. The interconnection diagram shown in Figure 4 details the connections among the various electronic components to be located at the inspection tank. These electronic components generate the transducer excitation pulse, preamplify the reflected signal, and provide the signals for positioning of the transducer in relation to the capsule end cap. The detailed curcuitry drawings for the ultrasonic circuits located at the remote tank are given in Fig. 5. In addition to the basic ultrasonic circuitry (transducer, pulse generator, clock, preamplifier, etc.), and the rotational and positional drive motors, two items are shown in Fig. 4 which produce the information necessary for the spiral data display. These items are the radial position potentiometer and the sin-cos potentiometer which are to be positioned as shown in Fig. 3.

COMPONENT INSPECTION TANK

The component inspection tank (shown in Fig. 6) is capable of performing the inspection of raw tubing sections, end cap materials, and "cold" end cap welds. Thus it is a more versatile inspection tank than the remote inspection tank although the basic design is similar. The chuck provides the positioning and rotation of the capsule or tubing section. Two test heads are provided. The first is for performing weld inspections and end cap material inspections. The second test head ("alternate test head" shown in Fig. 6) can perform inspections of raw tubing. The longitudinally driven carriage allows a 26" scan length.

The electronic components located at the component inspection tank are listed on the interconnection diagram in Fig. 7. These items perform the same basic electronic functions as the remote tank electronic components. As on the remote tank, the potentiometers required for data display are provided. Figure 8 is the detailed circuit diagram of the ultrasonic circuits to be located at the local test tank. The dual pulser and preamplifier circuits allow bi-directional inspections of raw tubing sections to be made simultaneously, thus reducing over-all inspection time requirements.

CONTROL CONSOLE

The main control center for the remote inspection tank and the component inspection tank is the control console. This console contains the motor controls for the rotation and positioning motors of both inspection tanks and the ultrasonic signal processing electronics and data handling equipment. These functions are listed in Fig. 2. Transducer position monitoring to 0.001 inch is provided by digital "nixie tube" readout of the position of resolver units located at the inspection tanks. The SCR motor controls will control the transducer positioning motors and the chuck rotation motors located at the inspection tanks.

The interconnection diagram shown in Fig. 9 outlines the electronic functions to be performed by the control console. The detailed electronic circuit diagram for the delay, gating, amplification and detection circuitry for processing the ultrasonic signal is given in Fig. 10. Two units of this portion of the electronics are to be

included in the control console system. This allows the simultaneous use of two transducers in the testing of raw tubing at the component inspection tank. This also provides a back-up system for the signal processing portion of the end cap weld inspection electronics. The data presentation circuitry is detailed in Fig. 11. The spiral scan circuitry is used to produce the suitable recorder scan for presentation of the end cap weld test data. The pen lift and CRT Z axis drive circuit indicates the presence or absence of a flaw signal on the recording by controlling the recording pen or the oscilloscope beam intensity. This circuit can also be used as an alarm drive to notify the operator that a defect indication has been received. An operator actuated pen lift and intensity modulation circuit is included in this circuitry.

Three instruments are available at the control console for recording the test data: an X-Y oscilloscope, an X-Y recorder, and a strip chart recorder. This allows a high degree of flexibility in the data presentation and recording methods. The oscilloscope serves a dual purpose in the function of the control console. As previously mentioned, it can be used as a data recording instrument; however, its primary function is to provide a video display of the ultrasonic signal that the operator can use during set-up and calibration of the inspection system. The X-Y recorder can be used to record end cap weld inspection data and the strip chart recorder permits the recording of the raw tubing inspection data.

EXAMPLES OF WELD INSPECTION RESULTS

It is appropriate to include in this report a few examples of the results obtained with a breadboard prototype of the ultrasonic inspection system previously described. The breadboard prototype was used primarily to inspect end cap welds made by the ARHCO weld development personnel during development and evaluation of end cap welding parameters. Some examples of the results obtained are given below to illustrate the abilities and effectiveness of the ultrasonic inspection system.

END CAP WELD TEST STANDARD

An ultrasonic test standard was fabricated for laboratory use in determining the detection capabilities of the end cap weld inspection system and to serve as a reference standard for evaluating various inspection methods. This test standard simply consists of a standard end cap into which six flat bottomed holes were drilled around its perimeter to a depth equalling the weld joint. These six holes vary in diameter from 0.062 inch to 0.013 inch. Ultrasonic inspection of this standard with the end cap weld inspection system produced the results shown in Fig. 12. The recording on the left is a slightly reduced version of the trace made with an X-Y recorder wherein a flaw signal is indicated by an interruption of the trace. The recording on the right is a photograph of the same scan as recorded by an intensity modulated oscilloscope (CRT). The distortion of the circular holes in the CRT is a result of slight circuit modifications to accommodate the small size of the CRT face. The hole diameters represented in these scans are (counterclockwise starting with the largest) 0.0625, 0.052, 0.040, 0.0292, 0.020, and 0.0135 inches respectively.

SAMPLE END CAP WELDS

Some examples of sample end cap welds inspected with the ultrasonic inspection system are shown in Figures 13 and 14. Figure 13 illustrates the scan results obtained when a weld, intentionally fabricated to contain variations in weld penetration, was ultrasonically inspected. The weld penetration variations are clearly visible and the adjoining photomicrograph of section A-A confirms the ultrasonic data. The results of placing impurities in the weld area during the welding process is illustrated in the ultrasonic data shown in Fig. 14. The areas where impurities were added are clearly visible on the recording and a photomicrograph of the weld area (section A-A) indicates that the impurities caused a slight penetration variation which was detected during the ultrasonic inspection.

These examples of end cap welds which have been ultrasonically inspected serve only to illustrate the inspection results and the data display. Many additional samples have been inspected in support of the ARHCO weld development program and it is anticipated that still more sample welds will be inspected in the future with the breadboard prototype system as the weld development continues. Thus, even more data will be obtained concerning the resolution detection capabilities of the inspection system.

SUMMARY

The basic development and design of the ultrasonic inspection system has been completed. This included detailed design of the electronic system, functional design of the inspection tank mechanical

systems, and specifications of data display and recording mechanisms. A laboratory breadboard prototype has been fabricated and used to confirm design parameters. The prototype system has also been used to perform end cap weld inspections as required by the ARHCO weld development program. Future weld development may require additional ultrasonic inspections which can be performed with the laboratory prototype system.

Figure 1. General System Outline

Figure 2. Ultrasonic Test System Functions

Remote Test Tank

Component Test Tank

Control Console

Figure 3

WASTE CAPSULE ULTRASONIC TEST SYSTEM

REMOTE TANK SPEC DRAWING

DWG. NO. H-2-36241

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CHECKED		S. J. Ostrom		REMOTE TANK SPEC DRAWING	
SCALE		1/2" = 1"		SHEET NO. 1	
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NEXT USED ON		DRAWING STATUS		DATE	
				NONE	
				41-2-36241	

Figure 4. Remote Test Tank Interconnection Diagram

Figure 5

WASTE CAPSULE ULTRASONIC TEST SYSTEM

REMOTE TEST TANK ELECTRONICS

DWG. NO. H-2-36237

Figure 6

WASTE CAPSULE ULTRASONIC TEST SYSTEM

COMPONENT TANK SPEC. DRAWING

DWG. NO. H-2-36238

ALTERNATE TEST HEAD

SIN-COS POTENTIOMETER & DIGITAL RESOLVER (GEARING TO EQUAL CHUCK ROTATION)

CHUCK

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COMPONENT TANK													
SPEC. DRAWING													
BLDG. NO. <i>4-2-36238</i>													
INDEX NO. <i>1/1</i>													

Figure 7. Component Inspection Tank Interconnection Diagram

Figure 8

WASTE CAPSULE ULTRASONIC
TEST SYSTEM-LOCAL TEST
TANK ELECTRONICS
DWG. NO. H-2-36238

SYNCHRONIZATION, PULSE GENERATION, & PREAMPLIFYING CIRCUITRY

Semiconductor
Circuits, Inc.
Model 1.15.200

7440

FAIRCHILD
9601

Classified by *12-16-70*
Classification *None*

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WASTE CAPSULE ULTRASONIC TEST SYSTEM-LOCAL TEST TANK ELECTRONICS		
Drawn CLK 11-70		
DWG NO.	H-2-36738	SHEET NO. SHEETS

Figure 9. Control Console Interconnection Diagram

Figure 10

WASTE CAPSULE ULTRASONIC TEST SYSTEM

SIGNAL PROCESSING ELECTRONICS

DWB. NO. H-2-36240

7	6	5	4	3	2	1
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[illegible]

Figure 11

WASTE CAPSULE ULTRASONIC TEST SYSTEM

DATA PRESENTATION CIRCUITRY

DWG. NO. H-2-36239

SP'RAL SCAN DISPLAY CIRCUIT

(1-EACH-REMOTE AND LOCAL TANK)

CRT Z AXIS AND PEN LIFT DRIVE CIRCUIT

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BLOG NO.				SCALE				CLASSIFIED BY			
DATE 12-16-76				CLASSIFICATION				NONE			
DWG NO. H-2-36239										SHEET NO. SHEETS

X-Y RECORDER SCAN RECORD

CRT SCAN RECORD

Figure 12. X-Y Recorder and CRT Scan Records for Test Standard

X-Y RECORD SCAN OF SAMPLE END CAP WELD

PHOTOMICROGRAPH OF SECTION A-A

Figure 13. Ultrasonic Scan Record for Sample End Cap Weld

X-Y RECORD SCAN OF INTENTIONALLY DEFECTED WELD

PHOTOMICROGRAPH OF SECTION A-A

Figure 14. Ultrasonic Scan Record for Intentionally Defected Weld Samples

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