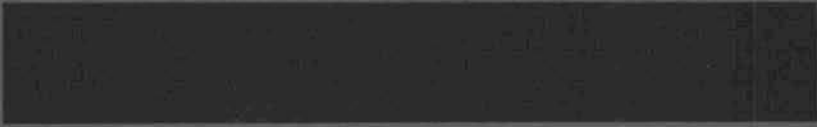
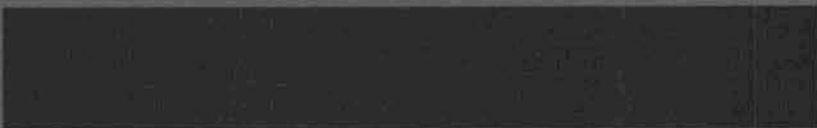


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NONDESTRUCTIVE TESTING OF ISOTOPE  
CONTAINMENT CAPSULES:  
REMOTE ULTRASONIC TEST STATION UT-40

NOVEMBER 1968



AEC RESEARCH &  
DEVELOPMENT REPORT


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NONDESTRUCTIVE TESTING OF ISOTOPE CONTAINMENT CAPSULES:  
REMOTE ULTRASONIC TEST STATION UT-40

By

R. W. Steffens, F. M. Coffman

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NONDESTRUCTIVE TESTING OF  
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## 1.0 INTRODUCTION

Because of the toxic nature of the radioactive materials contained in an isotopic capsule, the ultrasonic evaluation of the containment vessel is most safely performed remotely. Pacific Northwest Laboratory (PNL), under the sponsorship of the Atomic Energy Commission,\* developed the Remote Ultrasonic Test Station UT-40 for installation at Oak Ridge National Laboratories (ORNL) in cooperation with the Minnesota Mining and Manufacturing Company and ORNL. The basis for the UT-40 design was established at PNL during the ultrasonic test development program for the establishment of the integrity of the SNAP-21 and SNAP-23 peripheral end-cap welds.<sup>1,2,3</sup>

SNAP-21 capsules were used to evaluate the UT-40 tester, and the resultant ultrasonic waveforms and recordings are used as examples throughout this report. The test station was designed to accommodate a wide range of right cylinder capsules and to provide ORNL with a versatile broadband test instrument.

The remote UT-40 test tank facilitates right cylinder capsules with diameters up to eight inches and lengths up to twelve inches; thus versatility for testing future isotope capsule designs is provided. The broadband ultrasonic tester is a "general use" laboratory instrument with special facilities for integration with the UT-40 remote test tank.

This report gives the operating instructions and system descriptions of the UT-40 Test Station.

## 2.0 SUMMARY

The remote ultrasonic test station UT-40 shown in Figures 1 through 5 was designed for the remote evaluation of the container integrity of fueled isotope capsules. The tester consists of two parts: (1) an ultrasonic test tank which is placed in the hot cell, and (2) an electronic console which is placed outside the cell. The test tank provides: (1) rotation of the capsule,

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(\* ) United States Atomic Energy Commission Contract AT(45-1)-1830

(2) axial translation of the ultrasonic transducer, (3) linear and angular positioning of the ultrasonic transducer, (4) devices to monitor the location of the incident ultrasonic beam on the capsule, and (5) provisions for circulating cooling water. The electronic console provides: (1) motor controls for the test tank, (2) electrical power for ultrasonic-beam position monitoring devices, (3) broadband excitation for the ultrasonic transducer and amplification of the resulting signals, (4) analog synthesis of the ultrasonic signals, and (5) recording of defect signals as a function of circumferential and axial defect position on the capsule. An oscilloscope is used with the test station for equipment calibration and monitoring test waveforms.

The ultrasonic test tank will readily facilitate right cylinder capsules other than the SNAP-21 capsules by replacing the SNAP-21 collar with a collar of the proper diameter. The electronic console portion of this ultrasonic test station was designed as a general-application broadband ultrasonic instrument with special facilities for integration with the SNAP-21 test tank. Thus the electronic console can be used for a variety of ultrasonic test applications in addition to providing instrumentation for the isotope capsule testing.

Operating instructions for the test tank and electronic console are contained in sections 3.0 and 4.0. Sections 5.0, 6.0, and 7.0 describe the digital logic and special circuits in the electronic console.

### 3.0 OPERATION OF TEST TANK

#### 3.1 General Description

The UT-40 ultrasonic test tank shown in Figs. 1, 2, and 3 was designed to provide the "in-cell" mechanical facilities for the automated, remote ultrasonic NDT of fueled isotope capsules. The pertinent points of interest are numbered in Figures 1 through 5. These points are referred to throughout this report by the point and figure numbers (p. \_\_, f. \_\_). The capsule is held with the major axis vertical and is rotated at 3 rpm. The ultrasonic transducer is traversed vertically at 0.003 inches per revolution. Thus, thorough scanning of the test capsule is obtained. The rotational and axial location of the incident ultrasonic beam on the capsule is monitored, and when the ultrasonic test is performed with the associated electronic console, a map which shows defect position in the capsule can be obtained. Plumbing is provided for connection into the cell water-exchange system, and a special fixture is provided to protect the ultrasonic transducer from thermal water gradients.

This tester will facilitate right cylinder isotope containment capsules other than the SNAP-21 capsule by addition of simple adapters (p. 2, f. 2). The assembly and fabrication drawings are given in Table A-1 - Appendix A. Table 1 is a guide for operating the transducer positioning and capsule rotation devices. Specific test tank operating instructions are given in the following paragraphs.

TABLE 1  
TRANSDUCER POSITIONING AND CAPSULE ROTATION GUIDE

<u>Device</u>	<u>Adjustment</u>	<u>Transducer Travel</u>
Axial Drive Knob (p. 7, f. 3)	Counterclockwise Clockwise	Down Up
Traverse Position Knob (p. 5, f. 2)	Counterclockwise Clockwise	Back Forward
Radial Position Knob (p. 6, f. 2)	Counterclockwise Clockwise	Toward Test Sample Away From Test Sample
Goniometers - Angular (p. 4, f. 2)	Counterclockwise Clockwise	Up Down
		<u>Meter Movement</u>
Axial Potentiometer Coupling Gear (p. 6, f. 3)	Counterclockwise Clockwise	Upscale Downscale
		<u>Capsule Rotation</u>
Motor Control Switch (p. 6, f. 4)	Reverse	Capsule Turns Clockwise Transducer Goes Up
	Forward	Capsule Turns Counterclockwise Transducer Goes Down

### 3.2 Interconnections with Electronic Console

Automation of the test tank requires three interconnecting cables with the electronic console. Each cable is 15 feet long, and each is a different type. The coaxial cable is connected to the test tank at p. 8, f. 2 and is connected to the console on its upper left side (p. 1, f. 4). This cable couples the transducer excitation voltage from the console to the ultrasonic transducer at the tank and couples the rf representations of the detected ultrasonic signals

from the transducer to the console. The six-lead cable is wired into the drive motor (p. 4, f. 1) on the test tank and plugs into the six-pin socket (p. 3, f. 4) on the lower left side of the console. This cable provides coupling of the electrical power from the motor control switches in the console to the drive motor.

The ten-lead cable connects into the junction box (p. 3, f. 1) on the test tank and into the ten-pin connector (p. 2, f. 4) on the lower left side of the console. This cable provides: (1) connections for bias voltages and wiper positions on the rotational-position monitor pot (p. 2, f. 1) and the axial-position monitor pots (p. 1, f. 3), and (2) contact connections for the microswitch located on the vertical drive shaft just above the speed reducer.

### 3.3 Capsule Placement

The capsule is placed vertically into the adapter collar which is centered on the turntable as shown at p. 1, f. 2. The collar diameter is slightly larger than the capsule diameter, and the capsule is held for rotation by gravity. If capsules with diameters different from the SNAP-21 diameter are to be tested, the SNAP-21 adapter (p. 2, f. 2) is easily lifted off the turntable, and an adapter with a collar of proper diameter can be set in place.

### 3.4 Axial Drive Disengage

The axial drive shaft (p. 7, f. 2) drives the transducer holder and transducer alignment devices up and down. This shaft is disengaged from the motor drive and axial-position potentiometer by lifting up on the disengage rod (p. 9, f. 2; p. 2, f. 3). Disengagement is complete when the disengage lock (p. 4, f. 3) is positioned beneath the disengage hold (p. 5, f. 3). After disengagement, the transducer holder and alignment mechanisms can be raised or lowered by turning the knob (p. 7, f. 3) on the top of the axial drive shaft. Clockwise rotation of the knob drives the transducer up, and counterclockwise drives the transducer down. The wipers on the axial-position potentiometers can be repositioned by turning the disengaged coupling-gear (p. 6, f. 3). Caution: Ten turns on the axial-position monitoring pots are equivalent to a one-inch axial travel of the ultrasonic transducer. The wipers must not be driven against the stops at either end of the pots. A meter which monitors the wiper positions is provided on the motor control panel in the console (p. 26, f. 4).

When the wipers approach either end of the pots, the axial drive shaft must be disengaged, and the wipers must be repositioned.

### 3.5 Transducer Positioning

Positioning of the ultrasonic transducer (p. 3, f. 2) with respect to the capsule is accomplished with the devices p. 4, p. 5, and p. 6, f. 2, and p. 7, f. 3. Table 1, page 3, gives the direction of transducer travel when the positioning knobs are rotated. Two goniometers and transducer holders (p. 4, f. 2) are provided. The goniometers provide a  $\pm 30^\circ$  angular alignment of the transducer in the axial plane of the capsule. The crossfeed (p. 5, f. 2) provides traverse transducer positioning. The radial (toward or away from the capsule) transducer positioning is adjusted with the drive p. 6, f. 2. The transducer holder should be tightened to the point where the transducer is securely held in place; however, caution should be used to prevent excessive tightening of the holder.

### 3.6 Water Circulation System

Plumbing is provided for cooling water circulation in the tank during the testing of the fueled capsules as shown in Drawing H-3-27974. Note the provisions for a water flow across the face of the transducer. Transducer cooling must be provided during the inspections of a fueled capsule. The adapter provided for optimum distribution of the cooling water across the transducer is shown in Drawing No. H-3-28908.

### 3.7 Motor Controls

The drive motor is controlled by three switches on the motor control panel in the console. The forward-reverse switch (p. 4, f. 4) determines the direction of capsule rotation and the direction of transducer travel. In the reverse position the capsule will rotate clockwise, and the transducer will travel up. In the forward direction the capsule will rotate counterclockwise, and the transducer will travel down. Power is supplied to the motor by the "off-on" switch (p. 6, f. 4) or the "jog" switch (p. 5, f. 4). The "off-on" switch provides continuous power to the motor in the "on" position. Power can be supplied in incremental steps by pushing the "jog" switch when the "on-off" switch is in the "off" position. Power is supplied to the motor as long as the "jog" switch is held in.

The "forward-reverse" switch should be operated only while the motor is deactivated ("on-off" switch in "off" position). Rotation of the capsule without driving the transducer up or down can be accomplished by disengaging the axial drive as instructed in section 3.4.

## 4.0 OPERATION OF ELECTRONIC CONSOLE

### 4.1 General Description

Since most isotope capsules are produced in low quantities, the electronic console was designed as a "general use" ultrasonic broadband tester with special facilities for integration with the UT-40 ultrasonic test tank. Broadband excitation for 5 MHz through 15 MHz ultrasonic transducers can be obtained. The amplifier has a 55 db gain from 300 Hz to 30 MHz. Two independent gating systems with noise discrimination analog detectors are provided. The gates may be positioned at a fixed time referenced to the transducer excitation pulse or a fixed time referenced to the ultrasonic "surface reflection." For readout versatility the analog signals from the detectors may be added to other d-c voltages (such as voltages proportional to transducer position) by the use of two summing amplifiers. Although an X-Y recorder is installed in the console, the tester can be advantageously used with strip chart recorders. The console has circuits which control the up or down position of the recorder pen as a function of a preset defect signal amplitude. Thus, both pen-lift X-Y recordings and oblique X-Y recordings can be obtained (see Figures 7 and 8).

The following circuit schematics and wiring diagrams are included in Appendix A of this report: H-3-28903, H-3-28904, H-3-28905, H-3-28906, and H-3-28907. The circuit description section of this report gives specific information about the Battelle-Northwest developed circuitry. The pertinent waveforms are shown in the oscillograms in Figures 10 through 15. These waveforms can be used as an aid in operating and maintaining the electronic console. The vendor's instruction manuals for the commercial instruments incorporated into the system are available from the vendors at nominal cost.

### 4.2 Transducer Excitation

Proper excitation of the ultrasonic transducer is one of the most critical parts of a broadband ultrasonic system. Due to this criticality, a complete description of the pulser circuit, waveforms, and waveform shaping techniques are given in section 5.1, page 14. Section 5.1 also shows the advantage of capacitive tuning in the evaluation of the SNAP-21 welds. The waveform which excites the transducer can be monitored at p. 8, f. 2. The excitation pulse and the resultant ultrasonic signals are coupled between the electronic console and the test tank through a coaxial cable which connects

p. 1, f. 4 on the console to the junction box at p. 8, f. 2 on the test tank. The unamplified rf representations of the ultrasonic signals are coupled out the front panel at p. 7, f. 4. The exciting pulse is clipped prior to p. 7, f. 4 to protect the amplifier input circuitry.

#### 4.3 Signal Amplification

The unamplified signals may be connected directly from p. 7, f. 4 to the amplifier input p. 8, f. 4 with coaxial cable, or an attenuator (p. 9, f. 4) may be inserted to provide additional amplification ranges. The amplified rf representations of the ultrasonic signals can be monitored with an oscilloscope at the amplifier output p. 10, f. 4. The basic amplification can be varied in ten increments from 40 db to 55 db with the gain control switch, p. 11, f. 4. Since the amplifier has a  $\pm 3$  volt output limit, the attenuator should be inserted when aligning the ultrasonic transducer to permit observation of the unsaturated surface reflection. The specific amplification to be used during an ultrasonic test is dependent on many variables unique to that test. Fifty-five db amplification should be sufficient for most ultrasonic tests. The amplifier is fully recovered within four (4) microseconds after the transducer excitation pulse.

The amplified waveforms appearing at p. 10, f. 4 are rf representations of the ultrasonic signals which are detected by the transducer. These signals, when displayed on the oscilloscope, are used to align the ultrasonic beam on the test piece, evaluate the transducer response, position the gates, and in the set-up procedure for an ultrasonic test. The amplified rf representations of the ultrasonic signals are connected to the signal synthesis circuitry by connecting a coaxial cable between p. 10, f. 4 and p. 12, f. 4.

#### 4.4 Gate Positioning

The two modes of gate operation available are: (1) normal-mode gates referenced in time to the transducer excitation pulse, and (2) gate-follower mode referenced in time to the ultrasonic surface reflection. Two independent signal gates are available in each of the gating modes. The gate mode of operation is selected with the properly labeled switch position at p. 13, f. 4.

The normal-mode gate operation is used: (1) when ultrasonic defect signals occur at a constant time after the transducer excitation pulse, or (2) when the ultrasonic surface reflection has insufficient amplitude

to activate the gate-follower mode circuitry. The gate-follower mode operation is used when critical positioning of the signal gates is necessary. The descriptions of the gate circuitry and waveforms are given in the signal gates section, 5.4. The pulse logic sequence description is given in section 7.0. Refer to Figure 10 for the oscillograms which show the time relationships of the delays and pedestals for the normal mode gate operation. In the normal mode operation, the signal gates A and B are referenced to the leading edge of the normal gate pedestal. The normal-gate pedestal can be monitored at p. 19, f. 4. The normal-gate is referenced to the transducer excitation time with the normal-gate variable delay potentiometer at p. 14, f. 4, and the pedestal width is adjusted with the width potentiometer at p. 14, f. 4. The signal gate pedestals A and B can be monitored at p. 17 and p. 18, respectively, as shown in Fig. 4. The leading edges of the signal gates are positioned with respect to the leading edge of the normal-gate with the variable delay potentiometers at p. 15 and p. 16, f. 4. The signal gate pedestal widths, which determine the portions of the rf ultrasonic signal to be detected, are adjusted with the variable width potentiometers at p. 15 and 16, f. 4.

Refer to Figure 10 for the oscillograms which show the time relationships of the delays and pedestals for the gate-follower mode gate operation. In the gate-follower mode the signal gates A and B are referenced to the surface reflection of the rf ultrasonic signal. To actuate the signal gate, the normal-gate pedestal (p. 19, f. 4) is positioned in time coincidence with an ultrasonic signal which is over +1.5 volts in amplitude, and which is present each time the transducer is excited. When the above conditions are met, the signal gate delays are referenced to the coincident ultrasonic signal, and the signal gate pedestals can be positioned with their respective delay and width potentiometers at p. 15 and p. 16, f. 4.

#### 4.5 Analog Signal Detection

The electronic console contains independent detection circuitry for both signal gates A and B. Refer to Figure 14 for the detector waveforms. The detection circuitry produces a dc voltage level proportional to the largest negative rf ultrasonic signal which is coincident in time with the respective A or B gate pedestals. The detected-signal voltage level can be monitored at the recorder supply terminals p. 21, and p. 22, f. 4. The signal synthesis chassis is mounted on slides, and the intermediate waveforms between initial gating and the analog output can thus be conveniently monitored.

The detectors are reset to the "noise" rejection voltage level approximately thirty microseconds after the transducer is excited. The "noise" rejection voltage level (see oscillogram E, Figure 14) is adjusted with the potentiometer on the detector boards behind the signal synthesis panel (p. 10, f. 5). The "noise" rejection increases as the "noise" rejection voltage level is made more negative. If ultrasonic signals occur closer than thirty-five microseconds after the transducer excitation pulse, the reset pedestal must be proportionately shortened. Refer to section 5.5 for the description of the signal detection sequence.

#### 4.6 Summing Amplifiers

Refer to Figure 6 for signal preparation for recording diagram. The four available inputs to the X-Y recorder are: (1) the analog signal from gate A, (p. 21, f. 4), (2) the analog signal from gate B (p. 22, f. 4), (3) a voltage linearly proportional to the axial (longitudinal) position of the ultrasonic transducer (p. 23, f. 4), and (4) a voltage linearly proportional to the rotational (traverse) position of the capsule with respect to the ultrasonic transducer (p. 24, f. 4). The analog voltage from gate A and B can range from 0 to -6 volts. The axial position voltage ranges from 0 to +15 volts for one-inch axial travel of the transducer. The rotation position ranges from 0 to +15 volts every two complete rotations of the capsule. The two summing amplifiers will each facilitate three external inputs (p. 3, f. 5). Each summing amplifier has an internal input for adjusting the quiescent output voltage levels. The internal adjustment voltages to each summing amplifier may be varied from -15 volts to +15 volts with the respective zero set potentiometers (p. 1 and 2, f. 5). The four available analog signals at p. 21-24, f. 4, may be added to each other in any desired combination by connecting the analog signals into the common inputs (p. 5, f. 5) on one or both summing amplifiers. When the analog signals are connected directly into the summing amplifier inputs, the amplifiers have a gain of minus one (-1). The gain at each amplifier input can be decreased by adding series attenuating resistance ( $Z_a$ ) at the amplifier inputs. The gain of the amplifier is

$$|A| = \frac{-10}{10 + Z_a}$$

where A is the gain, and  $Z_a$  is the series resistance in kilohms. The two

outputs of the summing amplifiers (p. 3, p. 4, f. 5) can thus provide multiple-variable driving voltages for the pen and carriage inputs on the X-Y recorder. When defect indications overlap on the X-Y recording (Figure 9-A), limiting diodes ( $D_L$ , Figure 6) can be placed across the peak pulse outputs to obtain better definition of defect indications. Since the nominal conduction voltages for a solid-state diode is .6 volts, the upper limit of the detector voltages can be easily limited in 0.6 volt increments by a series combination of diodes.

#### 4.7 Recorder Pen Lift Operation

When the toggle switch on the back of the X-Y recorder is placed in the "R" position, the recorder is programmed to set the pen down only when defect signals larger than a preset minimum are encountered and during every second revolution of the test capsule. The pen lift capability permits "pen lift" recordings to be made in addition to the normal recordings obtained with an X-Y recorder. Recording every second revolution of the capsule insures against missing defect indications during pen reset.

The pen lift discrimination level for defects detected in gate A or gate B is set with the respective level-set potentiometers, p. 6, f. 5. The discrimination levels increase as the potentiometers are turned toward 10. The pen will remain down during an entire revolution of the capsules when one or both discrimination levels are set to zero. If only one gate-detector channel is being used during a "pen lift" recording, the level-set potentiometer for the other gate-detector channel should be set at ten (10) to prevent false defect indications.

The pen should be in the "up" position during the capsule revolution in which the rotation monitor voltage switches between the 0 and +15 voltage levels. The revolution to be recorded can be changed by pushing the reset button, p. 25, f. 4. Refer to the pen lift logic and special circuits section, 6.0, for the description of the pen lift circuitry and logic sequence.

#### 4.8 Recording

Three of the combinations obtainable by unique adding of the four available inputs and the pen lift options are described below.

The oblique X-Y recording shown in Figure 7 is convenient for data interpretation in welds which contain small, randomly spaced defects. To set up this type of recording, the rotational position voltage is added with the analog defect signal through one summing amplifier, and the resulting

voltage is applied to the pen input of the recorder. The axial position voltage is added to a portion of the rotation position through the other summing amplifier and is applied to the carriage input of the recorder. With the aid of a standard, the "noise" rejection level and the pen and carriage sensitivities are adjusted to obtain the desired scan.

The "pen lift" recording shown in Figure 8 is convenient when large portions of the weld are defective. Examples are: (1) lack of joint fusion due to misalignment of the weld volume, and (2) welds which display areas with high concentration of large defects. To set up the "pen lift" recording, the rotation monitor voltage is connected to the recorder pen input, and the axial position monitor voltage is connected to the recorder carriage input. With the aid of a standard, the pen lift discrimination levels and recorder sensitivity are adjusted to obtain the desired scan.

Limiting diodes across the detector outputs can be advantageously used when superimposed defect signals hinder recording interpretations. Figure 9-A shows a recording of the SNAP-21 weld standard without diode limiting. Note the superimposed defect indications for the .040" through .070" standard holes. Figure 9-B shows the separation of all defect indications by use of diode limiting.

## 5.0 SPECIAL CIRCUIT DESCRIPTIONS

The following paragraphs describe the functions of the noncommercial, Battelle-developed circuitry contained in the electronic portion of the UT-40 ultrasonic tester. The pertinent waveforms shown in the oscillograms are an aid in understanding the operation and maintenance of the electronic console.

### 5.1 Pulse Generators

The pulse generators, Drawing No. H-3-28906, Appendix B, are solid state circuits which provide the excitation pulse for the ultrasonic transducer. The clock pulse from the digital logic, oscillogram A, Fig. 12, drives the 2N3501 transistor into avalanche to initiate the pulser sequence. Upon avalanche, the collector of the transistor is shorted to ground, and a 200 to 270 volt, 16 nanosecond rise time pulse results as shown in oscillogram B of Figure 12. In pulse generator No. 2 the transistor collector pulse is differentiated to produce the "spike" pulse for transducer excitation. In pulse generator No. 1 the transistor collector voltage is coupled to the negative side of the Shockly diode, and thereby the Shockly is driven into

avalanche. A 325 to 475 volt 20-nanosecond rise time pulse results at the positive terminal of the Shockly as shown in oscillogram C of Figure 12. This pulse is then differentiated to form the "spike" pulse for transducer excitation as shown in oscillogram D, Figure 12.

The output differentiators on each board were fabricated with 100 ohm output resistors to match the 15-foot 93 ohm cable used in the SNAP-21 weld evaluation. This output resistor can be changed to match the characteristic impedance of different cables if desired.

The rise time of the transducer excitation pulse and the duration of the "spike" is determined by the action of the time constant of the output differentiating circuit on the collector waveforms. Varying the time constant is generally done by changing the capacitor. The time constant is made shorter to increase the high frequency characteristics of the excitation pulse and is made longer to increase the low frequency characteristics of the excitation pulse.

Additional excitation-pulse shaping can be performed at the transducer connector on the test tank when the most optimum transducer excitation pulse is required. Parallel capacitive tuning has been found advantageous when the transducer active element is the ceramic PZT-5. Comparison of oscillograms A and B, Figure 13, shows the PZT-5 transducer response improvement obtained with capacitive tuning.

The specific transducer excitation pulse selected for exciting the 15 MHz, PZT-5 ultrasonic transducer during the ultrasonic evaluation of the weld on the SNAP-21 isotope containment vessels is shown in the oscillogram C, Figure 13. A 470-pf capacitor was used to parallel tune the transducer, and a 300-pf capacitor with a 100-ohm output resistor was used in the pulse generator differentiation circuit. The high voltage power supply was set at +265 volts.

If transducers with different diameters, resonate frequencies, and/or active element materials are used, the optimum tuning impedance (capacitive or inductive) will vary. Optimum tuning impedance is experimentally determined.

## 5.2 Clipper

The clipper and emitter follower, Drawing No. H-3-28906, Appendix A, uses back-to-back diodes to limit the voltages applied to the input of the main amplifier. Thus, the main amplifier recovers completely within 4 microseconds after the saturation produced by the transducer excitation pulse. See oscillogram A in Figure 10.

### 5.3 SC-5 Pulse Shaper

The SC-5 pulse shaping circuit, Drawing H-3-28905, Appendix A, transforms the amplified rf ultrasonic surface signal into a pulse which is compatible with the DEC logic. If any portion of the rf signal from the main amplifier exceeds 1.5 volts, the pulse shaper simultaneously produces a standard pulse as shown in oscillograms A and B, Figure 11. Coincidence of a pulse from the pulse shaper with the normal gate pedestal is required to operate the gate-follower mode sequence.

### 5.4 Signal Gates A and B

The signal gates A and B, Drawing No. H-3-28906, Appendix A, are used to gate selected signals from the amplified rf representations of the detected ultrasonic signals. The gating sequence is actuated by the gate pedestals A and B which are generated in the digital logic (see Figures 10 and 11). The gate pedestals are positioned as instructed in the gate positioning paragraph, section 4.4.

Presence of a gate pedestal on input pin E of the gate board drives the transistor into saturation. Upon saturation, the transistor collector voltage switches from the quiescent -15 volts to 0 volts, the pinch-off voltage is thereby removed from the FET gate, and free conduction between the FET source and drain is permitted. The rf signal from the main amplifier is the drain supply, and only the rf signals coincident in time with the gate pedestal are passed through the FET to the gate output pin K. Oscillograms A, B, and C in Figure 14 show the time relationships between the gate pedestal, amplified rf signal, and the gated rf signal.

### 5.5 Analog Signal Detector

The analog signal detector, Drawing No. H-3-28906, Appendix A, uses a single diode to detect the negative portions of the gated rf signal. Prior to detection the gated signal is further amplified by the C-COR-3582 rf amplifier which has a gain of ten. The rf signal from the C-COR is ac coupled to the cathode of the detector diode. When a negative going rf signal appears in the gate signal, the diode is forward biased and the 300-pf capacitor will charge to the highest negative voltage present in the rf signal. When the negative signal passes, the diode is reverse biased, and the capacitor will remain charged until the reset transistor is turned on just before the next gating sequence.

The emitter of the reset transistor is biased with a variable negative voltage through the emitter potentiometer. The detector capacitor is reset to the emitter voltage level, and the detector diode will not be forward biased by the negative portion of the gated rf signal unless the signal is larger than the reset voltage. Thus, "noise" discrimination is provided.

The detection sequence occurs each time the transducer is excited. Oscillograms D through H in Figure 14 show the detection sequence of a defect signal in a SNAP-21 weld.

### 5.6 Summing Amplifiers

The operational amplifier board contains two LM-201 operational amplifiers which can be used to combine up to six analog signals for the X-Y recorder. The amplifier board has a 10-K input and feedback resistors and a gain of -1.

### 6.0 Pen Lift Logic and Special Circuits

The pen lift logic and special circuits as shown in Figure 14, Drawing H-3-28903 and H-3-28906, provide two functions. They permit recording of every second revolution of the capsule to ensure recording over the entire capsule circumference, and secondly, they permit recording of only those defect indications which are over a predetermined amplitude to obtain "pen lift" recordings. The pen lift function is categorized into four operations as follows: (1) the microswitch contact on the vertical drive shaft closes once during each revolution of the capsule, (2) the output voltage level of the pen-lift level-set circuits A and B changes when a defect indication over a present discrimination level is encountered, (3) the digital logic processes the signals from the microswitch, pen-lift level-set circuits, and the reset switch into one output, and (4) the pen lift circuit SC-4 converts the output of the digital logic into a signal compatible with the recorder's pen lift solenoid. This pen lift circuitry controls the position of the pen only when the local-remote switch on the reverse of the recorder is in the remote "R" position.

#### 6.1 Pen Lift Level Set A and B

The pen lift level circuits, Drawing H-3-28906, Appendix A, are designed to produce minus three volts when the absolute value of the detector voltage is smaller than the pen lift reference voltage and to produce zero volts when the detector voltage is greater than the reference voltage.

The negative dc detector voltage is fed into one input of the LM-201 operational amplifier. The other input to this amplifier comes from a 10-turn reference potentiometer biased with a positive voltage. If the detector voltage is the same absolute value as the reference voltage, zero volts will appear at pin 2 (the amplifier input). As the detector voltage goes more negative, the amplifier output will go more positive, and the lower diode will conduct. This will cause a large amount of feedback and consequently low amplifier gain, resulting in a near zero output. If the detector voltage goes less negative, the amplifier input will be slightly positive and the output negative. Since the amplifier now has no feedback, its gain will be very large, and the amplifier output will immediately go to minus 3 volts. At this point, the top diode will be forward biased, and again, the feedback will increase holding the output at minus 3 volts.

## 6.2 Microswitch and Reset Button Function

The microswitch is located on the main drive shaft of the test tank, and its contacts are mechanically closed at 360° intervals. Thus, the closure of the microswitch contacts signifies the end of one revolution and the beginning of another. The reset contacts are manually closed by depressing the reset button at p. 25, f. 4. The reset button is used to change the revolution to be recorded.

## 6.3 Pen Lift Logic

The pen lift digital logic shown in Figure 15 and Drawing H-3-28903 synthesizes the outputs of the pen lift level circuits, microswitch, and reset button into one command output to the pen lift special circuit-four (SC-4). Only two voltage levels, 0 and -3 volts, are encountered in the digital logic. The voltage level from each block which initiates the following digital sequence is known as the assertion level and is shown on the block diagram in Figure 15.

Each time the microswitch or the reset contacts are closed, the Schmitt Trigger generates a 0 volt pulse as shown in Figure 15, waveform A. The 0 volt assertion level from the Schmitt Trigger causes the flip-flop output to change voltage level and initiates the -3 volt assertion level in the Trace Mark Pedestal (refer to Figure 15, waveforms A, B, and C). The pen lift level circuits A and B produce 0 volt assertion levels when a defect signal larger than the discrimination level is encountered (waveform D). The pen lift level circuits will produce to 0 volt assertion

level continuously if the discrimination level potentiometers are set to zero (refer to pen lift level set A and B, paragraph 6.1 page 17). The pen lift assertion level is inverted to the -3 volt level for input to the NAND (negative AND) gates as shown in waveform E.

The NAND gates produce the 0 volt assertion level for Inverter-3 when both assertion levels of the Inverter-1 and the flip-flop are present (compare waveforms B, E, and F). The Inverter-3 produces the 0 volt assertion level for Inverter-3 during the presence of the Trace Mark Pedestal. Thus, the Inverter-3 produces the -3 volt assertion level to the pen lift solenoid switch (SC-4) when (1) a defect is present in A or B detector and the flip-flop is in the assertion state or, (2) during the Trace Mark Pedestal.

Since the flip-flop is in the assertion level every second revolution, the pen can be set down for defect recording only during every second revolution. The output level of flip-flop can be changed by closing the reset contacts, and thereby, the revolution to be recorded can be changed. When the defect discrimination levels are set to zero, the pen lift level set is in the assertion level continuously, and the pen will set down during the entire revolution that the flip-flop is at the assertion level. The pen is set down at the beginning and end of each X-Y trace through the microswitch-Trace Mark Pedestal-Inverter-2 sequence.

#### 6.4 Pen Lift Special Circuit-4

The pen lift special circuit-4 permits current to flow through the pen lift solenoid coil when the voltage level from the pen lift logic is at the minus three volt level. The 2N618 transistor is bias "off" when the voltage level from the pen lift logic is at the zero volt level, thus, current flow through the solenoid coil is impossible.

#### 7.0 Pulse Logic Description

Digital Equipment Corporation (DEC) plug-in modules, wire-wrap racks, and power supply were used to implement the pulse logic for the gates, detectors, system clock and the digital logic for the pen lift sequence. Pertinent waveforms and their time sequence are given in Figures 10, 11, 12, and 14 for the pulse logic and in Figure 15 for the digital logic.

The pulse and digital logic diagram H-3-28903, Appendix A, gives the interconnections between the plug-in modules. This drawing shows the pulse polarities for the pulse logic and the assertion levels for the digital logic.

ACKNOWLEDGEMENTS

The authors wish to acknowledge S. J. Ostrom and V. Wilgus for the design of the remote test tank and B. Dozer for the design consultation during development of the Broadband Ultrasonic Tester.

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2. R. W. Steffens, F. M. Coffman. Nondestructive Testing of Isotope Containment Capsules Intermediate Phase SNAP-21. To be published.
3. R. W. Steffens, F. M. Coffman. Nondestructive Testing of Isotope Containment Capsules SNAP-21 Final Report. To be published.

APPENDIX

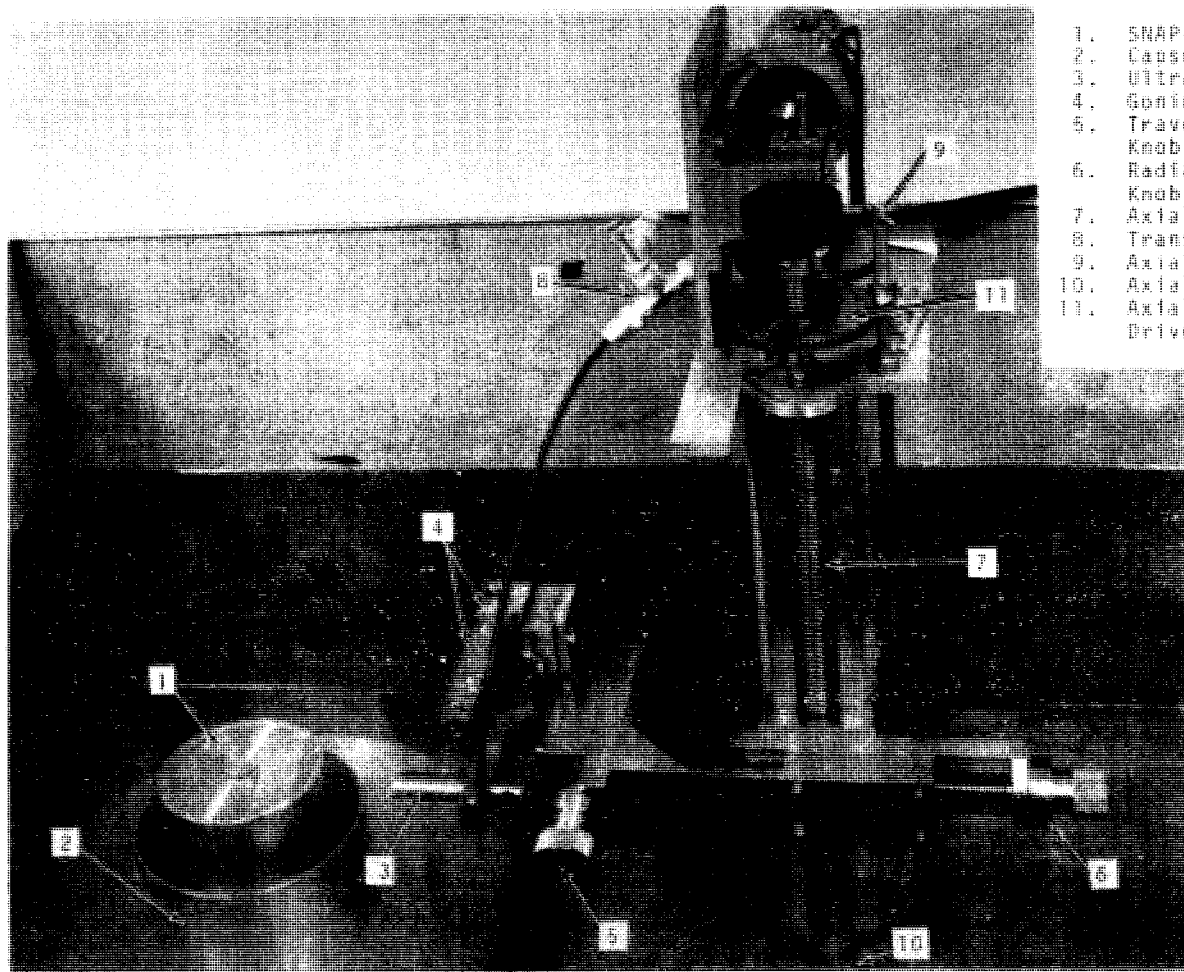
UT-40 Electronic and Mechanical Fabrication,  
Assembly, and Circuit Drawings





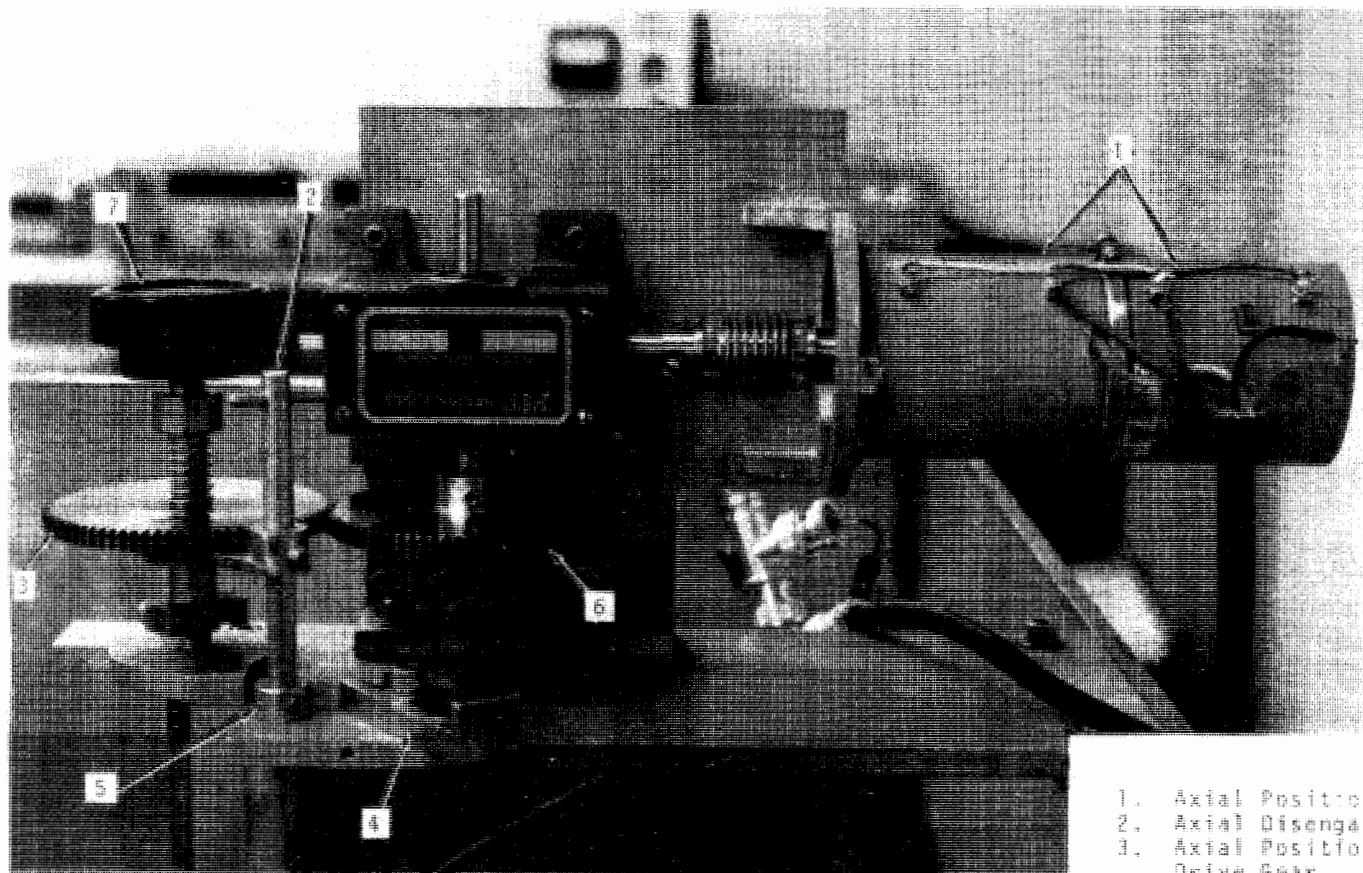
1. Drive Motor
2. Rotation Position Monitor Potentiometer
3. Position Monitoring Device Terminal Box

FIGURE 1  
UT-40 Remote Ultrasonic Test Station



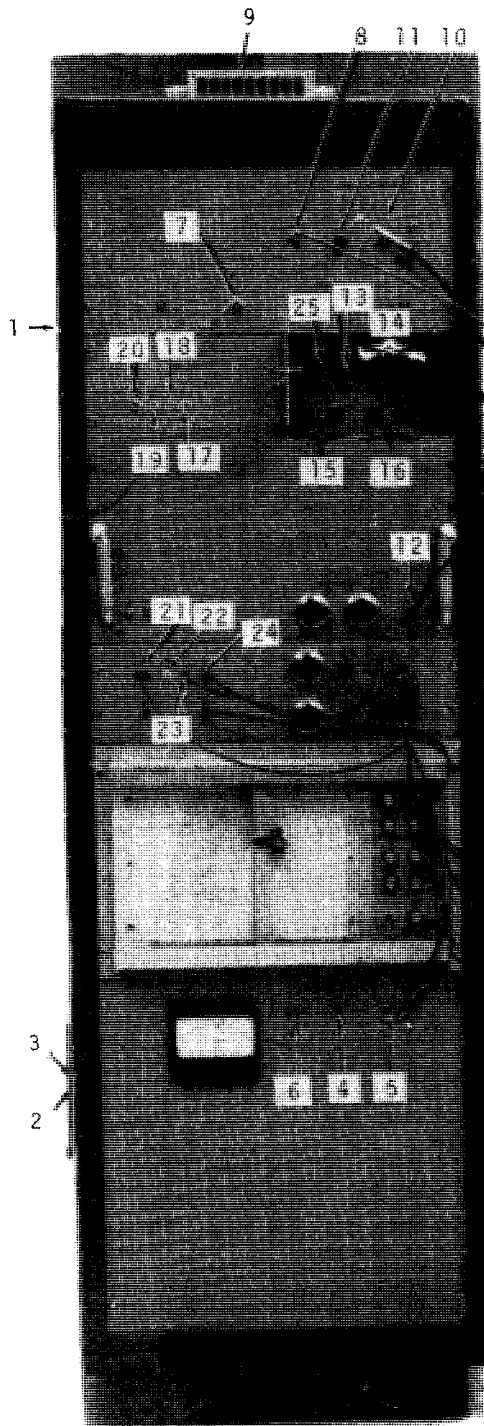
1. SNAP-21 Mock Capsule
2. Capsule Holding Collar
3. Ultrasonic Transducer
4. Goniometers
5. Traverse Transducer Position Knob
6. Radial Transducer Position Knob
7. Axial Drive Shaft
8. Transducer Connecting and Tuning
9. Axial Drive Disengage Rod
10. Axial Shaft Drive Gear
11. Axial Position Monitor Potentiometer Drive Gear

FIGURE 2  
Capsule Rotation and Scanning Mechanisms Description



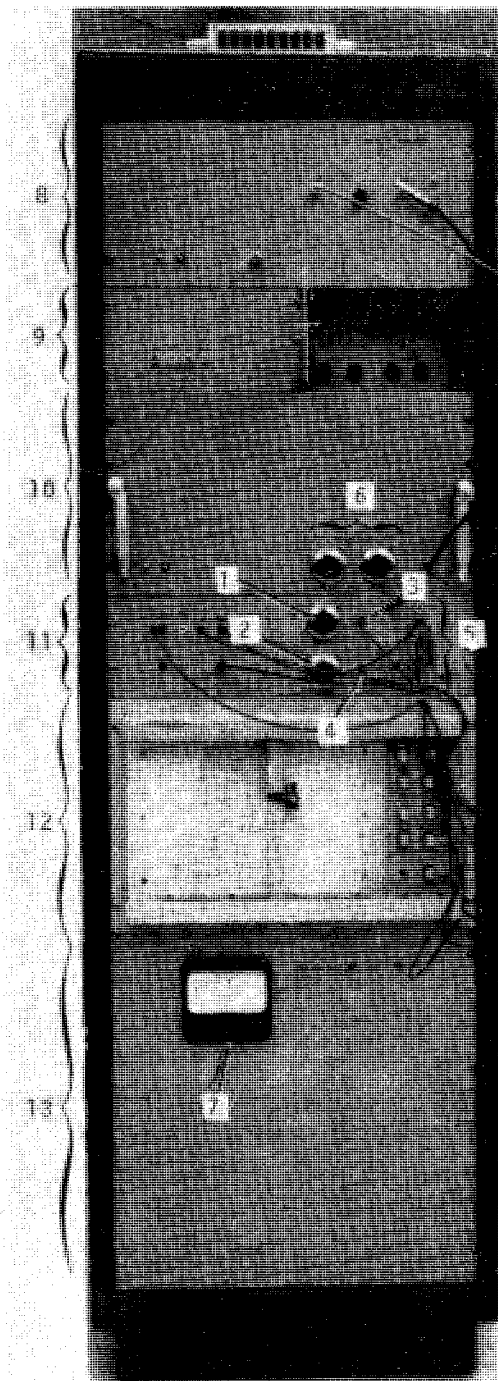
- 1. Axial Position Monitor Potentiometers
- 2. Axial Disengage Rod
- 3. Axial Position Monitor Potentiometer Drive Gear
- 4. Disengage Lock
- 5. Disengage Hold
- 6. Axial Position Monitor Potentiometer Coupling Gear
- 7. Manual Axial Drive Knob

FIGURE 3  
 Axial Drive and Position Monitoring Mechanisms Description



1. Transducer Excitation Output
2. Position Potentiometer and Microswitch Connector
3. Motor Control Connector
4. Capsule Rotation Direction Switch
5. Jog Switch for Incremental Capsule Rotation
6. Continuous Capsule Rotation Switch
7. Unamplified rf Output
8. Amplifier Input
9. Attenuator
10. Amplifier Output
11. Amplifier Gain Control
12. Input to Signal Synthesis Chaisse
13. Digital Logic Power Switch
14. Normal Gate Delay and Width Controls
15. Gate Pedestal A Delay and Width Controls
16. Gate Pedestal B Delay and Width Controls
17. Gate Pedestal B Monitor Point
18. Gate Pedestal A Monitor Point
19. Normal Gate Monitor Point
20. Sync Pulse for Oscilloscope
21. Detector A Output
22. Detector B Output
23. Longitudinal (Axial) Position Voltage
24. Traverse (Rotational) Position Voltage
25. Pen Lift Reset

FIGURE 4  
UT-40 Ultrasonic Test Console Description I



1. Quiescent Amplifier Voltage Adjust A
2. Quiescent Amplifier Voltage Adjust B
3. Summing Amplifier Output
4. Summing Amplifier Output
5. Summing Amplifier Inputs
6. Pen Lift Discrimination Level Adjust Potentiometers
7. Axial Potentiometer Wiper Position Monitor
8. Signal Generation and Amplification Panel
9. Digital Logic Panel
10. Signal Synthesis Panel
11. Signal Preparation for Recording Panel
12. X-Y Recorder
13. Motor Control Panel

FIGURE 5  
UT-40 Ultrasonic Test Console Description II

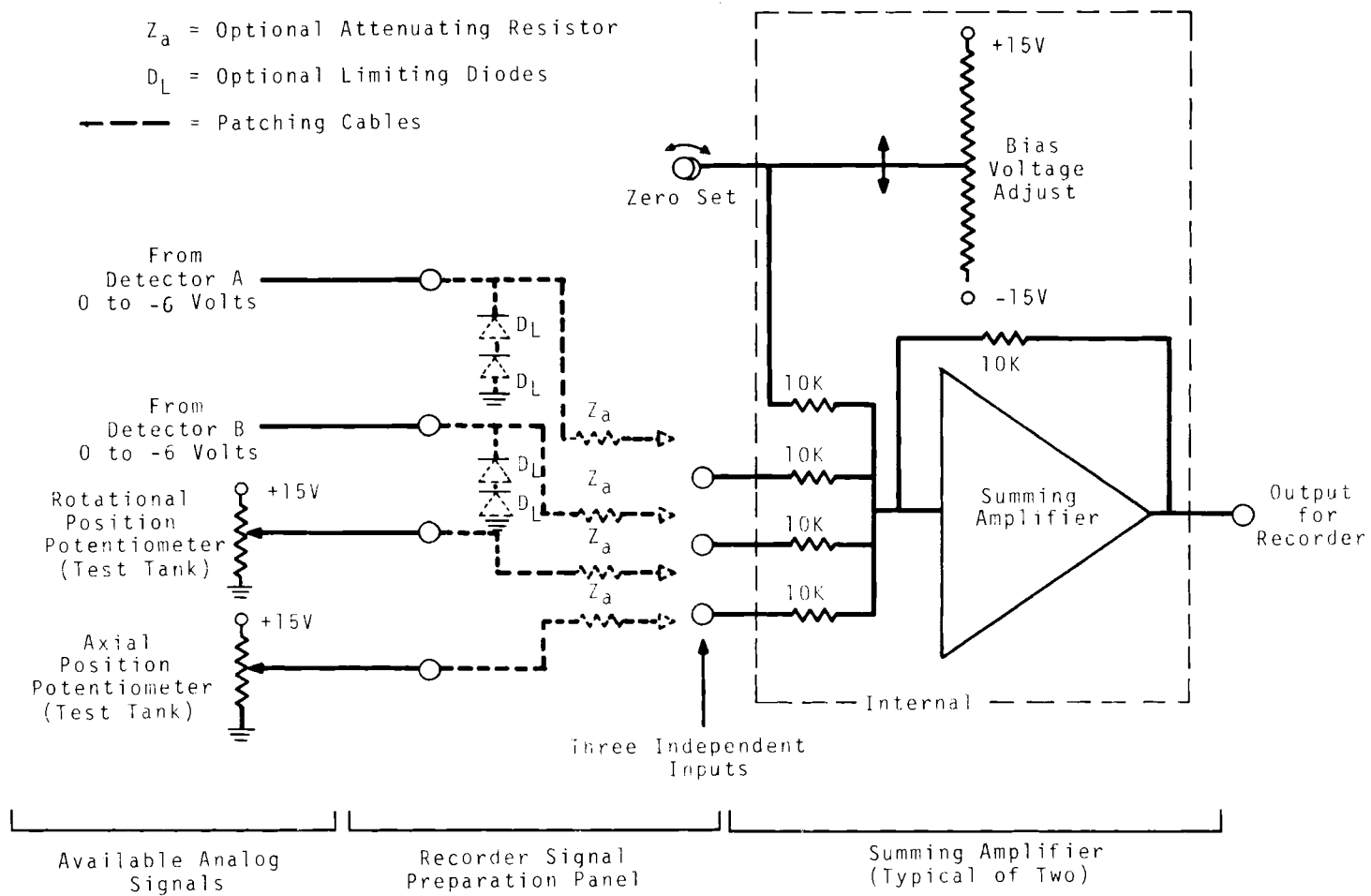


FIGURE 6  
 Recorder Drive Signal Preparation Diagram

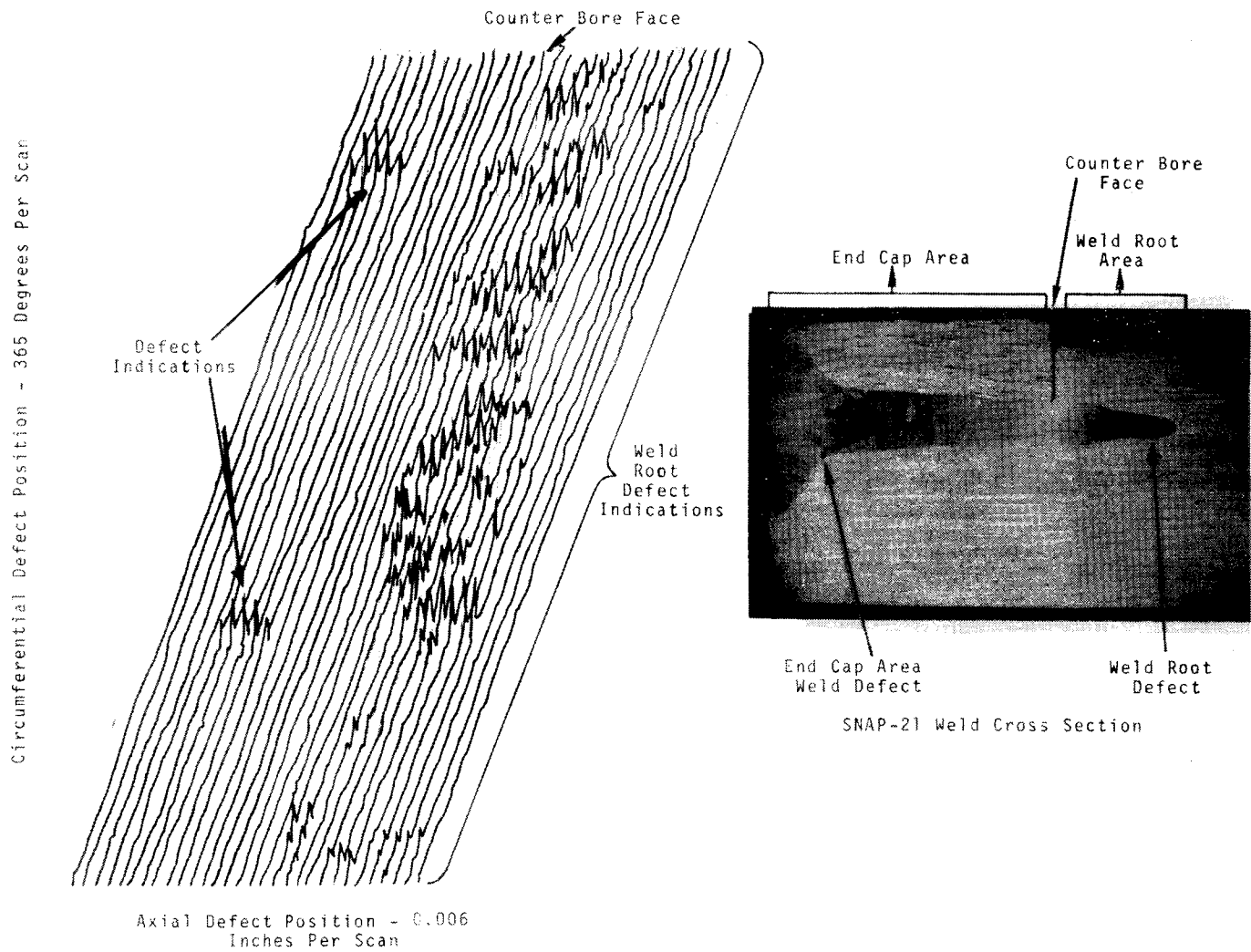


FIGURE 7  
Oblique X-Y Defect Recording of SNAP-21 Sample Weld

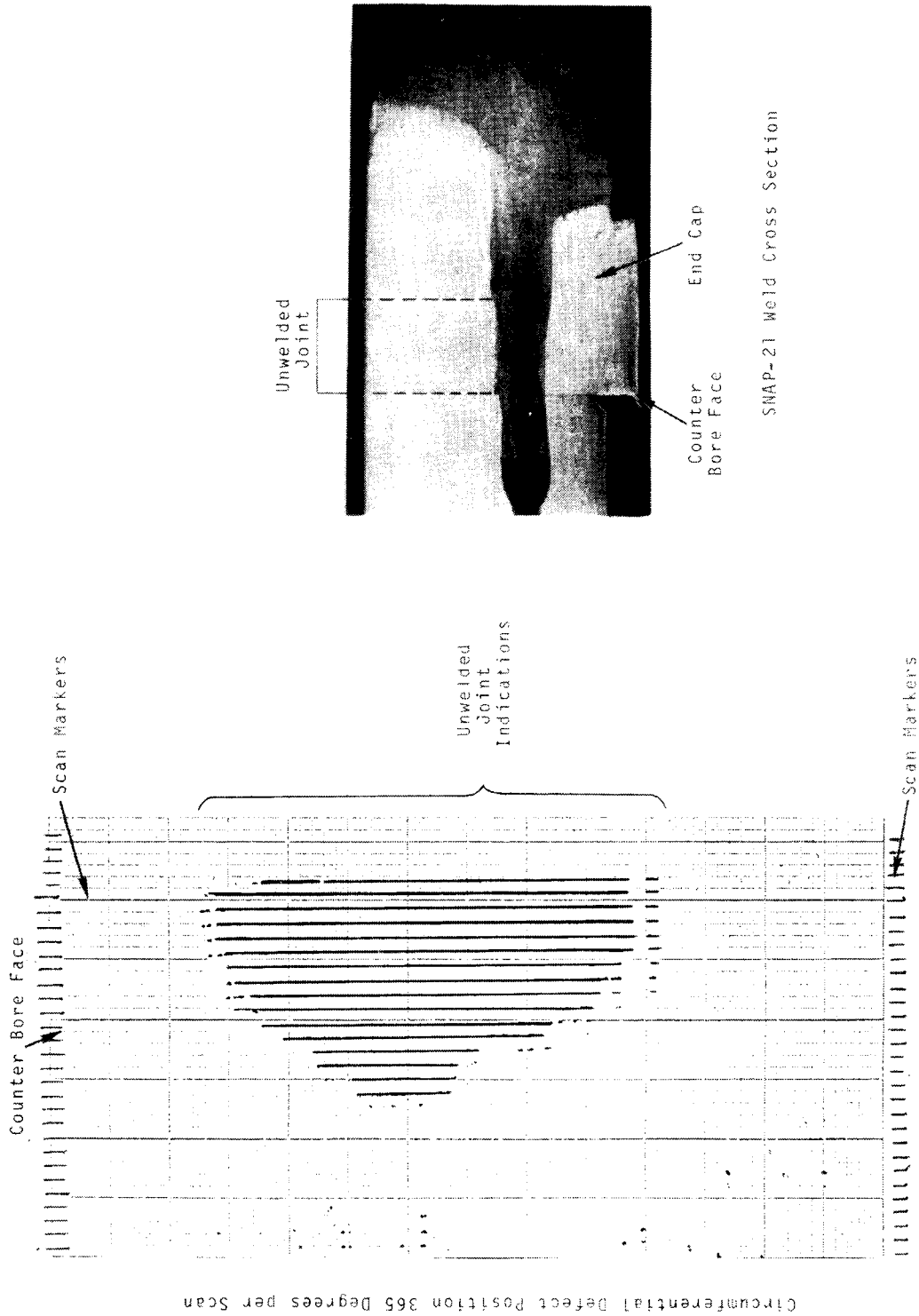


FIGURE 8  
X-Y Pen Lift Recording of a SNAP-21 Sample Weld

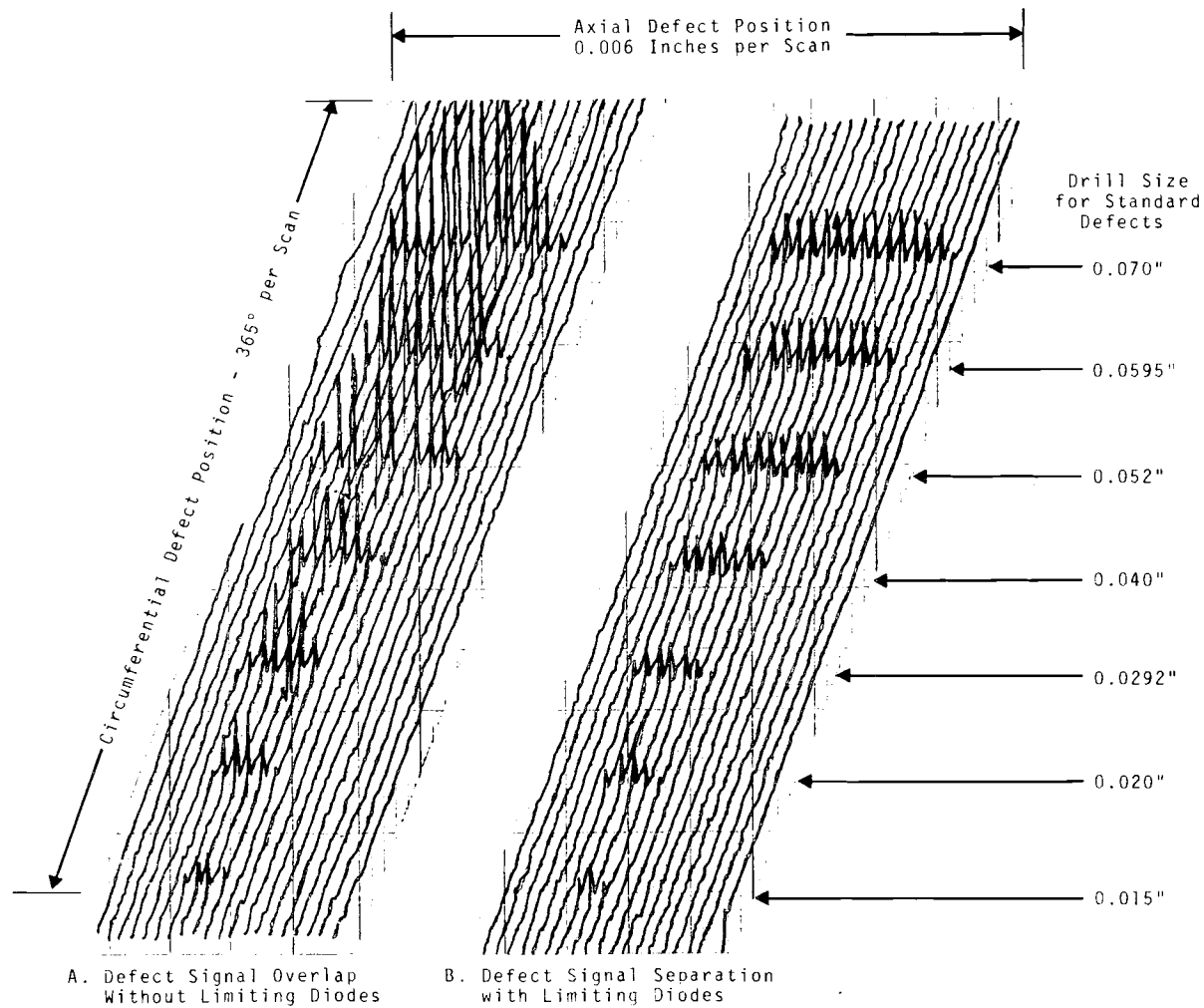


FIGURE 9  
Example of Oblique X-Y Recording of SNAP-21 Standard with and Without Diode Limiting

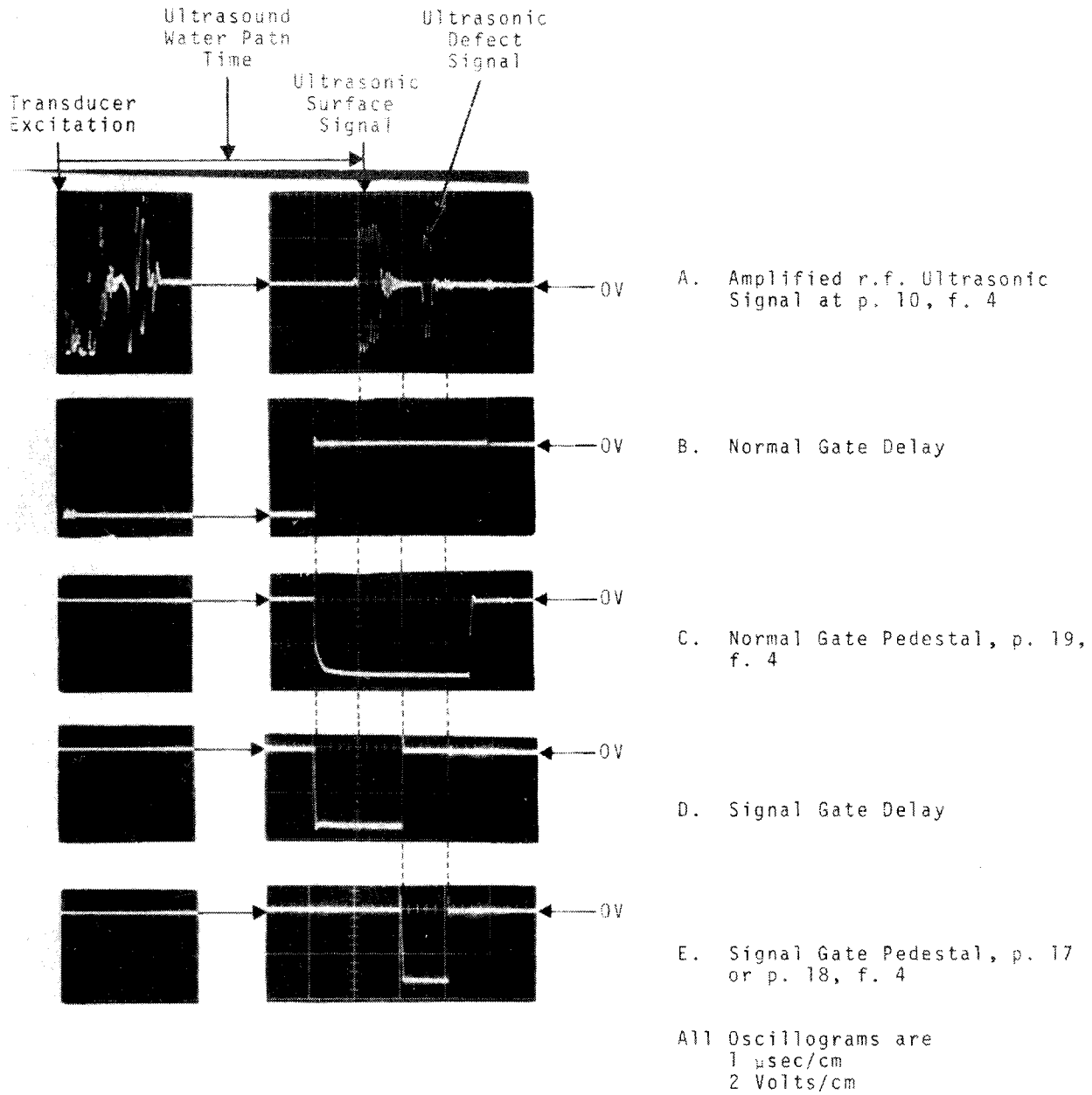


FIGURE 10  
 Time Relationship of the Delays and Pedestals for Normal  
 Mode Gate Operation

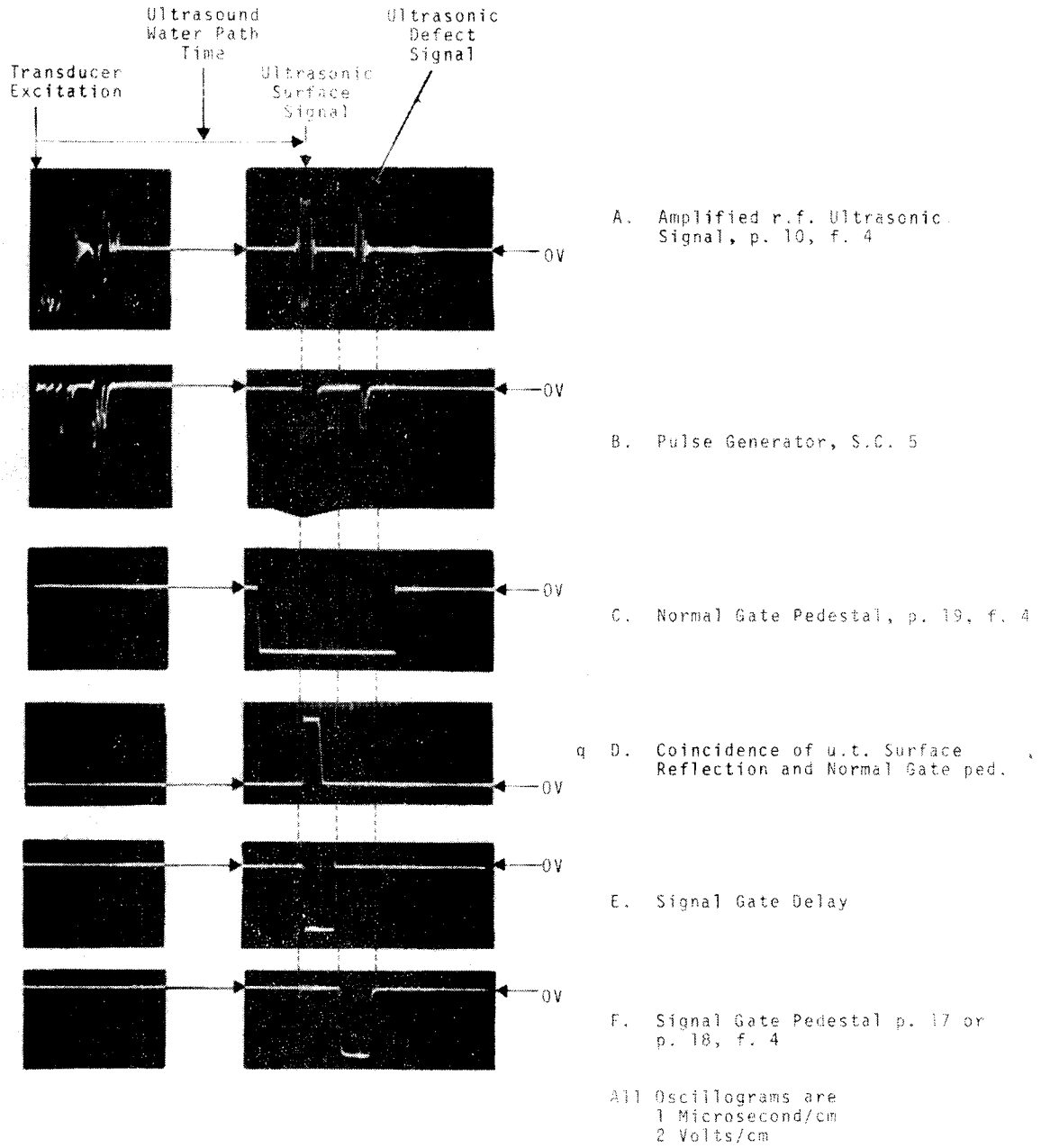
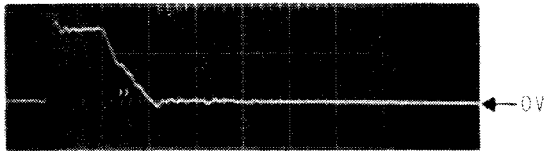
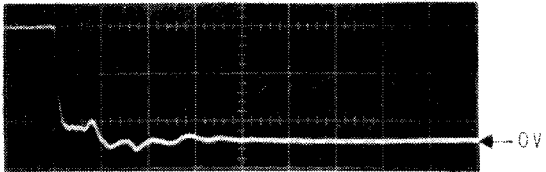


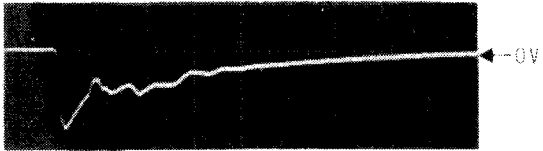
FIGURE 11  
Time Relationship of the Delays and Pedestals for Gate-Follower Mode Gate Operation



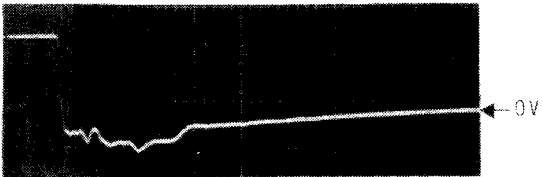
A. Clock Pulse  
2 Volts/cm



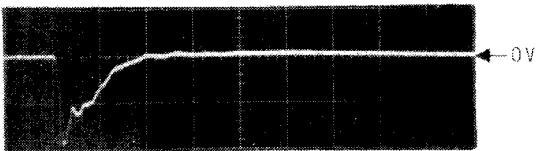
B. 2N3501 Collector Voltage in  
Avalanche Mode  
100 Volts/cm



C. Negative Side of Shockley Diode  
100 Volts/cm



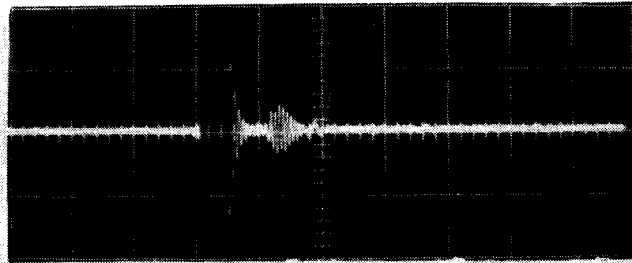
D. Shockley Diode Collector Voltage  
in Avalanche Mode  
100 Volts/cm



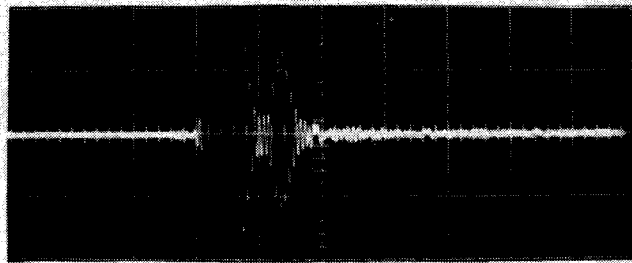
E. "Spike" Transducer Excitation Voltage  
100 Volts/cm

All Oscillograms are  
0.1 Microsecond/cm

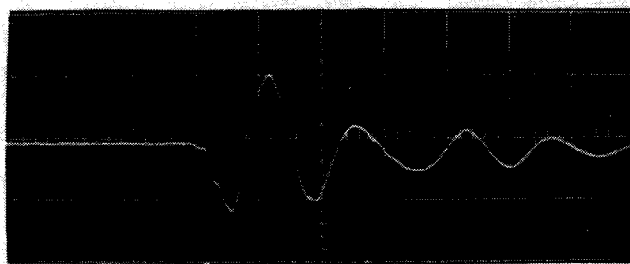
FIGURE 12  
Pulse Generator Waveforms



A. 15 mc PZT-5 Transducer  
Response - Untuned  
1 Microsecond per cm  
0.5 Volts per cm

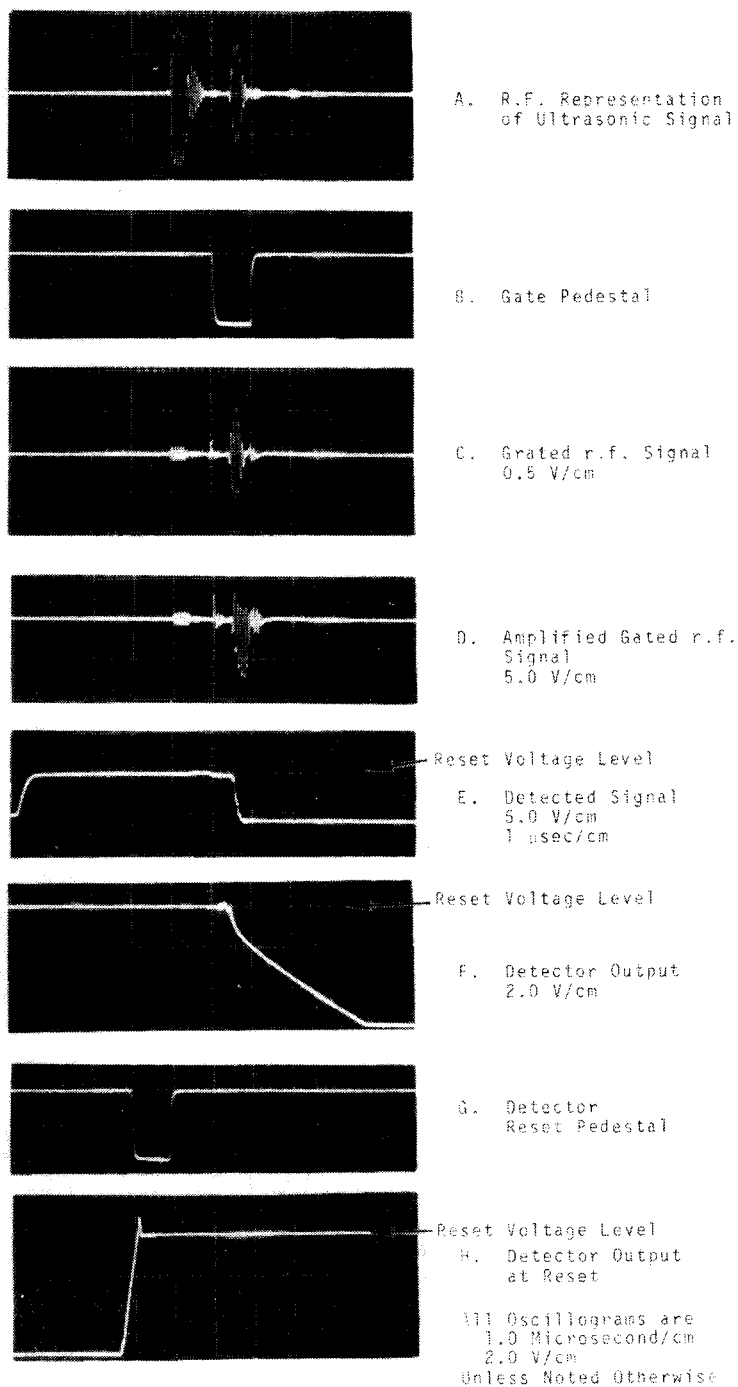


B. 15 mc PZT-5 Transducer  
Response - Tuned  
1 Microsecond per cm  
0.5 Volts per cm



C. Tuned Transducer  
Excitation Voltage of  
Test Tank Connection  
0.05 Microsecond per cm  
50 Volts per cm

FIGURE 13  
Transducer Response and Excitation for SNAP-21 Weld  
Evaluation



NOTE: Oscillogram G and H Precedes Others by Approximately 20 Microseconds

FIGURE 14  
Waveforms for Gating and Detecting Sequence

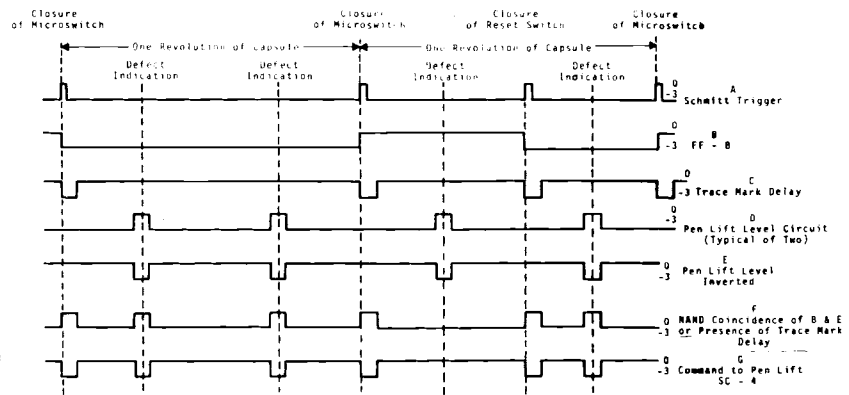
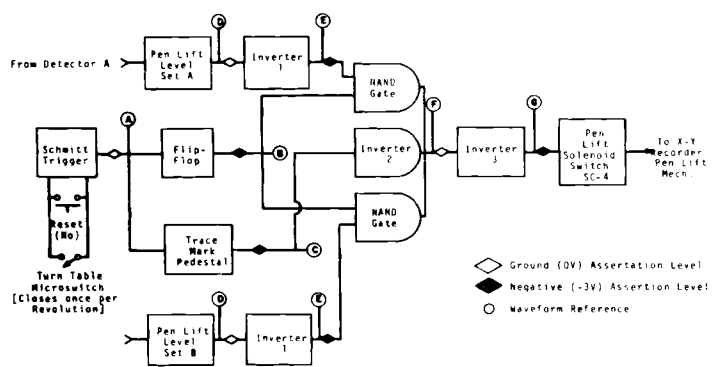


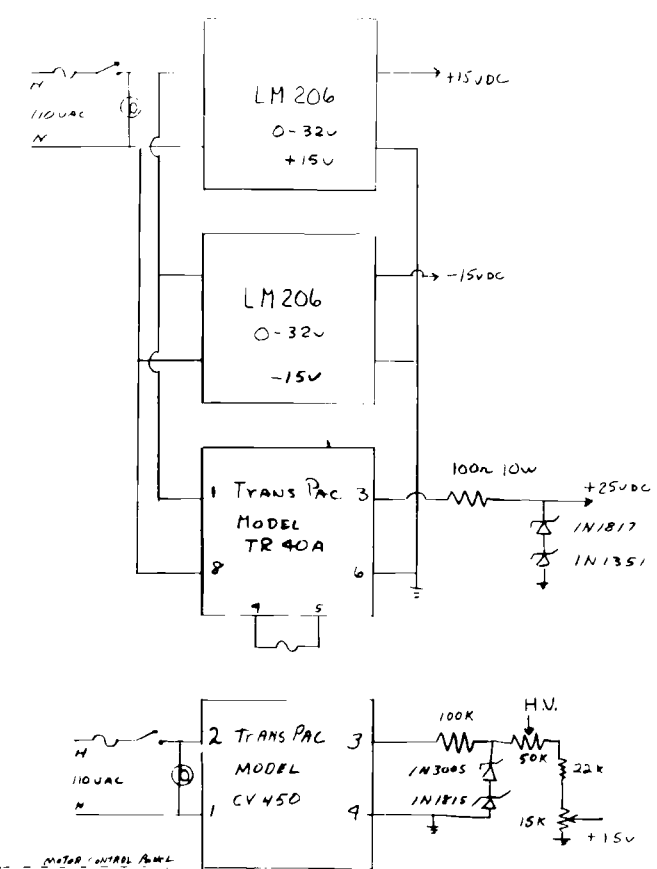
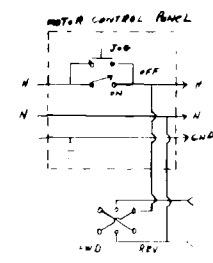
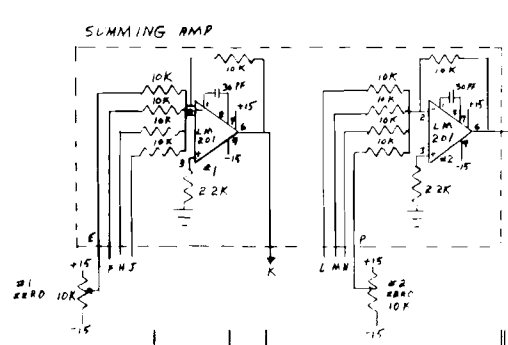
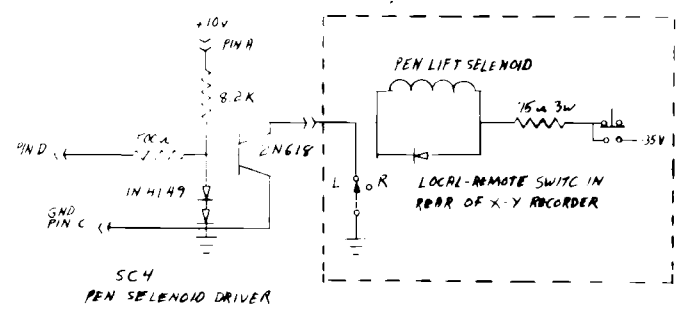
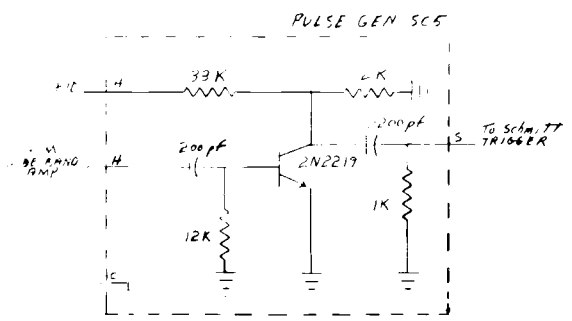
FIGURE 15  
Pen Lift Digital Logic Block Diagram and Waveform Chart

TABLE A-1  
REMOTE TEST TANK FABRICATION AND ASSEMBLY DRAWINGS\*

<u>Drawing No.</u>	<u>Sheets</u>	<u>Title</u>
H-3-27765	1	Goniometer Assembly and Details
H-3-27974	5	Weld Tester - Isotope Heat Source Assembly and Details
H-3-27975	2	Gear Drive Assembly and Details
H-3-27976	1	Slide - Assembly and Details
H-3-28908 (See Fig. A-6)	1	UT-40 Transducer Coolant Adapter Assembly and Details

\*These drawings are obtainable from Battelle-Northwest, Richland, Washington at a nominal cost.





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NEXT USED ON					BY-DATE		FOR		APPD.		DATE	DESCRIPTION	REV. NO.	SCALE	CLASSIFIED BY	DATE	BLOG NO.	INDEX NO.	DWG. NO.	SHEET NO.	TOTAL SHEETS
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 559A  
 5900  
 4-2-65

A BAWL-918



D

C

B

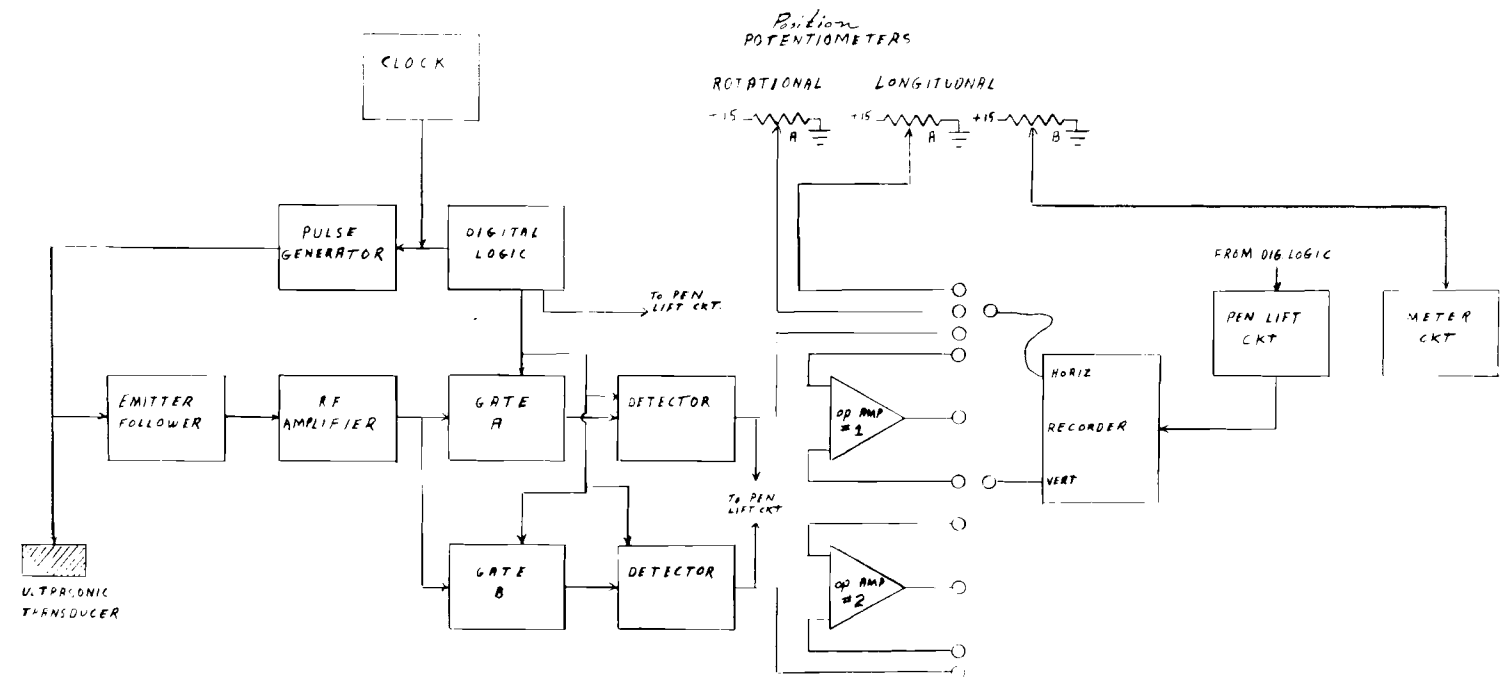
A

D

C

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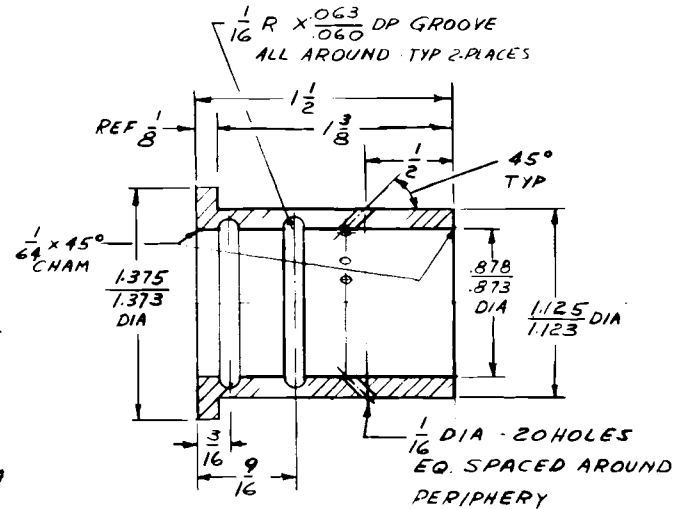
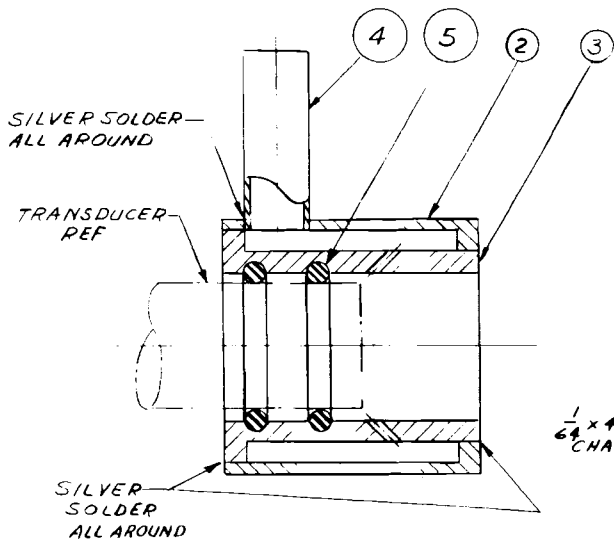
  

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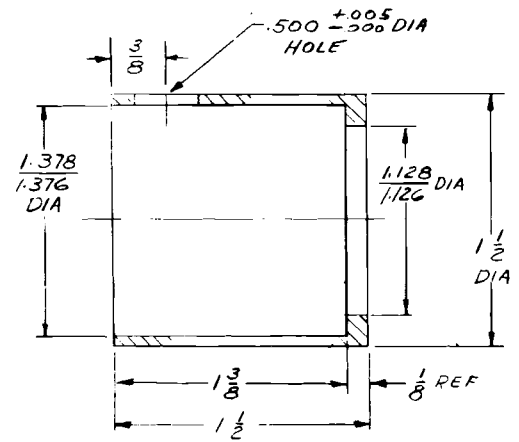
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FOR		BLOCK DIAGRAM	
APPD			
ENGR			
DRWNG			
CHECKED			
SCALE			
CLASSIFIED BY		BLDG NO. 55AA	INDEX NO. 5900
DATE		DWG NO. H-3-28901	SHEET NO. SHEETS
ELABORATION		NONE	

A B N M L 1 9 10

QTY	PART No	DESCRIPTION	MATL OR CAT No
X	1	ADAPTER ASSEMBLY	
1	2	OUTER SHELL	
1	3	INNER SHELL	
1	4	TUBING $\frac{1}{8}$ OD X .032 WALL X $\frac{1}{16}$ LG	COPPER
2	5	O-RING $\frac{3}{16}$ ID X $\frac{1}{16}$ X $\frac{1}{8}$ BUNA-N	PARKER HANNIFIN # 2-212-N103-7



1 ASSEMBLY



2 OUTER SHELL  
MATL BRASS

3 INNER SHELL  
MATL BRASS

GENERAL NOTES

- UNLESS OTHERWISE SPECIFIED
- 1 TOLERANCES: FRACTIONS  $\pm \frac{1}{64}$  ANGLES  $\pm 0^{\circ}30'$  DECIMALS  $\pm .005$
- 2 REMOVE ALL BURRS AND BREAK ALL SHARP CORNERS
- 3 ALL MACHINED SURFACES  $\sqrt{32}$  (ASA B46.1 1962)
- 4 ALL MATERIAL SHALL BE AS SPECIFIED OR AN APPROVED EQUAL

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		NEXT USED ON H-3-2797A

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APPD		PACIFIC NORTHWEST LABORATORY	
		OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
ENGR	JOSTROM	UT 40	
DFTG APPD		TRANSUCER COOLANT	
CHECKED	W. J. Jones	ADAPTER ASSY & DETS	
DRAWN	W. J. Jones	BLDG NO.	55 AA
SCALE	NONE	INDEX NO.	490306
CLASSIFIED BY		DWG. NO.	H-3-28908
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		SHEETS	1

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          J. L. Deichman  
          G. E. Driver  
          R. J. Hoch  
          V. I. Neeley  
          H. N. Pedersen  
          N. S. Porter  
          J. T. Russell  
          C. B. Shaw  
          R. W. Steffens (10)  
          J. C. Spanner (3)  
          W. G. Spear  
          E. E. Voiland (3)  
          D. C. Worlton  
          Technical Information Files (5)  
          Technical Publications (2)