MEMORANDUM REPORT ARLCB-MR-83017

IMPROVED INSPECTION TECHNIQUES FOR INGOTS AND PREFORMS FOR ROTARY FORGING

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ESR Ingot Inspection
Non-Destructive Testing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report outlines the work conducted in developing a semi-automatic production inspection facility for the inspection of ingots and preforms prior to hot forging. The details of the system including descriptions, procedures and drawings are available as a Technical Date Package from Watervliet Arsenal, Watervliet, N. Y.

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ILLUSTRATIONS

INTRODUCTION

A nondestructive test to insure the internal soundness of an ingot or preform is required prior to rotary forging. Ultrasonic scanning by means of a hand-held transducer was the initial nondestructive approach. However, this method is very time consuming and prone to operator fatigue and error. The time required to completely inspect all of the material was extensive enough to impede the rotary forge process. As a consequence, only a percentage of the ingots and preforms were tested. In order to inspect all of the material while maintaining the production schedules, the design of an automatic ultrasonic NDT system was established.

BACKGROUND

Two matters of grave concern that were encountered in the engineering phases of the project were the sonic transfer capabilities due to the surface condition of the ingots and preforms and the internal grain structure of the ingots. The state of the art for this type of inspection has been established with regard to feasibility. However, each installation requires a different engineering approach. Flaw dimensions, search frequency and the sonic transfer medium were determined in-house and were given to outside contractors for evaluation tests.

The flaw dimensions inspection standard definitions are referenced and taken from the Metals Handbook Nondestructive Inspection and Quality Control, Volume II, Pages 187, 188 and 189, published by the American Society for Metals. The ultrasonic test criteria have been established by the American Society of Nondestructive Testing and the American Society for Testing Material. Examples of defect sizes are as follows: a number 1 defect is a flat bottom hole 1/64" in diameter, and a number 2 defect is a flat bottom hole 2/64" in diameter. These indicators are drilled into different size test blocks.

The internal structure of the ingots and the surface variations of all the material to be tested supplanted the use of test blocks. The desired reflectors were placed into the center of the test material. The test material was four inch discs of ingots and preforms. Figure 1 is a diagram showing how the reflectors are placed in the center of the test pieces. A detailed explanation of the reflectors and material conditions is presented in the approach to the problem section of this report.

The type of material, the couplant and surface conditions are all of the parameters that have to be taken into consideration to determine the search frequency. This frequency will also establish the smallest size defect that can be detected. The frequency established for this project was 2.25 MHz in the longitudinal mode.

The following ultrasonic sizes were established and incorporated into the data presented to contractors for the evaluation test.

The ultrasonic instrument and the associated equipment shall be capable of detecting a #5 size defect at the center of a 20" diameter ESR melted ingot and a #4 defect size at the center of a 15" diameter and a 13" diameter preform.

The following vendors were contracted to perform the evaluation test:

Sonics Instruments, Inc.
1018 White Head Road
Trenton, New Jersey

Krautkramer-Branson, Inc.
250 Long Beach Blvd.
Stratford, Conn.

Automation Industries
Sperry Products Division
Shelter Rock Road
Danbury, Conn.

All three contractors declared that they are capable of detecting the determined flaw and/or reflector dimensions.

A 1095 form for the procurement of the Ultrasonic system was sent to the Purchasing and Contracting Division at the Watervliet Arsenal on 13 March 1980.

Automation Industries, Sperry Division, was awarded the contract to design the scanning system and to provide the ultrasonic instrumentation and search transducer as called for in the specification.

Approach and Objective

As previously stated, the surface condition of the ingots and preforms and the internal structure of the ESR ingots presented engineering difficulties that were specific to this type of nondestructive automatic ultrasonic scanning application.

The surfaces of the ESR ingots are slightly convoluted; this is a condition that is inherent to the ESR process. The surface of the preforms contain many facets and indentures; these are caused by the hammer blows encountered during the rotary forge process. The unevenness of the surfaces results in a non-uniform transfer of the ultrasonic energy to and from the search transducer and the workpiece.

The surface variations, couplant medium for the sonic energy transfer, internal structure of the material and the scanning method all have to be considered in order to design a workable system.

It was decided that the couplant medium shall be water. Oil was eliminated because it created smut problems in the heating furnaces that are part of the rotary forge heat treating production line.

In order to compensate for the surface conditions, a method of overlap scanning was designed. The scanning system is comprised of a circumferential scan with longitudinal indexing. The numerical readout from the starting point along the longitudinal axis will be adjustable to within one-half inch along the axis. Each circumferential scan will have an overlapping coverage of the preceding scan. With this form of indexing, every part or section of the ingot or preform will be investigated. This method of overlapping will establish the capability to institute programming defect repeatability.

With respect to the internal structure, the ESR ingots presented the greatest problem. These ingots are in the as-cast state and, therefore, contain very large columnar and equiax grains. Each grain in the agglomeration has a radically different acoustic impedance and consequently produce severe scattering. It is possible to encounter scattering in a material in just one crystal type if the crystals exhibit velocities of different values when measured along axes in different directions.(1) This phenomenon is known as anistropy. The preforms are forge material. The forging process breaks up large grains and orients them in the direction of the forging process. Forging greatly reduces the anistropic transmission problems that are manifested in cast material.

As previously stated in this report, it was decided by calculation and experimentation at Benet Weapons Laboratory that the optimal search frequency was 2.25 MHz. The reflector sizes are stated in the background and introduction section of this report. These reflector holes were placed in the material in a prescribed manner and are described as follows: the reflectors are an ASTM #5 in the center of a 20" diameter ESR ingot and an ASTM #4 in the center of a 15" diameter solid preform and a 13" diameter solid preform. Refer again to Figure 1 to see the orientation of these reflectors with respect to the direction of the ultrasonic sound beam. Figure 2 is a representation of the Cathode Ray

(1) Al Smith Ultrasonic Testing Battelle Northwest

Tube display showing the initial pulse, echoes and backwall reflections. Figure 3 shows photographs of an experimental set-up of an immersion system.

Immersion testing was chosen because it is preferable to contact testing for forging and casting that have irregular surfaces. This type of part cannot be completely inspected by the contact method by any practical means.

RESULTS

The Benet Weapons Laboratory received the design drawings and instrumentation for a complete automatic ultrasonic non-destructive system to test ingots and preforms prior to the rotary forge process. (Figure 4 is a sketch of the test system).

The sensitivity for defect sizes exceeded that required by the specifications. This was accomplished by the use of a focused immersion transducer (2.25 MHz) (1 x 1/2 resolution) (Harrisonic 18A0208161) (Sperry #77A336). The ultrasonics utilize the Pulse-Echo Method and the energy transfer is accomplished by a couplant-column dispenser/chamber arrangement using water as the sonic transfer medium. The size of the defect at the center of a 20" diameter ESR ingot under actual conditions was a number 2 (3/64" diameter) longitudinally oriented flat bottom hole perpendicular to the longitudinal center line. The instrument is a Sperry Model S-80 Reflectoscope. The instrument and the integrated components used detected this size defect exceedingly well. The signal to noise ratio averaged 7 to 1. The state of the art has increased the sensitivity to a number 3 ASNT defect at 2.25 MHz. The equipment (instrument transducer) has the capability to examine solid ingots and preforms for center condition ultrasonic "reflectors" to an ASNT number 3 size.

The test system is capable of completely scanning any of the listed ingots and preforms at a production rate of twenty minutes.

Steel ingots and preforms per Watervliet drawings are listed below:

#11579641-RF01 (20" dia. ingot, solid, 8' long approx.)
#11579641-RF04 (13" dia. preform, solid, 7'-4" long approx.)
#11579641-RF05 (13" dia. preform, hollow, 7'-4" long approx.)

#11579504-RF01 (20" dia. ingot, solid, 8' long approx.)
#11579504-RF04 (15" dia. preform, solid, 11' - 4" long approx.)
#11579504-RF05 (15" dia. preform, hollow, 11' - 4" long approx.)

The output of this type of scanning will be applied to a C-scan recorder. This method of scanning also has the capability of operating in an automatic mode or by means of using a jog control.

A Technical Data Package containing descriptions, directions and drawings of the complete system is located at the Benet Weapons Laboratory, Watervliet Arsenal, Watervliet, New York 12189.

CONCLUSION

The increased sensitivity of ultrasonics and the use of focused ultrasonic beams has rendered this application of nondestructive testing from the prototype status to a functional unit in the rotary forge production line.

The developed technique will also be capable of being utilized by the preform producers, thereby enabling them to relate production practice to quality and soundness. This should result in an overall increase in the quality of incoming material.

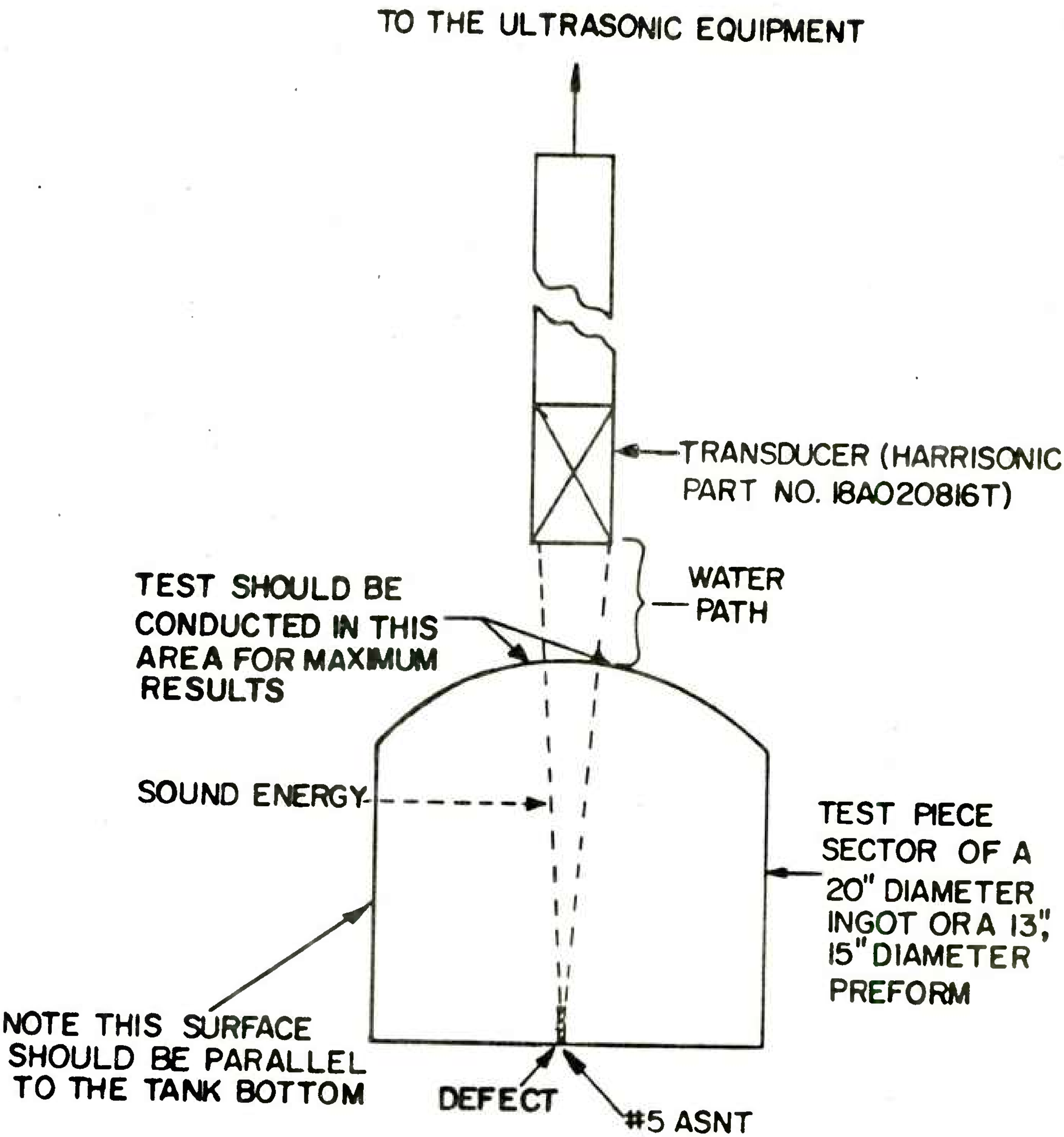
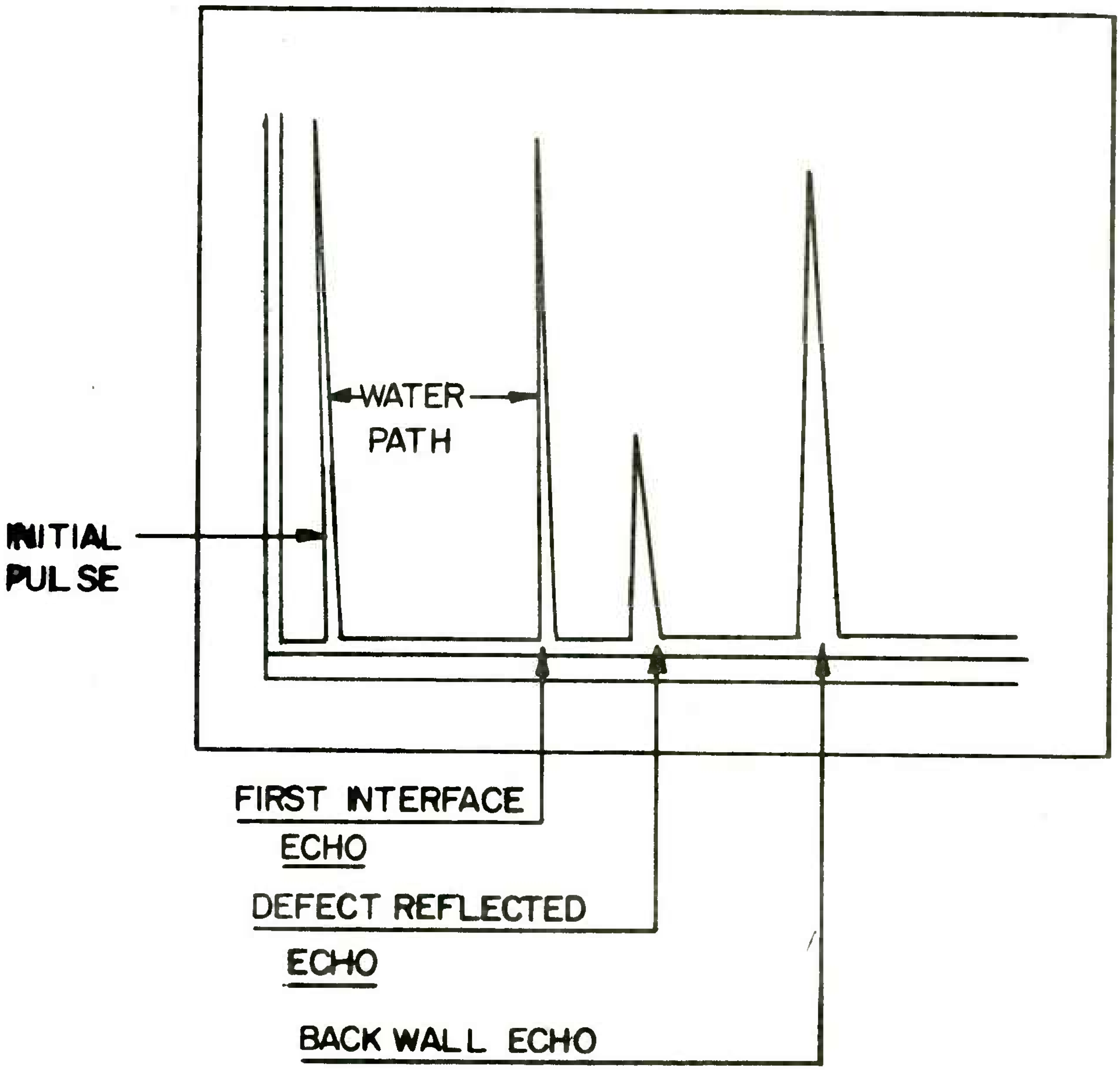

TO THE ULTRASONIC EQUIPMENT
TRANSDUCER (HARRISONIC PART NO. 18A020816T)
WATER PATH
TEST SHOULD BE CONDUCTED IN THIS AREA FOR MAXIMUM RESULTS
SOUND ENERGY
TEST PIECE SECTOR OF A 20" DIAMETER INGOT OR A 13", 15" DIAMETER PREFORM
NOTE THIS SURFACE SHOULD BE PARALLEL TO THE TANK BOTTOM
DEFECT
#5 ASNT

FIGURE 1

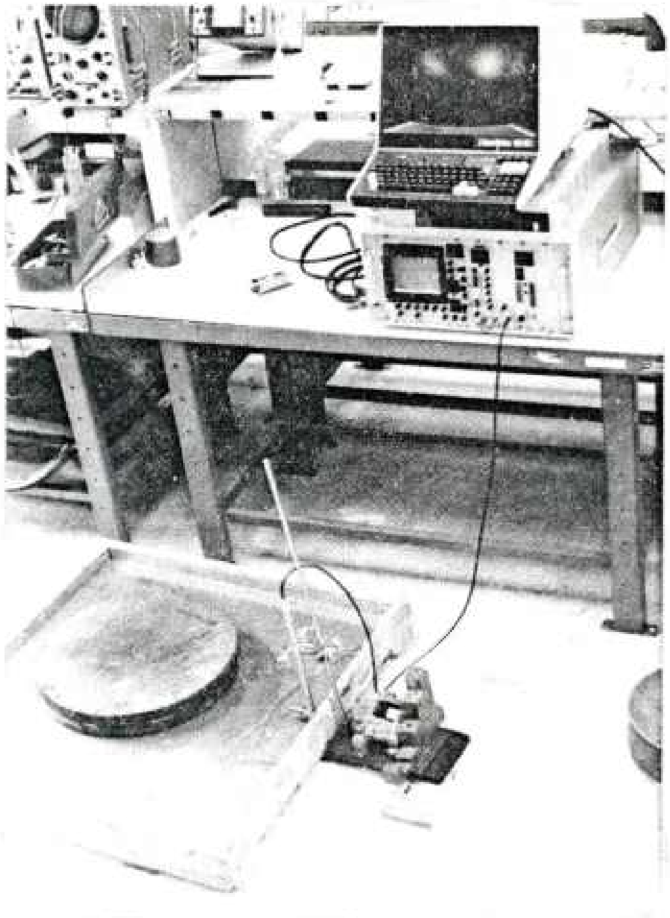
STANDARD CRT DISPLAY FOR IMMERSION TESTING

THE CRT IS ON THE ULTRASONIC INSTRUMENT



WATER PATH IS NORMALLY NOT SHOWN IN IMMERSION TESTING. THE USABLE AREA IS BETWEEN INTERFACE ECHO AND BACKWALL ECHO

FIGURE 2



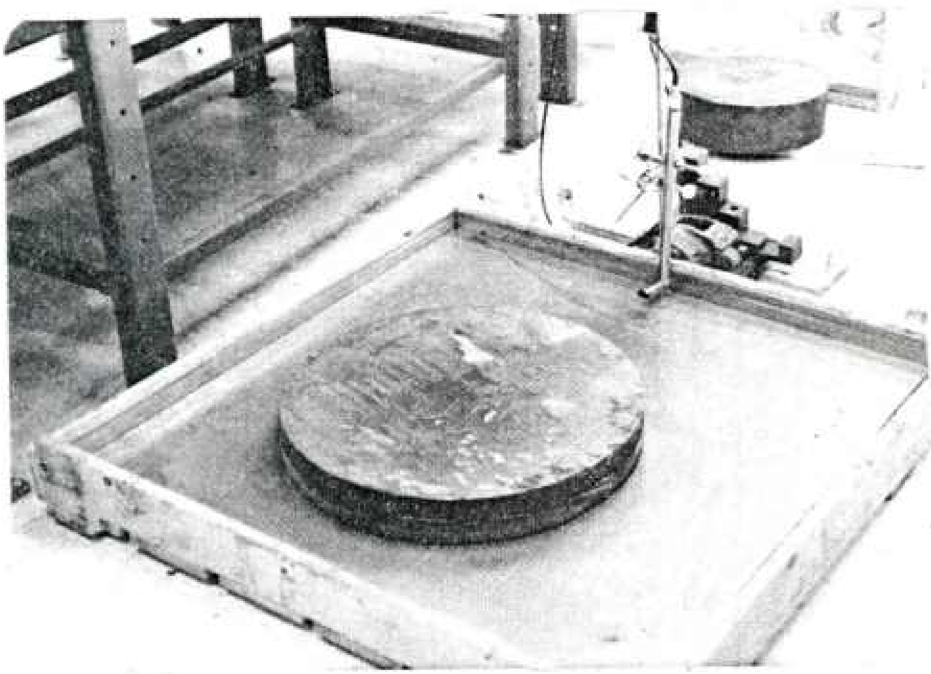


FIG. 3 - Test System to evaluate ultrasonic transmission capabilities under actual conditions. Disc from a 20"dia. ESR ingot.

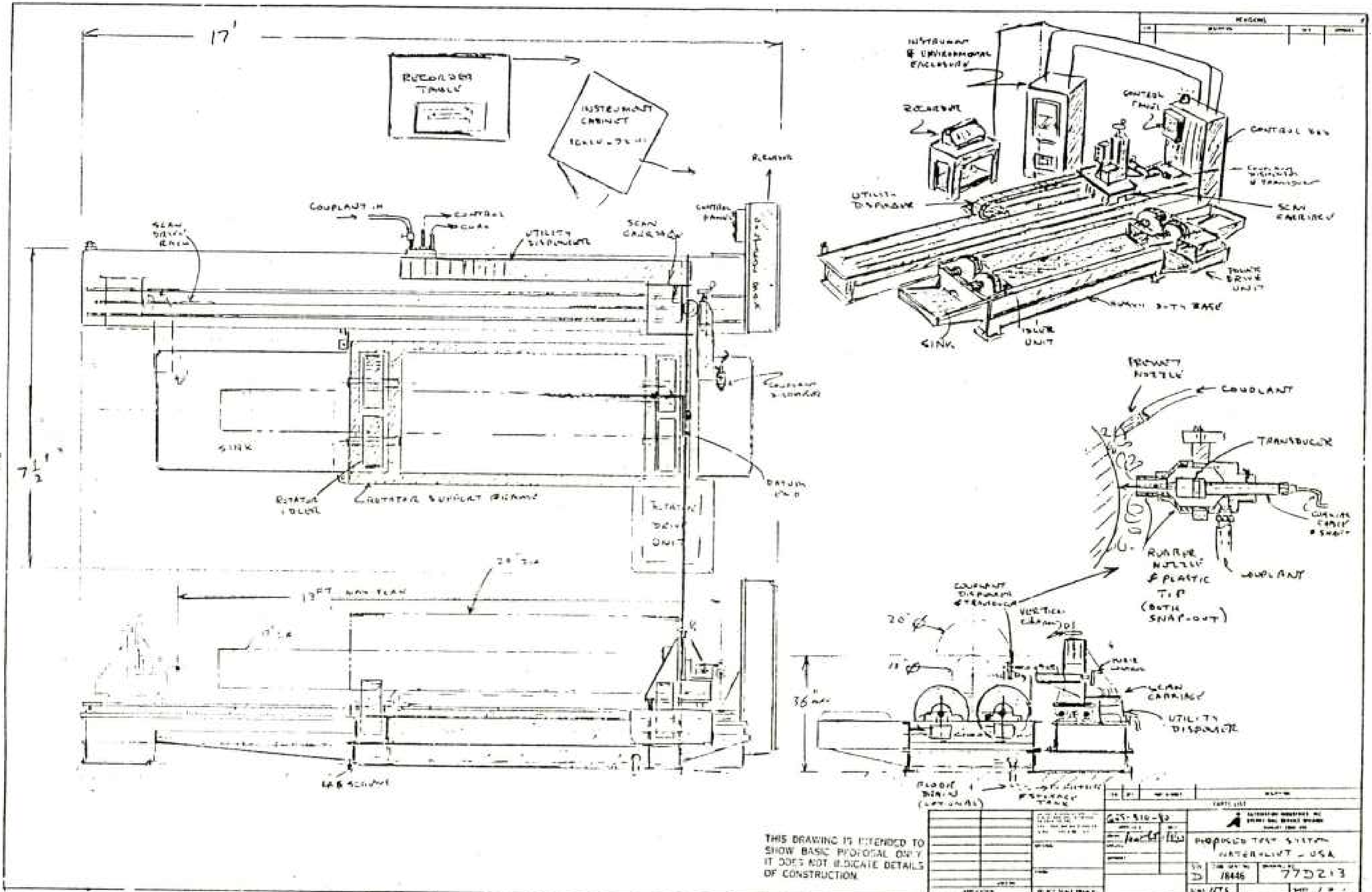


FIG. 4 Sketch of Automatic Scanning System

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