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TECHNICAL REPORT

EATR 4601

# ULTRASONIC DETECTION AND MEASURING OF INTERNAL CORROSION IN CHEMICAL MUNITIONS

by


Laird A. Johnson

Ronald L. Frailer


February 1972




DEPARTMENT OF THE ARMY
EDGEWOOD ARSENAL
Product Assurance Directorate
Edgewood Arsenal, Maryland 21010

AUTOMATION INDUSTRIES, INC.
Boulder, Colorado




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13. ABSTRACT

As a result of a successful preliminary application of ultrasonic inspection techniques in detecting corrosive pitting, an ultrasonic C-scan inspection system was developed for field inspection of chemical munitions. The system can detect pits as small as 10 by 10 mils in walls 35 and 65 mils thick. It can resolve pits separated 1/16 inch or greater. The system can inspect cylindrical munitions up to 4.5 inch OD, and with a minor modification, could inspect up to 6.0-inch OD. This system is being used for surveillance procedures aimed at establishing the integrity of chemical-filled munitions. It will enhance the reliability of shelf life estimates and assist in categorizing munitions for disposal.



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EATR 4601

# ULTRASONIC DETECTION AND MEASURING OF INTERNAL CORROSION IN CHEMICAL MUNITIONS

Final Report

by

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Ronald L. Frailer
Product Assurance Test Division

February 1972

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DEPARTMENT OF THE ARMY
EDGEWOOD ARSENAL
Product Assurance Directorate
Edgewood Arsenal, Maryland 21010

Contract DAAA 15-71-C-0169
Project 5701180

AUTOMATION INDUSTRIES, INC.
Boulder, Colorado

## FOREWORD

The work described in this report was authorized under Project 5701180, Ultrasonic Detection and Measuring Methods for Tracing the Progress of Internal Corrosion in Chemical Munition Items. This work was started in January 1970 and completed in July 1971.

# DIGEST

As a result of a successful preliminary application of ultrasonic inspection techniques in detecting corrosive pitting, an ultrasonic C-scan inspection system was developed for field inspection of chemical munitions. The system can detect pits as small as 10 by 10 mils in walls 35 and 65 mils thick. It can resolve pits separated 1/16 inch or greater. The system can inspect cylindrical munitions up to 4.5-inch OD, and with a minor modification, it could inspect up to 6.0-inch OD.

This system is being used for surveillance procedures aimed at establishing the integrity of chemical-filled munitions. It will enhance the reliability of shelf life estimates and assist in categorizing munitions for disposal.

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# ULTRASONIC DETECTION AND MEASURING OF INTERNAL CORROSION IN CHEMICAL MUNITIONS

## I. INTRODUCTION.

In order to preclude the possibility of internal corrosion in chemical munitions, an effort was made to develop a nondestructive system capable of detecting and measuring the presence of pitting on the inside of the munitions. An initial survey of techniques available and cursory type investigations indicated that the ultrasonic approach would have the highest success potential.

Under contract DAAA 05-68-C-0064, Automation Industries, Inc. (AII), Research Division, conducted initial studies to determine the capabilities of ultrasonic inspection and to develop techniques required to perform the inspection. The results of this program have been reported previously.* Two contract type shear wave inspection fixtures were fabricated and submitted to Rocky Mountain Arsenal for use in a manual inspection and correlation program on typical tubing type samples.

Under contract DAAA 15-71-C-0169, an ultrasonic applications program has been completed on double-walled munitions tubing samples containing artificial defects representative of corrosion pitting. Specific objectives of this application program were as follow:

1. To determine the capabilities and limitations of ultrasonic inspection techniques to detect pit-type defects occurring on the ID of the outer tube and the OD of the inner tube of the munitions tubing, and to establish specific test parameters for tubing inspection.

2. To design a portable ultrasonic C-scan inspection system based on previous concepts and the parameters established in step 1.

3. To fabricate the portable C-scan inspection system developed as a result of steps 1 and 2. The system would be constructed as a field inspection device using modular components that would be assembled at the inspection sites.

The program objectives have been satisfactorily completed. Ultrasonic inspection techniques and the portable inspection system design were continually reviewed by project personnel prior to construction of the apparatus. It was determined during the program that, because of the lack of concentricity between the inner and outer tubes demonstrated by actual munitions samples, the C-scan ultrasonic inspection could be satisfactorily performed only on the outer tube of the double-walled configuration. The variation in the position of the inner burster tube precludes inspection by semi-automatic C-scan methods.

This report summarizes the results of the ultrasonic evaluation and equipment development program for the cylindrical wall inspection and outlines specific inspection procedures for the three types of munitions tubing investigated.

## II. EXPERIMENTATION.

### A. Test Samples.

Five test samples were used in the evaluation program. The samples consisted of sections of actual munitions tubing containing eloxed pits of various depths and diameters. The samples

*Ellerington, H., and Abbott, D. Calibration Procedure for Ultrasonic Evaluation of Munitions Tubing. Automation Industries, Inc. TR 68-17. April 1968. UNCLASSIFIED Report.

were identified as M55-1, M55-2, XM74-1, XM74-2, and MK67. Sample dimensions are shown in the table.

Table. Test Samples

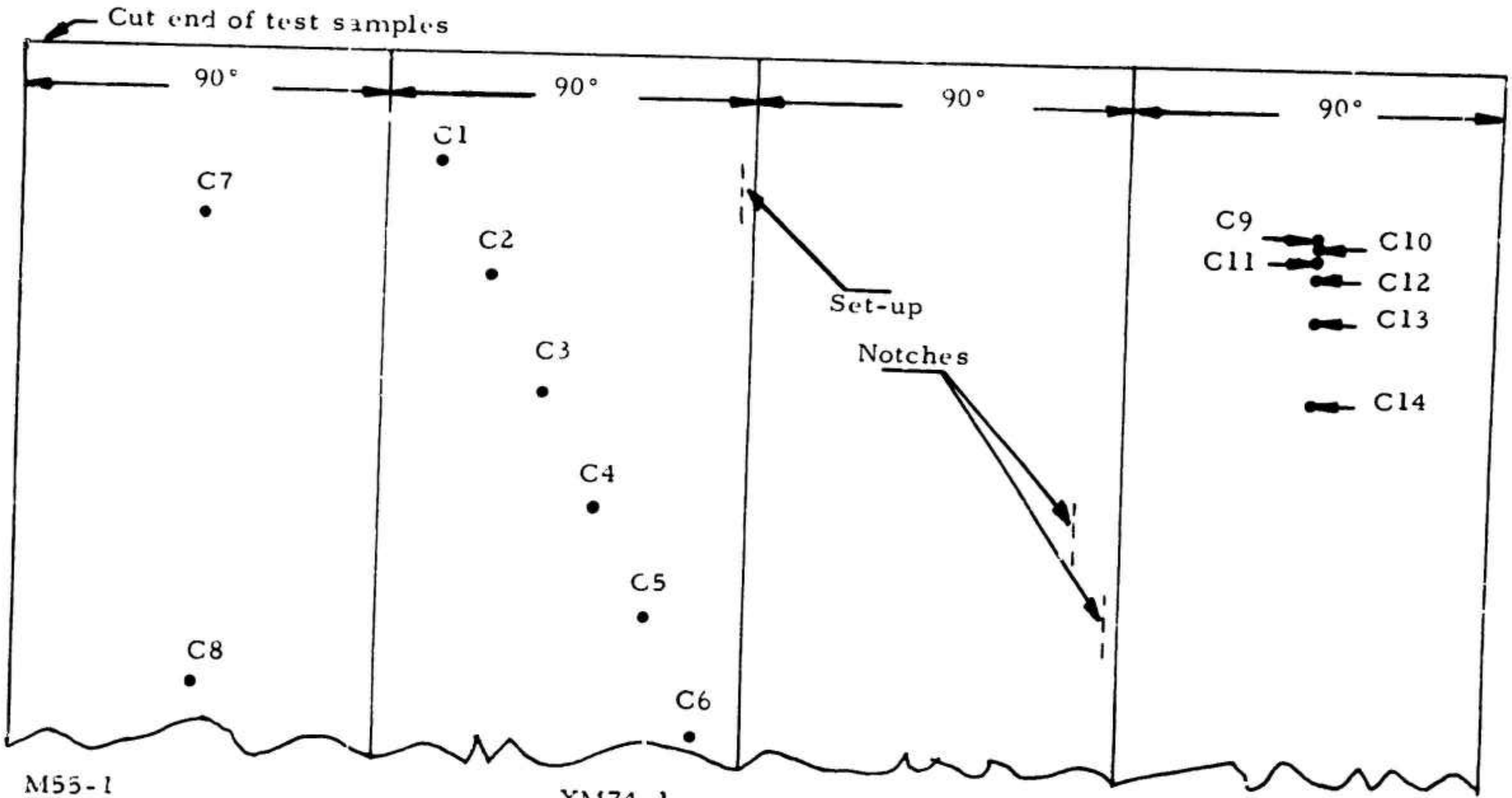
| Sample No. | Outer tube dia | Outer tube wall thickness | Sample length | Material |
|---|---|---|---|---|
| | | *in.* | | |
| M55-1 | 4.5 | 0.060-0.065 | 7.0 | Alum. 6061 |
| M55-2 | 4.5 | 0.060-0.065 | 23.7 | Alum. 6061 |
| XM74-1 | 2.65 | 0.030-0.035 | 7.2 | Alum. 6061 |
| XM74-2 | 2.65 | 0.030-0.035 | 10.6 | Alum. 6061 |
| MK67 | 2.75 | 0.085-0.090 | 9.7 | Alum. 6061 |

Samples M55-1 and XM74-1 each contained 14 eloxed pits of size and location as shown in figure 1. Pits C1 through C6 are representative of scattered pitting of varying size. Pits C7 and C8 represent broad shallow pitting and deep narrow pitting respectively. Pits C9 through C14 are spaced at various distances to show the effect of spacing between pits on ultrasonic response. Samples M55-2, XM74-2, and MK67 each contained three eloxed pits and one eloxed notch of size and location as shown in figure 2. These artificial defects are intended for use as sensitivity references for field inspection. Naturally occurring pitting of various degrees was also noted on the ID of the outer tubes of samples M55-1, XM74-1, and MK67.

B. Equipment List.

The following inspection equipment was used during the ultrasonic application work and is recommended for inspection of munitions tubing:

1. Type UM reflectoscope, style 50B721.
2. Type HFN pulser/receiver, style 50C527, modified per 57A6026.
3. HFN 15-MHz frequency board, style 50B955.
4. Fast transigate, style 50C753.
5. Type 1/2S recording amplifier, style 50E616.
6. Type SIL search unit, style 57A2770 (1/4-inch diameter, 15 MHz, medium focus).
7. Coaxial cable, style 57A5978.
8. Portable ultrasonic C-scan inspection system, style 57A5432.
9. Little Giant submersible pump, model 1.
10. Norgren low pressure needle valve, model 17-001-010.
11. 1/4-Inch ID by 1/16-inch wall tygon flexible tubing.




| M55-1 | XM74-1 |
|---|---|
| C1 - 0.005" dia. x 0.005" dp | 0.005" dia. x 0.005" dp |
| C2 - 0.011" dia. x 0.011" dp | 0.011" dia. x 0.010" dp |
| C3 - 0.017" dia. x 0.015" dp | 0.017" dia. x 0.015" dp |
| C4 - 0.027" dia. x 0.025" dp | 0.022" dia. x 0.020" dp |
| C5 - 0.037" dia. x 0.035" dp | 0.027" dia. x 0.025" dp |
| C6 - 0.046" dia. x 0.046" dp | 0.032" dia. x 0.030" dp |
| C7 - 0.032" dia. x 0.050" dp | 0.022" dia. x 0.030" dp |
| C8 - 0.046" dia. x 0.030" dp | 0.032" dia. x 0.020" dp |

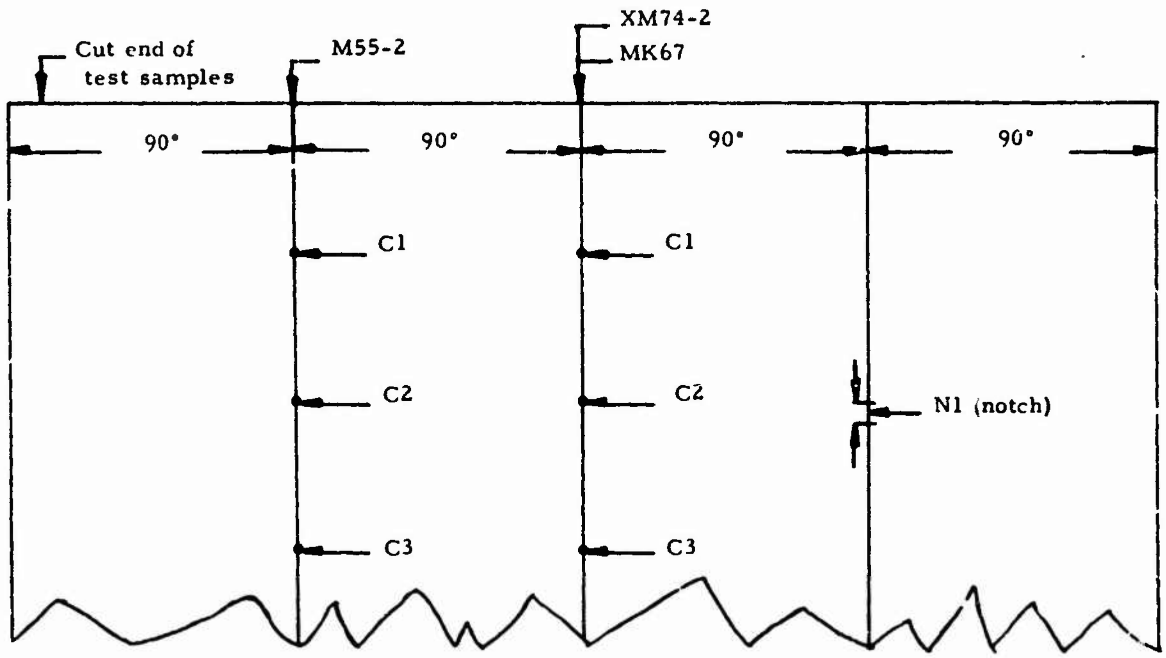
M55-1

C9 - C14 - 0.032" dia. x 0.030" dp spaced 1/32", 1/16", 1/8", 1/4", and 1/2" apart.

XM74-1

C9 - C14 - 0.022" dia. x 0.020" dp spaced 1/32", 1/16", 1/8", 1/4", and 1/2" apart.

Figure 1. Reference Hole Placement and Dimensions for Tubing Samples M55-1 and XM74-1




M55-2 & MK67
C1 - 0.010" dia. x 0.010" dp
C2 - 0.025" dia. x 0.025" dp
C3 - 0.045" dia. x 0.045" dp
N1 - 0.005" deep x 0.125" long

XM74-2
C1 - 0.010" dia. x 0.010" dp
C2 - 0.020" dia. x 0.020" dp
C3 - 0.030" dia. x 0.030" dp
N1 - 0.005" dp x 0.125" long

Figure 2. Reference Hole Placement and Dimensions for Tubing Samples M55-2, XM74-2, and MK67

C. Equipment Development.

A portable C-scan inspection system has been designed and fabricated to allow field C-scan inspection of cylindrical munitions up to approximately 4.5 inches in diameter (see figures 3 and 4). The inspection system hardware consists of a scanner/recorder module, which contains the scanning bridge and wet-paper recorder, and a control/rotator tray module, which contains the system operating controls and tubing rotating fixtures. The two modules are designated to be assembled at the field inspection site.

The C-scan inspection system scans a 10-inch tubing length as the tubing is indexed by the rotator fixture. Recorder paperfeed and rotator mechanisms are indexed by the same time sequence circuitry, resulting in a 1/1 plan view recording of the munitions tubing being inspected. Tubing samples greater than 10 inches long are inspected in 10-inch segments until the full length of the tubing is covered. Vertical and horizontal adjustments for the various tubing diameters are provided in the search tube manipulator block. Couplant for the water squirter scanning head is supplied by a small, low pressure recirculating pump located in the rotator tray. The tray acts as a catch basin to contain the couplant and supply the recirculating pump.

D. Ultrasonic Inspection Technique.

The basic inspection technique developed for the evaluation of munitions tubing is a pulse-echo, shear wave inspection at 15 MHz frequency. A center beam, refracted, shear wave angle of 45° in the aluminum material provides the optimum combination of test sensitivity and defect

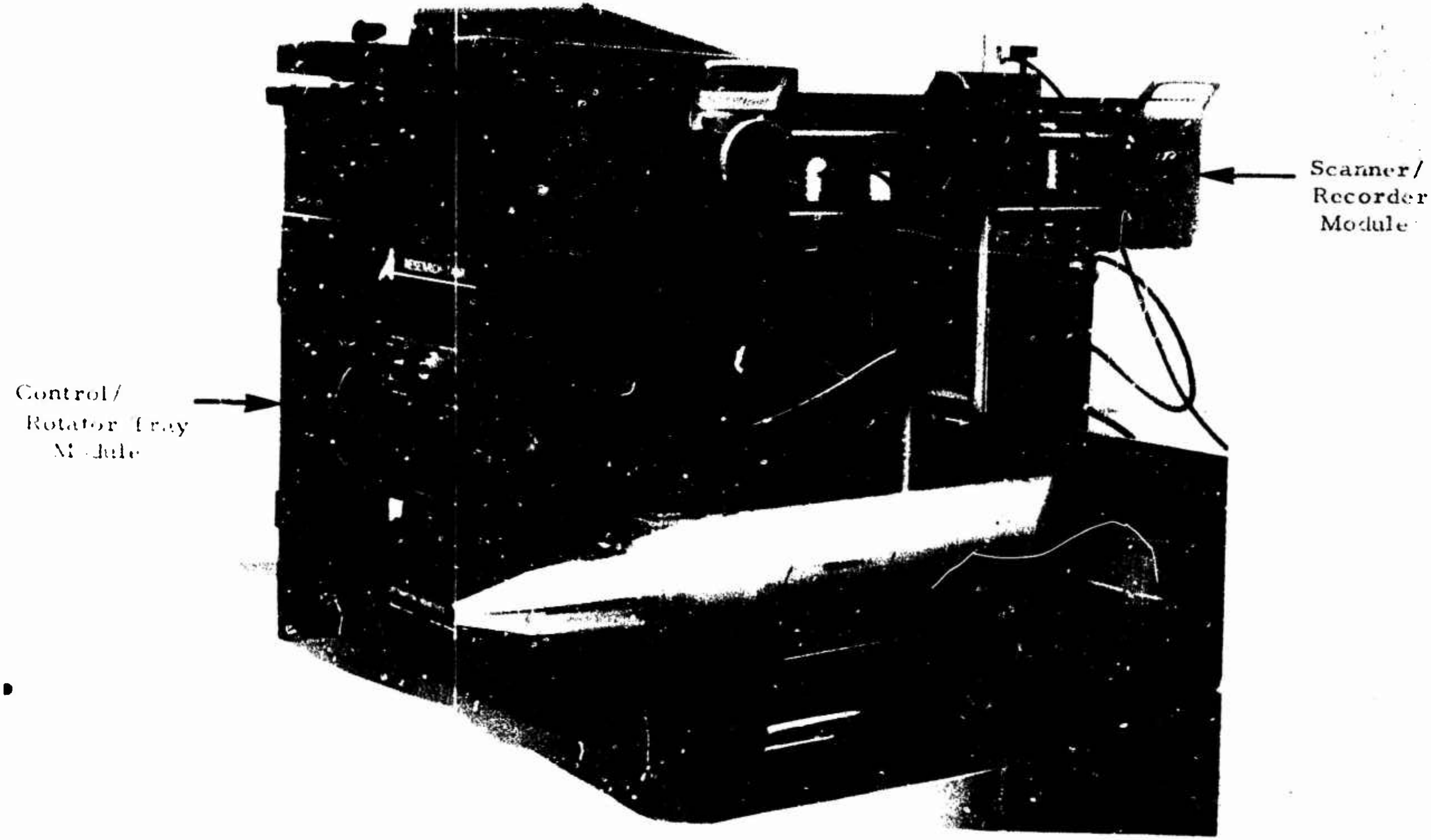



Figure 3 Portable C-Scan Inspection System

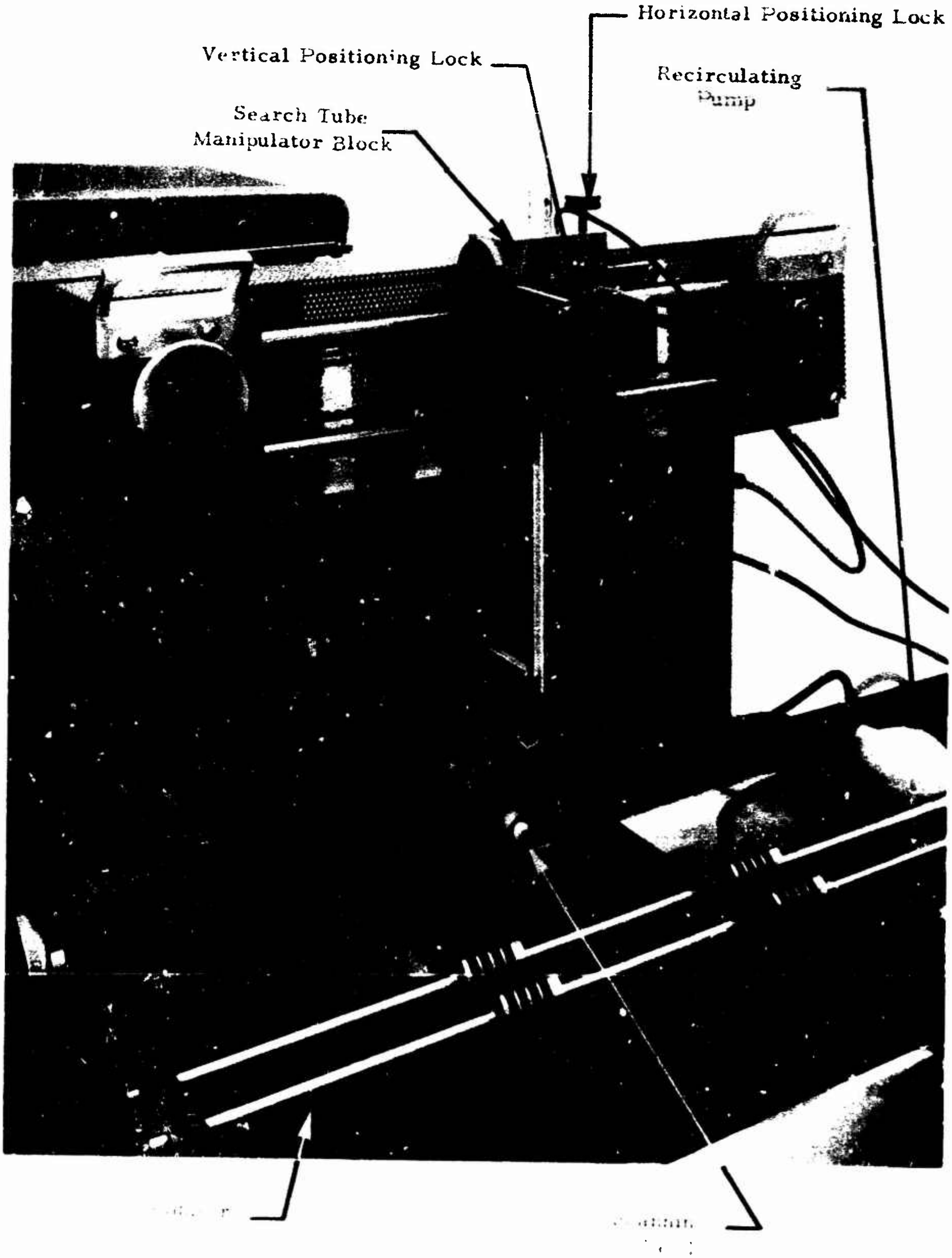



Figure 4. Detail of Portable Inspection System

detection capability. To achieve this required angle, an offset distance of 0.75 inch is used for the M55 size tubing and an offset of 0.45 inch for the XM74 and MK67 size tubing. The water squirter scanning head is used to couple the sound energy into the tubing sample, providing immersion test capability without requiring complete immersion of the test sample.

With this technique, the sound beam incident on the tube OD surface is refracted at the water/aluminum interface and focused at the critical ID surface inspection area. In areas containing pitting type discontinuities, a portion of the sound beam, proportional to the reflective area (depth X diameter) of a single pit or to the total reflective area (depth X diameter X number of pits) of a series of closely spaced pits, is reflected back to the ultrasonic search unit. This reflected energy is displayed on the Reflectoscope screen at a time interval corresponding to the 45° diagonal wall thickness of the tubing sample being inspected. In areas containing no discontinuities, the sound energy is propagated around the tube wall and attenuated in the material. No reflected signals, other than entry surface indications, occur on the Reflectoscope screen. The inspection area is monitored with an electronic recording gate. Reflected signals, greater in amplitude than a preset sensitivity reference, that occur in the inspection area are recorded as defect information on a 1/1 plan view C-scan recording. Typical scope presentations for a pitting discontinuity and for an area containing no pits are shown in figure 5.

The 15-MHz frequency search unit combined with the resolution modified 15-MHz HFN pulser/receiver provided maximum resolution and sensitivity to defects for the three tubing wall thicknesses evaluated. The use of the focusing lens on the search unit enabled the sound energy to be concentrated in a small diameter beam so that a large portion of the beam was affected by even a small discontinuity on the ID surface of the tubing.

Inspection sensitivity settings were investigated using the various size eloxed pits in the five samples. C-scan recordings, using the portable C-scan inspection system, were made at various sensitivity levels to determine the effects of discontinuity size, spacing, and geometry on the ultrasonic inspection.

## III. ULTRASONIC INSPECTION RESULTS.

### A. Tubing Samples M55-1 and XM74-1 (figures 6 and 7).

#### 1. Defect Size.

All artificial defects were successfully detected and identified in both samples with the exception of eloxed pits C-1 (0.005-inch diameter by 0.005-inch deep) and C-2 (0.011-inch diameter by 0.011-inch deep). The size of the C-1 pits in each sample was less than the realistic recordable defect size for the C-scan recording system. At the sensitivity level required to detect and record the C-2 pits, indications from naturally occurring pitting were recorded in both tubes that exceeded and consequently masked the indications from the C-2 pits.

#### 2. Defect Spacing.

The investigation of the C9 through C14 pits showed that individual pits spaced 1/16 inch or greater apart could be successfully identified. The C9 and C10 pits, spaced 1/32 inch apart, were recorded on the C-scan recording as a single indication.

#### 3. Defect Geometry.

The C7 and C8 pits, representing deep narrow defects and broad shallow defects respectively, were recorded at approximately the same size on the C-scan. This indicates that the

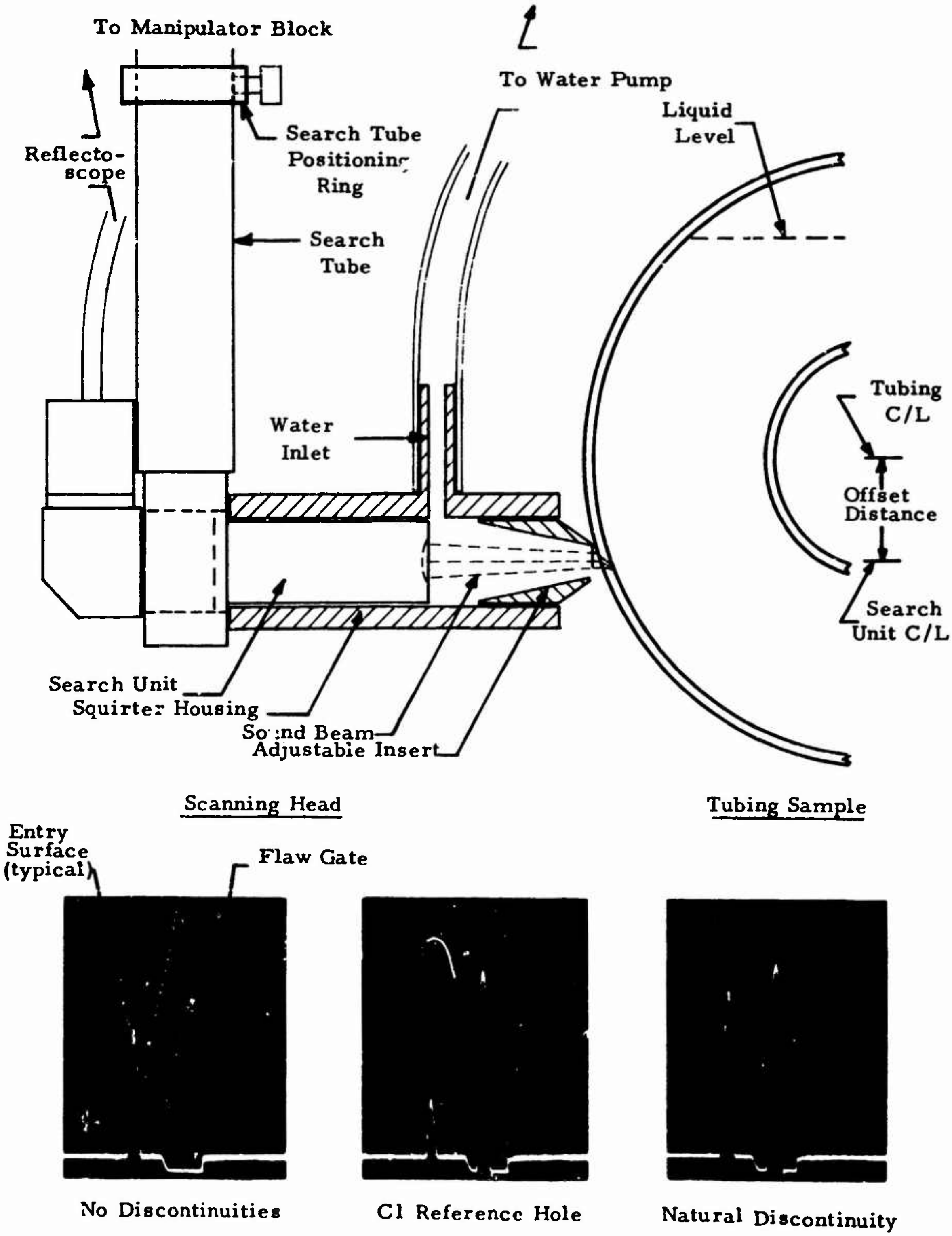



Figure 5. Ultrasonic Inspection of Munition Tubing

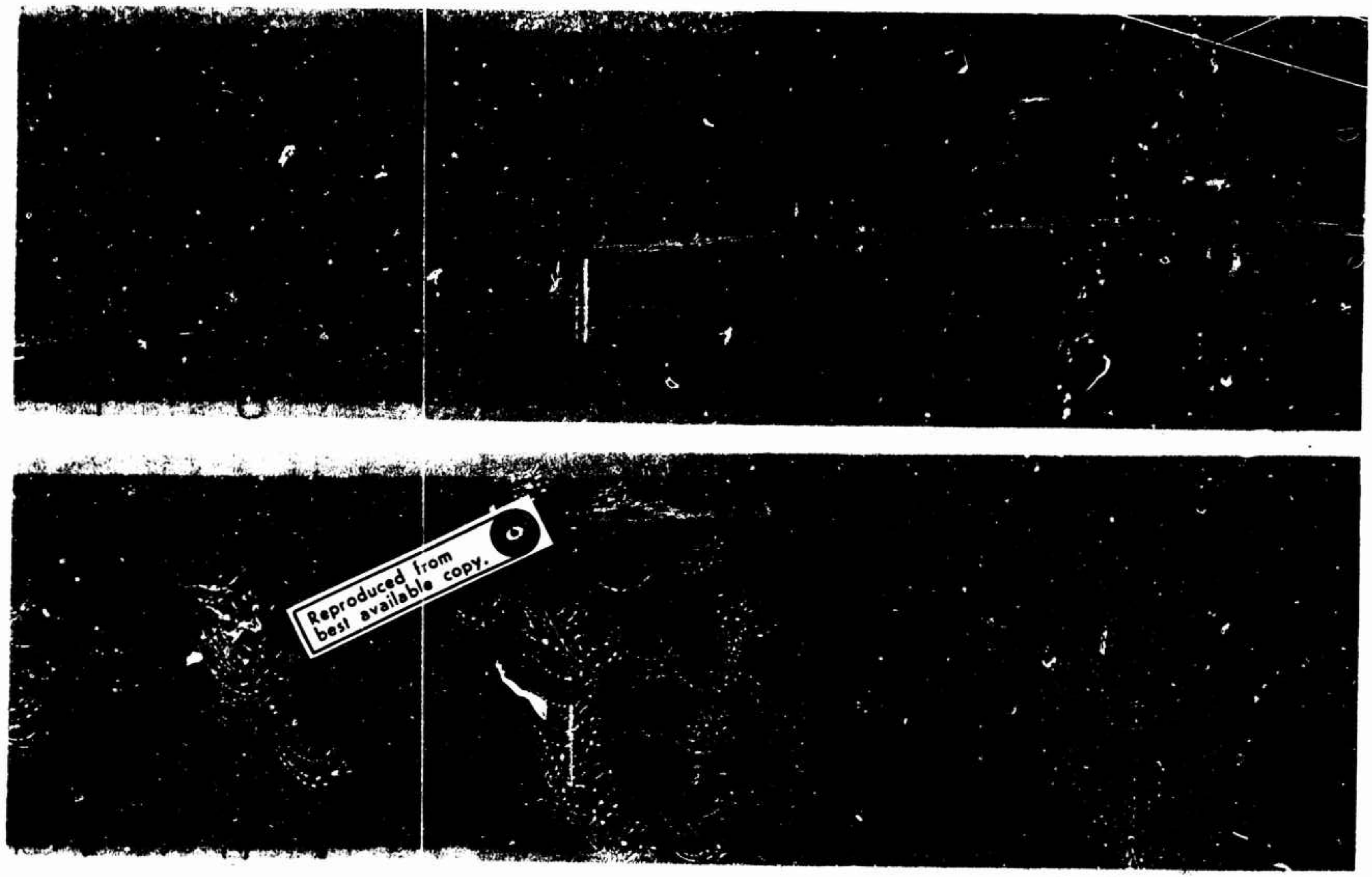





Figure 6. C-Scan Recordings of Test Sample M55-1 at C-2 and C-3 Hole Detection Sensitivity

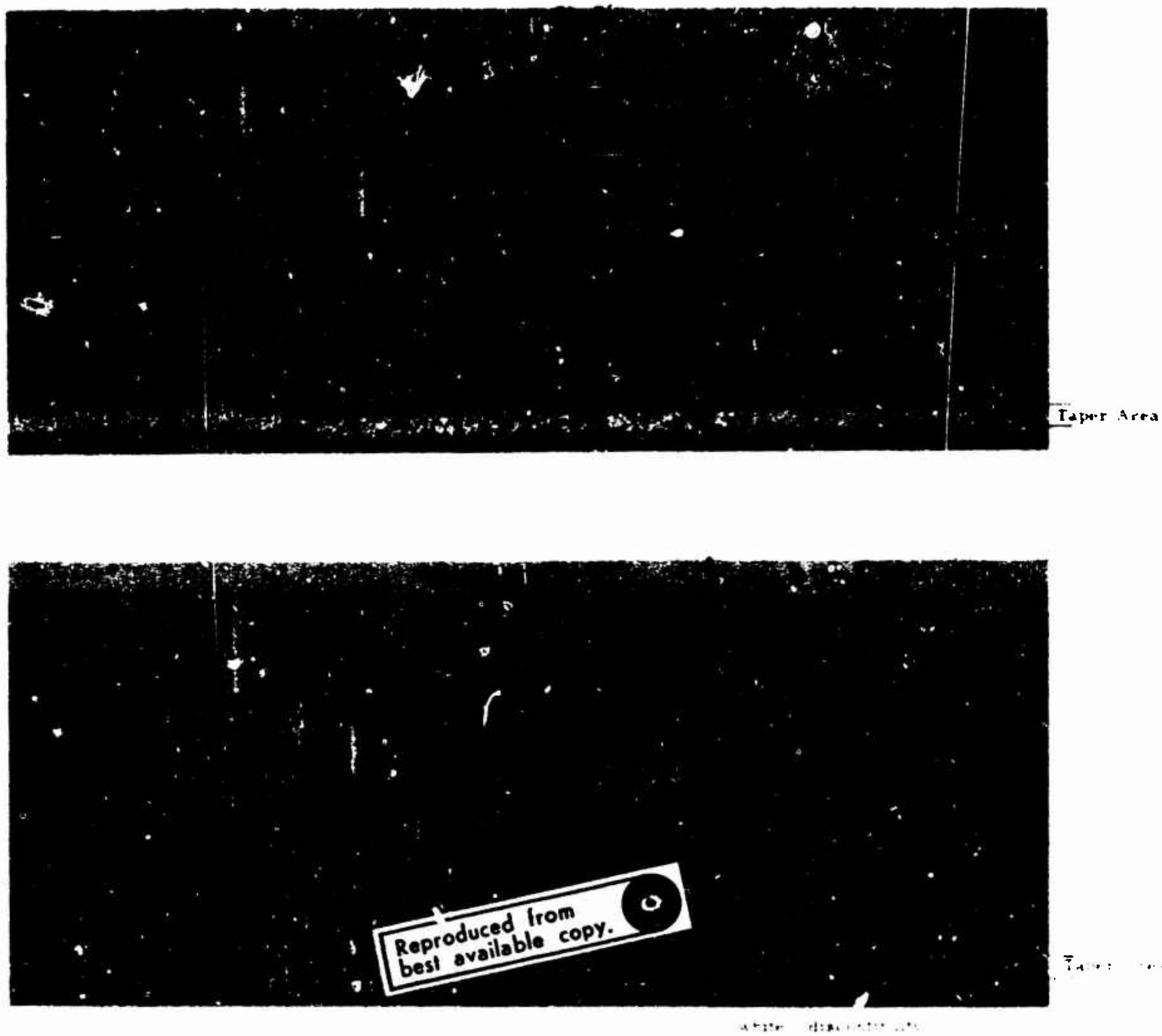




Figure 7. C-Scan Recordings of Test Sample XM74-1 at C-2 and C-3 Hole Detection Sensitivity

reflective area (depth X diameter) of the pit is the detection criterion and that neither the depth nor the diameter of a specific pit can be individually identified.

B. Tubing Samples M55-2 and XM74-2 (figure 8).

The C-scan recordings of these tubing samples showed satisfactory detection of the three eloxed pits and the setup notch. No naturally occurring pitting was noted on the scans of either tubing sample.

C. Tubing Sample MK67 (figure 9).

The C-scan recording of this sample showed satisfactory detection of the three eloxed pits and the reference notch. Naturally occurring pitting of a significant degree was also recorded in this

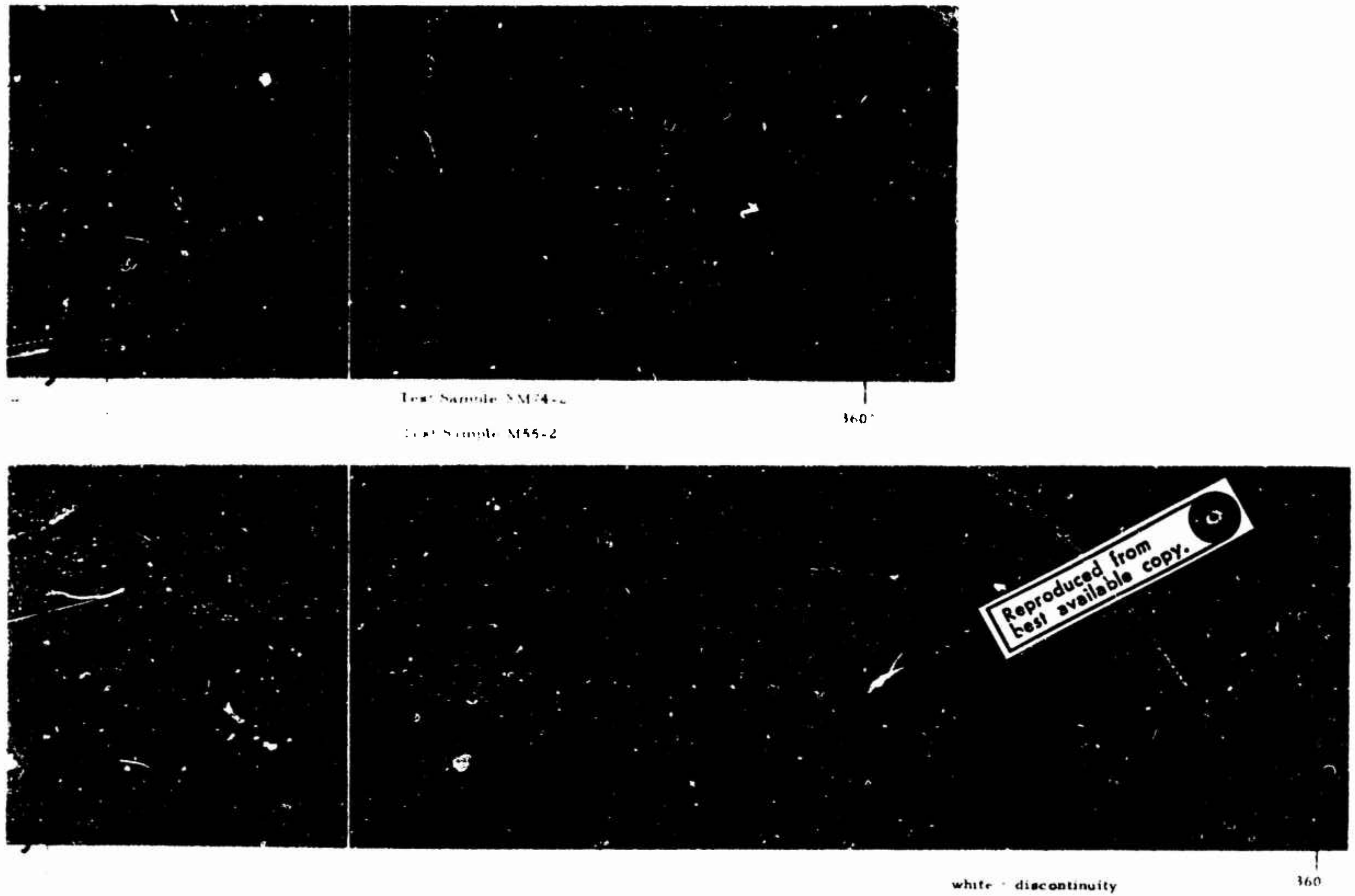




Figure 8. C-Scan Recording of Reference Hole Areas of Test Samples M55-2 and XM74-2
Sensitivity set for 90% amplitude signal from C1 reference.

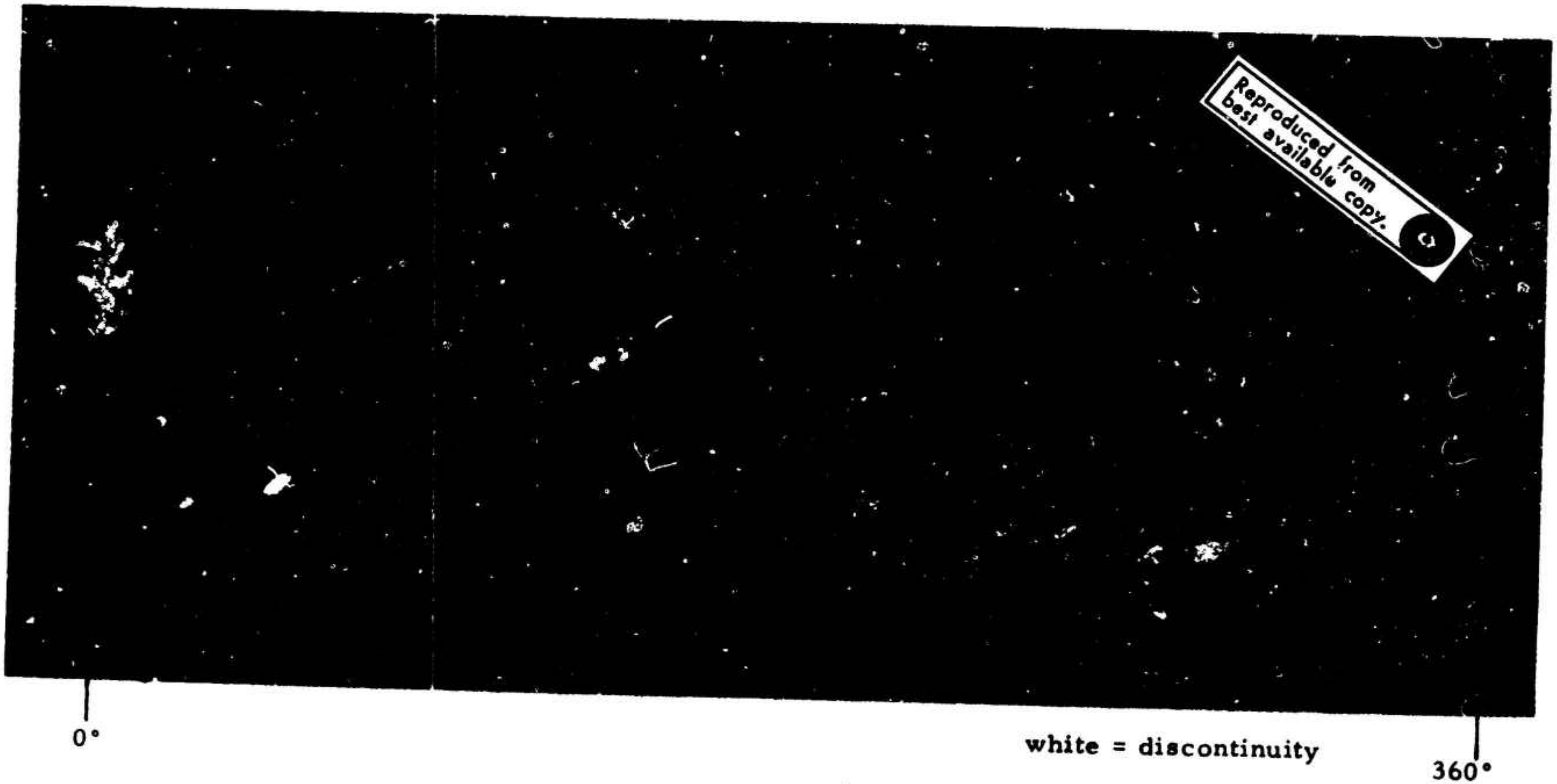




Figure 9. C-Scan Recording of Reference Hole Area of Test Sample MK67
Sensitivity set for 90% amplitude signal from C1 reference.

sample; however, the presence of the natural indications did not interfere with the detection of the reference defects.

## IV. DISCUSSION AND CONCLUSIONS.

As a result of this study, the following conclusions have been drawn.

1. The ultrasonic inspection technique and portable C-scan inspection system developed for munitions tubing has been successfully used to detect individual simulated pitting down to 0.010-inch deep by 0.010-inch diameter in the three tubing sizes. With the same test parameters, naturally occurring pitting has been detected in three of the five test samples submitted.

2. Individual pits spaced 1/16 inch or greater apart can be identified with the C-scan inspection techniques.

3. Pit depth cannot be determined using ultrasonic inspection techniques. The indication size on the C-scan recording is related to the reflective area (depth X diameter) of a single pit and/or the spacing (less than 1/16 inch) between two pits.

4. The inspection of the inner burster tube of the double-walled configuration is not feasible because of the lack of concentricity between the inner and outer tubes.

5. Liquid-filled cylinders such as those evaluated in this program must be inspected from below the liquid level. Extraneous signals from the liquid flowing on the ID of the outer tube will invalidate the test results if the inspection is performed above the liquid level.

6. The ultrasonic inspection can be calibrated successfully using pit type references of known size. The test parameters for this program were established to detect a 0.010-inch deep by 0.010-inch diameter reference pit in samples M55-2, XM74-2, and MK67. A destructive analysis and correlation of actual defects detected should be performed during the initial phases of the field inspection program to verify the selected test sensitivity. Possibly the detection criterion established is more severe than necessary for field inspection work.

7. Inspection of tubing of materials and thicknesses different from those evaluated may require changes in test frequency and search units; however, the basic inspection system should be adaptable to a variety of cylindrical configurations and materials.

8. Some difficulties were encountered with longitudinal and circumferential run-out in the tubing samples evaluated. If this problem persists during field inspection work, it is recommended that a second search unit be incorporated in the scanning head to track the part surface and provide positive gating control.

9. The inspection system as designed is capable of inspecting tubing up to 4.5-inch OD. Minor modification of the search tube/scanning head system would permit inspection of tubing up to approximately 6.0 inches in diameter.

10. Samples M55-2, XM74-2, and MK67 will be used as references for field inspection programs. These samples do not exhibit the "background noise" associated with naturally occurring pitting that was noted on samples M55-1 and XM74-1.

The system is now being used under surveillance procedures aimed at establishing the integrity of chemical filled cylindrical munitions. It will provide more reliable estimates of shelf life for each munition.