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THE DETECTION OF FATIGUE CRACKS BY NONDESTRUCTIVE TESTING METHODS

by Ward D. Rummel, Paul H. Todd, Jr., Sandor A. Frecska, and Richard A. Rathke

Prepared by
MARTIN MARIETTA AEROSPACE
DENVER DIVISION
Denver, Colo. 80201
for Lyndon B. Johnson Space Center

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16. Abstract

X-radiographic, penetrant, ultrasonic, eddy current, holographic, and acoustic emission techniques were optimized and applied to the evaluation of 2219-T87 aluminum alloy test specimens. One hundred eighteen specimens containing a total of 328 fatigue cracks were evaluated. The cracks ranged in length from 0.500 inch (1.27 cm) to 0.007 inch (0.018 cm) and in depth from 0.178 inch (0.451 cm) and 0.001 inch (0.003 cm). Specimen thicknesses were nominally 0.060 inch (0.152 cm) and 0.210 inch (0.532 cm) and surface finishes were nominally 32 and 125 rms and 64 and 200 rms respectively. Specimens were evaluated in the "as-milled" surface condition, in the chemically milled surface condition and, after proof loading, in a randomized inspection sequence. Results of the nondestructive test (NDT) evaluations were compared with actual crack size obtained by measurement of the fractured specimens. Inspection data were then analyzed to provide a statistical basis for determining the threshold crack detection sensitivity (the largest crack size that would be missed) for each of the inspection techniques at a 95% probability and 95% confidence level.

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PREFACE

This report was prepared by Martin Marietta Aerospace under Contract NAS9-12276. The study was initiated by the Johnson Space Center of NASA to determine the ability of current nondestructive testing techniques to detect and evaluate surface cracks in 2219-T87 aluminum alloy sheet. The work described herein was completed between November 9, 1971 and June 29, 1973. Work was conducted under the technical cognizance of Mr. W. L. Castner of the Johnson Space Center. Mr. James Maxwell provided monitor and direction for Quality Assurance at Johnson Space Center.

At Martin Marietta Aerospace, Mr. Ward D. Rummel provided technical direction and program management. Mr. Paul H. Todd was Principal Investigator for the nondestructive testing techniques and Mr. Richard A. Rathke was Principal Investigator for the statistical data analysis. Mr. Emory J. Beck provided support in all sample preparation; Mr. Thomas L. Tedrow led the X-radiography investigations; Mr. Sandor A. Frecska performed all holography studies at Martin Marietta; Mr. Robert Penn performed holography studies on subcontract to G. C. Optronics, Inc; and Mr. Earl M. Pracht led all acoustic emission studies. The inspection and analysis studies of evaluation samples were supported by Messrs. W. J. Vette Jr., D. W. Applebaum, S. Mullen, H. D. Brinkerhoff, S. R. Marston, A. T. Minne, J. Walker, and Ms. H. Cassens.

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Table

THE DETECTION OF FATIGUE CRACKS
BY NONDESTRUCTIVE TESTING METHODS

By Ward D. Rummel, Paul H. Todd, Jr,
Sandor A. Frecska, and Richard A. Rathke
Martin Marietta Aerospace

SUMMARY

This program was conducted to investigate the reliability of various nondestructive testing techniques to detect small tight cracks in 2219 T-87 aluminum alloy. X-radiographic, penetrant, ultrasonic, and eddy current techniques were extensively evaluated and holographic and acoustic emission techniques were evaluated to compare sensitivities.

X-radiography was determined to be the least reliable of the techniques in all evaluations. An 70% detection probability for cracks over 0.125 inch (0.318 cm) in length was demonstrated for inspection of as-milled panels by the penetrant method. Penetrant detection probability was increased to 92.5 and 97.5% respectively, for inspection after chemical milling and after proof loading.

Ultrasonic detection probability was determined to be 90% for cracks over 0.100 inch (0.254 cm) in length, was decreased slightly by chemical milling, and was increased by proof loading. Eddy current detection probability was established at 80% for cracks 0.100 inch (0.254 cm) in length and was increased with both chemical milling and proof loading operations. The holographic and acoustic emission techniques demonstrated comparable sensitivities.

X-radiographic detection was better for thin smooth panels in all inspections. Penetrant results were better for both thick and thin smooth panels. Ultrasonic detection was better for smooth thin panels. Eddy current detection was better for thick smooth panels and was similar for all panels after proof testing.

Results of the program demonstrate that current state-of-the-art nondestructive test methods are capable of reliably detecting small, tightly closed cracks when the NDT methods are properly applied. Proof loading was demonstrated to improve inspection results by all methods, while chemical milling was demonstrated to improve X-radiographic and penetrant detection probability and to decrease ultrasonic detection probability.

INTRODUCTION

A major portion of modern materials engineering technology is devoted to the description, documentation, and control of material properties. Material property data are then used by designers to match materials to the required service and environmental performance conditions. For structural component designs, mechanical property data such as ultimate and yield strength have been major design factors and have been used as primary bases for material selections. In recent years, the fracture characteristics of materials have been extensively evaluated and are now considered to also be major elements of design criteria. Fracture control design criteria, in simplified form, are the largest (or critical) flaw size(s) that a given material can sustain without fracture when subjected to design stresses and environmental conditions. To produce hardware to fracture control design criteria, it is thus necessary to assure that the hardware contains no flaws larger than the critical size.

For simple pressure vessels, fracture control may be assured by proof pressure testing of the vessels to a stress level higher than the operating stress. If the vessel does not fracture, the proof test assures the absence of critical flaws.* For complex structural designs, proof test logic cannot be used because of difficulties in representatively stressing the structure. Nondestructive testing is the only practical means for assuring conformance to design criteria. This means that nondestructive testing techniques must be capable of reliably detecting all flaws larger than the critical design size.

Traditionally nondestructive testing technology has been oriented to detection of small flaws, and the thrust of most nondestructive test evaluation programs has been identification of the smallest flaw that can be detected by a given technique. Virtually no statistically reliable flaw detection data for various NDT methods are available.† The lack of such data is an indicator of the infant state of nondestructive test engineering technology and of the complexity and cost of generating such statistical data.

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*Fracture Control of Metallic Pressure Vessels. NASA SP-8040, May 1970 (Space Vehicle Design Criteria, Structures).

†Neuschaefer, Robert W.; and Beal, James B.: Assessment of and Standardization for Quantitative Nondestructive Testing. NASA TMX-64706, September 30, 1972.

Experience has shown that one of the most difficult flaws to detect by NDT are small tightly closed cracks and that these cracks are one of the flaw types most detrimental to load-carrying structures. Crack detection is in turn affected by many variables such as crack orientation, crack location, crack type, surface finish, stress state, and service history of the structure. A tight crack can be closely simulated by artificially induced fatigue cracks. By using the fatigue crack as a primary flaw type, the influences of crack orientation, location, etc can be evaluated by systematic variation of sample preparation and the inspection sequence.

The program described herein was conducted to investigate the reliability of various NDT methods to detect small tight cracks as represented by artificially induced fatigue cracks. Optimized NDT methods, calibration techniques, and personnel training were used in evaluating a sufficiently large number of specimens to provide a statistical basis for establishing crack detection reliability. The primary objective of the program was to demonstrate that current state-of-the-art NDT methods are capable of reliably detecting small, tightly closed cracks when the NDT methods are properly applied. The secondary objectives of the program were to evaluate the influence of various surface finishes and of proof stress loading on crack detection by NDT methods.

SUMMARY OF THE PROGRAM APPROACH

The success of any nondestructive testing program depends on:

1) A sound understanding of the material fabrication techniques for, and service demands on, the items to be evaluated;

2) An accurate and precise definition of the anomalies to be evaluated by nondestructive techniques;

3) Definition and understanding of all parameters that will directly and indirectly affect the results of nondestructive evaluation techniques;

4) Fabrication of test samples that are representative of actual fabricated parts;

5) Use of test samples to establish nondestructive test sensitivity as verified by destructive and/or functional tests;

6) Establishment of well-defined procedures and controls to assure the integrity and uniformity of production inspection;

7) Fabrication and verification of calibration test specimens for use in executing inspection to defined procedures;

8) Training of production inspection personnel;

9) Establishment of an audit/liaison system to maintain inspection integrity and relevance to production requirements.

In short, rigorous inspection qualification and application programs are required to utilize nondestructive test data as design allowables.

Program Orientation

In the NASA Space Shuttle and other advanced spacecraft programs, fracture control will be assured by a combination of fracture mechanics and nondestructive testing. The detectable flaw size, as determined by nondestructive testing, will be a design allowable. A program to establish flaw detection sensitivities was therefore required to provide preliminary design data.

Use of 2219-T87 aluminum alloy in thicknesses ranging from 0.060 inch (0.152 cm) to 0.250 inch (0.634 cm) is planned for the Space Shuttle primary skin material. Experience has shown that small, tightly closed cracks are one of the most difficult types of flaws to detect and are one of the flaw types most detrimental to load-carrying structures. The program described herein was conducted to demonstrate that current state-of-the-art nondestructive test (NDT) methods can reliably detect small tightly closed cracks in the 2219-T87 aluminum alloy and to evaluate the influence of various surface finishes and of proof test loading on crack detection.

Flaw Detection Parameters

A good simulation of a tight crack can be obtained by an artificially induced fatigue crack. The fatigue crack technique was selected for preparation of all specimens. The test specimen descriptions and variations are summarized in the following tabulation.

Test Parameter	Rationale
Specimen Size 3.5 x 16 in. (8.9 x 40.6 cm)	Ease of introducing fatigue cracks.
Specimen Thickness 0.060 in. (0.152 cm) and 0.225 in. (0.570 cm)	Preliminary Space Shuttle design criteria.
Surface Finishes 125 rms, 32 rms, and chemically milled	Good machining practices.
Flaw Conditions As-machined As chemically milled After proof loading	Simulated production operations.

Nondestructive Testing Techniques Evaluated

X-radiography, ultrasonic, penetrant, and eddy current techniques were selected as primary state-of-the-art inspection methods and holographic interferometry and acoustic emission were selected as secondary inspection methods that could be developed and applied in production. The primary NDT methods were applied throughout all program phases and the secondary methods were applied selectively to evaluate their respective sensitivities.

SPECIMEN PREPARATION

Materials and Processing

The 2219-T87 aluminum alloy sheet used in this program was obtained in the fully heat-treated condition. Ultimate strength, yield strength, elongation, and microstructure were verified by test before accepting the material for evaluation. These values were used as a basis for subsequent proof loading.

Specimen Geometry

Test specimen blanks were milled to a 3.5 x 16 inch (8.9 x 40.5 cm) configuration with the rolling grain direction of the sheet oriented in the transverse (3.5 in.) direction. Initial stock thicknesses of 0.125 inch (0.137 cm) and 0.250 inch (0.634 cm) were used for all specimens. All specimens of equal thickness were cut from the same sheet. A hole was drilled in the lower left-hand corner of each specimen for attachment of specimen identification tags. With the panel in this orientation, Side A was designated as the facing side and Side B as the opposite side.

Fatigue Crack Growth Procedure

Six different crack configurations were selected for introduction in test specimens as shown.

	Material Thickness				
	0.225 in. (0.570 cm)			0.060 in. (0.152 cm)	
Case	a/2c	a/t	Case	a/2c	a/t
1	0.5	0.25	4	0.5	0.5
2	0.25	0.5	5	0.1	0.5
3	0.1	0.2	6	0.25	0.25

These configurations encompass a range of crack sizes and geometries that might be encountered in actual inspection.

Elements of the Test Program

The experimental test program was divided into the following elements:

1) Specimen preparation;

2) NDT optimization;

3) NDT evaluation in the sequence shown in Figure 1;

4) Data analysis and correlation.

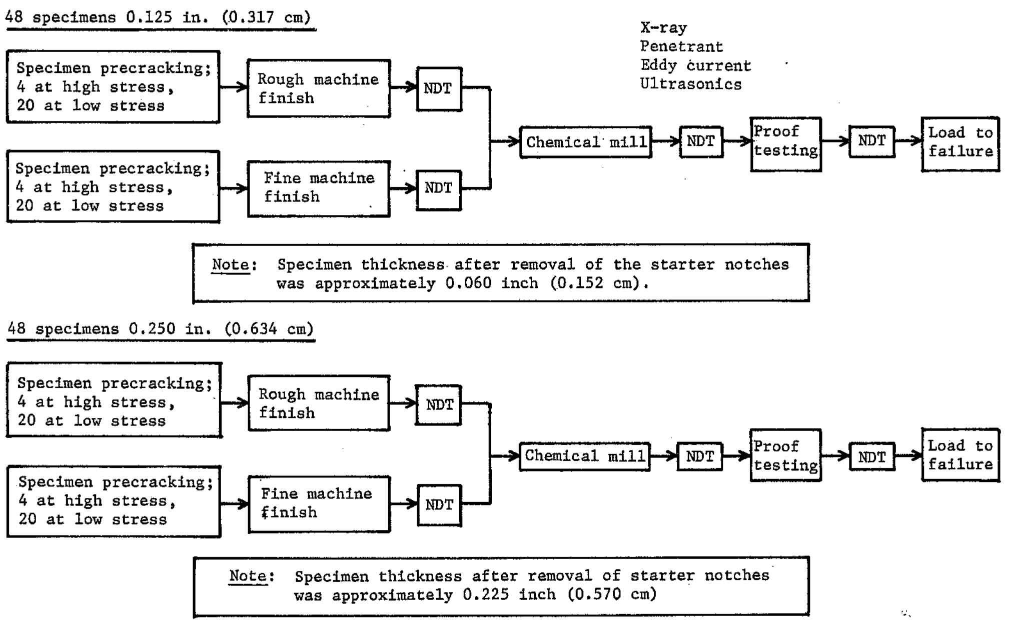

Figure 1.- NDT Evaluation Sequence

The variation in crack configuration required variations in both crack initiation and growth techniques. Several evaluation specimens were prepared, fractured, and analyzed to verify selection of crack growth characteristics. Specific preparation and growth procedures were established for each crack configuration as summarized in Table 1. A schematic representation of the starter crack and the final crack configuration are shown in Figure 2. Cross-section macrophotographs of actual cracks and starter cracks are shown in Figure 3.

Table 1.- Parameters for Growth of Fatigue Cracks

Case	a/2c	a/t	Final specimen thickness, in. (cm)	EDM starter type, in. (cm)*	Type of loading	Maximum fatigue stress, psi (N/m^2)
1	0.5	0.25	0.210 (0.532)	Hole 0.003 (0.0076) diameter	Axial	30,000 ($20.7x10^6$)
2	0.25	0.5	0.210 (0.532)	Hole 0.003 (0.0076) diameter	3-point bending	30,000 ($20.7x10^6$)
3	0.1	0.2	0.210 (0.532)	Shape 0.3 (0.76) long	3-point bending	20,000 ($13.8x10^6$)
4	0.5	0.5	0.060 (0.152)	Hole 0.003 (0.076) diameter	Axial	30,000 ($20.7x10^6$)
5	0.1	0.5	0.060 (0.152)	Shape 0.3 (0.76) long	3-point bending	30,000 ($20.7x10^6$)
6	0.25	0.25	0.060 (0.152)	Shape 0.06 (0.153) long	Axial	30,000 ($20.7x10^6$)

*Starter flaw depths on thick (0.250-in.) samples are restricted to 0.010 inch; on thin (0.125-in.) samples to 0.020 inch.

Note: A = depth of flaw;
t = thickness of material;
2c = length of crack.

Note: t = thickness of material; a = depth of crack; 2c = length of crack; shaded area = EDM starter notch shape;] = final machined thickness.

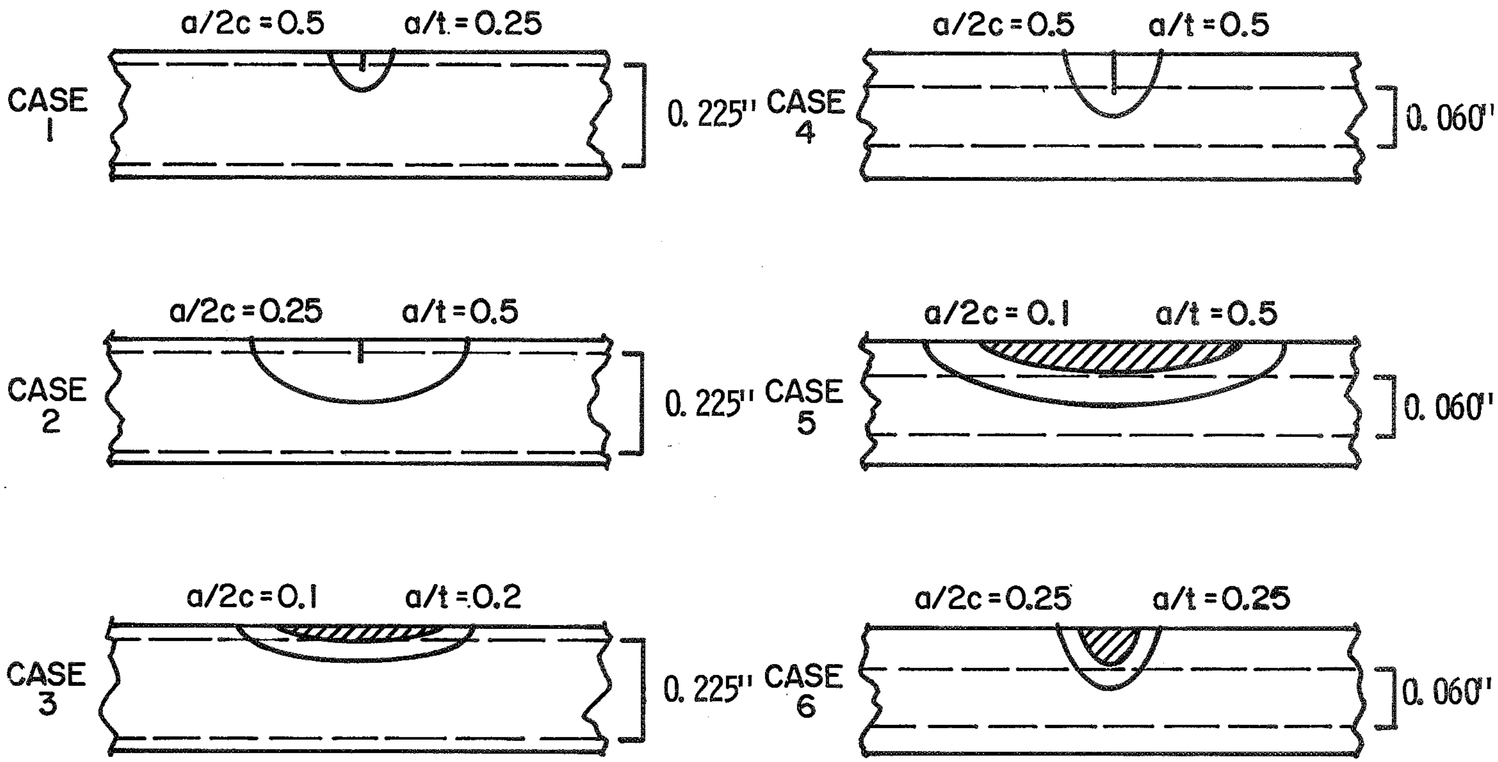

Figure 2.- Schematic, Side View of Starter and Final Crack Configuration

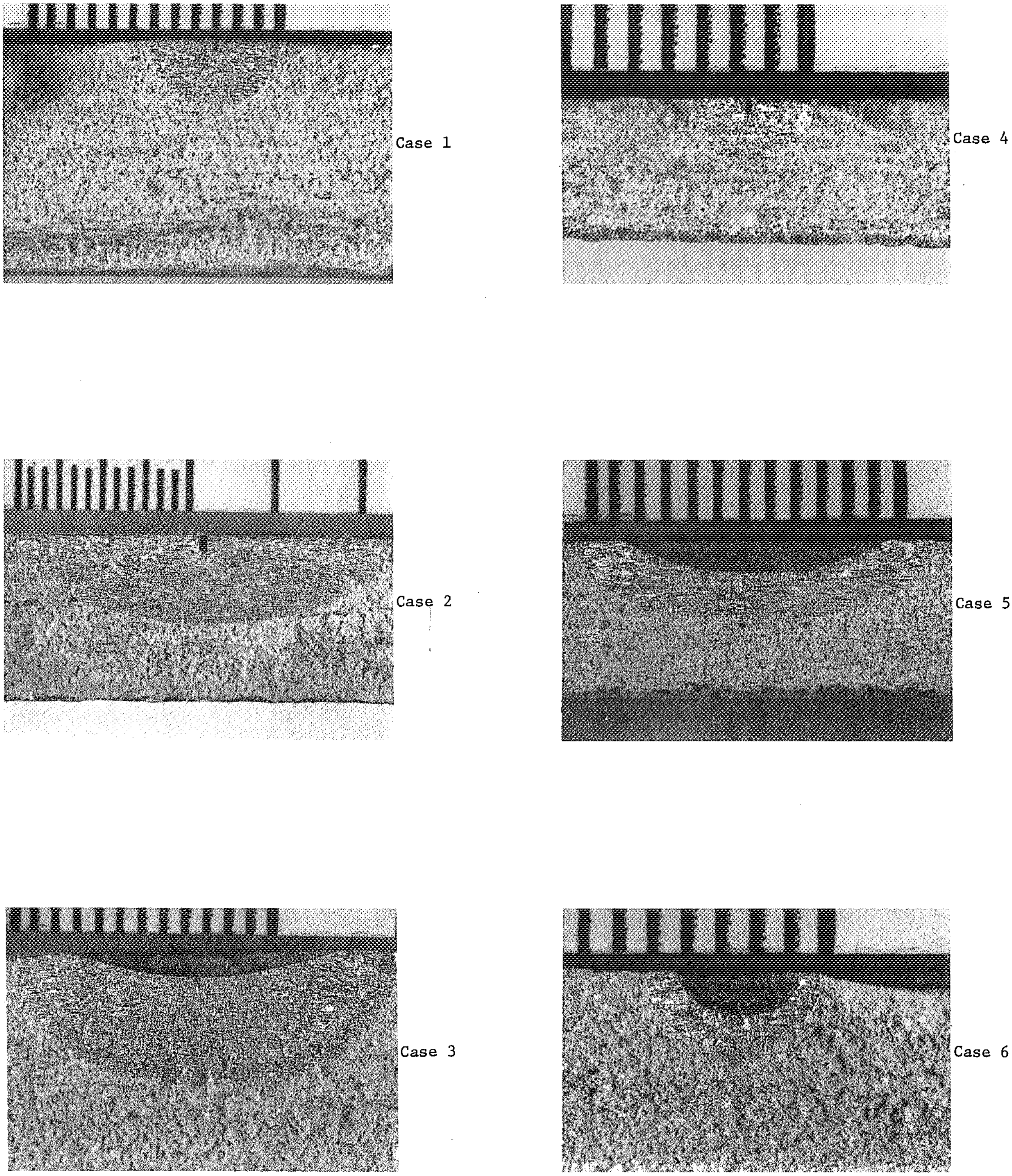

Figure 3.- Cross-Section Microphotographs of Cracks with Starter Cracks

Introduction of Fatigue Cracks in Test Specimens

Cracks were then initiated and grown in NDT test specimens. One hundred eighteen specimens containing 328 cracks were prepared. Sixty specimens were approximately 0.060 inch (0.152 cm) thick and contained 167 initiated cracks. Fifty eight specimens were approximately 0.210 inch (0.532 cm) thick and contained 161 initiated cracks. On final specimen sectioning, 155 cracks were confirmed in the 0.060-inch (0.152-cm) specimens and 155 cracks were confirmed in the 0.210-inch (0.532-cm) specimens. Sixteen cracks were grown at higher cyclic stress levels of 45,000 psi maximum, 4,500 psi minimum, or an R = 0.1. The higher stress levels were expected to cause significant plastic flow around the crack tip and result in a variation in crack tightness. Cracks were placed randomly on both sides of the specimens in the location shown in Figure 4. The number of cracks in flawed specimens was varied from one crack to six cracks to randomize results. Thirteen flaw-free specimens were included in the total number to further randomize inspection results.

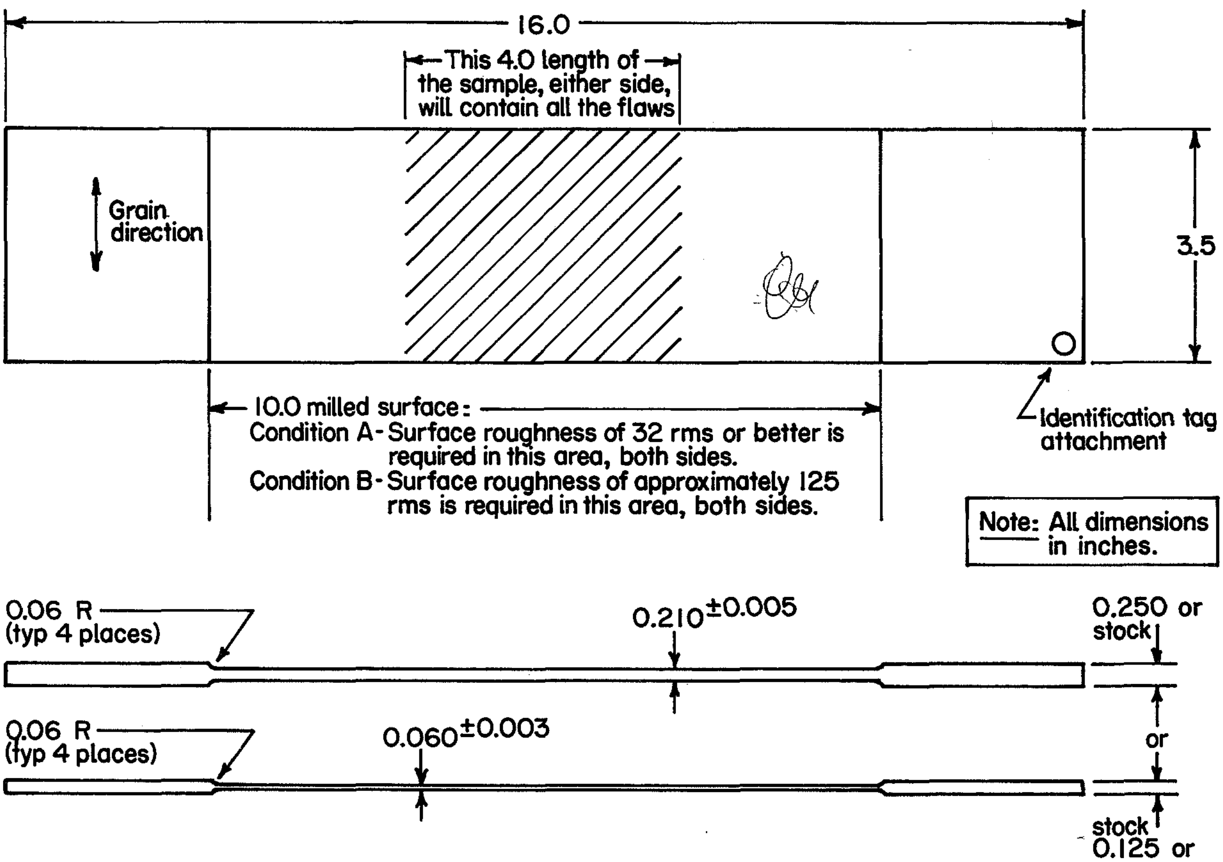

Figure 4.- NDT Specimen Configuration

Specimen Machining

Cracked specimens were mechanically machined on both sides to remove starter notches and to produce variations in surface finish that were representative of typical aerospace machining practices. The final specimen configuration is shown in Figure 4.

Machining was done with an end mill and fly cutter mounted so a 10-inch (25.4-cm) swath was cut across the sample in a single pass. Machining marks were thus oriented perpenducular to the axis of cracks located in the center of the sample and were oriented at an angle to cracks located at the ends of the sample. This variation in angle was introduced to further randomize results of surface finish variations. A 125-rms (rough) surface finish was produced at a spindle speed of 135 rpm (revolutions per minute) and a table feed of 1 5/8 inches (4.25 cm) per minute. A 32-rms (smooth) surface finish was produced at a spindle speed of 1115 rpm and a table feed of 1 1/4 inches (3.17 cm) per minute.

Specimen Characterization

The specimens were vapor-degreased, alkaline-cleaned, and dried. The thickness and surface finishes (both sides) of each specimen were measured and recorded. A measured variation in thickness of 0.054 to 0.068 inch (0.136 to 0.172 cm) and 0.197 to 0.214 inch (0.500 to 0.542 cm) was obtained. Variation in surface finish ranged from 28 to 64 rms on smooth specimens and from 125 to 420 rms on rough specimens.

Identification tags were attached to each specimen and submitted for initial nondestructive evaluation. Cracks in each specimen were located by orienting the specimen with the identification tag on the bottom left corner and measuring a X-axis location from left to right in the narrow direction and a Y-axis location from the edge of the milled area toward the top of the specimen. The same convention was used for both sides of the specimen. In the case of X-radiographic results, a translation of the X coordinate was necessary to tabulate both Side A and Side B cracks.

NONDESTRUCTIVE TESTING OPTIMIZATION

A review of current literature reveals a variety of nondestructive evaluation techniques that are applicable to crack detection and evaluation. Many reported are special-purpose techniques or are in an initial feasibility evaluation status. Since the objective of this program was to demonstrate crack detection reliability for current state-of-the-art NDT techniques, applicable mathods were limited to these techniques.

X-radiography, ultrasonic, eddy current, and penetrant testing methods were selected for overall specimen evaluation. These techniques were selected on the basis of their current industrial use in material evaluations and their applicability to near-term production of space hardware.

Holographic interferometry was selected for evaluation and comparison of sensitivities during one inspection cycle. Acoustic emission was selected as a technique for detection and location of growing cracks during the specimen proof loading and failure loading cycles. These techniques were selected as potential space hardware evaluation techniques for application to near-term production.

Before initiating the overall specimen evaluation program, a combined effort was conducted to characterize the nondestructive test materials and techniques and to optimize techniques for inspection of fatigue crack specimens. Material characterization was based on previous work at Martin Marietta and was updated to include evaluation of fatigue-cracked specimens.

Nondestructive Test Reference Specimens

One set of NDT reference and calibration specimens was prepared. Each set contained at least one crack of each crack type (Cases 1 thru 6) in both smooth and rough surface finish configurations. These specimens were then used to compare and evaluate the sensitivities of various NDT materials and techniques.

X-radiography

Discussion of the technique.- X-radiography is well established as a nondestructive evaluation tool and has been used indiscriminantly as an all-encompassing inspection method. X-radiographic inspection involves placing an X-ray-sensitive film close to one side of a test object, exposing the opposite side to a controlled source of X-radiation for a predetermined exposure time, chemically developing the film, and visually examining the resultant image by reference to "known" standards. The quality or sensitivity of a radiograph is measured by reference to a penetrameter image on the film at a location of maximum obliquity from the source. A penetrameter is a physical standard made of material radiographically similar to the test object with a thickness less than or equal to 2% of the test object thickness and containing three holes of diameters four times (4T), two times (2T), and equal to (1T) the penetrameter thickness. Normal space hardware inspection sensitivity is 2% as noted by perception of the 2T hole. The penetrameter can be viewed as a measure of changes in absorption characteristics of a volume of material.

The ability of an X-radiographic technique to detect cracks is influenced by the overall quality of the X-radiograph exposure as determined by the penetrameter and is also critically dependent on orientation of incident radiation with respect to the crack, on internal scatter in the test object, and on the resolution or grain size of the X-ray film. Consider, for example, a test object (Fig. 5) that contains three cracks, A, B, and C, whose principal axes lie at differing orientations with respect to incident X-ray energy. Crack A lies along the axis of the cone of X-radiation and should be detected at crack depths approaching 2% of the material thickness. Crack B will not be detected since its depth and hence greatest exposed volume lies at an oblique angle to the incident radiation. Crack C lies in part along the axis of radiation but will not be detected over its entire length. The best crack detection sensitivity is obtained by careful alignment and collimation of the X-ray source with respect to the axis of the crack. The effects of internal scatter in a material may be minimized by placing the film on the test object on the side nearest the crack and by use of energy-absorbing screens placed on the part.

Film resolution preimarily depends on the basic film characteristics, on the exposure process, and on the film development process. As with all X-radiograph exposures, care must be taken to control factors affecting resolution to assure maximum crack detection sensitivity.

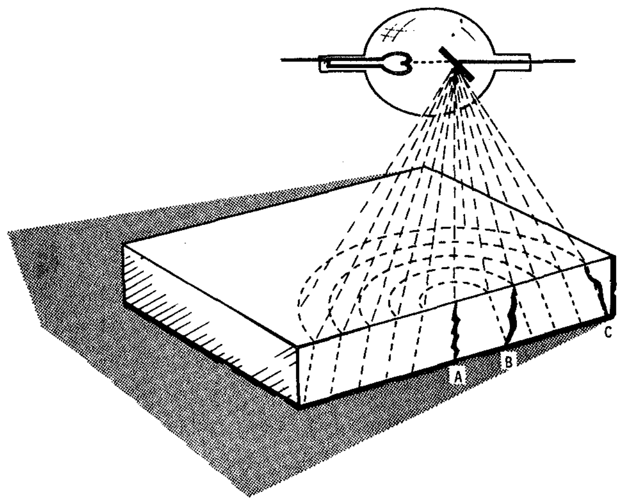

Figure 5.- Schematic View of Crack Orientation with Respect to the Cone of Radiation from an X-ray Tube (Half Section)

Evaluation of the X-radiographic technique.- To optimize crack detection by X-radiographic techniques, a comparison and evaluation program was initiated. Six commercially available film types were selected for evaluation. An initial exposure procedure was established for each film type using standard (MIL-STD-453) penetrameters for evaluation of detection sensitivity. Internal scatter effects were controlled by locating test specimens with the crack side nearest the film. Alignment was controlled by collimating the X-ray source at the tube and by orientation of the X-ray source perpendicular to the center of the test panel.

The NDT reference and calibration specimens were then used to compare film types. All specimens were examined by three independent operators using the established procedure on six films. Case 1, 3, and 6 cracks were not consistently detected by this process. Films of equivalent advertised speed were equivalent in the crack detection. Kodak Type M film was selected for use in all subsequent evaluations on the basis of its performance and its compatibility with available automatic film processing equipment.

The effects of angulation and offset of the X-ray source with respect to the axis of the crack were evaluated using NDT reference specimens. The incident angle of radiation was varied by rotating the X-ray tube incrementally from an initially aligned position. The offset was varied by moving the reference panel laterally in the panel length direction. Results of this evaluation are shown in Table 2.

Table 2.- Effects on Varying the Alignment of Incident X-radiation on Crack Detection Sensitivity

Panel No.	Angle, deg						Offset, in. (cm)				
	0	3	6	9	12	15	1 (2.54)	2 (5.08)	3 (7.62)	4 (10.16)	5 (12.7)
1S	Not detected										
2S	X	X	X				X	X	X	X	
3S	Not detected										
4S	X	X					X	X	X		
5S	X	X									
6S	Not detected										
1-R	X	X									
2-R	X	X	X	X	X		X	X			
3-R	Not detected										
4-R	Not detected										
5-R	X										
6-R	Not detected										

<u>Selection of an X-radiographic technique</u>.- The criticality of the X-ray source alignment was demonstrated by the results shown. Since all cracks in the test specimen are not located in the center of the panel, some offset with respect to the crack axis is unavoidable. It was recognized at this time that some cracks would be missed due to panel alignment. The smallest cracks were beyond the resolution capability of the technique and would also be missed.

The best X-ray procedure using Kodak Type M film was selected for all exposures of the NDT test specimens. The details of this procedure are shown in Appendix A.

Ultrasonic Inspection

Discussion of the technique.- Ultrasonic inspection involves generation of an acoustical wave in a test object; detection of resultant reflected, transmitted, and scattered energy from the volume of the test object; and evaluation of results by comparison to "known" physical reference standards. Traditional ultrasonic inspections for cracks oriented perpendicular to a part surface utilize shear waves for inspection. Figure 6 illustrates a typical shear wave technique and the corresponding oscilloscope presentation from a test object containing a crack. In the shear wave technique, an acoustical wave is generated at an angle to a part surface, travels through the part, and is reflected by boundaries of the part and by included flaw surfaces. The presence of a reflected signal indicates the presence of an included flaw. The relative position of the reflected signal and the signal amplitude locate and describe the size of the flaw. By scanning and electronically gating signals obtained from the volume of a part, a plan view of a C-scan recording may be generated to provide uniform scanning and control of the inspection and to provide a permanent record of inspection.

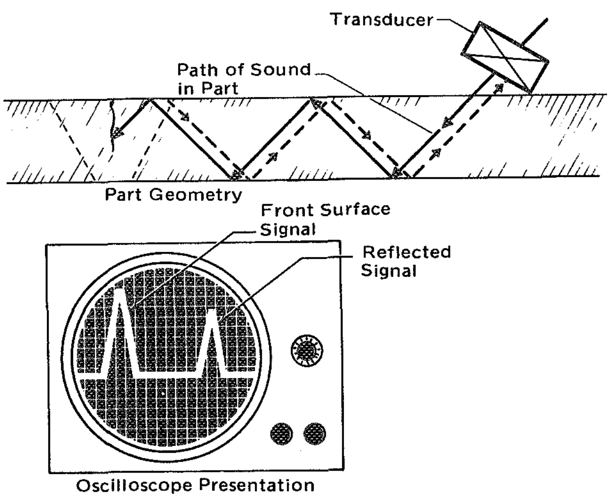

Figure 6.- Shear Wave Inspection

The shear wave technique and related modes are applicable to detection of tight cracks. Planar (crack life) interfaces were reported to be detectable by ultrasonic shear wave techniques when a test specimen was loaded in compression up to the yield point.* Variable parameters influencing the sensitivity of shear wave inspection include test specimen thickness; configuration uniformity; surface finish; transducer size, frequency, and type; and incident sound angle. A technique is best optimized by analysis and by evaluation of representative reference specimens.

It was noted that a shear wave is generated by placing a transducer at an angle to a part surface. Variation of the incident angle results in variation in ultrasonic wave propagation modes and variation of the technique. In aluminum, a variation in incident angle between approximately 14 to 29 degrees (water immersion) inclination to the normal results in propagation of energy in the shear mode (particulate motion transverse to the direction of propagation).

At an angle of approximately 30 degrees, surface or Rayleigh waves that have a circular particulate motion in a plane transverse to the direction of propagation and a penetration of about one-half wavelength are generated. At angles of approximately 7.8, 12.6, 14.7, 19.6, 25.6 and 31 to 33 degrees, complex Lamb waves that have a particulate motion in symmetrical or assymmetrical sinusoidal paths along the axis of propagation and that penetrate through the material thickness are generated in the thin (0.060 in.) aluminum.

In recent years, a technique known as "Delta" inspection has gained considerable attention in weldment evaluation. The technique consists of irradiating a part with ultrasonic energy propagated in the shear mode and detecting redirected, scattered, and mode-converted energy from an included flaw at a point directly above the flaw (Fig. 7). The advantage of the technique is the ability to detect crack-like flaws at random orientations.

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*Martin, B. G.; and Adams, C. J.: Detection of Lack of Fusion in Aluminum Alloy Weldments by Ultrasonic Shear Waves. Technical Paper No. 3499, Douglas Aircraft Company, 1965.

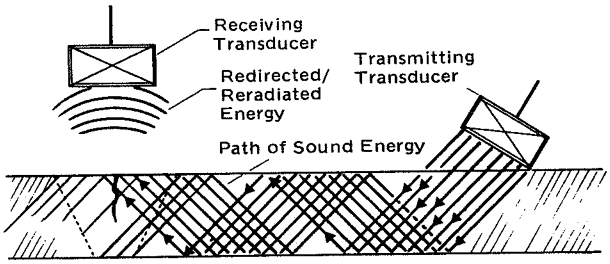

Figure 7.- Schematic View of the Delta Inspection Technique

In addition to variations in the ultrasonic energy propagation modes, variations in application may include immersion or contact, variation in frequency, and variation in transducer size and focus. For optimum detection sensitivity and reliability, an immersion technique is superior to a contact technique because several inspection variables are eliminated and a permanent recording may be obtained. Although greater inspection sensitivity is obtained at higher ultrasonic frequencies, noise and attenuation problems increase and may blank out a defect indication. Large transducer size in general decreases the noise problems but also decreases the selectivity because of an averaging over the total transducer face area. Focusing improves the selectivity of a larger transducer for interrogation of a specific material volume, but decreases the sensitivity in the material volume located outside the focal plane.

Evaluation of ultrasonic inspection techniques.- The ultrasonic inspection technique was optimized by analysis and experimental determination of the best overall signal-to-noise ratio of various techniques using the NDT reference and calibration specimens for comparison. Shear wave, surface wave, Lamb wave, and Delta inspection techniques were determined by analysis to be suitable candidates for evaluation. Test frequencies of 2.25, 5.0, and 10.0 MHz were selected in both flat and focused configurations. A Sperry UM 715 reflectoscope and 10-N pulser/receiver unit; a Budd scanning bridge, manipulator and tank; and an Alden Alfax recorder were used as the basic test equipment. All evaluations, with exception of the surface wave, were accomplished by the immersion technique.

Shear wave: Twelve NDT reference and calibration specimens were evaluated using various transducers. A Case 5S panel was used for comparison of signal response at various angles. Figures 8 and 9 show plots of signal response versus incidence angle for a 10-MHz flat transducer and a 10-MHz focused transducer. The water path of the focused transducer was varied and similar results were obtained for signal amplitude versus incidence angle. The 21- and 27¼-degree incidence angles were selected for further comparison. The 2.25- and 5.0-MHz transducers compared at 21 and 27¼ degrees and at slight angle variations on either side were not equal to the 10-MHz results. C-scan recordings were then made of the 12 NDT reference panels at 21 and 27¼ degrees to compare total system output. The 27¼-degree incidence angle was selected as the optimum shear technique based on these results. Figure 10 shows typical C-scan recordings for the six crack cases. C-scan recordings were also made from the opposite side of all panels and the larger cracks were consistently detected.

Surface wave: The surface wave technique was evaluated using a hand scan, 5-MHz fixed-angle transducer on the 12 NDT reference and calibration panels. Cracks detected by the shear wave technique could also be detected by the surface wave technique. The rougher surface finish resulted in an extremely noisy presentation. Signal noise made interpretation difficult and would be predicted to cause both erroneous crack callouts and failure to call out actual cracks if crack locations were not known. Due to the noise and comparative sensitivities obtained, the surface wave technique was not evaluated at 2.25 or 10 MHz. Further, the hand scan technique was determined to not be suitable for reliable crack detection.

Lamb wave: Propagation in Lamb wave modes was investigated during the shear wave versus incident angle evaluations. No detectable change in response was noted at the angle/thickness values reported for Lamb wave propagation. Actual Lamb mode propagation was not confirmed at the angles reported. Since no increase in response in the Lamb mode configurations was noted, no further evaluation was made.

Delta mode: Delta mode evaluation was made using an Automation Industries Delta transducer holder and the recommended 10-MHz transducers. The technique was not as sensitive as the shear wave techniques in evaluation of the 12 NDT reference and calibration specimens. To verify these results, five of the specimens were taken to an independent laboratory (Automation Industries, Incorporated, Boulder, Colorado) for a second Delta evaluation. Some improvement was demonstrated but results were similar to those obtained by other techniques. Improvement was primarily in detection of farside cracks.

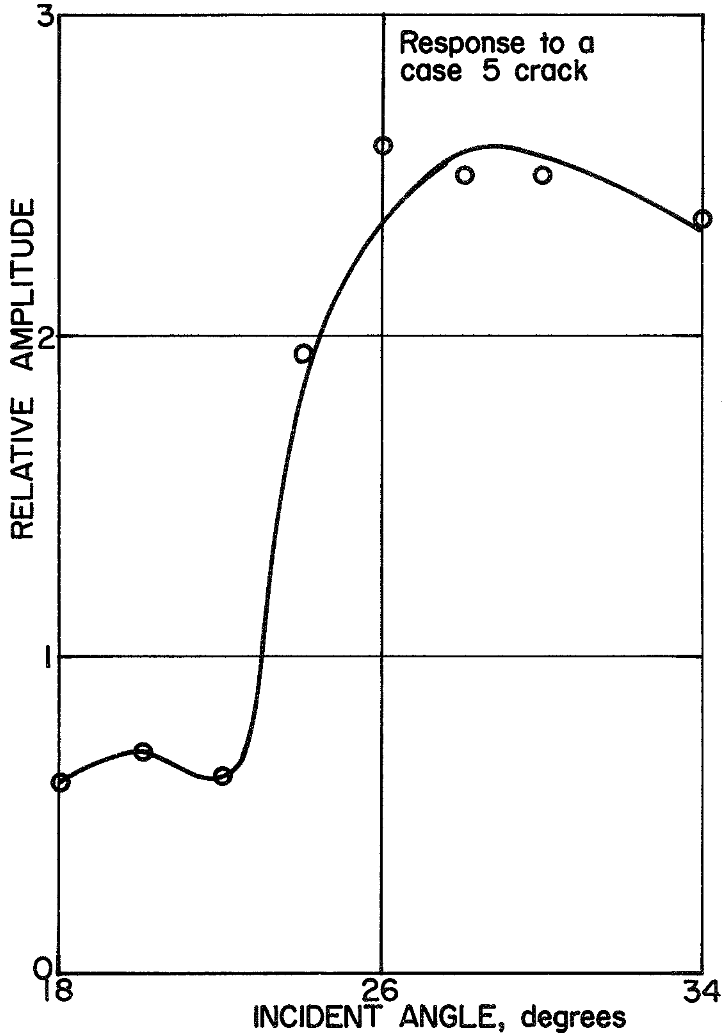

Figure 8.- Transducer Response at 23-dB External Attenuation (Type SIJ, 10 MHz, FS, 0.375-in. diameter, SN 244776)

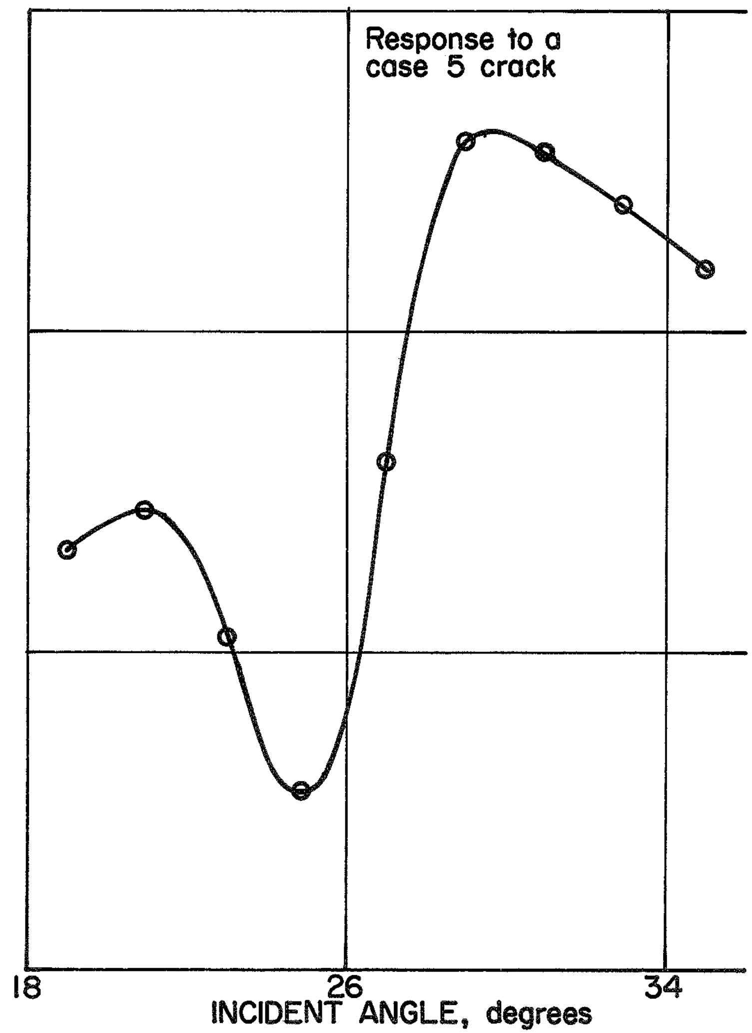

Figure 9.- Transducer Response at 13-dB External Attenuation (Type SIZ, 10 MHz, Flat, 0.500-in. diameter, SN 6966)

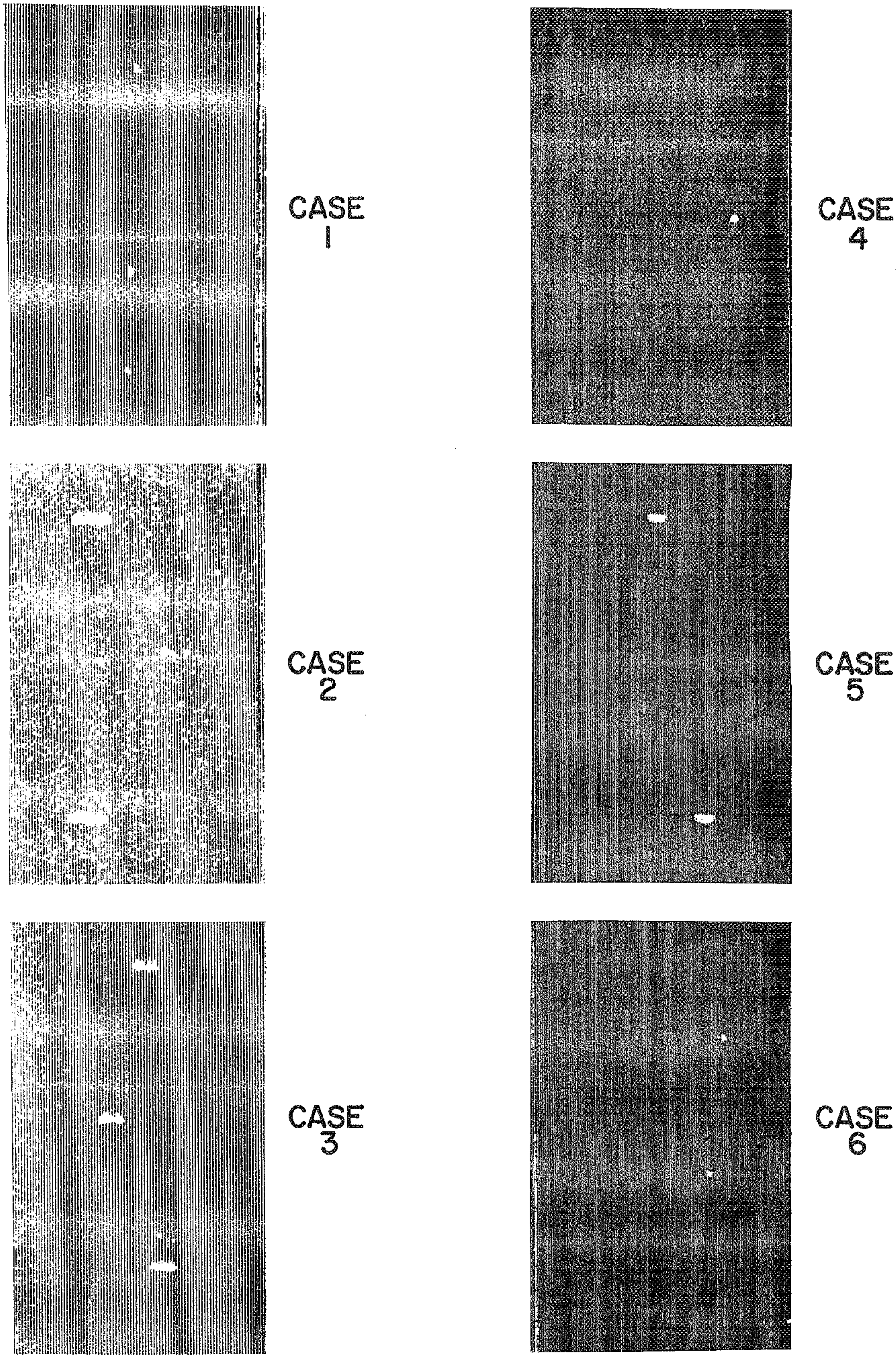

Figure 10.- C-Scan Ultrasonic Recordings of Case 1 thru Case 6 Crack Types

Results: A summary comparison of results obtained by all ultrasonic techniques is shown in Table 3.

Table 3.- Summary of Reference Panel Evaluation by Selected Ultrasonic Methods

Panel no.	Crack no.	Shear at 21 deg	Shear at 27¼ deg	Delta	Delta*	Contact surface	Remarks
1R	1	X	X	No	Not evaluated	X	
	2	X	X	No	Not evaluated	X	
	3						Not present
	4	X	X	No	Not evaluated	X	
	5	X	X	No	Not evaluated	X	
	6	X	X	No	Not evaluated	X	
	7	X	X	No	Not evaluated	X	
2R	1	X	X	X	X	X	
	2	X	X	X	X	X	
	3	X	X	X	X	X	
3R	1	X	X	No	Not evaluated	X	
	2	X	X	X	Not evaluated	X	
	3	X	X	X	Not evaluated	X	
4R	1	X	X	No	X	X	
	2	No	No	No	No†	No	
	3	X	X	No	X	X	
	4	X	X	No	X	X	
5R	1	X	X	X	Not evaluated	X	
6R	1	X	X	No	X	X	
1S	1	X	X	X	Not evaluated	X	
	2	X	X	No	Not evaluated	X	
	3	X	X	No	Not evaluated	X	
2S	1	X	X	X	X	X	
	2	X	X	X	X	X	
	3	X	X	X	X	X	
3S	1	X	X	X	Not evaluated	X	
	2	X	X	X	Not evaluated	X	
4S	1	X	X	No	Not evaluated	X	
5S	1	X	X	X	Not evaluated	X	
	2	X	X	X	Not evaluated	X	
6S	1	No	X	No	No†	No	
	2	No	No	No	No†	No	
	3	No	No	No	No†	No	

*Independent laboratory.

†Cracks visible on the A-scan monitor but not evident on the C-scan recordings.

Selection of an ultrasonic technique.- The results of the overall control and reproducibility offered by the technique were also considered in its selection as the optimum technique for test panel evaluation. A procedure was written in detail for this technique and was used by all operators in subsequent panel evaluations. This procedure is included in Appendix B.

Eddy Current Inspection

Discussion of the Technique.- Eddy current inspection has been demonstrated to be sensitive to small cracks in thin aluminum alloy components* and offers considerable potential for routine application.

Flaw detection by eddy current methods involves scanning the surface of a test object with a coil probe, electronically monitoring the effect of such scanning, and varying the test frequency to ascertain flaw depths. In principle, if a probe coil is energized with an alternating current, an alternating magnetic field will be generated along the axis of the coil (Fig. 11). If the coil is placed in contact with a conductor, eddy currents will be generated in the plane of the conductor around the axis of the coil. The eddy currents will in turn generate a magnetic field of opposite sign along the coil. This effect will "load" the coil and cause a resultant shift in impedance of the coil (phase and amplitude). Eddy currents generated in a material depend on the material's conductivity (p), thickness (T), magnetic permeability (μ), and continuity. For aluminum alloys, the permeability is unity and need not be considered.

*Recommended Practice for Standardizing Equipment for Electromagnetic Testing of Seamless Aluminum Alloy Tube. ASTM E-215-67, September 1967.

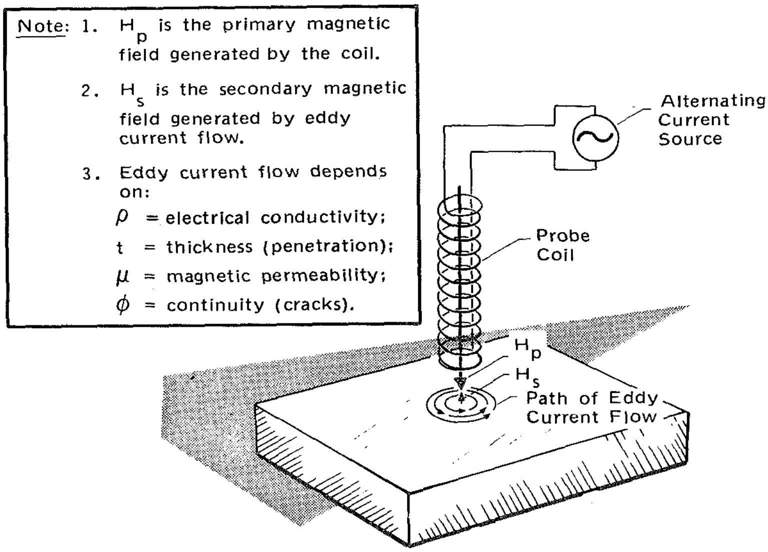

Figure 11 Schematic View of an Eddy Current Inspection

The conductivity of 2219-T87 aluminum alloy varies slightly from sheet to sheet but may be considered to be a constant for a given sheet. Overheating due to manufacturing processes* will change the conductivity and therefore must be considered as a variable parameter. The thickness (penetration) parameter may be controlled by properly selecting the test frequency. This variable may also be used to evaluate defect depth and to detect part-through cracks from the opposite side. For example, since at 60 kHz the eddy current penetration depth is approximately 0.060 inch in 2219-T87 aluminum alloy, cracks should be readily detected from either available surface for the 0.060-inch specimens. Sensitivity to cracks (continuity) is the desired parameter to be measured and may be exploited if other material parameter changes are eliminated or are factored into the overall results.

In practical application the material parameters must be known and defined and the system parameters known and controlled. Liftoff (i.e., the spacing between the probe and material surface) must be held constant or must be factored into results. Electronic readout of coil response must be held constant or defined by reference to calibration samples. Inspection speeds must be held constant or accounted for. Probe orientation must

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*Rummel, Ward D.: Monitor of the Heat-Affected Zone in 2219-T87 Aluminum Alloy Weldments. Transactions of the 1968 Symposium on NDT of Welds and Materials Joining, Los Angeles, California, March 11-13, 1968.

be constant or the effects defined, and probe wear must be minimized. Quantitative inspection results are obtained by accounting for all material and system variables and by reference to physically similar "known standards."

Evaluation of eddy current inspection techniques.- If conductivity, magentic permeability, and part thickness are held constant, continuity may be independently evaluated as a material variable at varying instrument sensitivities. Instrument sensitivities may be varied by varying amplifier gain and readout, by varying test frequency, and by varying probe liftoff and orientation. The Nortec NDT-3 was selected for evaluation as a representative, commercially available unit for which both test frequency and amplification can be conveniently varied.

A tool for scanning test panels was fabricated to hold the panel and to provide convenient indexing for incrementally scanning a panel (Fig. 12). The standard Nortec probes were mounted in a plastic shoe to aid in maintaining constant probe orientation. A single thickness of vinyl tape was attached to the probe and shoe face to provide constant liftoff. Panels were scanned by moving the probe over the panel length using the tool index bar as a guide. The index guide was then moved in 1/8-inch (0.318-cm) increments with successive scans across the panel.

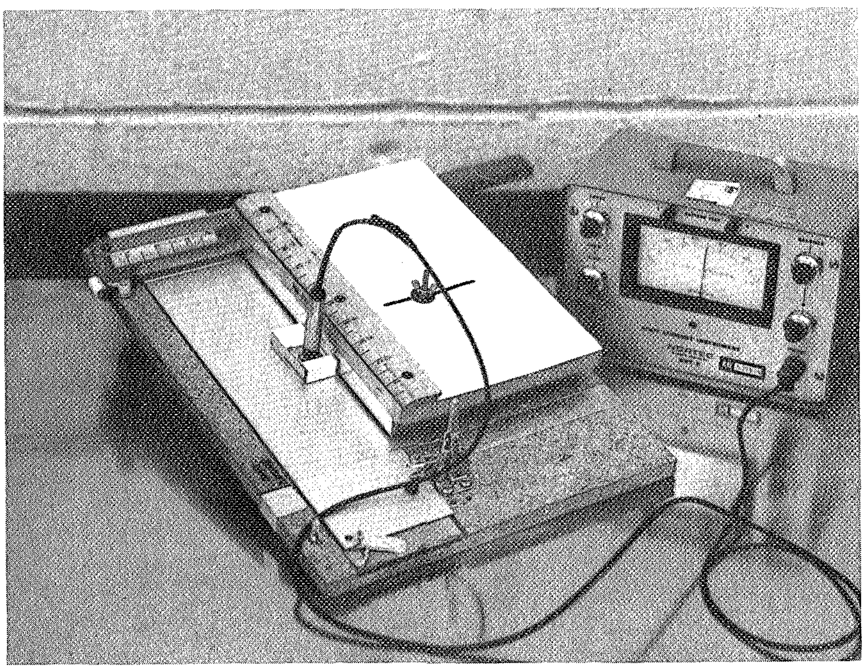

Figure 12.- Eddy Current Test Fixture and Instrument

NDT reference and calibration panels were evaluated at 50, 100, 200, and 500 kHz respectively. Comparison of results is shown in Tables 4, 5, 6, and 7.

Selection of an eddy current technique.- The results of overall eddy current technique evaluation show the sensitivity of the 100-kHz technique to be equal to or better than that of other frequencies. Less noise due to panel surface roughness was obtained at 100 kHz and the results were the easiest to evaluate. 100 kHz was selected as the optimum technique for test panel evaluation. A detailed evaluation procedure was written and used by all operators in subsequent evaluations. This procedure is included in Appendix C.

Table 4.- Eddy Current Evaluation of Reference Panels at 50 kHz

Panel	Crack 1	Crack 2	Crack 3	Others
1R	Strong +	Moderate	--	Moderate/Weak
2R	Strong +	Strong +	Strong +	--
3R	Strong +	Strong +	Strong +	--
4R	Moderate	Weak	Moderate	Weak
5R	Strong +	--	--	--
6R	Weak	--	--	--
1S	Strong +	Moderate	Moderate	--
2S	Strong +	Strong +	--	--
3S	Strong +	Strong +	--	--
4S	Moderate	--	--	--
5S	Strong +	Strong +	--	--
6S	Weak	Weak	Weak	--

Note: Weak - 10 μA deflection or less.

Moderate - 10 μA to 40 μA deflection.

Strong - 40 μA to 45 μA deflection.

Strong + - 65 μA deflection.

Nortec NDT-3 Setup

Frequency	50 kHz
Probe	50 kHz
Level	0.12
Gain "f"	6.25
Gain "C"	3
Balance "X"	4.10
Balance "R"	7.00

Table 5.- Eddy Current Evaluation of Reference Panels at 100 kHz

Panel	Crack 1	Crack 2	Crack 3	Others
1R	Strong +	Strong	--	Moderate
2R	Strong +	Strong +	Strong +	--
3R	Strong +	Strong +	Strong +	--
4R	Strong +	Moderate	Strong +	Strong +
5R	Strong +	--	--	--
6R	Moderate	--	--	--
1S	Strong +	Strong +	Strong +	--
2S	Strong +	Strong +	--	--
3S	Strong +	Strong +	--	--
4S	Strong +	--	--	--
5S	Strong +	Strong +	--	--
6S	Moderate	Weak	Weak	--

<u>Note:</u> Weak - 10 μA deflection or less.

Moderate - 10 μA to 40 μA deflection.

Strong - 40 μA to 65 μA deflection.

Strong + - 65 μA deflection or more.

Frequency	100 kHz
Probe	100 kHz
Level	3.90
Gain "f"	500
Gain "C"	3
Balance "X"	3.00
Balance "R"	7.00

Table 6.- Eddy Current Evaluation of Reference Panels at 200 kHz

Panels	Crack 1	Crack 2	Crack 3	Others
1R	Strong	Moderate	--	Moderate/Weak
2R	Strong +	Strong +	Strong +	--
3R	Strong +	Strong +	Strong +	--
4R	Strong	Weak	Strong	Moderate
5R	Strong +	--	--	--
6R	Wear	--	--	--
1S	Strong +	Moderate	Strong +	--
2S	Strong +	Strong +	--	--
3S	Strong +	Strong +	--	--
4S	Strong	--	--	--
5S	Strong +	Strong	--	--
6S	Moderate	Moderate	Weak	--

<u>Note:</u> Weak - 10 μA deflection or less.

Moderate - 10 μA to 40 μA deflection.

Strong - 40 μA to 65 μA deflection.

Strong + - 65 μA deflection or more.

Frequency	200 kHz
Probe	200 kHz
Level	7.78
Gain "f"	3.34
Gain "C"	3
Balance "X"	3.32
Balance "R"	7.00

Table 7.- Eddy Current Evaluation of Reference Panels at 500 kHz

Panel	Crack 1	Crack 2	Crack 3	Others
1R	Strong	Moderate	--	Weak
2R	Strong +	Strong +	Strong +	--
3R	Strong +	Strong +	Strong +	--
4R	Moderate	Weak	Moderate	Moderate
5R	Strong +	--	--	--
6R	Moderate	--	--	--
1S	Strong +	Moderate	Strong	--
2S	Strong +	Strong +	--	--
3S	Strong +	Strong +	--	--
4S	Strong	--	--	--
5S	Strong +	Strong	--	--
6S	Weak	Weak	Weak	--

Note: Weak - 10 μA deflection or less.

Moderate - 10 μA to 40 μA deflection.

Strong - 40 μA to 65 μA d deflection.

Strong + - 65 μA deflection or more.

Frequency	500 kHz
Probe	500 kHz
Level	0.66
Gain "f"	2.67
Gain "C"	3
Balance "X"	4.24
Balance "R"	7.00

Penetrant Inspection

Discussion of the technique.- Surface penetrants are commonly used in surface flaw detection. This method uses a penetrating liquid to enter surface-connected flaws by capillary action. After a prescribed dwell time, the excess material is removed by wiping or washing with a solvent that will not remove the penetrant from surface openings. A developer is then applied to absorb and remove penetrant from the flaws and to magnify the indication. Many penetrant materials are commercially available for use in a variety of applications. Since the penetrant process consists of multiple critical steps for which a number of materials may be used, a number of parameters are involved in selection and application. The material considerations for penetrant selection include:

1) Material to be inspected and compatibility with inspection materials;

2) Penetrant sensitivity required;

3) Condition of the specimen to be inspected;

4) Inspection conditions;

5) Compatibility of penetrant materials with automatic inspection equipment.

Evaluation of the penetrant technique.- Since maximum flaw detection sensitivity was desired for test panel evaluation, the primary efforts in technique optimization were devoted to selection of a penetrant system by comparison of sensitivities. The number of materials evaluated was further limited by consideration of materials that have been used for major space hardware production. A total of six fluorescent penetrant materials and three visible penetrant materials were selected for evaluation.

Numerous tests have been used to measure and compare penetrant performance. The test penetrants were compared by the meniscus and ceramic block test methods and by the results of inspecting NDT reference panels. The meniscus method is a qualitative technique for measurement of the ability to see a penetrant in thin films as described by Alberger* and by Bailey and Kraska.[†] In the meniscus method, a drop of penetrant is placed on an optical flat and a spherical lens is pressed against the flat at the center of the penetrant. This procedure results in distributing the penetrant from a very thin layer at the contact point of the lens to a maximum thickness away from the center point (Fig. 13). In very thin layers, the penetrant will not be visible but will become visible as the film thickness increases. The penetrant is then a dark spot at the contact point surrounded by a ring whose inner diameter depends on the film thickness required to make the penetrant visible. A superior penetrant will then show a small dark spot at the contact point surrounded by a ring whose inner diameter depends on the film thickness required to make the penetrant visible. A superior penetrant will then show a small dark spot at the contact point while a less sensitive penetrant will show a larger spot. Figure 14 shows a comparison of two penetrants by the meniscus method. From these data, two sensitivity indices are determined. A direct reading of the extinction spot diameter by the meniscus method is stated as the dimensional or comparative thin-film brightness sensitivity. The spot boundary is not a sharp line of demarcation but is instead a transition area that increases from the first point of visibility to an outer boundary where a constant area of brightness is present. The diameter of the outer boundary

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*Alberger, James R.: Theory and Application of Liquid Tracers. Nondestructive Testing, Vol XX, No. 2, 1962, p 91.

[†]Bailey, W. H. and Kraska, I. R.: Penetrant Brightness Measurement Test. AFML TR-70-141, July 1970.

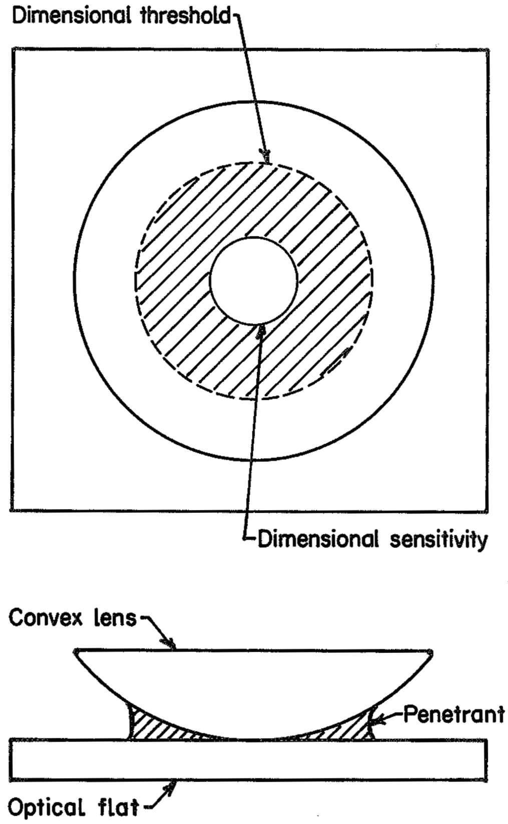

Figure 13.- Experimental Configuration, Penetrant Film Thickness Measurement, Meniscus Method

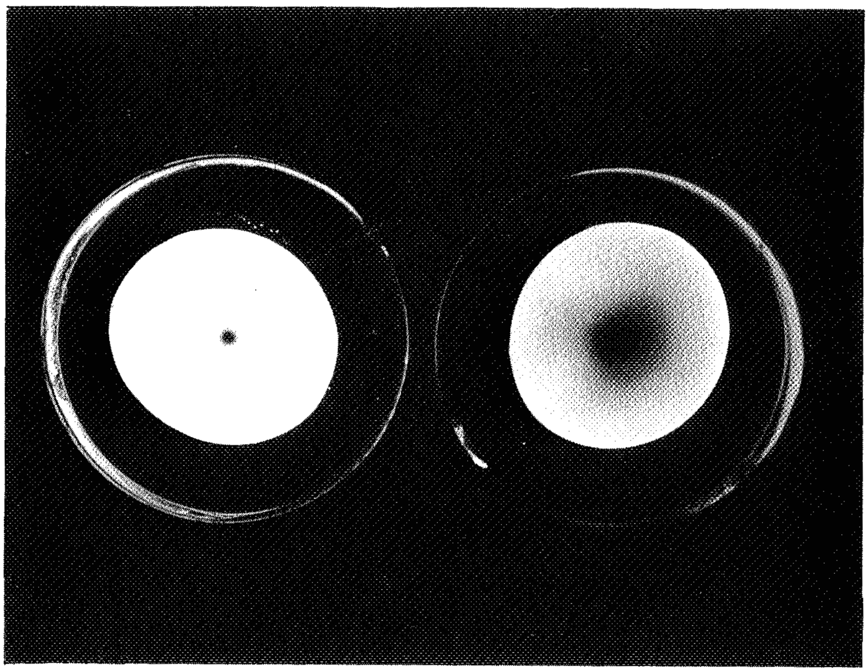

Figure 14.- Comparison of Two Fluorescent Penetrants by the Meniscus Test Method (Penetrant on the Left has Superior Thin Film Sensitivity)

is termed the threshold dimensional thickness* and represents the minimum film thickness at which consistent penetrant inspection results would be anticipated with proper application. The dimensional thickness and threshold thickness values are quantitative measures of relative thin-film brightness and are useful for comparison of materials. These values can be converted to actual film thicknesses by calculation from the known lens curvature for comparison of absolute values. Rankings of the nine evaluation penetrants by the meniscus test method are shown in Table 8.

The ceramic block test as described by Alberger† was used as an overall measure of comparative penetrant system sensitivity. In this test, an unglazed ceramic block of known porosity is used as a test object. Ceramic material was selected with a pore size distribution in the same dimensional range as the threshold thickness range previously measured. Two penetrant materials were compared by placing a small quantity of each material in adjacent halves of the block. After the recommended dwell time, excess material is removed. The adjacent spots of material are compared visually by examining the number and apparent brightness of pore indications. The penetrants evaluated are then ranked in the order of their overall performance. Figure 15 is a typical presentation obtained by the ceramic block test. Ranking of the nine evaluation penetrants by the ceramic block test is shown in Table 8.

A relative brightness/contrast ranking was made by modifying a technique described by Parker and Schmidt.§ The technique consists of diluting the penetrant materials to a known concentration with a suitable solvent (Freon TE-35 was used), immersing a Whatman No. 2 filter paper in the mixture, drying the mixture, and measuring the relative brightness or contrast by an instrumental technique. A digital densitometer was used for comparing the nine evaluation penetrants and a comparative brightness or contrast value was obtained in a millivolt output. These results are shown in Table 8.

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*Alberger, op cit.

†Development of a Ceramic Block Test. Uresco Bulletin No. 640110, Sec P-004.00, Uresco, Inc. (Division of Shannon Luminous Materials Co.), 12412 Benedict Avenue, Downey, California, 90242.

§Parker, D. W.; and Schmidt, J. T.: Brightness of Fluorescent Penetrants, Its Measurement and Influence in Detecting Defects. Nondestructive Testing, Vol XV, No. 6, p 330, 1957.

Table 8.- Penetrant Evaluation Results

Penetrant	Group	Manufacturer's stated sensitivity	Dimensional sensitivity*	Dimensional threshold*	Ceramic block overall performance†	Fluorescent relative brightness§	Visible relative contrast¶
Fluorescent A	VI Extra	Ultra	1.1 mm	1.7 mm	1	(1) 3.41	
Fluorescent B	IV	High	1.3	2.7	2	(6) 3.15	
Fluorescent C	VI & VII	High	2.0	4.2	4	(5) 3.20	
Fluorescent D	VI & VII	High	2.0	4.9	3	(3) 3.28	
Visible A	I & II	High	3.5	8.0	8		(1) 2.46
Visible B	II	High	3.8	9.0	7		(2) 3.06
Fluorescent E	V	High	4.1	10.0	6	(4) 3.21	
Fluorescent F	IV	High	4.2	9.0	5	(2) 3.29	
Visible C	I	High	7.5	10.0	9		(3) 3.48

*After Alberger

†After Uresco

§Lowest number in parentheses indicates brightest penetrant.

¶Lowest number in parentheses indicates most contrast.

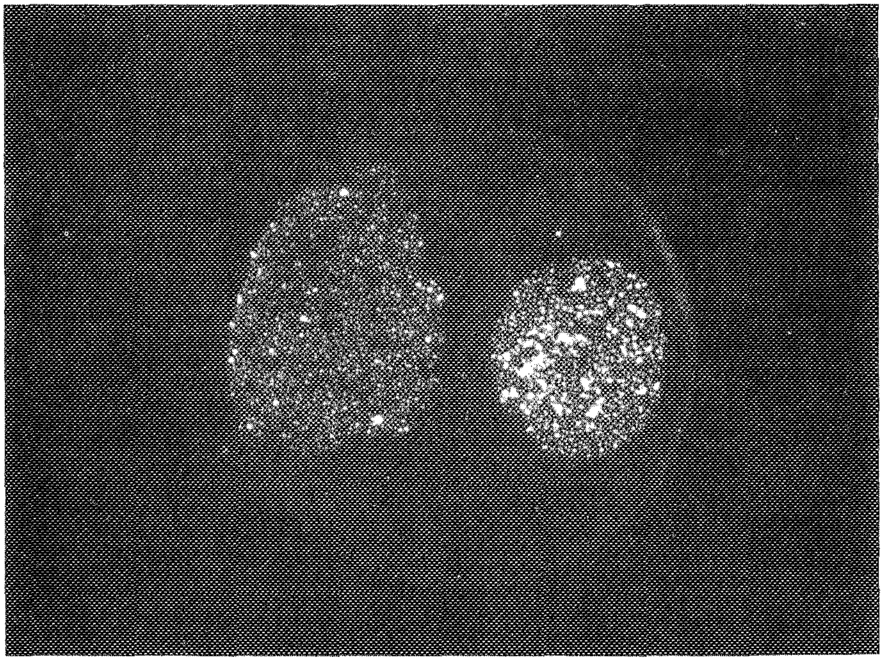


Figure 15.- Comparison of Two Fluorescent Penetrants by the Ceramic Block Test Method (Penetrant on the Left has Superior Brightness)

All penetrants were then compared by application to the 12 NDT reference specimens. The manufacturer's recommendations were used in each case for all process steps. The results of this evaluation are shown in Table 9.

Removal of penetrant materials between inspections was a major concern for both evaluation of the NDT reference panels and the subsequent test panels. Two steel blocks with lapped mating surfaces were bolted together at known torque values. Penetrant was applied to the faying surfaces and allowed to penetrate in excess of the recommended dwell time. Excess penetrant was removed and a candidate cleaning cycle applied. The test blocks were then demated and the lapped surfaces examined for traces of residual penetrant. An efficient candidate procedure was established by this technique. It was then validated by applying penetrant to two fatigue-cracked panels, cleaning one of the panels by the selected removal technique, and breaking both specimens open for comparison. Figure 16 illustrates the penetration obtained in a fatigue crack and a similar crack after processing to remove the penetrant material.

Selection of a penetrant technique.- The fluorescent A penetrant, i.e., Uresco P-151 penetrant system, was selected for evaluation of test panels based on overall analysis and comparison of materials. It is a high-sensitivity solvent-removable fluorescent penetrant system that could be applied in production. A procedure written for inspection of the NDT test specimens was used by all operators in performing penetrant inspection. Details of this procedure are shown in Appendix D.

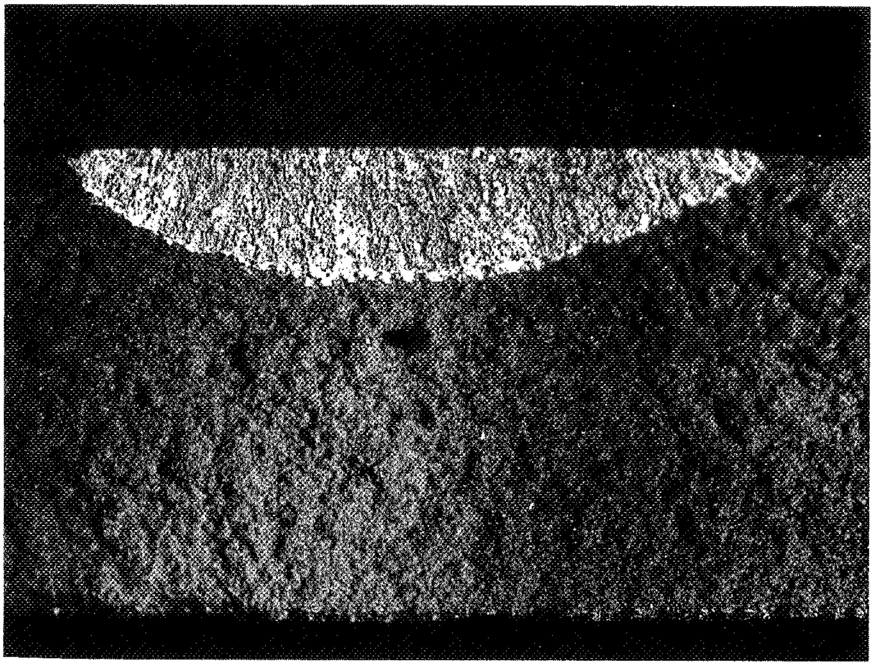
A penetrant removal procedure was selected based on the evaluation described. A written removal procedure was used during all subsequent test specimen evaluation. Details of this procedure are shown in Appendix E.

Table 9.- Evaluation of Reference Panels by Penetrants

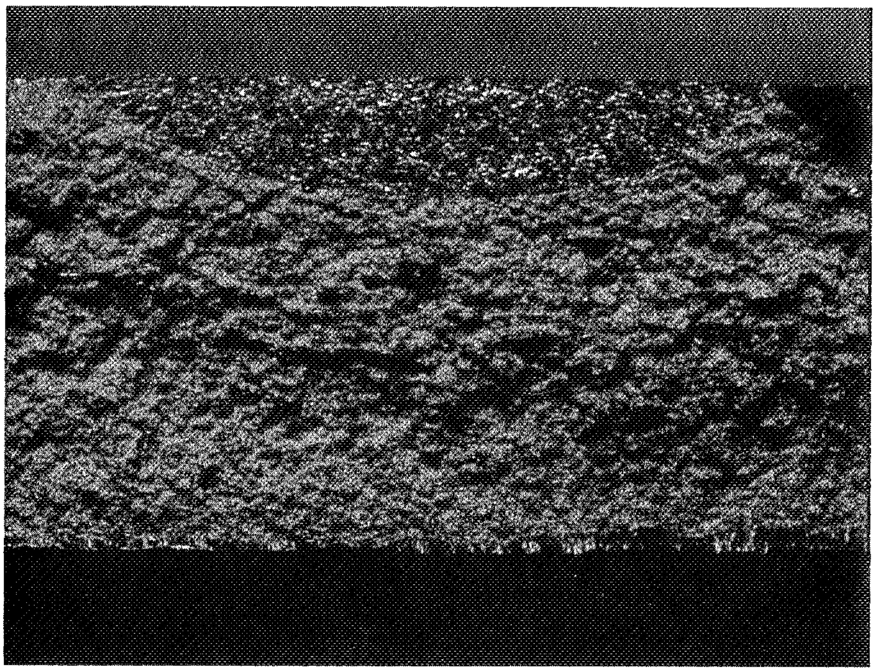
Panel no.	Crack no.	Fluorescent A	Fluorescent B	Fluorescent C	Fluorescent D	Visible A	Visible B	Fluorescent E	Fluorescent F	Visible C	Fluorescent A*
1S	1	X	X	X	X	X	X		X	X	X
	2	X		X	X		X			X	
	3	X		X	X						X
2S	1	X	X	X	X	X	X		X		X
	2	X	X	X	X	X	X	X	X		X
	3	X		X	X	X	X	X	X		
3S	1	X	X	X	X	X	X		X		X
	2	X	X	X	X	X	X	X	X		X
4S	1	X		X	X	X	X		X	X	X
5S	1	X	X	X	X	X	X		X		X
	2	X	X	X	X	X	X				X
6S	1	X		X			X				
	2										
	3	X									
1R	1	X	X	X	X	X	X				X
	2	X	X	X	X					X	X
	3										
	4	X		X	X	X	X		X	X	X
	5	X		X	X	X	X		X		X
	6	X		X	X	X	X		X	X	X
	7	X		X	X	X	X			X	X
2R	1	X	X	X	X	X	X	X	X	X	X
	2	X	X	X	X	X	X	X	X	X	X
	3	X	X	X	X	X	X	X	X	X	X
3R	1	X	X	X	X	X	X		X		X
	2	X	X	X	X	X	X		X	X	X
	3	X	X	X	X	X	X				X
4R	1	X	X	X	X						X
	2	X	X	X							X
	3	X	X	X	X						X
	4	X		X	X						X
5R	1	X	X	X	X	X	X		X		X
6R	1	X	X	X	X						X
		31	20	30	28	21	23	6	17	11	27

*Fluorescent A material without developer.

Note: X indicates detection.



(a) Depth of Penetration of Fluorescent Penetrant on a Fatigue Crack



(b) Fatigue Crack under Blacklight with Fluorescent Penetrant Removed

Figure 16.- Fatigue Crack Showing Removal of Fluorescent Penetrant Material

Holographic Interferometry

Discussion of the technique.- With the invention of the laser, holography became a practical tool for analysis of structures. Holographic NDT is considered to be potentially applicable to detection of cracks and was selected for comparative evaluation in this program. The basic principles of holography have been extensively discussed in detail in current literature* and need not be repeated here. Briefly all holographic techniques involve exposure of a hologram that is a recorded pattern of light intensity and phase information as obtained by diffraction of coherent light from a test object. By comparison of two different hologram exposures of a test object at two different states of deformation, interferometric analysis is possible. Holographic interferometry provides a visual pattern of motion of the surface of an object when subjected to a stress field. This pattern will be smooth and uniform across the object if it is free of discontinuities. The presence of a discontinuity, such as a crack, will distort the stress pattern thus giving an indication of the presence and location of the discontinuity.

A fundamental requirement for holographic NDT evaluation is the application of a stress field to the object. Such stress may be applied by vacuum, pressure, heat, vibration, creep, bending, etc.

Evaluation of a holographic NDT technique.- Parameters for comparative evaluation of the holographic NDT techniques' sensitivity to fatigue cracks include both the method of stressing and the holographic procedure. Selected for evaluation were vacuum, heat, vibration, bending, and tension loadings, and double-exposure, real-time, oblique viewing, and interference speckle techniques. Low stress requirements were anticipated for all evaluations because of the sensitivity of holographic techniques.

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*Erf, R. K.; Waters, J. P.; Gagosz, R. M.; Micheal, R.; and Whitney, G.: Nondestructive Holographic Techniques for Structures Inspection. AFML-TR-72-204, October 1972.

Heat, vibration, and bending and tension loading methods were evaluated by double-exposure and real-time holographic techniques in Martin Marietta laboratories. Vacuum and tension loading using oblique viewing and speckle techniques were evaluated in the G. C. Optronics Inc., laboratories. A low applied panel stress limitation was imposed in both laboratories.

Martin Marietta evaluations: Both double-exposure and real-time live-fringe techniques were evaluated using a heat gun as a source of thermal stress, using sonic and ultrasonic generators as vibration stress sources, loading the panels in tension over mandrels of varying diameters for bend stressing, and by low-level tension stress. Scattered success was achieved by these techniques. The sensitivity, as determined by analysis of NDT reference panels, was poor for all techniques. The most consistent results were obtained by the low-level stress load techniques.

The tension loading fixture was then modified to incorporate hydraulic loading in tension on the optical bench. Figure 17 shows this fixture in place in the optical path. Tension loads up to 5000 pounds were obtained with this setup. A schematic diagram of the optical path is shown in Figure 18. By imposing differential tensile stresses of approximately 5100 to 6850 psi in thin specimens and 5950 to 7100 psi in thick specimens, cracks were detected in all but Case 6 cracks in NDT reference specimens using real-time live-fringe techniques.

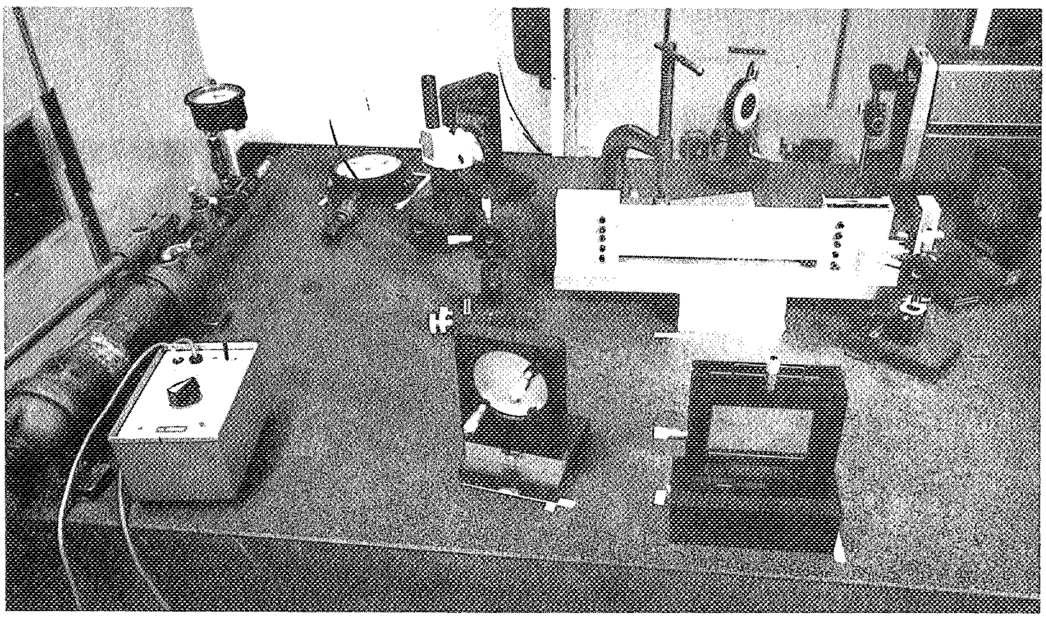

Figure 17.- Test Fixture Setup for Specimen Evaluation by the Holographic Interferometry Method

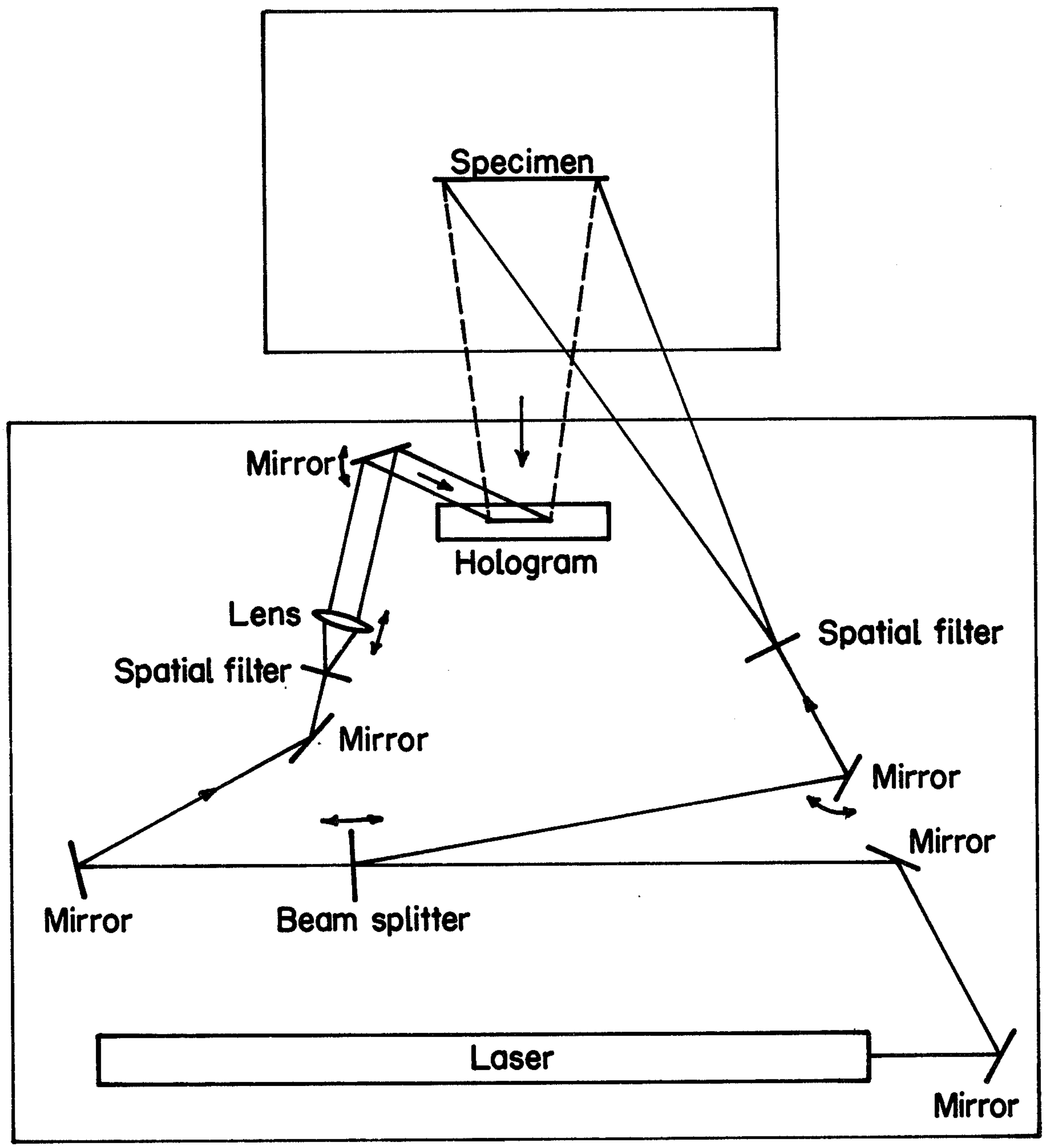

Figure 18.- Schematic Diagram of the Optical Path Used for Holographic Evaluation

The real-time live-fringe technique involves making a hologram of the specimen while holding the specimen under a constant stress load. The specimen is then viewed through the hologram at a second constant stress level. The incremental difference in stress is viewed as an interference fringe pattern corresponding to slight incremental movement of the part surface. If the specimen contains a flaw, the stress distribution at the surface and the resulting specimen movement are detected as a perturbation in the fringe pattern.

Figure 19 is a live-fringe holographic presentation of a 0.220-inch-thick specimen that contains three fatigue cracks. The sharp breaks in the fringes show the location of the cracks. The two outside cracks are nearside cracks as viewed, while the center crack is a farside crack. This illustrates the sensitivity of the technique to the volume of material rather than a surface phenomenon. Figure 20 is the same panel in which optical fringe control has been used to increase the number of fringes and thereby enable a better description of flaw size. If the fringes are too close because of the high incremental load, fringe control may be used to spread them out and thus continue analysis. Fringe control is judged to be a necessary and effective tool for efficient analysis.

Small fatigue cracks (Case 6) in the specimens were not visible by the conventional live-fringe evaluation technique at low stress. Because materials are assumed to be perfectly elastic in nature for evaluation by the live-fringe technique, equal results are expected at increasing or decreasing differential stress loads. In actual evaluation of specimens at decreasing differential loads, elastic behavior was not observed. Instead a residual stress pattern was observed around each included crack. The presentation obtained by the compressive stress (hysteresis) technique was easier to identify and interpret than that of the tension stress technique. Both techniques enabled detection of both nearside and farside cracks. Smaller Case 6 cracks were detected by the compressive stress method.

Figure 21 is a representative live-fringe hologram of a specimen as evaluated by the compressive stress technique. Crack presence and location are shown as a dark line in a bright fringe pattern or as a bright line in a dark fringe pattern. This phenomenon is believed to be due to compressive stresses concentrated around the crack on relaxation of the specimen.

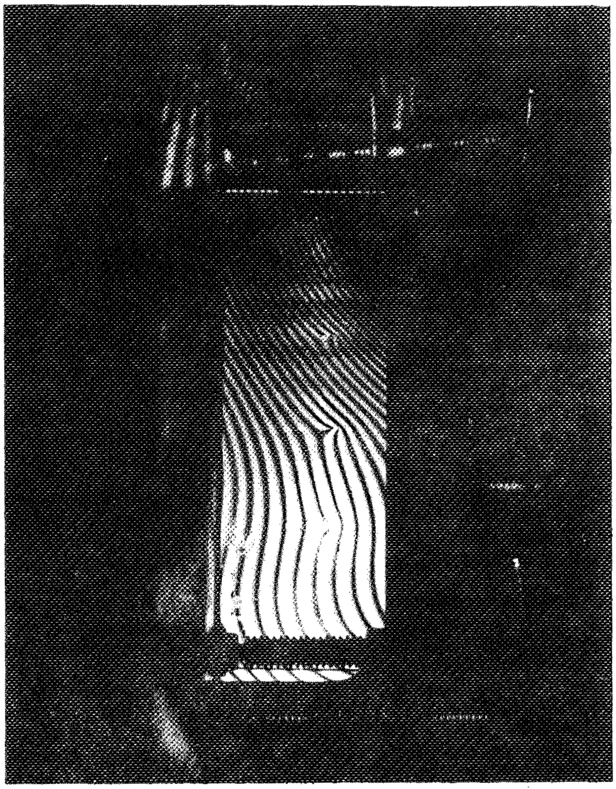

Figure 19.- Live-Fringe Holograph

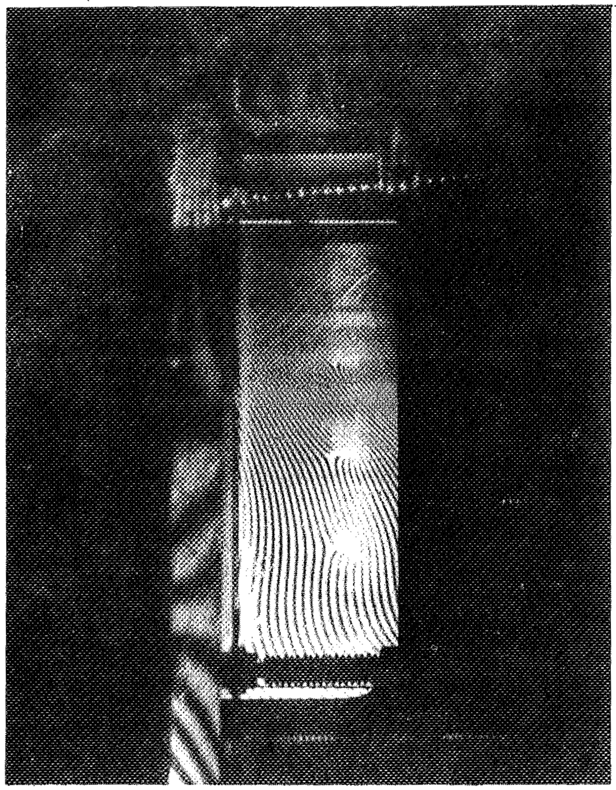

Figure 20.- Condensed-Fringe Holograph

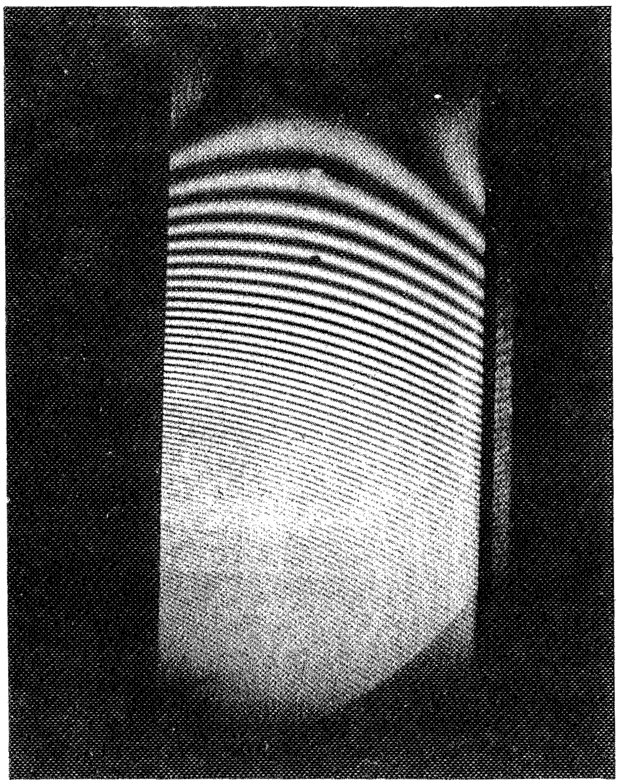

Figure 21.- Live-Fringe Holograph
Following Prestress

G.C. Optronics, Inc.: Vacuum stress techniques were evaluated because of their potential for selectively loading specimens. No results were obtained.

If the stress field is applied to a panel, maximum distortion in the holographic pattern should occur in the vicinity of a crack. Holography is most sensitive to motion along the line of sight, which would be normal to the object surface. Since the distortion we are concerned about is the plane of the object surface, only a secondary effect will be detected by holography. This condition can be improved by looking at the object obliquely so the in-plane motion has a significant component along the line of signt. Some sacrifice is exacted, however, in having an oblique view of the object. The oblique viewing technique was applied while loading test panels at low tension loads. No acceptable results were obtained at the low stresses.

The speckle technique for evaluation involves direct illumination of a test object with coherent light and viewing the scattered energy from the object. On a second observation, optical interference between two such speckle patterns can be used to give a highly sensitive method of measuring surface displacement.* NDT reference panels were evaluated by this technique at low stresses without success.

No evaluation of the oblique or speckle techniques was attempted at higher panel stressing loads.

Selection of a holographic NDT technique.- The real-time live-fringe technique using differential tensile loading was selected for subsequent evaluations. A test procedure was written for use in all subsequent evaluations. This procedure is included in Appendix F.

Acoustic Emission Monitor

Discussion of the technique.- Acoustic emission is an active evaluation technique that may be used to detect and locate growing flaws. Basically, the technique consists of the detection and analysis of the elastic energy released when incremental flaw

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*Waters, James P.: Object Motion Compensation by Speckle Reference Beam Holography. Applied Optics, Vol II, No. 3, March 1972, pp 630 - 636.

growth occurs. The energy is dissipated in the form of acoustical energy and may be detected, amplified, and analyzed by the same basic methods as used for ultrasonic inspection. The objective of evaluating NDT test specimens was to detect flaw growth during proof test and fracture load cycles and to locate the growing flaw in both cases.

Evaluation of acoustic emission techniques.- In previous work with aluminum alloy tensile specimens, basic monitoring techniques were established. The technique consists of bonding a selected transducer to the test specimen and amplifying and recording transducer output on magnetic tape during specimen loading. The tape is then played back at slow speeds to enable analysis and comparison of the data obtained. Although real-time monitor and analysis techniques are available, the recording technique was used for this program to maintain maximum retention of data. Data can also be filtered on playback to evaluate the spectral character of the emissions.

For location of growing flaws, triangulation techniques were used. This involved mounting three separate transducers on the specimen as shown in Figure 22 and recording data in three channels along with a timing signal. On playback, differences in time of arrival of an emission at a transducer can be measured and by dividing by the known sound velocity in the test specimen material, the source distance for an emission can be located. By multiple calculation for three adjacent transducers, the source can be located.

Shear wave propagation velocity in 2XXX series aluminum alloys is reported to be 1.16×10^{-5} inches/second. This was verified by mounting three transducers in line and equidistant along specimens of both thicknesses. Lead shot was dropped from a known height to produce a reproducible sound source. Twelve specimens containing known fatigue cracks were loaded to failure and the resultant emission monitored to select a transducer, mounting method, the instrumentation, and an analysis method. Crack growth was detected at 40% of proof load for the largest cracks and near yield for the smallest cracks.

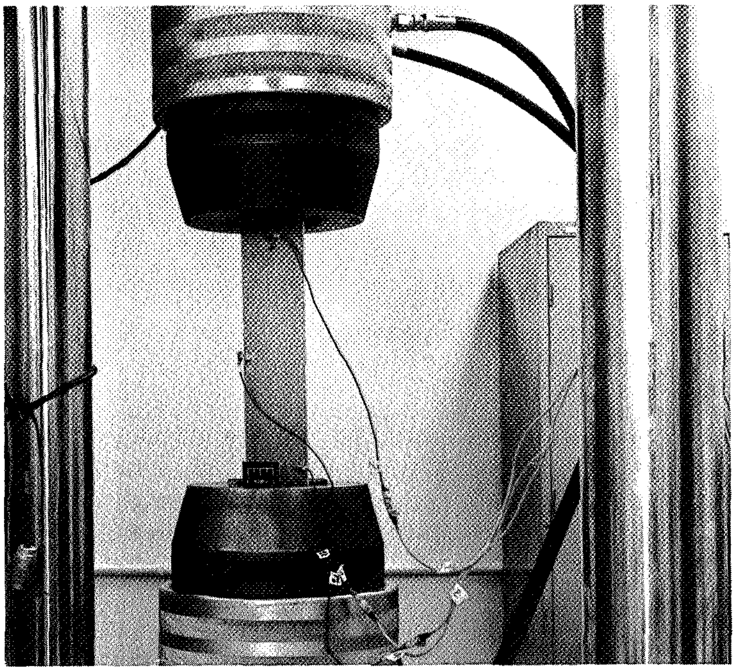

Figure 22.- Acoustic Emission Test Setup Showing Transducer Location

The following instrumentation was used to locate growing cracks within ±½ inch (1.26 cm) of their true location:

1) Endevco Model 2222B accelerometers as basic transducers;

2) Kistler Model 504A charge amplifiers;

3) Hewlett Packard Model 202C oscillator for timing;

4) Ampex Model FR-1300 14-channel tape recorder, 0 to 20,000 Hz;

5) Dana Model 2860 dc amplifiers;

6) Honeywell Model 1912 oscillograph.

Equivalent results were obtained by electronic counting techniques utilizing the same transducers and amplifiers.

Selection of an acoustic emission monitor technique.- The recording and hand plotting technique was selected for subsequent evaluations because a permanent recorder was obtained for use in potential further analysis. A test procedure written for use in all subsequennt evaluations is included in Appendix G.

TEST SPECIMEN EVALUATION

The NDT evaluation sequence was carried out by three independent operators using X-ray, ultrasonic, eddy, and penetrant techniques. Holography and acoustic emission were performed on selected specimens. After familiarization with the specific procedure to be used, the 118 test specimens were evaluated three times by different operators. Results were analyzed and recorded by each operator without knowledge of the total number of cracks present, identification with previous operations, or previous inspection results. Panel identification tags were changed between inspection sequences to further randomize inspection.

Each X-ray operator and ultrasonic operator made his own set of recordings and interpreted his own recordings. Each penetrant operator applied his penetrant, completed the inspection cycle, and interpreted his own results. Eddy current inspections were completed and results interpreted independently by each operator.

Sequence 1, Inspection of As-Machined Specimens

The Sequence 1 inspection included X-radiography, ultrasonic, eddy current, and penetrant methods. In the as-milled condition, few cracks were visible for detection by visual inspection. Inspections were carried out using the optimized methods established and documented in Appendices A thru E. Results of inspection for 328 total cracks predicted were as tabulated.

X-Radiography	
Detection by one operator*	51/328 = 15%
Detection by all three operators†	20/328 = 6%
Ultrasonic	
Detection by one operator	280/328 = 85%
Detection by all three operators	236/328 = 72%
Eddy Current	
Detection by one operator	259/328 = 79%
Detection by all three operators	154/328 = 47%
Penetrant	
Detection by one operator	262/328 = 80%
Detection by all three operators	143/328 = 44%

*Denotes cracks detected by at least one of the operators.

†Denotes cracks detected by all three of the operators.

Sequence 2, Inspection of Chemically Milled Specimens

At completion of the first inspection sequence, all specimens were cleaned, flash etched by chemical milling, and recleaned. The thickness and surface finish of each specimen were again measured and recorded. The chemical milling operation resulted in an average thickness decrease of 0.002 inch (0.005 cm) and a 35 to 100 rms finish on smooth panels and a 120 to 300 rms finish on rough panels. Many of the cracks were visible on close visual inspection after chemical milling. Identification tags on all panels were changed to randomize inspection results.

Inspections were again carried out using the optimized methods established. The chemical milling operation made both ultrasonic and eddy current inspections more difficult since some localized pitting of specimens occurred. Results of inspection of Martin Marietta panels for 328 total predicted cracks were as tabulated.

chem milled

X-Radiography	
Detection by one operator	197/328 = 60%
Detection by all three operators	113/328 = 35%
Ultrasonic	
Detection by one operator	302/328 = 92%
Detection by all three operators	220/328 = 67%
Eddy Current	
Detection by one operator	284/328 = 87%
Detection by all three operators	199/328 = 61%
Penetrant	
Detection by one operator	295/328 = 90%
Detection by all three operators	240/328 = 74%

At this point in the program, all panels were packaged and shipped to General Dynamics Corporation, San Diego. Forty eight panels were in turn received from General Dynamics for Martin Marietta inspection. These panels were received, their thickness and surface finish measured and documented, and submitted for inspection.

The basic X-ray and penetrant procedures were applied. Ultrasonic inspection was modified to use a 31-degree incident angle and a galvanometer-recorder system was adapted to replace the meter readout of the Nortec NDT-3 eddy current unit. This modification resulted in approximately a threefold increase in eddy current sensitivity and enabled recording of relative crack size by traversing each crack. Recordings for Case 1 through Case 6 cracks are shown in Figure 23. This recording technique proved difficult to repeat due to probe/crack alignment and the results must be regarded as relative values only. Modifications to the basic inspection procedures are shown in Appendices A through E.

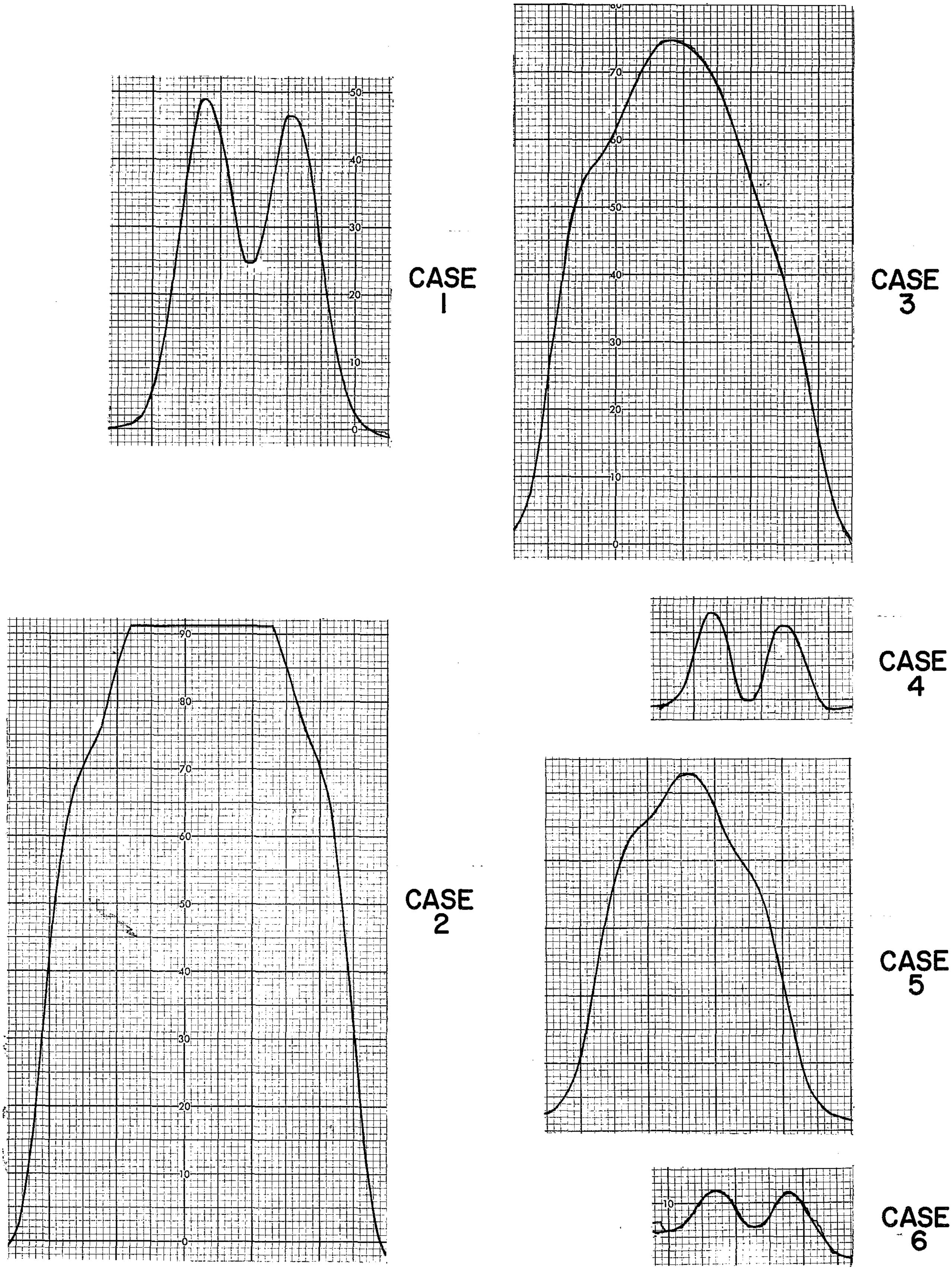

Figure 23.- Eddy Current Recordings of Case 1 thru 6 Cracks

The General Dynamics panels were inspected using the modified procedures. The results for the Series A 0.060-inch (0.152-cm) panels, with 56 total cracks predicted, are tabulated.

X-Radiography	
Detection by one operator	25/26 = 46%
Detection by all three operators	10/56 = 18%
Ultrasonic	
Detection by one operator	51/56 = 91%
Detection by all three operators	48/56 = 86%
Eddy Current	
Detection by one operator	52/56 = 93%
Detection by all three operators	38/56 = 68%
Penetrant	
Detection by one operator	53/56 = 95%
Detection by all three operators	39/56 = 70%

The Series B 0.210-inch panel results, with 60 total cracks predicted, are also tabulated.

X-Radiography	
Detection by one operator	36/60 = 60%
Detection by all three operators	21/60 = 35%
Ultrasonic	
Detection by one operator	60/60 = 100%
Detection by all three operators	57/60 = 95%
Eddy Current	
Detection by one operator	59/60 = 98%
Detection by all three operators	46/60 = 77%
Penetrant	
Detection by one operator	60/60 = 100%
Detection by all three operators	43/60 = 72%

On return of the Martin Marietta specimens, they were again packaged and shipped to Rockwell International, Downey, California, for a second independent evaluation. At their return, 48 panels were selected for holographic evaluation. One inspection was carried out in the Martin Marietta laboratories and a second inspection was completed by G.C. Optronics, Inc., Plymouth, Michigan. Both laboratories used the optimized procedure shown in Appendix F. A special procedure utilizing a stress relaxation technique developed at Martin Marietta was applied to panels that had not revealed cracks in the initial evaluation. The Martin Marietta data are a composite of both inspection methods. Details of the stress relaxation technique are shown in Appendix F.

Results of the inspections for 144 total predicted cracks are tabulated.

Martin Marietta	73/144 = 51%
Combined data using stress relaxation technique	84/114 = 59%
G. C. Optronics	53/144 = 37%

Sequence 3, Inspection of Specimens after Proof Loading

Following Sequence 2 inspection, all specimens were proof-loaded to 85% of yield strength based on nominal 0.060- and 0.210-inch thicknesses. Sixty six of the specimens were monitored by acoustic emission to detect and locate growing cracks. Emissions indicating subcritical crack growth were detected in 23 of the specimens. Emission was located at an actual flaw location for all but one specimen, which contained no actual cracks. Test results by specimen are shown in Table 10. Six specimens that failed during the proof load operation were not included in the Sequence 3 inspection.

All remaining specimens were again inspected by three operators using the established X-ray, ultrasonic, eddy current, and penetrant procedures. Results of inspections for 322 predicted cracks are tabulated.

Table 10.- Acoustic Emission Monitor during Specimen Proof Loading to 85% of Yield Stress

Panel Number	Load Initiating Crack Growth, lb (kg)	Load to Proof, lb (kg)	Number of Major Emissions	Propagating Flaws Identified	Panel Number	Load Initiating Crack Growth, lb (kg)	Load to Proof, lb (kg)	Number of Major Emissions	Propagating Flaws Identified
2	0	8,400	0		69	15,000	31,200	4	200
4	0	8,400	0		69	17,500	31,200		200
6	0	8,400	0		69	20,000	31,200		Can't plot
8	0	8,400	0		69	27,500	31,200		200
10	0	8,400	0		70	7,500	31,200	3	202
12	0	8,400	0		70	7,500	31,200		202
14	0	8,400	0		70	10,000	31,200		202
16	0	8,400	0		71	0	31,200	0	
18	0	8,400	0		72	0	31,200	0	
20	0	8,400	0		73	0	31,200	0	
22	0	8,400	0		74	0	31,200	0	
24	6,000	8,400	1	68	75	0	31,200	0	
25	6,500	8,400	1	69	76	0	31,200	0	
26	0	8,400	0		77	22,500	31,200	1	219
27	0	8,400	0		78	0	31,200	0	0
28	0	8,400	0		79	0	31,200	0	0
29	2,000	8,400	1	79	80	0	31,200	0	0
30	0	8,400	0		81	12,500	31,200	2	223
32	0	8,400	0		81	25,000	31,200		221
36	0	8,400	0		83	17,500	31,200	1	237
38	0	8,400	0		84	10,000	31,200	1	239
40	3,900	8,400	1	122	85	13,000	31,200	1	242
42	8,300	8,400	1	128	86	0	31,200	0	
44	2,200	8,400	6	131	88	0	31,200	0	
44	3,500	8,400		131	90	27,000	Failed	1	255
44	4,500	8,400		131			at		
44	4,500	8,400		131			27,000		
44	7,000	8,400		131	92	Not tested - cracks too large			
44	8,200	8,400		131	94				
46	6,000	8,400	3	No flaw	95	0	31,200	0	
46	6,000	8,400		No flaw	96	Not tested - cracks too large			
46	6,000	8,400		No flaw	98	0	31,200	0	
48	7,300	8,400	1	No flaw	100	25,500	31,200	2	277
50	4,700	8,400	2	147	100	25,500	31,200		277
50	6,300	8,400		144	102	0	31,200	0	
51	6,000	8,400	1	148	104	0	31,200	0	
52	4,600	8,400	3	150	106	0	31,200	0	
52	4,600	8,400		150	107	0	31,200	0	
52	5,700	8,400		150	109	0	31,200	0	
54	4,100	8,400	1	155	110	0	31,200	0	
55	5,000	8,400	4	158	111	0	31,200	0	
55	5,000	8,400		158	112	0	31,200	0	
55	5,000	8,400		158	114	0	31,200	0	
55	5,000	8,400		150	116	0	31,200	0	
					117	0	31,200	0	
					118	0	31,200	0	

Note: Strain rate = 0.05 in./in./minute (0.05 cm/cm/minute).

X-Radiography	
Detection by one operator	207/322 = 64.5%
Detection by all three operators	137/322 = 42.7%
Ultrasonic	
Detection by one operator	298/322 = 92.5%
Detection by all three operators	240/322 = 75%
Eddy Current	
Detection by one operator	287/322 = 89.5%
Detection by all three operators	241/322 = 75%
Penetrant	
Detection by one operator	293/322 = 91.0%
Detection by all three operators	254/322 = 78.5%

Following Sequence 3, all specimens were loaded to failure. Sixty five were monitored by acoustic emission to detect and locate growing flaws. Emissions indicative of subcritical crack growth were detected in 46 of the specimens. Test results by specimen are shown in Table 11.

DATA ANALYSIS

Data Tabluation

After loading to failure, all specimens were cross-sectioned through the cracks and actual crack length and depth measured with a traveling microscope. Actual crack data and all NDT inspection data were keypunched and input to a computer for ordering and data analysis. A tabulation of actual crack data is shown in Table 12. These actual crack data were used as a basis for all subsequent data sorting and analysis.

Table 11.- Acoustic Emission Monitor during Specimen Tension Loading to Failure

Panel Number	Load Initiating Crack Growth, lb (kg)	Failure Load, lb (kg)	Elongation, in. (cm)	Number of Major Emissions	Propagating Flaw
2	12,000	13,600	0.42	5	
4	10,600	10,600	0.07	1	10
6	11,000	12,300	0.26	3	18
8	11,000	12,850	0.22	4	24
10	11,800	12,180	1.05	3	33
12	10,800	12,000	0.86	4	40
14	11,000	11,700	0.70	4	47
16	10,000	10,000	0.32	2	52
18	12,200	14,300	0.50	3	No flaw
20	13,300	15,400	1.45	5	No flaw
22	11,800	13,600	0.28	4	60
24	10,800	11,300	0.19	2	No data
25	12,000	13,100	0.23	3	
26	11,500	12,100	0.18	3	71
27		13,300	0.32	5	No data
28	11,000	12,300	0.20	3	75
29	10,000	14,400	0.14	5	Broke next to grip
30	10,800	11,100	0.09	2	81
32	11,200	12,900	0.32	5	Broke next to grip
36	Not evaluated				
38	11,400	11,700	0.22	4	110
40	10,600	12,100	0.21	3	122
42	Broke during installation				No data
44	11,500	11,500	0.10	1	131
46	11,000	14,700	0.71	6	No flaw
48	12,700	13,600	0.37	6	No flaw
50	11,200	12,200	0.16	3	147
51	10,800	11,800	0.27	3	148
52	10,900	10,900	0.10	2	Broke next to grip
54	8,700	8,700	0.06	1	Broke next to grip
55	10,000	11,300	0.20	4	157
69	No value (Electronic Counter)	35,600	No value	1	No data
70	34,400	34,400	0.10	1	202
71	(Broke during installation				No data
72	38,500	38,500	0.11	1	206
73	41,500	42,500	0.21	2	208

Panel Number	Load Initiating Crack Growth, lb (kg)	Failure Load, lb (kg)	Elongation, in. (cm)	Number of Major Emissions	Propagating Flaw
74	35,500	43,000	0.26	2	209
75	41,000	42,100	0.35	5	212
76	38,500	42,900	0.25	2	216
77	Broke during installation				No data
78	40,000	49,500	1.07	4	No flaw
79	41,000	49,000	1.02	8	No flaw
80	35,500	48,500	0.97	6	No flaw
81	39,000	43,500	0.27	3	223
82	35,500	43,000	0.24	2	No data
83	No value (Electronic Counter)	42,900	No value	1	223
84	36,000	42,000	0.22	2	239
85	35,500	42,500	0.25	4	241
86	37,000	44,000	0.29	2	246
88	No value (Electronic Counter)	43,900	No value	1	No data
92	36,000	36,000	0.10	1	256
94	36,500	40,000	0.14	3	261
95	35,500	35,500	0.10	1	263
96	35,200	35,200	0.10	1	265
98	40,000	43,000	0.29	2	269
100	42,500	42,500	0.25	1	No data
102	39,000	40,000	0.13	1	No data
104	39,000	40,200	0.15	1	No data
106	33,900	33,900	0.10	1	296
107	41,000	42,000	0.22	2	298
109	47,300	48,000	0.93	2	No flaw
110	38,500	38,800	0.12	1	302
111	42,000	46,900	0.50	2	No flaw
112	48,200	48,200	0.89	1	No flaw
114	42,000	42,000	0.25	1	No data
116	40,000	41,500	0.20	1	324
117	41,000	43,000	0.22	1	326
118	42,000	43,800	0.26	1	No data

Table 12.- Actual Crack Data

PANEL NO.	CRACK NO.	CRACK LENGTH	CRACK DEPTH	INITIAL FINISH	INITIAL THICKNESS	FINAL FINISH	FINAL THICKNESS	CRACK POSITION X	CRACK POSITION Y	FAILURE LOAD	A/T INIT	A/T FINAL	A/2C	LINE
M1A	1	.242	.025	42	.0540	85	.0515	1.75	5.20	-0	.463	.485	.103	1
M1B	2	.279	.038	48	.0540	40	.0515	1.63	2.83	-0	.704	.738	.136	2
M1B	3	.269	.039	48	.0540	40	.0515	1.63	8.83	8825	.722	.757	.145	3
M2A	4	.056	.014	38	.0600	45	.0575	1.75	5.13	-0	.233	.243	.250	4
M2B	5	.062	.013	44	.0600	40	.0575	1.00	4.00	13600	.217	.226	.210	5
M2B	6	.051	.012	44	.0600	40	.0575	2.50	5.90	-0	.200	.209	.235	6
M3A	7	.060	.026	64	.0600	60	.0580	2.30	3.50	-0	.433	.448	.433	7
M3A	8	.082	.032	64	.0600	60	.0580	2.50	4.50	11675	.533	.552	.390	8
M3A	9	.067	.014	64	.0600	60	.0580	2.60	5.50	-0	.233	.241	.209	9
M4A	10	.253	.031	60	.0600	50	.0585	2.00	2.20	10600	.517	.530	.123	10
M4A	11	.248	.030	60	.0600	50	.0585	2.38	4.50	-0	.500	.513	.121	11
M4A	12	.257	.033	60	.0600	50	.0585	2.00	6.50	-0	.550	.564	.128	12
M5A	13	.082	.020	34	.0600	40	.0585	2.50	4.25	-0	.333	.342	.244	13
M5A	14	.079	.011	34	.0600	40	.0585	2.50	6.00	12300	.183	.188	.139	14
M5B	15	0.	0.	44	.0600	45	.0585	1.75	3.00	-0	0.	0.	0.	15
M5B	16	.058	.011	44	.0600	45	.0585	1.75	5.00	-0	.183	.188	.190	16
M5B	17	.074	.015	44	.0600	45	.0585	1.75	7.00	-0	.250	.256	.203	17
M6A	18	.069	.026	44	.0590	60	.0570	2.13	2.88	12300	.441	.456	.377	18
M6A	19	.040	.010	44	.0590	60	.0570	.88	7.13	-0	.169	.175	.250	19
M7B	20	.083	.029	44	.0590	45	.0600	.75	4.25	12075	.492	.483	.349	20
M7B	21	0.	0.	44	.0590	45	.0600	2.75	7.75	-0	0.	0.	0.	21
M8A	22	.007	.001	42	.0620	45	.0610	1.75	3.00	-0	.016	.016	.143	22
M8A	23	.072	.016	42	.0620	45	.0610	1.13	5.38	-0	.258	.262	.222	23
M8A	24	.091	.021	42	.0620	45	.0610	.88	6.13	12850	.339	.344	.231	24
M8A	25	.025	.003	42	.0620	45	.0610	.75	7.00	-0	.048	.049	.120	25
M8B	26	.035	.006	40	.0620	50	.0610	1.50	6.13	12850	.097	.098	.171	26
M8B	27	.021	.004	40	.0620	50	.0610	1.06	6.63	-0	.065	.066	.190	27
M9A	28	.247	.036	40	.0620	45	.0610	1.25	3.00	10925	.581	.590	.146	28
M9A	29	.258	.035	40	.0620	45	.0610	2.25	5.00	-0	.565	.574	.136	29
M9B	30	.247	.043	24	.0620	40	.0610	2.38	7.00	-0	.694	.705	.174	30
M10A	31	.030	.004	38	.0600	60	.0580	.88	3.75	-0	.067	.069	.133	31
M10A	32	.086	.017	38	.0600	60	.0580	1.13	6.13	-0	.283	.293	.198	32
M10B	33	.086	.019	36	.0600	55	.0580	.75	3.00	12180	.317	.328	.221	33
M10B	34	.079	.015	36	.0600	55	.0580	1.38	4.50	-0	.250	.259	.190	34
M10B	35	.070	.016	36	.0600	55	.0580	1.13	5.50	-0	.267	.276	.229	35
M10B	36	.083	.015	48	.0600	55	.0580	.75	7.00	-0	.250	.259	.181	36
M11A	37	.115	.028	48	.0610	40	.0588	1.00	5.00	-0	.459	.476	.243	37
M11A	38	.084	.020	48	.0610	40	.0588	2.38	6.00	-0	.328	.340	.238	38
M12A	39	.032	.009	40	.0610	40	.0590	2.38	3.50	-0	.148	.153	.281	39
M12A	40	.085	.033	40	.0610	40	.0590	1.25	4.00	12000	.541	.559	.388	40
M12A	41	.047	.015	40	.0610	40	.0590	1.00	5.50	-0	.246	.254	.319	41
M13A	42	.087	.018	42	.0610	50	.0590	2.50	3.50	11650	.295	.305	.207	42
M13A	43	.067	.027	42	.0610	50	.0590	1.25	4.00	-0	.443	.458	.403	43
M13A	44	.060	.026	42	.0610	50	.0590	1.00	5.50	-0	.426	.441	.433	44
M14A	45	.	0.	52	.0620	55	.0590	1.00	2.00	-0	.	0.	0.	45
M14A	46	.010	.004	52	.0620	55	.0590	1.00	7.00	-0	.065	.068	.400	46

Table 12.- Continued

M14B	47	.092	.025	40	.0620	55	.0590	1.00	4.75	11700	.403	.424	.272	47
M15A	48	.259	.035	34	.0580	45	.0580	1.75	3.00	-0	.603	.603	.135	48
M15A	49	.275	.034	34	.0580	45	.0580	1.13	7.00	-0	.586	.586	.124	49
M15B	50	.342	.041	38	.0580	50	.0580	2.13	5.00	9425	.707	.707	.120	50
M16A	51	.258	.033	34	.0590	40	.0570	1.25	5.00	-0	.559	.579	.128	51
M16B	52	.287	.038	30	.0590	55	.0570	2.38	3.00	10000	.644	.667	.132	52
M16B	53	.241	.032	30	.0590	55	.0570	1.75	7.00	-0	.542	.561	.133	53
M17A	54	.066	.024	30	.0600	50	.0568	1.50	3.00	12160	.400	.423	.364	54
M21A	55	.044	.007	40	.0660	40	.0622	1.88	3.00	-0	.106	.113	.159	55
M21A	56	.065	.013	40	.0660	40	.0622	1.88	4.38	14350	.197	.209	.200	56
M21A	57	.062	.011	40	.0660	40	.0622	1.88	5.88	-0	.167	.177	.177	57
M21A	58	0.	0.	40	.0660	40	.0622	1.88	7.00	-0	0.	0.	0.	58
M22A	59	0.	0.	42	.0630	45	.0613	2.88	3.00	-0	0.	0.	0.	59
M22A	60	.079	.018	42	.0630	45	.0613	1.88	4.00	13600	.286	.294	.228	60
M22A	61	.030	.010	42	.0630	45	.0613	.88	4.88	-0	.159	.163	.333	61
M22A	62	.015	.021	42	.0630	45	.0613	3.00	5.88	-0	.333	.343	1.400	62
M22A	63	.031	.002	42	.0630	45	.0613	1.00	7.00	-0	.032	.033	.065	63
M23A	64	.077	.014	30	.0640	35	.0618	2.75	3.00	13475	.219	.227	.182	64
M23A	65	0.	0.	30	.0640	35	.0618	1.00	4.38	-0	0.	0.	0.	65
M23A	66	0.	0.	30	.0640	35	.0618	2.00	5.63	-0	0.	0.	0.	66
M23A	67	0.	0.	30	.0640	35	.0618	2.63	7.13	-0	0.	0.	0.	67
M24A *	68	.083	.029	340	.0570	290	.0555	1.25	4.00	11300	.509	.523	.349	58
M25A *	69	.077	.014	40	.0620	35	.0593	2.38	4.13	13100	.226	.236	.182	69
M26A *	70	.048	.013	34	.0610	50	.0585	.88	7.13	-0	.213	.222	.271	70
M26B *	71	.083	.030	28	.0610	45	.0585	2.38	3.13	12100	.492	.513	.361	71
M27A *	72	.077	.015	40	.0620	40	.0608	2.88	3.13	13300	.242	.247	.195	72
M27A *	73	.017	.003	40	.0620	40	.0608	2.00	5.75	-0	.048	.049	.176	73
M27A *	74	.068	.012	40	.0620	40	.0608	1.50	7.13	-0	.194	.197	.176	74
M28A *	75	.079	.030	38	.0610	45	.0585	1.75	3.50	12300	.492	.513	.380	75
M28A *	76	.032	.008	38	.0610	45	.0585	1.75	7.50	-0	.131	.137	.250	76
M28B *	77	.059	.020	44	.0610	50	.0585	1.00	5.25	-0	.328	.342	.339	77
M29A	78	.011	.004	72	.0680	55	.0691	1.75	3.06	-0	.059	.058	.364	78
M29B	79	.095	.027	42	.0680	35	.0691	2.50	4.06	-0	.397	.391	.284	79
M29B	80	.055	.010	42	.0680	35	.0691	1.00	2.06	-0	.147	.145	.182	80
M30A	81	.252	.036	160	.0620	120	.0587	1.75	5.00	11100	.581	.613	.143	81
M31A	82	.256	.035	180	.0580	160	.0567	2.00	2.50	9925	.603	.617	.137	82
M31A	83	.260	.033	180	.0580	160	.0567	2.38	4.50	-0	.569	.582	.127	83
M31A	84	.258	.035	180	.0580	160	.0567	2.00	6.50	-0	.603	.617	.136	84
M32A	85	.045	.008	180	.0610	160	.0598	1.25	2.75	-0	.131	.134	.178	85
M32A	86	.061	.011	180	.0610	160	.0598	1.25	5.75	-0	.180	.184	.180	86
M32A	87	.077	.011	180	.0610	160	.0598	1.00	6.38	-0	.180	.184	.143	87
M33A	88	.025	.003	170	.0620	140	.0604	1.19	3.00	-0	.048	.050	.120	88
M33A	89	.026	.017	170	.0620	140	.0604	1.00	5.00	12650	.274	.281	.654	89
M33A	90	.033	.017	170	.0620	140	.0604	.75	7.00	-0	.274	.281	.515	90
M33B	91	.052	.011	190	.0620	140	.0604	1.50	4.00	-0	.177	.182	.212	91
M33B	92	.058	.011	190	.0620	140	.0604	1.00	6.00	-0	.177	.182	.190	92
M34A	93	.249	.032	190	.0610	150	.0602	2.13	3.00	10550	.525	.532	.129	93
M34A	94	.249	.033	190	.0610	150	.0602	.88	7.00	-0	.541	.548	.133	94
M35A	95	.066	.026	150	.0600	140	.0640	.75	3.00	-0	.433	.406	.394	95
M35A	96	.045	.007	150	.0600	140	.0640	1.50	5.75	-0	.117	.109	.156	96

Table 12.- Continued

M35A	97	.041	.006	150	.0600	140	.0640	2.00	7.00	-0	.100	.094	.146	97
M35B	98	.102	.026	170	.0600	145	.0640	2.00	3.38	12450	.433	.406	.255	98
M35B	99	.061	.010	170	.0600	145	.0640	1.63	4.44	-0	.167	.156	.164	99
M35B	100	.067	.015	170	.0600	145	.0640	.94	6.50	-0	.250	.234	.224	100
M36A	101	.070	.014	190	.0620	150	.0605	2.50	3.75	-0	.226	.231	.200	101
M36A	102	.058	.013	190	.0620	150	.0605	2.19	4.50	-0	.210	.215	.224	102
M36A	103	.050	.008	190	.0620	150	.0605	1.50	5.50	-0	.129	.132	.160	103
M36A	104	.052	.010	190	.0620	150	.0605	1.00	6.50	-0	.161	.165	.192	104
M36B	105	.075	.020	180	.0620	130	.0605	2.56	3.69	-0	.323	.331	.267	105
M36B	106	.090	.022	180	.0620	130	.0605	.94	6.00	12000	.355	.364	.244	106
M37A	107	.257	.035	170	.0620	150	.0602	1.25	3.00	10250	.565	.581	.136	107
M37A	108	.261	.037	170	.0620	150	.0602	1.25	7.00	-0	.597	.615	.142	108
M37B	109	.261	.033	180	.0620	140	.0602	1.31	5.00	-0	.532	.548	.126	109
M38A	110	.082	.031	190	.0610	150	.0592	2.81	3.00	11700	.508	.524	.378	110
M38A	111	.060	.021	190	.0610	150	.0592	2.50	5.00	-0	.344	.355	.350	111
M38A	112	.049	.017	190	.0610	150	.0592	2.00	7.00	-0	.279	.287	.347	112
M38B	113	.062	.024	180	.0610	150	.0592	1.94	4.00	-0	.393	.405	.387	113
M38B	114	.078	.028	180	.0610	150	.0592	2.63	5.69	-0	.459	.473	.359	114
M39A	115	.047	.017	160	.0620	150	.0594	1.94	7.13	-0	.274	.286	.362	115
M39A	116	.108	.033	160	.0620	150	.0594	2.38	4.63	11650	.532	.556	.306	116
M39A	117	.067	.025	160	.0620	150	.0594	2.63	3.38	-0	.403	.421	.373	117
M39B	118	.062	.021	170	.0620	160	.0594	2.69	5.44	-0	.339	.354	.339	118
M39B	119	.036	.014	170	.0620	160	.0594	2.13	4.00	-0	.226	.236	.389	119
M40A	120	.058	.020	150	.0610	80	.0590	1.00	3.63	-0	.328	.339	.345	120
M40A	121	.070	.027	150	.0610	80	.0590	2.50	5.13	-0	.443	.458	.386	121
M40A	122	.080	.030	150	.0610	80	.0590	2.00	6.63	12100	.492	.508	.375	122
M40A	123	.062	.024	150	.0610	80	.0590	1.00	7.63	-0	.393	.407	.387	123
M41A	124	.045	.018	210	.0610	160	.0594	.75	4.66	-0	.295	.303	.400	124
M41A	125	.026	.020	210	.0610	160	.0594	2.44	4.38	-0	.328	.337	.769	125
M41A	126	.085	.033	210	.0610	160	.0594	1.00	5.75	11700	.541	.556	.388	126
M41A	127	.079	.031	210	.0610	160	.0594	2.75	6.00	11700	.508	.522	.392	127
M42A	128	.268	.035	250	.0630	220	.0608	1.75	4.25	-0	.556	.576	.131	128
M43A	129	.279	.037	240	.0630	200	.0609	1.50	2.81	9950	.587	.608	.133	129
M43A	130	.262	.037	240	.0630	200	.0609	2.00	6.81	-0	.587	.608	.141	130
M44A	131	.073	.017	200	.0630	140	.0609	1.00	5.69	-0	.270	.279	.233	131
M44A	132	0.	0.	200	.0630	140	.0609	2.44	6.06	-0	0.	0.	0.	132
M45A	133	0.	0.	180	.0650	140	.0630	1.00	3.13	-0	0.	0.	0.	133
M45A	134	0.	0.	180	.0650	140	.0630	2.50	7.13	-0	0.	0.	0.	134
M45B	135	.096	.021	180	.0650	140	.0630	1.38	3.63	13000	.323	.333	.219	135
M49A	136	0.	0.	260	.0630	180	.0608	2.13	3.00	-0	0.	0.	0.	136
M49A	137	.086	.020	260	.0630	180	.0608	.88	4.25	12650	.317	.329	.233	137
M49A	138	.035	.005	260	.0630	180	.0608	2.50	4.63	-0	.079	.082	.143	138
M49A	139	.049	.006	260	.0630	180	.0608	1.50	5.50	-0	.095	.099	.122	139
M49A	140	.041	.007	260	.0630	180	.0608	2.50	6.00	-0	.111	.115	.171	140
M49A	141	.090	.017	260	.0630	180	.0608	1.00	7.00	-0	.270	.280	.189	141

Table 12.- Continued

M50B	142	.091	.022	240	.0630	170	.0609	1.75	3.00	-0	.349	.361	.242	142
M50B	143	.067	.013	240	.0630	170	.0609	2.63	3.88	-0	.206	.213	.194	143
M50B	144	.068	.013	240	.0630	170	.0609	1.00	4.50	-0	.206	.213	.191	144
M50B	145	.063	.013	240	.0630	170	.0609	2.38	5.25	-0	.206	.213	.206	145
M50B	146	.065	.011	240	.0630	170	.0609	.75	5.88	-0	.175	.181	.169	146
M50B	147	.097	.025	240	.0630	170	.0609	1.63	7.00	12200	.397	.411	.258	147
M51A	148	.069	.015	240	.0630	240	.0608	.88	4.00	11800	.238	.247	.217	148
M51A	149	.021	.004	240	.0630	240	.0608	2.38	5.25	-0	.063	.066	.190	149
M52B *	150	.086	.031	320	.0600	290	.0583	1.56	5.38	-0	.517	.532	.360	150
M53A *	151	.020	.005	400	.0630	300	.0608	1.50	5.59	-0	.079	.082	.250	151
M53A *	152	.101	.037	400	.0630	300	.0608	.75	7.13	-0	.587	.609	.366	152
M53B *	153	.063	.021	360	.0630	300	.0608	.88	4.25	-0	.333	.345	.333	153
M54A *	154	.018	.003	340	.0630	260	.0603	1.88	3.06	-0	.048	.050	.167	154
M54A *	155	.015	.003	340	.0630	260	.0603	2.25	5.38	-0	.048	.050	.200	155
M54A *	156	.080	.021	340	.0630	260	.0603	1.50	7.06	-0	.333	.348	.262	156
M55A *	157	.076	.025	420	.0600	300	.0536	2.38	3.06	11300	.417	.466	.329	157
M55A *	158	.041	.011	420	.0600	300	.0536	.88	7.06	-0	.183	.205	.268	158
M55B *	159	.069	.022	400	.0600	300	.0536	2.56	3.88	-0	.367	.410	.319	159
M56A *	160	.495	.097	50	.2080	35	.2060	.88	3.13	33850	.466	.471	.196	160
M56A *	161	.518	.096	50	.2080	35	.2060	1.63	7.13	-0	.462	.466	.185	161
M57A	162	.290	.031	46	.2090	40	.2070	.75	3.00	-0	.148	.150	.107	162
M57A	163	.336	.059	46	.2090	40	.2070	1.75	7.00	39050	.282	.285	.176	163
M57B	164	.408	.058	60	.2090	40	.2070	1.75	5.00	-0	.278	.280	.142	164
M58A	165	.326	.105	30	.2090	50	.2070	2.25	3.00	-0	.502	.507	.322	165
M58A	166	.568	.117	30	.2090	50	.2070	2.25	5.00	35000	.560	.565	.206	166
M58B	167	.523	.114	30	.2090	50	.2070	2.25	7.00	-0	.545	.551	.218	167
M59A	168	.330	.053	33	.2100	35	.2080	2.25	2.94	-0	.252	.255	.161	168
M59A	169	.362	.050	33	.2100	35	.2080	2.50	4.94	39600	.238	.240	.138	169
M59A	170	.323	.044	33	.2100	35	.2080	2.00	6.94	-0	.210	.212	.136	170
M60A	171	.046	.014	40	.2110	45	.2090	2.19	3.94	-0	.066	.067	.304	171
M60A	172	.080	.025	40	.2110	45	.2090	2.50	5.56	-0	.118	.120	.313	172
M60A	173	.071	.023	40	.2110	45	.2090	2.25	6.56	-0	.109	.110	.324	173
M60B	174	.060	.061	50	.2110	40	.2090	2.06	4.31	41625	.289	.292	1.017	174
M60B	175	.035	.007	50	.2110	40	.2090	2.25	5.31	-0	.033	.033	.200	175
M61A	176	.326	.048	48	.2090	40	.2080	2.25	3.13	39900	.230	.231	.147	176
M61A	177	.331	.044	48	.2090	40	.2080	2.50	5.13	-0	.211	.212	.133	177
M61A	178	.310	.034	48	.2090	40	.2080	2.00	7.13	-0	.163	.163	.110	178
M62B	179	.496	.178	34	.2100	45	.2080	2.44	2.94	31850	.848	.856	.359	179
M62B	180	.129	.049	34	.2100	45	.2080	1.13	3.69	-0	.233	.236	.380	180
M62B	181	.103	.036	34	.2100	45	.2080	1.56	4.44	-0	.171	.173	.350	181
M62B	182	.158	.057	34	.2100	45	.2080	1.94	5.44	-0	.271	.274	.361	182
M62B	183	.054	.015	34	.2100	45	.2080	1.19	6.19	-0	.071	.072	.278	183
M62B	184	0.	0.	34	.2100	45	.2080	.94	6.31	-0	0.	0.	0.	184
M63A	185	.345	.057	42	.2110	40	.2090	1.75	2.81	39400	.270	.273	.165	185
M63A	186	.318	.052	42	.2110	40	.2090	1.25	6.88	-0	.246	.249	.164	186
M63B	187	.313	.054	36	.2110	50	.2090	1.19	4.81	-0	.256	.258	.173	187
M64B	188	.321	.053	42	.2110	55	.2100	2.19	3.13	-0	.251	.252	.165	188
M64B	189	.317	.051	42	.2110	55	.2100	.94	7.13	40000	.242	.243	.161	189
M65A	190	.519	.110	36	.2100	50	.2090	1.13	6.94	-0	.524	.526	.212	190
M65A	191	.535	.114	36	.2100	50	.2090	1.13	2.94	-0	.543	.545	.213	191

Table 12.- Continued

M65B	192	.475	.108	42	.2100	60	.2090	1.13	4.94	-0	.514	.517	.227	192
M66A	193	.484	.111	38	.2130	50	.2110	.88	5.06	-0	.521	.526	.229	193
M67B	194	0.	0.	52	.2140	45	.2110	1.69	5.13	-0	0.	0.	0.	194
M68A	195	.182	.071	38	.2080	45	.2060	2.81	3.31	40800	.341	.345	.390	195
M68A	196	.045	.011	38	.2080	45	.2060	2.25	4.19	-0	.053	.053	.244	196
M68A	197	0.	0.	38	.2080	45	.2060	2.25	6.88	-0	0.	0.	0.	197
M68B	198	0.	0.	42	.2080	35	.2060	2.38	5.63	-0	0.	0.	0.	198
M68B	199	.020	.005	42	.2080	35	.2060	2.56	6.38	-0	.024	.024	.250	199
M69B	200	.539	.115	30	.2130	40	.2100	1.25	5.06	35600	.540	.548	.213	200
M70A	201	.250	.036	46	.2090	40	.2070	1.19	3.13	-0	.172	.174	.144	201
M70A	202	.494	.106	46	.2090	40	.2070	1.75	7.13	34400	.507	.512	.215	202
M71A	203	.381	.076	20	.2130	30	.2120	2.00	3.00	-0	.357	.358	.199	203
M71A	204	.333	.063	20	.2130	30	.2120	1.31	5.00	-0	.296	.297	.189	204
M71A	205	.340	.063	20	.2130	30	.2120	1.75	7.00	-0	.296	.297	.185	205
M72A	206	.283	.109	50	.2120	55	.2110	1.00	5.63	38500	.514	.517	.385	206
M73A	207	.125	.040	90	.2120	60	.2090	2.75	4.94	-0	.189	.191	.320	207
M73A	208	.153	.054	90	.2120	60	.2090	.81	6.25	42500	.255	.258	.353	208
M74A	209	.129	.051	42	.2080	35	.2060	2.00	3.06	43000	.245	.248	.395	209
M74A	210	.124	.046	42	.2080	35	.2060	1.88	5.75	-0	.221	.223	.371	210
M74A	211	.117	.042	42	.2080	35	.2060	1.81	7.06	-0	.202	.204	.359	211
M75A	212	.119	.040	42	.1970	50	.1960	1.00	5.00	42100	.203	.204	.336	212
M76A	213	.075	.026	50	.2100	40	.2080	.81	3.38	-0	.124	.125	.347	213
M76A	214	.100	.035	50	.2100	40	.2080	2.38	5.31	-0	.167	.168	.350	214
M76A	215	.088	.033	50	.2100	40	.2080	1.38	6.13	-0	.157	.159	.375	215
M76A	216	.135	.050	50	.2100	40	.2080	2.81	6.63	42900	.238	.240	.370	216
M77A	217	.459	.107	50	.2080	50	.2060	2.13	3.06	-0	.514	.519	.233	217
M77A	218	.508	.110	50	.2080	50	.2060	2.31	7.06	-0	.529	.534	.217	218
M77B	219	.489	.107	34	.2080	45	.2060	1.75	5.06	-0	.514	.519	.219	219
M81A	220	.030	.008	28	.2110	45	.2090	1.13	3.38	-0	.038	.038	.267	220
M81A	221	.061	.019	28	.2110	45	.2090	2.81	4.13	-0	.090	.091	.311	221
M81A	222	.064	.023	28	.2110	45	.2090	.88	4.81	-0	.109	.110	.359	222
M81A	223	.122	.046	28	.2110	45	.2095	1.31	5.81	43500	.218	.220	.377	223
M81A	224	.084	.027	28	.2110	45	.2090	2.75	6.69	-0	.128	.129	.321	224
M81A	225	.038	.011	28	.2110	45	.2090	1.50	7.38	-0	.052	.053	.289	225
M82A	226	.028	.007	30	.2120	45	.2100	2.38	2.94	-0	.033	.033	.250	226
M82A	227	.049	.016	30	.2120	45	.2100	1.25	3.69	-0	.075	.076	.327	227
M82A	228	.069	.021	30	.2120	45	.2100	.06	4.56	-0	.099	.100	.304	228
M82A	229	.105	.041	30	.2120	45	.2100	.06	5.44	-0	.193	.195	.390	229
M82A	230	.136	.049	30	.2120	45	.2100	2.50	6.06	43000	.231	.233	.360	230
M82A	231	.080	.028	30	.2120	45	.2100	1.94	6.94	-0	.132	.133	.350	231
M83A	232	.066	.020	30	.2110	50	.2090	2.25	3.13	-0	.095	.096	.303	232
M83A	233	.131	.049	30	.2110	50	.2090	2.25	4.13	42900	.232	.234	.374	233
M83A	234	.096	.036	30	.2110	50	.2090	.75	4.63	-0	.171	.172	.375	234
M83A	235	.115	.042	30	.2110	50	.2090	2.25	5.25	-0	.199	.201	.365	235
M83A	236	.064	.021	30	.2110	50	.2090	2.25	6.31	-0	.100	.100	.328	236
M83A	237	.071	.025	30	.2110	50	.2090	2.31	7.13	-0	.118	.120	.352	237
M84A *	238	.146	.054	36	.2110	45	.2090	1.13	7.06	-0	.256	.258	.370	238
M84B *	239	.153	.064	32	.2110	45	.2090	1.06	3.88	42000	.303	.306	.418	239
M85A *	240	.087	.022	32	.2080	45	.2060	.94	3.06	-0	.106	.107	.253	240
M85A *	241	.134	.049	32	.2080	45	.2060	2.50	7.06	42500	.236	.238	.366	241

Table 12. - Continued

M85B *	242	.106	.038	52	.2080	40	.2060	1.75	5.25	-0	.183	.184	.358	242
M86A *	243	.108	.041	32	.2080	35	.2060	1.31	3.06	-0	.197	.199	.380	243
M86A *	244	.095	.032	32	.2080	35	.2060	1.50	4.31	-0	.154	.155	.337	244
M86A *	245	.097	.028	32	.2080	35	.2060	.81	5.38	-0	.135	.136	.289	245
M86A *	246	.138	.050	32	.2080	35	.2060	2.00	7.06	44000	.240	.243	.362	246
M87A	247	.559	.115	180	.2110	160	.2090	1.00	3.00	-0	.545	.550	.206	247
M87A	248	.710	.126	180	.2110	160	.2090	1.00	7.00	-0	.597	.603	.177	248
M88A	249	.148	.060	150	.2090	140	.2080	1.75	5.13	43900	.287	.288	.405	249
M88B	250	.017	.008	160	.2090	130	.2080	2.44	4.13	-0	.038	.038	.471	250
M88B	251	.073	.026	160	.2090	130	.2080	.94	6.13	-0	.124	.125	.356	251
M89A	252	.329	.053	170	.2110	150	.1970	2.31	5.13	39450	.251	.269	.161	252
M89A	253	.310	.049	170	.2110	150	.1970	2.50	7.50	-0	.232	.249	.158	253
M90A	254	.979	.149	200	.2120	260	.2100	1.75	7.06	27000	.703	.710	.152	254
M90B	255	.513	.109	300	.2120	280	.2100	2.19	5.06	-0	.514	.519	.212	255
M92A	256	.543	.116	170	.2100	140	.2090	1.38	3.06	36000	.552	.555	.214	256
M92A	257	.495	.108	170	.2100	140	.2090	1.88	7.06	-0	.514	.517	.218	257
M92B	258	.466	.109	180	.2100	140	.2090	1.19	5.06	-0	.519	.522	.234	258
M93A	259	.508	.113	150	.2100	140	.2090	1.75	5.06	-0	.538	.541	.222	259
M94A	260	.312	.025	180	.2010	160	.2090	1.00	3.00	-0	.124	.120	.080	260
M94A	261	.331	.043	180	.2010	160	.2090	1.00	7.00	40000	.214	.206	.130	261
M94B	262	.306	.040	160	.2010	150	.2090	.69	5.00	-0	.199	.191	.131	262
M95B	263	.500	.103	160	.2080	145	.2050	2.56	5.13	35500	.495	.502	.206	263
M96A	264	.304	.036	170	.2110	140	.2100	2.50	3.13	-0	.171	.171	.118	264
M96A	265	.503	.109	170	.2110	140	.2100	1.75	5.13	35200	.517	.519	.217	265
M97A	266	.295	.047	160	.2100	160	.2090	2.31	5.00	39990	.224	.225	.159	266
M97B	267	.301	.034	170	.2100	150	.2090	2.19	3.00	-0	.162	.163	.113	267
M97B	268	.298	.037	170	.2100	150	.2090	1.69	7.00	-0	.176	.177	.124	268
M98A	269	.134	.048	170	.2100	150	.2090	1.69	3.75	43000	.229	.230	.358	269
M98A	270	.070	.023	170	.2100	150	.2090	2.00	5.13	-0	.110	.110	.329	270
M98A	271	.095	.036	170	.2100	150	.2090	.63	5.13	-0	.171	.172	.379	271
M98A	272	.073	.024	170	.2100	150	.2090	1.75	7.13	-0	.114	.115	.329	272
M99A	273	.535	.116	160	.2100	145	.2080	1.63	3.38	-0	.552	.558	.217	273
M99A	274	.610	.126	160	.2100	145	.2080	2.25	7.38	32450	.600	.606	.207	274
M99B	275	.492	.107	160	.2100	150	.2080	1.88	5.38	-0	.510	.514	.217	275
M100A	276	.076	.033	160	.2100	160	.2080	1.00	2.00	-0	.157	.159	.434	276
M100A	277	.151	.059	160	.2100	160	.2080	1.00	5.00	42500	.281	.284	.391	277
M100A	278	.063	.024	160	.2100	160	.2080	1.00	7.00	-0	.114	.115	.381	278
M100B	279	0.	0.	140	.2100	160	.2080	1.00	4.00	-0	0.	0.	0.	279
M100B	280	.066	.018	140	.2100	160	.2080	1.00	6.00	-0	.086	.087	.273	280
M101A	281	.098	.035	120	.2110	140	.2100	1.63	3.25	-0	.166	.167	.357	281
M101A	282	.076	.026	120	.2110	140	.2100	2.50	4.44	-0	.123	.124	.342	282
M101A	283	.153	.060	120	.2110	140	.2100	1.63	5.56	-0	.284	.286	.392	283
M101A	284	.162	.063	120	.2110	140	.2100	1.63	6.56	42625	.299	.300	.389	284
M102A	285	.098	.031	190	.2110	145	.2090	2.63	3.75	-0	.147	.148	.316	285
M102A	286	.075	.027	190	.2110	145	.2090	1.00	4.63	-0	.128	.129	.360	286
M102A	287	.185	.074	190	.2110	145	.2090	.63	6.75	-0	.351	.354	.400	287
M103A	288	.338	.060	220	.2100	190	.2080	2.25	2.69	38750	.286	.288	.178	288
M103A	289	.322	.044	220	.2100	190	.2080	1.38	4.69	-0	.210	.212	.137	289
M103A	290	.328	.051	220	.2100	190	.2080	1.00	6.69	-0	.243	.245	.155	290
M104A	291	.171	.067	130	.2110	100	.2090	.94	6.94	40200	.318	.321	.392	291

Table 12.- Continued

M104A	292	.092	.032	130	.2110	100	.2090	2.44	7.44	-0	.152	.153	.348	292
M105A	293	.313	.044	190	.2090	180	.2070	.94	3.00	-0	.211	.213	.141	293
M105A	294	.347	.059	190	.2090	180	.2070	2.38	5.00	-0	.282	.285	.170	294
M105A	295	.393	.077	190	.2090	180	.2070	.88	7.00	37800	.368	.372	.196	295
M106A	296	.521	.112	200	.2090	175	.2070	2.63	2.94	33900	.536	.541	.215	296
M106A	297	.520	.109	200	.2090	175	.2070	1.69	5.00	-0	.522	.527	.210	297
M107A	298	.126	.057	150	.2110	145	.2100	1.75	4.81	42000	.270	.271	.452	298
M108A	299	.514	.111	340	.2120	280	.2100	.94	3.00	-0	.524	.529	.216	299
M108A	300	.499	.114	340	.2120	280	.2100	1.00	5.00	-0	.538	.543	.228	300
M108A	301	.509	.119	340	.2120	280	.2100	2.25	7.00	33225	.561	.567	.234	301
M110A	302	.342	.062	300	.2110	250	.2080	.94	7.06	38800	.294	.298	.181	302
M113A	303	.040	.010	240	.2100	205	.2080	2.63	3.00	-0	.048	.048	.250	303
M113A	304	.041	.011	240	.2100	205	.2080	.88	3.63	-0	.052	.053	.268	304
M113A	305	.055	.017	240	.2100	205	.2080	2.50	4.06	-0	.081	.082	.309	305
M113A	306	.076	.034	240	.2100	205	.2080	1.88	4.88	-0	.162	.163	.447	306
M113A	307	.097	.032	240	.2100	205	.2080	.88	6.13	-0	.152	.154	.330	307
M113A	308	.131	.045	240	.2100	205	.2080	.88	6.94	42950	.214	.216	.344	308
M114A	309	.057	.013	220	.2090	180	.2070	.63	2.63	-0	.062	.063	.228	309
M114A	310	.042	.014	220	.2090	180	.2070	2.69	3.00	-0	.067	.068	.333	310
M114A	311	.072	.022	220	.2090	180	.2070	.63	4.31	-0	.105	.106	.306	311
M114A	312	.117	.041	220	.2090	180	.2070	1.88	5.13	-0	.196	.198	.350	312
M114A	313	.069	.025	220	.2090	180	.2070	2.75	6.13	-0	.120	.121	.362	313
M114A	314	.124	.044	220	.2090	180	.2070	.63	6.63	42000	.211	.213	.355	314
M115A	315	.064	.023	420	.2110	300	.2100	1.13	3.00	-0	.109	.110	.359	315
M115A	316	.140	.052	420	.2110	300	.2100	2.63	4.00	42325	.246	.248	.371	316
M115A	317	.094	.032	420	.2110	300	.2100	1.00	4.50	-0	.152	.152	.340	317
M115A	318	.103	.035	420	.2110	300	.2100	2.50	5.13	-0	.166	.167	.340	318
M115A	319	.106	.035	420	.2110	300	.2100	1.00	6.00	-0	.166	.167	.330	319
M115A	320	.055	.016	420	.2110	300	.2100	1.50	7.00	-0	.076	.076	.291	320
M116A *	321	.078	.028	280	.2110	200	.2080	1.00	3.06	-0	.133	.135	.359	321
M116A *	322	.119	.040	280	.2110	200	.2080	.94	7.06	-0	.190	.192	.336	322
M116B *	323	.129	.058	280	.2110	220	.2080	.94	4.25	-0	.275	.279	.450	323
M116B *	324	.183	.068	280	.2110	220	.2080	1.19	6.00	41500	.322	.327	.372	324
M117A *	325	.141	.057	440	.2130	300	.2110	1.25	3.69	-0	.268	.270	.404	325
M117A *	326	.136	.053	440	.2130	300	.2110	2.25	6.19	43000	.249	.251	.390	326
M118A *	327	.132	.050	340	.2110	300	.2090	1.69	3.88	43800	.237	.239	.379	327
M118A *	328	.105	.037	340	.2110	300	.2090	.75	6.44	-0	.175	.177	.352	328

*DENOTES PANELS IN WHICH CRACKS WERE GROWN AT HIGH STRESS.

Nondestructive test observations.- Crack size or relative magnitude was measured for each of the NDT methods. In each inspection crack detection was emphasized.

Crack size or magnitude was measured or estimated to the nearest 1/16 inch (0.16 cm) and recorded. For X-radiographic and penetrant inspections, crack length was measured. Crack length and crack depth measurements were made for ultrasonic inspection. Relative magnitudes were measured for eddy current inspection and were weighted as tabulated.

Observation	Factor
Full-scale deflection	1.000
Greater than 65μA deflection	0.750
40μA to 65μA deflection	0.650
10μA to 40μA deflection	0.400
10μA or less deflection	0.100
No indication	0.000

Tabulation of nondestructive test observations by panel number and by crack number are shown in Table 13 for inspection Sequence 1 (Set 1 data), in Table 14 for inspection Sequence 2 (Set 2 data), and in Table 15 for inspection Sequence 3 (Set 3 data).

Actual crack data for the General Dynamics panels are shown in Table 16. The corresponding (Martin Marietta) nondestructive test observations for General Dynamics panels are shown in Table 17. Holographic test observations are shown in Table 18. The weighted values recorded for holographic evaluation were obtained by counting the number of fringes affected by the crack, dividing by the number of fringes per inch observed, and multiplying by the fringe shift observed. The values were then recorded as values from 0.010 to 0.900. Cracks not detected were indicated by a 0.000 entry.

Table 13. - Tabulation of Nondestructive Test Observations, Sequence 1 (Set 1)

PANEL NUMBER	CRACK NUMBER	X-Radiography			Penetrant			Ultrasonic by Length			Ultrasonic by Depth			Eddy Current		
		NO. 1	NO. 2	NO. 3	NO. 1	NO. 2	NO. 3	NO. 1	NO. 2	NO. 3	NO. 1	NO. 2	NO. 3	NO. 1	NO. 2	NO. 3
M1	1	0.	0.	0.	.250	.250	.250	.250	.250	.250	.125	.125	.063	.750	.750	.750
M1	2	0.	0.	0.	.250	.250	.250	.125	.063	.250	.125	.063	.125	.750	0.	.750
M1	3	0.	0.	0.	.250	.250	.250	.250	.313	.250	.125	.250	.250	.750	.400	.750
M2	4	0.	0.	0.	.031	.063	.094	.125	.063	.063	.125	.063	.063	0.	.650	.400
M2	5	0.	0.	0.	.063	.094	.063	.063	.063	0.	.063	.063	0.	0.	.650	.400
M2	6	0.	0.	0.	0.	.063	0.	.125	.063	.063	.125	.063	.063	0.	.100	.100
M3	7	0.	0.	0.	.063	0.	.063	.125	.094	.063	.125	.094	.063	.650	.750	0.
M3	8	0.	0.	0.	.063	.094	.063	.125	.125	.063	.125	.094	.063	.650	.650	.750
M3	9	0.	0.	0.	.063	.063	.063	.063	0.	.063	.063	0.	.063	0.	.650	0.
M4	10	0.	0.	0.	.375	.250	.250	.250	.250	.125	.125	.188	.063	.400	.750	0.
M4	11	0.	0.	0.	.375	.250	.250	.250	.250	.125	.125	.188	.063	.650	.750	0.
M4	12	0.	0.	0.	.375	.250	.250	.250	.250	.125	.125	.188	.063	.650	.750	0.
M5	13	0.	0.	0.	.063	.094	.125	.125	.094	.063	.125	.094	.063	.400	0.	0.
M5	14	0.	0.	0.	.063	.094	.125	.125	.094	.063	.125	.094	.063	.400	.650	0.
M5	15	0.	0.	0.	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	0.	0.
M5	16	0.	0.	0.	.063	0.	.063	0.	0.	0.	0.	0.	0.	0.	.400	.400
M5	17	0.	0.	0.	0.	0.	.063	0.	.094	0.	0.	.094	0.	.400	0.	.400
M6	18	0.	0.	0.	.063	.031	.063	0.	.063	.063	0.	.063	.063	.100	.650	.750
M6	19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.100	0.	0.
M7	20	0.	0.	0.	.063	.094	.094	.125	.031	.063	.125	.031	.188	.750	.650	.650
M7	21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M8	22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M8	23	0.	0.	0.	.125	.063	.063	.063	0.	0.	.063	0.	0.	0.	.400	.750
M8	24	0.	0.	0.	0.	.094	.063	.063	0.	0.	.063	0.	0.	0.	.650	0.
M8	25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M8	26	0.	0.	0.	0.	0.	.063	0.	0.	0.	0.	0.	0.	0.	0.	0.
M8	27	0.	0.	0.	0.	0.	.063	0.	0.	0.	0.	0.	0.	0.	0.	0.
M9	28	0.	0.	0.	.375	.250	.250	.250	.313	.250	.125	.188	.188	.650	.650	.750
M9	29	0.	0.	0.	.375	.250	.250	.250	.313	.250	.125	.188	.188	0.	.750	.750
M9	30	0.	0.	0.	.125	.250	.250	.250	.250	.125	.125	.188	.188	0.	.400	.750
M10	31	0.	0.	0.	.063	0.	.031	0.	0.	0.	0.	0.	0.	0.	0.	0.
M10	32	0.	0.	0.	.063	.063	.125	.063	.094	.063	.063	.063	.063	.650	.750	0.
M10	33	0.	0.	0.	.063	.094	.125	.063	.094	0.	.063	.094	0.	0.	0.	.400
M10	34	0.	0.	0.	.063	.063	.125	.063	.063	0.	.063	.063	0.	0.	.650	.400
M10	35	0.	0.	0.	0.	.063	.125	.063	0.	0.	.063	0.	0.	0.	0.	.100
M10	36	0.	0.	0.	.063	.063	.125	.063	0.	0.	.063	0.	0.	0.	.650	.400
M11	37	0.	0.	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	0.	0.	0.
M11	38	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M12	39	0.	0.	0.	0.	0.	.063	0.	0.	0.	0.	0.	0.	0.	0.	0.
M12	40	0.	0.	0.	.063	.094	.125	.063	.063	.063	.063	.031	.063	.650	.750	.750
M12	41	0.	0.	0.	.063	.031	.125	0.	.094	.063	0.	.094	.063	.400	0.	0.
M13	42	0.	0.	0.	.063	.063	.094	.063	.031	.063	.063	.031	.125	.750	.400	.750
M13	43	0.	0.	0.	.063	.063	.063	.063	.031	.063	.063	.031	.063	.750	.400	.750
M13	44	0.	.188	0.	.063	.031	.063	.063	.031	0.	.063	.031	0.	.400	0.	.650
M14	45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M14	46	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.400	0.

Table 13.- Continued

M14	47	0.	0.	0.	.125	0.	.125	.125	.313	.125	.125	.156	.125	.650	.750	.750
M15	48	0.	0.	0.	.375	0.	.250	.250	.188	.031	.125	.156	.031	.750	.650	.750
M15	49	0.	0.	0.	.375	0.	0.	.125	.313	.031	.125	.156	.031	.650	.400	.750
M15	50	0.	0.	0.	.375	0.	.375	.250	.375	.375	.125	.188	.375	.650	.100	.750
M16	51	.100	0.	.150	.063	.281	.250	.250	.250	.250	.125	.125	.375	.750	.750	.750
M16	52	0.	0.	0.	.250	.313	.250	.125	.313	.250	.125	.156	.375	.650	.750	.750
M16	53	0.	0.	0.	.250	.250	.250	0.	.250	.250	0.	.156	.375	.650	.650	.750
M17	54	0.	0.	0.	.063	.063	.094	.125	.125	.063	.125	.125	.125	.400	.750	.650
M21	55	0.	0.	0.	.063	.047	.063	0.	0.	0.	0.	0.	0.	0.	0.	0.
M21	56	.075	0.	0.	.063	.063	.063	.063	.063	.125	.063	.063	.125	0.	.400	.400
M21	57	0.	0.	0.	.063	.063	.063	.063	.063	.063	.063	.063	.063	0.	.400	.400
M21	58	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M22	59	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M22	60	0.	0.	.250	.031	.063	.094	.125	.094	.063	.125	.094	.063	.650	.650	.400
M22	61	0.	0.	0.	0.	.016	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M22	62	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M22	63	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M23	64	0.	0.	0.	.063	.094	.094	.125	.094	.063	.125	.094	.063	.650	0.	0.
M23	65	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M23	66	0.	0.	.100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M23	67	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M24	68	0.	0.	0.	.063	.063	.094	.125	.094	.063	.125	.094	.063	.100	.400	.650
M25	69	0.	0.	0.	.063	.063	.094	.063	.063	0.	.063	.063	0.	.100	.650	0.
M26	70	0.	0.	0.	.063	0.	.063	.125	0.	.125	.125	0.	.125	0.	.400	0.
M26	71	0.	0.	0.	.063	.094	.094	.125	.094	.125	.125	.094	.125	.100	.650	.750
M27	72	0.	0.	0.	.063	.063	.094	.125	.063	.125	.125	.063	.125	.650	.400	.650
M27	73	0.	0.	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	.400	0.	0.
M27	74	0.	0.	0.	0.	.094	.094	.125	.094	.125	.125	.094	.125	.400	0.	0.
M28	75	0.	0.	0.	0.	0.	.094	.125	.094	.125	.125	.094	.125	0.	.100	.750
M28	76	0.	0.	0.	.031	0.	.063	0.	0.	0.	0.	0.	0.	.400	0.	0.
M28	77	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	0.	.063	.650	.400	.100
M29	78	0.	0.	0.	.125	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M29	79	0.	0.	0.	.063	0.	.125	.063	0.	.063	.063	0.	.063	0.	0.	0.
M29	80	0.	0.	0.	0.	0.	.063	.125	0.	0.	.125	0.	0.	0.	.400	0.
M30	81	0.	0.	0.	.250	.250	.250	.250	.250	.250	.125	.156	.125	.750	.750	.650
M31	82	.185	0.	0.	.250	.250	.250	.250	.313	.250	.125	.156	.125	.750	.650	.650
M31	83	0.	0.	0.	.313	.250	.250	.250	.313	.250	.125	.156	.125	.400	.650	.650
M31	84	0.	0.	0.	.250	.250	.250	.250	.313	.250	.125	.156	.125	.650	.650	.650
M32	85	0.	0.	0.	0.	0.	.125	0.	0.	.063	0.	0.	.063	0.	0.	0.
M32	86	0.	0.	0.	0.	0.	.125	.063	.094	.125	.063	.094	.125	0.	0.	0.
M32	87	0.	0.	0.	0.	.063	.125	.063	.094	.125	.063	.094	.125	0.	0.	0.
M33	88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M33	89	0.	0.	0.	.063	.063	.125	.125	.031	.125	.125	.031	.125	.400	.650	0.
M33	90	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M33	91	0.	0.	0.	0.	0.	.063	.063	.031	.063	.063	.031	.063	.100	0.	0.
M33	92	0.	0.	0.	0.	0.	.063	.063	.063	.125	.063	.063	.125	0.	0.	0.
M34	93	0.	0.	0.	.250	.250	.250	.250	.250	.250	.125	.094	.125	.650	.650	.650
M34	94	0.	0.	0.	.250	.188	.250	.250	.250	.250	.125	.094	.125	.650	.650	.650
M35	95	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M35	96	0.	0.	0.	0.	0.	.031	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table 13.- Continued

M35	97	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M35	98	0.	0.	0.	.063	.125	.125	.125	.125	.125	.063	.125	.125	.650	.750	0.
M35	99	0.	0.	0.	.063	0.	0.	.063	.063	.063	.063	.063	.063	.400	.400	0.
M35	100	0.	0.	0.	0.	0.	.063	.063	.094	.125	.063	.094	.125	0.	0.	0.
M36	101	0.	0.	0.	0.	.063	.063	.063	.063	.125	.063	.063	.125	0.	.400	0.
M36	102	0.	0.	0.	0.	0.	.063	.063	.031	0.	.063	.031	0.	0.	0.	0.
M36	103	0.	0.	0.	0.	0.	0.	0.	.031	0.	0.	.031	0.	0.	0.	0.
M36	104	0.	0.	0.	0.	0.	.063	.063	.031	.125	.063	.031	.125	0.	0.	0.
M36	105	0.	0.	0.	0.	.031	.063	.063	.094	.188	.063	.094	.188	0.	.100	0.
M36	106	0.	0.	0.	.063	0.	.063	.125	.094	.188	.125	.094	.125	.750	.650	.650
M37	107	0.	0.	0.	.250	.250	.250	.250	.250	.250	.125	.125	.125	.650	.650	.650
M37	108	0.	0.	0.	.250	.250	.250	.250	.250	.250	.125	.125	.125	.750	.650	.650
M37	109	0.	0.	0.	.313	.250	.250	.250	.250	.250	.125	.156	.188	.750	.650	.650
M38	110	0.	0.	0.	.063	.094	.125	.125	.094	.188	.125	.094	.125	.750	.650	.750
M38	111	0.	0.	0.	.063	.063	.063	.125	.094	.188	.125	.094	.125	0.	.400	.650
M38	112	0.	0.	0.	0.	.031	.063	.063	.063	.125	.063	.063	.125	.400	.100	.400
M38	113	0.	0.	0.	.063	.031	.063	.125	.094	.188	.125	.094	.188	.650	.100	.400
M38	114	0.	0.	0.	.063	.063	.063	.125	.125	.188	.125	.125	.188	.650	.650	.400
M39	115	0.	0.	0.	0.	0.	.063	.125	.094	.125	.125	.094	.125	0.	0.	0.
M39	116	0.	0.	0.	.063	.063	.031	.125	.094	.125	.125	.094	.125	.750	.650	0.
M39	117	0.	0.	0.	.063	0.	.031	.125	.063	.125	.125	.094	.125	.650	.650	0.
M39	118	0.	0.	0.	.063	0.	.063	.063	.063	.063	.063	.063	.063	.650	.650	.400
M39	119	0.	0.	0.	0.	0.	.063	.063	.063	.125	.125	.063	.125	0.	0.	0.
M40	120	0.	0.	0.	0.	0.	.063	.125	.063	.125	.125	.063	.125	.750	.400	0.
M40	121	0.	0.	0.	.063	.063	.125	.125	.094	.125	.125	.094	.125	.650	.750	.750
M40	122	0.	0.	0.	.063	.063	.063	.125	.094	.188	.125	.094	.188	.650	.750	.650
M40	123	0.	0.	0.	0.	0.	0.	.125	.094	.188	.125	.094	.188	.100	.400	0.
M41	124	0.	0.	0.	0.	0.	.063	.125	.094	.125	.125	.094	.125	.100	0.	0.
M41	125	0.	0.	0.	0.	0.	.063	.125	.094	.125	.125	.094	.125	0.	.100	.400
M41	126	0.	0.	0.	.063	.063	.125	.125	.125	.188	.125	.125	.188	.750	.650	.400
M41	127	0.	0.	0.	.063	.063	.125	.125	.125	.188	.125	.125	.188	0.	.650	0.
M42	128	0.	0.	0.	.250	.250	.250	.250	.250	.250	.125	.125	.125	.750	.750	.750
M43	129	0.	0.	0.	.313	.250	.250	.250	.313	.250	.125	.156	.125	.100	.650	.750
M43	130	0.	0.	0.	.250	.250	.250	.250	.250	.250	.125	.188	.125	.100	.650	.750
M44	131	0.	0.	0.	0.	.063	.125	.063	.063	.063	.063	.063	.063	0.	.400	0.
M44	132	0.	0.	0.	0.	0.	.063	.063	.031	.125	.063	.031	.125	0.	0.	0.
M45	133	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M45	134	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M45	135	0.	0.	0.	.063	0.	.125	0.	.125	.125	0.	.125	.125	0.	.650	.650
M49	136	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M49	137	.500	0.	0.	.125	.094	.125	.125	.125	.125	.125	.094	.125	.650	.650	.400
M49	138	0.	0.	0.	0.	0.	.063	.063	.031	.063	.063	.031	.063	0.	.100	0.
M49	139	0.	0.	0.	0.	0.	.063	.063	.031	0.	.063	.031	0.	0.	0.	0.
M49	140	0.	0.	0.	0.	0.	.063	.063	.063	.063	.063	.063	.063	0.	0.	0.
M49	141	0.	0.	0.	.125	0.	.125	.125	.125	.188	.125	.125	.188	.100	0.	.400

Table 13.- Continued

M50	142	0.	0.	0.	0.	.125	.125	.125	.125	.125	.125	.094	.125	.750	.650	.100
M50	143	0.	0.	0.	0.	0.	.063	.125	.063	.063	.125	.063	.063	0.	.400	0.
M50	144	0.	0.	0.	0.	.063	.063	.125	.063	.125	.125	.063	.125	0.	0.	0.
M50	145	0.	0.	0.	0.	0.	.063	.125	.063	.063	.125	.063	.063	.100	0.	.100
M50	146	0.	0.	0.	0.	0.	.063	.125	.094	.125	.125	.094	.125	0.	0.	0.
M50	147	0.	0.	0.	0.	.125	.125	.125	.125	.188	.125	.125	.188	.650	.650	0.
M51	148	0.	0.	0.	.063	.063	.063	.063	.063	.063	.063	.063	.063	0.	0.	0.
M51	149	0.	0.	0.	0.	0.	.031	0.	0.	0.	0.	0.	0.	0.	0.	.650
M52	150	0.	0.	0.	.063	.063	.125	.125	.125	.188	.125	.125	.188	.650	.650	.650
M53	151	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M53	152	.270	0.	0.	.125	.063	.125	.125	.125	.188	.125	.125	.188	.750	0.	.650
M53	153	0.	0.	0.	.063	.063	.125	.125	.094	.188	.125	.094	.125	.100	.650	.750
M54	154	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M54	155	.430	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M54	156	0.	0.	0.	.125	.125	.125	.125	.094	.063	.125	.094	.063	.400	.400	.650
M55	157	0.	0.	0.	.063	0.	.063	0.	.094	.188	0.	.094	.188	.650	.400	0.
M55	158	0.	0.	0.	0.	0.	.031	0.	0.	0.	0.	0.	0.	.100	0.	0.
M55	159	0.	0.	0.	.063	.063	.125	.125	.094	.188	.125	.094	.188	0.	0.	0.
M56	160	.409	0.	.500	.500	.500	.500	.500	.500	.500	.156	.125	.125	.750	.750	.750
M56	161	0.	0.	0.	.500	.500	.500	.500	.500	.500	.125	.125	.125	.750	.750	.750
M57	162	0.	0.	0.	.313	.375	.250	.313	.375	.375	.156	.125	.125	.750	.750	.750
M57	163	0.	0.	0.	.313	.313	.250	.438	.375	.375	.125	.125	.125	.750	.750	.750
M57	164	0.	0.	0.	.313	.375	.313	.313	.375	.375	.156	.125	.125	0.	.750	.650
M58	165	0.	.438	0.	.500	.500	.500	.500	.500	.500	.188	.125	.125	.750	.750	.750
M58	166	0.	.375	0.	.500	.625	.625	.563	.500	.500	.125	.125	.125	.750	.750	.750
M58	167	.400	.563	.500	.500	.563	.563	.563	.500	.500	.188	.125	.125	.750	.750	.750
M59	168	0.	0.	0.	.313	.375	.375	.313	.375	.375	.188	.125	.125	.750	.750	.750
M59	169	0.	0.	0.	.313	.313	.375	.313	.375	.375	.281	.125	.125	.750	.750	.750
M59	170	0.	0.	0.	.250	.313	.375	.313	.375	.375	.281	.125	.125	.750	.750	.750
M60	171	0.	0.	.375	0.	0.	.063	0.	.063	.063	0.	.063	.063	0.	0.	.100
M60	172	0.	0.	0.	.063	.125	.063	.094	.063	.094	.094	.063	.063	.750	.650	.650
M60	173	0.	0.	0.	.063	.063	.063	.094	.063	.063	.094	.063	.063	.400	.650	.100
M60	174	0.	0.	0.	0.	0.	.250	.125	.125	.125	.125	.125	.063	.750	.750	.650
M60	175	0.	0.	0.	0.	0.	0.	.063	.063	.063	.063	.063	.063	0.	0.	0.
M61	176	0.	0.	0.	.313	.313	.250	.313	.250	.375	.188	.250	.125	.750	.750	.750
M61	177	0.	0.	0.	.313	.313	.250	.313	.250	.375	.156	.125	.125	.650	.750	.750
M61	178	0.	0.	0.	.313	.313	0.	.313	.250	.125	.125	.125	.125	.750	.750	.650
M62	179	.540	.438	0.	.500	.500	.500	.438	.375	.500	.300	.125	.125	.750	.750	.750
M62	180	0.	0.	.450	.125	0.	.063	.156	.250	.188	.156	.250	.125	0.	.750	.750
M62	181	0.	0.	0.	.094	0.	.063	.125	.250	.188	.125	.250	.125	0.	.750	.650
M62	182	0.	0.	0.	.156	0.	.063	.156	.250	.125	.125	.250	.125	.750	.750	.750
M62	183	0.	0.	0.	.031	0.	0.	.063	.063	.125	.063	.063	.125	0.	0.	.400
M62	184	0.	0.	0.	0.	0.	0.	.031	0.	.063	.094	0.	.063	0.	0.	0.
M63	185	0.	0.	0.	.188	.375	.375	.438	.375	.375	.188	.125	.125	.750	.750	.650
M63	186	0.	0.	0.	.188	.313	.375	.375	.375	.375	.156	.125	.125	.750	.750	.750
M63	187	0.	0.	0.	.313	.313	0.	.063	.250	.313	.063	.125	.125	.750	.750	.750
M64	188	0.	0.	.075	0.	.313	.313	.031	.375	.375	.031	.125	.125	.750	.750	.750
M64	189	0.	0.	0.	0.	.313	0.	.375	.375	.375	.156	.125	.125	.750	.750	.750
M65	190	.450	.500	.450	.500	.500	.563	.500	.500	.563	.188	.125	.125	.750	.750	.750
M65	191	.475	.500	.500	.500	.500	.563	.563	.500	.500	.188	.125	.125	.750	.750	.750

Table 13.- Continued

M65	192	.420	.500	.475	.500	.500	.563	.500	.500	.500	.188	.125	.125	.750	.750	.750
M66	193	.350	.500	.500	.438	.500	.500	.500	.500	.500	.156	.125	.125	.750	.750	.750
M67	194	.440	.500	.475	.531	.625	.625	.563	.500	.500	.125	.125	.125	.750	.750	.750
M68	195	0.	0.	0.	.156	.188	.375	.188	.250	.188	.125	.125	.125	.750	.750	.650
M68	196	0.	0.	0.	0.	0.	.063	.063	.063	.063	.063	.063	.063	0.	0.	.400
M68	197	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M68	198	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M68	199	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M69	200	.130	0.	.375	.531	.563	.563	.563	.500	.500	.156	.125	.125	.650	.750	.750
M70	201	0.	.188	0.	.250	.313	.313	.250	.250	.313	.156	.125	.125	.750	.750	.650
M70	202	.435	.563	.450	.438	.500	.500	.500	.500	.500	.156	.125	.125	.750	.750	.750
M71	203	0.	0.	0.	.313	.375	.375	.375	.375	.375	.156	.125	.125	.750	.750	.650
M71	204	0.	0.	0.	.313	.375	.375	.375	.375	.375	.125	.125	.125	.750	.750	.750
M71	205	0.	0.	0.	.313	.375	.375	.375	.375	.375	.156	.125	.125	.750	.750	.750
M72	206	0.	0.	0.	0.	.438	0.	.125	.125	.125	.094	.125	.063	.750	.750	.750
M73	207	0.	0.	0.	.188	.188	0.	.125	.125	.094	.125	.125	.063	.750	.750	.650
M73	208	0.	0.	0.	.109	0.	.125	.188	.125	.125	.094	.063	.063	.750	.750	.650
M74	209	0.	0.	0.	.094	.125	.125	.125	.125	.125	.125	.125	.094	.750	.750	.750
M74	210	0.	0.	0.	.125	.125	.125	.156	.125	.125	.094	.125	.094	.750	.750	.650
M74	211	0.	0.	0.	0.	0.	0.	.125	.125	.125	.094	.063	.094	.750	.750	.750
M75	212	0.	0.	0.	0.	0.	0.	.125	.125	.063	.094	.125	.063	.750	.750	.750
M76	213	0.	0.	0.	0.	0.	0.	.094	.031	.063	.094	.031	.063	.750	0.	.100
M76	214	0.	0.	0.	0.	0.	0.	.125	.031	.094	.125	.031	.094	.750	.750	.650
M76	215	0.	0.	0.	0.	0.	.063	.125	.031	.094	.125	.031	.094	.750	.750	.650
M76	216	0.	0.	0.	0.	0.	0.	.125	.031	.094	.094	.031	.094	.750	.750	.650
M77	217	0.	0.	.250	.094	0.	.500	.438	.500	.438	.094	.125	.125	.750	.750	.650
M77	218	0.	0.	0.	.375	.313	.500	.500	.500	.500	.125	.125	.094	.750	.750	.650
M77	219	.535	.625	.500	.313	.313	.500	.500	.500	.500	.156	.125	.125	.750	.750	.650
M81	220	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M81	221	0.	0.	0.	0.	0.	.063	.094	.125	.063	.094	.125	.063	0.	0.	0.
M81	222	0.	0.	0.	0.	0.	.063	.094	.125	.063	.094	.125	.063	.400	.650	.650
M81	223	0.	0.	0.	.094	.094	.125	.125	.125	.125	.094	.125	.063	.750	.750	.650
M81	224	0.	0.	0.	.094	0.	.063	.094	.125	0.	.094	.125	0.	.400	0.	.400
M81	225	.190	0.	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	0.	0.	0.
M82	226	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M82	227	0.	0.	0.	0.	0.	0.	.063	.125	.031	.063	.125	.031	0.	.400	.400
M82	228	0.	0.	0.	0.	0.	0.	.063	.125	.063	.063	.125	.063	.400	.400	.650
M82	229	0.	0.	0.	.094	0.	.031	.125	.125	.094	.094	.125	.063	.750	.750	.650
M82	230	0.	0.	0.	.125	.125	.031	.125	.125	.125	.125	.125	.063	.750	.750	.650
M82	231	0.	0.	0.	.063	.031	.031	.094	.125	.094	.094	.125	.063	.400	.400	.100
M83	232	0.	0.	0.	.063	0.	.063	.094	.125	.094	.094	.125	.094	.400	.400	0.
M83	233	0.	0.	0.	.188	.063	.125	.125	.125	.094	.094	.125	.094	.750	.750	.650
M83	234	0.	0.	0.	.094	0.	.188	.094	0.	.094	.094	0.	.094	.750	.750	.650
M83	235	0.	0.	0.	0.	0.	.125	.125	.125	.094	.094	.125	.094	.750	.750	.650
M83	236	0.	0.	0.	0.	0.	0.	.063	.125	.063	.063	.125	.063	.650	.400	0.
M83	237	0.	0.	0.	.016	0.	.125	.094	.125	.094	.094	.125	.094	.750	.400	.100
M84	238	0.	0.	0.	.188	0.	0.	.125	.125	.063	.094	.125	.063	.750	.750	.650
M84	239	0.	0.	0.	.188	.125	.188	.125	.125	.125	.125	.125	.125	.750	.750	.650
M85	240	0.	0.	0.	.156	0.	.063	.094	.125	.063	.094	.125	.063	.650	.650	.650
M85	241	0.	0.	0.	0.	0.	0.	.094	.125	.094	.063	.125	.063	.750	.750	.650

Table 13.- Continued

M85	242	0.	0.	0.	0.	0.	.125	.094	.063	.063	.094	.063	.063	.750	.750	.650
M86	243	0.	0.	0.	0.	0.	.125	.094	.125	.094	.094	.125	.094	.750	0.	.650
M86	244	0.	0.	0.	0.	0.	0.	.094	.125	.094	.094	.125	.094	.400	.750	.650
M86	245	0.	0.	0.	0.	0.	.063	.094	.125	.063	.094	.125	.063	.750	.750	.400
M86	246	0.	0.	0.	0.	0.	0.	.094	.125	.094	.094	.125	.094	.750	.750	.650
M87	247	.475	0.	0.	.625	.625	.563	.563	.563	.625	.156	.094	.125	.750	.750	.650
M87	248	.687	.625	.750	.750	.750	.750	.750	.750	.750	.125	.188	.125	.750	.750	.650
M88	249	0.	0.	0.	.188	.188	.188	.156	.188	.125	.125	.125	.125	.750	.750	.400
M88	250	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M88	251	0.	0.	.125	.063	0.	0.	.094	.125	.125	.094	.063	.125	.650	0.	0.
M89	252	0.	0.	0.	0.	0.	.250	.375	.125	.375	.125	.063	.125	.750	.750	.650
M89	253	0.	0.	0.	0.	0.	.250	.375	.125	.375	.125	.063	.125	.750	.750	.650
M90	254	.968	.875	.925	0.	1.000	1.000	1.000	.875	.875	.188	.188	.125	.750	.750	.650
M90	255	.290	.375	.375	0.	.500	.500	.500	0.	.375	.188	0.	.125	.750	.750	.650
M92	256	.475	.375	.475	.313	.313	.500	.500	.313	.500	.156	.125	.125	.750	0.	.650
M92	257	.450	.438	.125	0.	0.	.500	.500	.500	.500	.156	.094	.125	.750	.750	.650
M92	258	0.	0.	0.	.250	0.	.500	.500	.500	.500	.125	.125	.125	.750	.750	.650
M93	259	.325	.375	.350	.250	.375	.500	.500	.250	.500	.094	.125	.125	.750	.750	.650
M94	260	0.	0.	0.	.313	.250	.250	.250	.250	.375	.094	.125	.125	0.	.750	.550
M94	261	0.	0.	0.	.250	.250	.250	.375	.250	.375	.125	.125	.125	0.	.750	.650
M94	262	0.	0.	.175	.250	.281	.250	.313	.250	.250	.125	.125	.125	0.	.750	.650
M95	263	.365	0.	.525	0.	0.	.250	.500	.500	.500	.188	.125	.125	.750	.750	.650
M96	264	0.	0.	0.	.313	.313	.250	.375	.250	.250	.094	.125	.125	0.	.750	.650
M96	265	0.	.375	.300	.188	0.	.250	.500	.500	.500	.156	.125	.125	.750	.750	.650
M97	266	0.	0.	0.	0.	.250	.500	.094	.250	.250	.313	.125	.125	.650	.750	.650
M97	267	0.	0.	0.	.094	.063	.250	.313	.313	.250	.125	.125	.125	.750	.750	.750
M97	268	0.	0.	0.	.313	.313	.250	.313	.313	.250	.156	.125	.125	.750	.750	.650
M98	269	0.	0.	0.	0.	0.	0.	.125	.125	.125	.094	.125	.125	.650	.650	.650
M98	270	0.	0.	0.	0.	0.	0.	.063	.125	.125	.063	.125	.125	0.	0.	0.
M98	271	0.	0.	0.	0.	0.	0.	.125	.125	.125	.094	.125	.125	0.	.650	.400
M98	272	0.	0.	0.	0.	0.	0.	.094	.125	.125	.094	.125	.125	0.	.750	.650
M99	273	.375	.438	.400	.188	.250	.500	.563	.500	.500	.125	.125	.125	.750	.750	.650
M99	274	.500	.500	.500	.219	.625	.500	.625	.688	.625	.156	.125	.125	.750	.750	.650
M99	275	.370	0.	.350	.500	.188	.500	.500	.500	.375	.188	.125	.125	.750	.750	.650
M100	276	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M100	277	0.	0.	.100	0.	.063	.125	.125	.188	.125	.094	.125	.125	0.	.750	0.
M100	278	0.	0.	0.	.063	0.	0.	.094	.125	.125	.094	.125	.125	0.	0.	.650
M100	279	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M100	280	0.	0.	0.	0.	0.	0.	.094	.125	.125	.094	.125	.125	0.	0.	0.
M101	281	0.	0.	0.	0.	0.	0.	.094	.125	.125	.094	.125	.125	0.	.650	.650
M101	282	0.	0.	0.	0.	0.	0.	.094	.125	.125	.094	.125	.125	.750	.750	.650
M101	283	0.	0.	0.	0.	0.	0.	.094	0.	.125	.063	0.	.125	.650	.750	.650
M101	284	0.	0.	0.	0.	0.	0.	.156	0.	.125	.094	0.	.125	.750	.750	.650
M102	285	0.	0.	0.	0.	0.	0.	0.	.250	.125	0.	.125	.125	0.	.750	0.
M102	286	0.	0.	0.	0.	0.	.125	.063	.188	.125	.063	.188	.125	0.	0.	0.
M102	287	0.	0.	0.	0.	0.	0.	0.	.250	.250	0.	.125	.250	0.	.750	.650
M103	288	0.	0.	0.	.063	0.	0.	.063	.125	.125	.063	.125	.125	.400	0.	0.
M103	289	.510	0.	0.	.063	.063	0.	.094	.188	.125	.094	.188	.125	.400	.650	.400
M103	290	0.	0.	0.	.094	0.	.188	.125	.188	.125	.156	.188	.125	.650	.750	.400
M104	291	0.	0.	0.	.125	0.	0.	.125	.188	.125	.156	.125	.125	.750	.750	.650

Table 13.- Continued

M104	292	0.	0.	0.	0.	0.	.031	.094	.125	.125	.094	.125	.125	.750	.650	.650
M105	293	0.	0.	0.	.313	.313	.250	.375	.438	.375	.094	.125	.125	.750	.750	.650
M105	294	0.	0.	0.	.313	.375	.250	.375	.438	.375	.094	.125	.125	.750	.750	.650
M105	295	0.	0.	0.	.438	.375	.250	.375	.438	.375	.125	.125	.125	.750	.750	.650
M106	296	.535	.500	.500	.313	.500	.500	.563	.500	.500	.188	.125	.125	.750	.750	.650
M106	297	.515	.500	.500	.438	.500	.500	.563	.500	.500	.156	.125	.125	.750	.750	.550
M107	298	0.	0.	0.	.094	0.	0.	.094	.125	.063	.094	.125	.063	.750	.750	.650
M108	299	0.	.375	0.	.375	.438	.500	.500	.563	.500	.125	.125	.125	.750	0.	.650
M108	300	.475	.500	.500	.500	.500	.500	.500	.563	.500	.125	.125	.125	.750	0.	.650
M108	301	.495	.500	.400	.500	.500	.500	.563	.563	.500	.125	.125	.125	.750	0.	.750
M110	302	0.	0.	0.	.188	.375	.250	.375	.375	.375	.125	.125	.125	.750	.750	0.
M113	303	0.	0.	0.	0.	0.	0.	.313	0.	0.	.125	0.	0.	0.	.750	.650
M113	304	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M113	305	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M113	306	0.	0.	0.	.313	.313	.250	.313	.375	.375	.125	.125	.125	.750	.750	.650
M113	307	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.750	.650
M113	308	0.	0.	0.	.313	.375	.250	.375	.375	.375	.125	.125	.125	.750	0.	0.
M114	309	0.	0.	0.	.031	.063	.063	0.	.125	0.	0.	.125	0.	0.	.400	0.
M114	310	0.	0.	0.	0.	0.	.063	0.	.125	0.	0.	.125	0.	0.	0.	0.
M114	311	0.	0.	0.	.016	.063	.063	.063	.125	.125	.063	.125	.125	.400	.650	0.
M114	312	0.	0.	0.	0.	.063	0.	.094	.125	.125	.094	.125	.125	.750	.750	0.
M114	313	0.	0.	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	.400	.650	0.
M114	314	0.	0.	0.	0.	0.	.063	.094	.125	.125	.094	.125	.125	.650	.750	.650
M115	315	0.	0.	0.	0.	.063	0.	.031	.125	.125	.094	.125	.125	0.	0.	0.
M115	316	0.	0.	0.	.125	.125	.094	.094	.188	.125	.094	.188	.125	.750	.750	.650
M115	317	0.	0.	0.	.063	.063	.094	.094	.188	.125	.094	.125	.125	.750	.750	.650
M115	318	0.	0.	0.	.016	.063	0.	.094	.125	.125	.094	.125	.125	.750	.750	.650
M115	319	0.	0.	0.	.063	.053	.094	.094	.188	.125	.094	.125	.125	.750	.750	.650
M115	320	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.400	0.	0.
M116	321	0.	0.	0.	0.	.063	0.	.031	.125	.125	.094	.125	.125	.650	.650	0.
M116	322	0.	0.	0.	.125	.125	.188	.125	.125	.125	.094	.125	.125	.750	.650	.650
M116	323	0.	0.	0.	.125	.125	.125	.125	.125	.125	.125	.125	.125	.750	.750	0.
M116	324	0.	0.	.100	.156	.188	0.	.156	.125	.125	.156	.125	.125	.750	.750	0.
M117	325	0.	0.	0.	.094	.125	.125	.125	0.	.125	.125	0.	.125	.750	.750	.650
M117	326	0.	0.	0.	.125	.125	0.	.094	.125	.125	.094	.125	.125	.750	.750	.550
M118	327	0.	0.	0.	0.	.125	0.	.094	.063	.063	.094	.063	.063	.750	.750	.650
M118	328	0.	0.	0.	.094	.094	.125	.125	.063	.063	.094	.125	.063	.650	.750	.650

Table 14. - Tabluation of Nondestructive Test Observations, Sequence 2 (Set 2)

		X-radiography			Penetrant			Ultrasonic by Length			Ultrasonic by Depth			Eddy Current		
PANEL NUMBER	CRACK NUMBER	NO.1	NO.2	NO.3	NO.1	NO.2	NO.3	NO.1	NO.2	NO.3	NO.1	NO.2	NO.3	NO.1	NO.2	NO.3
M1	1	.240	.250	.250	.313	.250	0.	.250	.250	0.	.156	.125	0.	0.	.750	.750
M1	2	.280	.375	.300	.313	.250	.250	.313	.250	.250	.156	.125	.125	.750	.750	.750
M1	3	.270	.313	.300	.313	.250	.250	.313	.250	.250	.156	.125	.125	.750	.750	.750
M2	4	.085	.055	.075	0.	0.	.125	.125	.125	0.	.125	.125	0.	0.	.400	.400
M2	5	0.	.065	0.	0.	0.	.125	.094	.094	.125	.094	.094	.125	.400	.400	.400
M2	6	0.	.030	.050	0.	0.	.063	.094	.125	.125	.094	.125	.125	0.	.400	.400
M3	7	0.	.125	0.	.094	.063	.094	.063	.125	.125	.063	.063	.125	.650	.750	.650
M3	8	.100	.125	.075	.094	.125	.094	.063	.125	.125	.063	.125	.125	.750	.750	.650
M3	9	0.	.125	.075	.063	.063	.063	0.	.125	.125	0.	.063	.063	0.	.400	.650
M4	10	.235	.235	.250	.250	.250	.250	.250	.250	.250	.125	.125	.125	.750	.750	.750
M4	11	.255	.270	.275	.250	.250	.250	.250	.250	.250	.125	.125	.125	.750	.750	.750
M4	12	.250	.250	.275	.250	.250	.250	.250	.250	.250	.125	.125	.125	.750	.750	.750
M5	13	.100	.125	.100	.094	.125	.125	.094	.125	.125	.094	.125	.125	.650	.650	.650
M5	14	.060	0.	.100	.094	.125	.125	.094	.125	.125	.094	.125	.125	.750	.750	.650
M5	15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M5	16	0.	0.	.075	.094	.125	.063	.063	.125	.125	.063	.125	.125	0.	.650	0.
M5	17	.100	0.	0.	.125	.094	.063	.094	.125	.125	.094	.125	.125	0.	.750	.100
M6	18	.075	.095	.100	.031	.094	.125	.063	.125	.125	.063	.125	.125	.400	.100	.650
M6	19	0.	0.	0.	.047	.063	.063	0.	.063	0.	0.	.063	0.	.100	.100	.100
M7	20	.100	.125	.100	.094	.063	.125	.094	.063	.125	.094	.063	.125	.750	.650	.750
M7	21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M8	22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M8	23	.075	.075	.100	.094	.094	0.	.063	.125	.125	.063	.125	.125	.750	.100	0.
M8	24	.080	.100	.100	.125	.063	.125	.094	.125	.125	.094	.125	.125	.750	.650	.650
M8	25	0.	0.	0.	.031	0.	0.	0.	.063	.063	0.	.063	.063	0.	0.	0.
M8	26	0.	.050	0.	.031	.063	0.	.063	.094	.063	.094	.094	.125	0.	.100	0.
M8	27	0.	0.	0.	.031	.063	0.	0.	.094	.063	0.	.094	.125	0.	.100	0.
M9	28	.250	.250	.275	.313	.250	.250	.313	.250	.250	.156	.125	.125	.750	.750	.750
M9	29	.250	.313	.275	.313	.250	.250	.313	.250	.250	.125	.125	.125	.750	.750	.750
M9	30	.275	.250	.250	.313	.250	.250	.250	.188	.250	.125	.125	.125	.750	.750	.750
M10	31	0.	0.	0.	.031	0.	.063	0.	.063	.063	0.	.063	.063	0.	0.	0.
M10	32	.033	.100	.100	.094	.125	.125	.094	.125	.125	.094	.125	.125	.750	.650	.750
M10	33	.030	.090	.100	.125	.125	.125	.094	.125	.125	.094	.125	.125	0.	.650	.650
M10	34	.030	.080	.100	.125	.125	.125	.094	.125	.125	.094	.125	.125	.650	.650	.650
M10	35	.030	.065	.050	.094	.125	.063	.063	.125	.125	.063	.125	.125	.400	.400	0.
M10	36	.030	.075	.075	.094	.125	.063	.063	.125	.125	.063	.125	.125	.400	.400	.650
M11	37	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M11	38	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M12	39	0.	0.	0.	.031	.063	0.	.094	.094	.063	.094	.094	.125	0.	0.	0.
M12	40	.100	.090	.100	.094	.094	.125	.094	.125	.125	.094	.125	.125	.650	.650	.650
M12	41	.050	.035	.050	.047	.063	.063	.031	.125	.063	.031	.125	.063	.100	.400	0.

Table 14. - Continued

M13	42	.063	0.	.075	.094	.125	.125	.094	.125	.125	.094	.125	.125	.750	.750	.400
M13	43	0.	0.	0.	.063	.063	.125	.031	.125	.125	.094	.125	.125	.650	.650	.400
M13	44	.125	.065	.075	.125	.063	.125	.063	.125	.125	.063	.125	.125	0.	.650	0.
M14	45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M14	46	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M14	47	.115	.100	.125	.125	.125	.125	.094	.125	.125	.094	.125	.125	.400	.650	.650
M15	48	.250	.260	.275	.313	.250	.375	.250	.250	.250	.156	.125	.125	.750	.750	.650
M15	49	.313	.290	.300	.313	.250	.375	.250	.250	.250	.125	.125	.125	.750	.750	.750
M15	50	.313	.280	.350	.375	.250	.375	.375	.250	.250	.156	.125	.063	.750	.750	.750
M16	51	.300	.235	.250	.250	.281	.250	.250	.250	.250	.125	.125	.125	.750	.650	.750
M16	52	.325	.300	.300	.250	.313	.250	.313	.250	.250	.156	.125	.125	.750	.650	.750
M16	53	.200	.235	.250	.313	.250	.250	.250	.250	.250	.063	.125	.125	.750	.650	.750
M17	54	0.	.050	.050	.078	.125	.125	.063	.125	.063	.094	.125	.125	.750	.650	.400
M21	55	0.	0.	0.	.063	.063	.125	.094	.094	.125	.125	.094	.125	0.	.400	0.
M21	56	0.	0.	0.	.094	.125	.125	.094	.094	.125	.125	.094	.125	.400	.400	.400
M21	57	0.	.075	0.	.094	.125	.125	.094	.094	.125	.156	.094	.125	.100	.400	.400
M21	58	0.	0.	0.	.016	.031	0.	.063	0.	.125	.063	0.	.125	0.	0.	0.
M22	59	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M22	60	.075	0.	.075	.094	.125	.125	.125	.188	.125	.125	.188	.125	.650	.100	.400
M22	61	0.	0.	0.	.016	.063	0.	.094	.125	.125	.094	.125	.125	0.	0.	0.
M22	62	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M22	63	0.	0.	0.	.016	.063	0.	.063	.125	.063	.063	.125	.063	0.	0.	0.
M23	64	0.	0.	0.	.094	.125	.125	.125	.125	.125	.125	.125	.125	.650	.400	.400
M23	65	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M23	66	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M23	67	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M24	68	.060	.075	.100	.094	.063	.125	.125	.125	.125	.125	.125	.125	.750	.650	0.
M25	69	.125	.060	.100	.094	.125	0.	.125	.125	.125	.125	.125	.125	.750	.650	.400
M26	70	.060	.050	0.	.063	.063	.063	.063	.125	.063	.063	.125	.063	.400	.400	0.
M26	71	.100	.100	.100	.094	.125	.125	.125	.188	.125	.125	.188	.125	.750	.400	.650
M27	72	0.	0.	0.	.094	.125	.125	.125	.125	.125	.125	.125	.125	.750	.400	0.
M27	73	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M27	74	0.	0.	0.	.094	.125	.125	.094	.125	.125	.094	.125	.125	.650	.400	0.
M28	75	0.	.080	0.	.094	.063	.063	.094	.125	.063	.094	.125	.125	.750	.100	.650
M28	76	0.	0.	0.	.016	.031	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M28	77	0.	0.	.025	0.	0.	0.	.063	.125	0.	.063	.063	0.	.400	.400	0.
M29	78	0.	0.	0.	0.	.063	.063	.094	.063	.063	.094	.063	.063	0.	.100	0.
M29	79	.100	.100	.100	.125	.188	.125	.094	.125	.125	.094	.125	.125	.750	.650	.750
M29	80	0.	0.	0.	.063	.094	.063	.125	.125	.125	.125	.125	.125	.400	.100	.400
M30	81	.275	.260	.250	.250	.281	.250	.313	.313	.250	.250	.188	.125	.750	.750	.750
M31	82	.250	.260	.250	.313	.313	.375	.313	.250	.250	.250	.125	.125	.750	.750	.650
M31	83	.275	.300	.275	.313	.313	.375	.375	.250	.250	.250	.125	.125	.750	.750	.650
M31	84	.300	.265	.275	.313	.313	.375	.313	.250	.250	.250	.125	.125	.750	.750	.650
M32	85	0.	0.	0.	.094	.063	.125	.094	.125	.063	.094	.125	.063	.650	.100	0.
M32	86	0.	0.	.075	.094	.063	.125	.094	.125	.063	.094	.125	.063	.650	.100	.650
M32	87	0.	0.	0.	.094	.094	.125	.094	.125	.063	.094	.125	.063	0.	.400	.650
M33	88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M33	89	.085	.075	.075	.063	.125	.125	.094	.125	.250	.125	.125	.125	.400	.400	.400
M33	90	0.	0.	0.	0.	.063	.063	.094	.063	0.	.094	.063	0.	0.	0.	0.
M33	91	.055	.060	0.	.063	.063	.063	.094	.125	.125	.094	.125	.125	.100	.100	0.
M33	92	0.	0.	0.	.063	.094	.063	.094	.125	.125	.094	.125	.125	0.	.100	0.
M34	93	.260	.230	.225	.250	.250	.250	.313	.250	.250	.250	.188	.125	.750	.750	.750
M34	94	.250	.250	.250	.250	.250	.250	.313	.250	.250	.250	.188	.125	.750	.750	.750
M35	95	0.	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	0.	0.	0.	0.
M35	96	0.	0.	.050	.031	.063	.063	.094	.125	.063	.094	.125	.063	0.	.100	0.

Table 14. - Continued

M35	97	.050	0.	.050	.031	.063	.063	.094	.125	0.	.094	.125	0.	0.	.100	0.
M35	98	.100	.100	0.	.125	.125	.125	.125	.125	.125	.125	.125	.125	.650	.400	.650
M35	99	.080	.060	0.	0.	.094	.063	.094	.125	.063	.094	.125	.063	0.	.400	0.
M35	100	0.	0.	.050	.094	.094	.125	.125	.125	.063	.125	.125	.063	0.	.400	.400
M36	101	0.	.065	.075	.125	.125	.125	.094	.125	.063	.094	.125	.063	.400	.400	.650
M36	102	0.	.175	0.	.063	.063	.063	.094	.125	.063	.125	.125	.063	.400	.400	.650
M36	103	0.	0.	0.	.031	.063	.063	.094	.125	.063	.125	.125	.063	.400	.100	.100
M36	104	0.	0.	0.	.063	.063	.063	.094	.125	.063	.094	.125	.063	0.	.100	.400
M36	105	.060	0.	0.	.125	.125	.125	.125	.125	.125	.125	.125	.125	.650	.400	.400
M36	106	0.	0.	.100	.125	.125	.125	.125	.125	.125	.125	.125	.125	.650	.100	.100
M37	107	.265	.275	.275	.250	.313	.250	.313	.250	.250	.250	.125	.125	.750	.750	.750
M37	108	.250	.275	.275	.250	.313	.250	.313	.250	.250	.250	.125	.125	.750	.750	.750
M37	109	.265	.250	.275	.250	.313	.250	.313	.250	.250	.250	.125	.125	.750	.750	.750
M38	110	0.	.100	0.	.125	.188	.125	.125	.188	.125	.125	.188	.125	.750	.400	.750
M38	111	.075	0.	0.	.063	.125	.063	.125	.125	.125	.125	.125	.125	0.	.100	.400
M38	112	0.	0.	0.	0.	.063	.063	.094	.125	0.	.094	.125	0.	.650	.100	0.
M38	113	.070	.065	.075	.063	.188	0.	.125	.125	.125	.125	.125	.125	.400	.400	0.
M38	114	0.	.050	.075	.063	.125	0.	.125	.125	.125	.125	.125	.125	.400	.400	0.
M39	115	.055	0.	0.	.063	.094	.063	.125	.125	.125	.125	.125	.125	.400	.400	0.
M39	116	.075	0.	.050	.125	.125	.125	.125	.125	.125	.125	.125	.125	.400	.400	.650
M39	117	.080	.065	0.	.063	.125	.125	.125	.125	.125	.125	.125	.125	.400	.100	.100
M39	118	.065	0.	0.	.063	.094	.125	.063	.125	.125	.063	.125	.125	.400	.400	0.
M39	119	0.	.060	0.	.063	.063	.063	.094	.125	.063	.094	.125	.063	0.	.400	0.
M40	120	0.	.060	0.	.063	.125	.125	.094	.125	.125	.125	.125	.125	0.	.400	0.
M40	121	0.	0.	0.	.063	.125	.125	.094	.125	.125	.125	.125	.125	.400	.400	.400
M40	122	.110	.075	.075	.063	.125	.125	.125	.125	.125	.125	.125	.125	.400	.100	.650
M40	123	.060	.065	.050	.063	.125	.125	.125	.125	.125	.125	.125	.125	.400	.400	0.
M41	124	0.	0.	.050	.063	.063	.063	.094	.125	.125	.094	.125	.125	.650	.400	0.
M41	125	.045	0.	.050	.063	.063	.063	.094	.125	.125	.125	.125	.125	.400	.400	.650
M41	126	.170	.075	.075	.125	.125	.125	.125	.125	.125	.125	.125	.125	.650	.400	.650
M41	127	.060	.060	.100	.125	.125	.125	.125	.188	.125	.125	.188	.125	.650	.400	.100
M42	128	.275	.275	.275	.313	.250	.375	.313	.250	.250	.250	.125	.125	.650	.750	.750
M43	129	.275	.275	.275	.313	.313	.375	.375	.250	.250	.250	.125	.125	.750	.750	.750
M43	130	.275	.275	.275	.250	.313	.375	.313	.250	.250	.250	.125	.125	.750	.750	.750
M44	131	.100	.100	.075	.125	.125	.125	.125	.125	.125	.125	.125	.125	.400	.100	.400
M44	132	0.	0.	0.	.063	.063	.063	.094	.125	.125	.094	.125	.125	0.	.100	0.
M45	133	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M45	134	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M45	135	0.	.100	.100	.094	.125	.094	.125	.125	.125	.125	.125	.125	.650	.650	.650
M49	136	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M49	137	.100	.100	.100	.094	.125	.063	.125	.125	.125	.125	.125	.125	.650	.750	.750
M49	138	0.	0.	0.	0.	.063	.063	.094	.094	.125	.094	.094	.125	0.	.400	.400
M49	139	0.	0.	0.	0.	.063	.063	.094	.125	.125	.094	.125	.125	0.	.100	.100
M49	140	0.	0.	0.	0.	.063	.125	.063	.125	.125	.063	.125	.125	0.	.400	.400
M49	141	.100	.100	.100	.094	.125	.125	.094	.125	.125	.094	.125	.125	.650	.650	.650

Table 14.- Continued

M50	142	.100	.150	.150	.125	.125	.125	.125	.125	.125	.125	.125	.125	0.	.650	.400
M50	143	.075	.100	.100	.063	.094	.125	.094	.125	.125	.125	.125	.125	0.	.100	0.
M50	144	.060	.075	.075	0.	.094	.063	.094	.125	.125	.094	.125	.125	.400	.100	.400
M50	145	.075	.075	.075	.063	.125	.063	.125	.125	.125	.125	.125	.125	.400	.100	.400
M50	146	0.	0.	0.	0.	.063	.063	.094	.125	.125	.094	.125	.125	.400	.100	.400
M50	147	.100	.100	.100	.125	.188	.125	.125	.125	.125	.125	.125	.125	.650	.650	.650
M51	148	.100	.100	.100	.063	.125	.063	.094	.125	.063	.125	.125	.063	0.	.400	.100
M51	149	0.	0.	.075	0.	.063	0.	0.	.094	.063	0.	.094	.063	0.	0.	0.
M52	150	.100	.100	.100	.125	.125	.125	.125	.125	.125	.125	.125	.125	.650	.100	.750
M53	151	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M53	152	.150	.150	.100	.125	.125	.125	.156	.125	.125	.156	.125	.125	.650	.650	.650
M53	153	0.	0.	0.	.125	.094	.125	.094	.125	.125	.094	.125	.125	.400	.400	.650
M54	154	0.	0.	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	0.	0.	0.
M54	155	0.	0.	0.	0.	0.	0.	0.	.063	0.	0.	.063	0.	0.	0.	0.
M54	156	0.	.075	.075	.063	.125	.125	0.	.125	.125	0.	.125	.125	.650	.400	.650
M55	157	0.	.060	.050	.063	.094	.063	.125	.125	.125	.125	.125	.125	.650	.650	.650
M55	158	0.	0.	0.	0.	.063	0.	.063	.094	0.	.063	.094	0.	0.	.100	0.
M55	159	.075	.050	.075	.063	.063	.063	.094	.125	.125	.125	.125	.125	.400	.400	.400
M56	160	.475	.500	.500	.500	.436	.625	.500	.500	.500	.188	.125	.125	.750	.750	.750
M56	161	.525	.500	.300	.500	.438	.625	.500	.500	.500	.125	.125	.125	.750	.750	.750
M57	162	.275	.300	.325	.313	.375	.375	.438	.313	0.	.125	.188	0.	.750	.750	.750
M57	163	0.	.200	.150	.625	.375	.375	.375	.313	0.	.156	.188	0.	.750	.750	.750
M57	164	.300	.310	.300	.500	.375	.375	.250	.250	.375	.188	.125	.125	.750	.750	.750
M58	165	.500	.450	.450	.500	.563	.563	.500	.500	.500	.125	.125	.125	.750	.750	.750
M58	166	.500	.550	.450	.563	.563	.563	.500	.500	.500	.125	.125	.125	.750	.750	.750
M58	167	.500	.575	.500	.531	.500	.500	.500	.500	.500	.125	.125	.125	.750	.750	.750
M59	168	.325	.350	.325	.375	.375	.375	.375	.313	.375	.125	.188	.125	.750	.750	.750
M59	169	0.	.325	0.	.375	.375	.375	.375	.313	.375	.125	.188	.125	.750	.750	.750
M59	170	.200	.250	.200	.375	.375	.375	.375	.313	.375	.156	.188	.125	.750	.750	.750
M60	171	0.	0.	0.	.031	.063	.125	0.	.063	.125	0.	.063	.125	.400	0.	0.
M60	172	0.	0.	0.	.094	.094	.125	.094	.125	.125	.094	.125	.125	.400	.400	0.
M60	173	0.	0.	0.	.094	.094	.125	.063	.125	.125	.125	.125	.125	.400	.650	0.
M60	174	.160	.150	.200	.156	.156	.156	.188	.188	.125	.188	.188	.125	.650	.750	.750
M60	175	0.	0.	0.	.031	0.	0.	0.	0.	.063	0.	0.	.063	0.	0.	0.
M61	176	0.	.325	0.	.375	.375	.375	.375	.250	.375	.156	.125	.125	.750	.750	.750
M61	177	.250	.275	.300	.375	.375	.375	.375	.250	.375	.125	.125	.125	.750	.750	.750
M61	178	0.	.150	0.	.375	.375	.375	.375	.250	.375	.125	.125	.125	.750	.750	.750
M62	179	.400	.375	0.	.500	.563	.625	.375	.500	.500	.250	.125	.125	.750	.750	.750
M62	180	0.	0.	0.	.156	.156	.125	.094	.125	.125	.094	.125	.125	0.	.750	.400
M62	181	0.	0.	0.	.125	.125	.125	.094	.125	.125	.094	.125	.125	.750	.750	.650
M62	182	0.	.125	0.	.188	.188	.125	.094	.125	.125	.094	.125	.125	.750	.750	.400
M62	183	0.	0.	0.	.063	.063	.063	0.	.063	.125	0.	.063	.125	0.	0.	.400
M62	184	0.	0.	0.	.031	0.	0.	0.	.063	.063	0.	.063	.063	0.	0.	.400
M63	185	.250	.325	.275	.313	.375	.375	.375	.313	.375	.125	.125	.125	.750	.750	.750
M63	186	0.	.325	0.	.313	.313	.375	.313	.313	.375	.125	.125	.125	.750	.750	.750
M63	187	.300	.300	.250	.313	.375	.375	.375	.313	.375	.125	.125	.125	.750	.750	.750
M64	188	0.	0.	0.	.313	.375	0.	.250	.313	.375	.063	.125	.125	.750	.750	.750
M64	189	0.	0.	0.	.313	.313	0.	.188	.313	.375	.063	.125	.125	.750	.750	.750
M65	190	.500	.470	.475	.500	.500	.625	.563	.563	.500	.125	.125	.125	.750	.750	.750
M65	191	.575	.550	.525	1.000	.500	.625	.563	.563	.500	.125	.125	.125	.750	.750	.750

Table 14. - Continued

M65	192	.450	.250	.425	.500	.500	.625	.500	.500	.063	.125	.125	.063	.750	.750	.750
M66	193	.500	.425	.500	.500	.500	.625	.500	.313	.500	.125	.125	.125	.750	.750	.750
M67	194	.500	.450	.500	.563	.563	.625	.500	.563	.500	.125	.125	.125	.750	.750	.750
M68	195	0.	0.	0.	.188	.063	.250	.188	.188	.250	.188	.125	.125	.750	.750	.750
M68	196	0.	0.	0.	.347	.188	.063	0.	.125	.063	0.	.125	.063	0.	.400	0.
M68	197	0.	.175	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M68	198	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M68	199	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M69	200	.400	.425	.500	.563	.563	.625	.375	.500	.500	.125	.125	.125	.750	.750	.650
M70	201	.225	.275	0.	.250	.313	.375	.313	.375	.250	.188	.063	.125	.750	.750	.750
M70	202	.425	.500	.400	.500	.500	.625	.563	.313	.500	.125	.125	.125	.750	.750	.750
M71	203	0.	.400	.350	.375	.375	.375	.031	.375	.375	.031	.125	.125	.750	.750	.750
M71	204	.350	.325	.350	.375	.313	.375	.375	.375	.375	.125	.125	.125	.750	.750	.750
M71	205	.400	.200	.300	.375	.313	.375	.375	.375	.375	.125	.125	.125	.750	.750	.750
M72	206	.125	0.	0.	.125	.125	.125	.313	.188	.125	.125	.188	.125	.750	0.	.650
M73	207	0.	.100	.250	.125	0.	.250	.125	.125	.125	.125	.125	.125	.750	.750	.750
M73	208	0.	.200	.125	.188	.188	.250	.125	.188	.125	.125	.188	.125	.750	.750	.400
M74	209	0.	0.	0.	.156	.156	.125	.094	.188	.125	.094	.188	.125	.750	.750	.750
M74	210	0.	0.	0.	.156	.125	.125	.094	.188	.125	.094	.188	.125	.750	.750	.750
M74	211	0.	0.	0.	.125	.125	.125	.094	.188	.125	.094	.188	.125	.750	.750	.750
M75	212	0.	0.	.150	.156	.156	.188	.125	.125	.125	.125	.125	.125	.750	.750	.750
M76	213	0.	0.	0.	.094	.125	0.	0.	.125	.125	0.	.125	.125	.750	.650	.400
M76	214	0.	0.	0.	.125	.125	.125	0.	.188	.125	0.	.188	.125	.750	.650	.650
M76	215	0.	0.	0.	.094	.063	.063	0.	.188	.125	0.	.188	.125	.750	.650	.750
M76	216	0.	0.	0.	.156	.125	0.	0.	.188	.125	0.	.188	.125	.750	.750	.750
M77	217	.400	.325	.400	.531	.438	.625	.500	.500	.500	.125	.125	.125	.750	.750	.750
M77	218	.400	.325	.400	.531	.500	.625	.500	.500	.500	.125	.125	.125	.750	.750	.750
M77	219	.500	.300	.500	.500	.500	.625	.500	.500	.500	.188	.125	.125	.750	.750	.750
M81	220	0.	0.	0.	.031	.063	0.	0.	.125	.125	0.	.125	.125	0.	0.	0.
M81	221	0.	0.	0.	.078	.063	.125	0.	.125	.125	0.	.125	.125	.650	.650	.650
M81	222	0.	0.	0.	.094	.063	.125	0.	.125	.125	0.	.125	.125	0.	.750	.650
M81	223	0.	0.	0.	.156	.125	.125	0.	.125	.125	0.	.125	.125	.750	.750	.750
M81	224	0.	0.	0.	.094	.125	.125	0.	.125	.125	0.	.125	.125	.750	.750	.750
M81	225	0.	0.	0.	.031	.063	0.	0.	.125	.125	0.	.125	.125	0.	0.	0.
M82	226	0.	0.	.200	.016	.031	0.	0.	.094	.125	0.	.094	.125	0.	0.	0.
M82	227	0.	0.	.050	.063	.063	0.	0.	.094	.125	0.	.094	.125	0.	0.	.650
M82	228	0.	0.	0.	.063	0.	.125	.125	.125	0.	.125	.125	0.	.400	0.	0.
M82	229	.075	0.	0.	.125	.125	.125	.125	.125	.125	.125	.125	.125	.750	.750	.650
M82	230	0.	0.	0.	.156	.156	.125	.156	.094	.125	.156	.094	.125	.750	.750	.750
M82	231	0.	0.	.150	.094	.125	.125	.094	.125	.125	.125	.125	.125	.750	.750	.750
M83	232	0.	0.	0.	.094	.063	.125	0.	.125	.125	0.	.125	.125	.400	.650	0.
M83	233	0.	0.	0.	.156	.125	.125	0.	.125	.125	0.	.125	.125	.750	.750	.750
M83	234	0.	0.	0.	.125	.125	0.	.063	.125	.125	.063	.125	.125	.750	.400	.750
M83	235	0.	0.	0.	.125	.125	.125	.031	.125	.125	.031	.125	.125	.750	.750	.750
M83	236	0.	0.	0.	.063	.063	.125	0.	.125	.125	0.	.125	.125	.400	.650	.750
M83	237	0.	0.	0.	.094	.063	0.	0.	.125	.125	0.	.125	.125	.650	.750	0.
M84	238	0.	0.	0.	.156	.250	.250	.156	.125	.250	.156	.125	.125	.750	.750	.750
M84	239	0.	0.	.125	.156	0.	0.	.125	.094	.250	.125	.094	.125	.750	.750	.400
M85	240	.125	0.	0.	.078	.094	.125	0.	.125	.125	0.	.125	.125	.750	.650	.650
M85	241	0.	.150	.150	.281	.156	.125	.125	.188	.125	.125	.188	.125	.750	.750	.750

Table 14.- Continued

M85	242	0.	0.	.250	.125	.125	.125	.094	.125	.125	.094	.125	.125	.750	.750	.100
M86	243	0.	0.	0.	.125	.125	.125	0.	.125	.125	0.	.125	.125	.750	.750	.750
M86	244	0.	0.	0.	.094	.125	.125	0.	.125	0.	0.	.125	0.	.750	.750	.750
M86	245	0.	0.	0.	.094	.125	.125	0.	.125	.125	0.	.125	.125	.750	.400	.750
M86	246	0.	0.	0.	.156	.156	.125	0.	.125	.125	0.	.125	.125	.750	.750	.750
M87	247	.525	.525	.500	.563	.563	.563	.500	.500	.563	.125	.125	.125	1.000	1.000	.750
M87	248	.750	.600	.750	.750	.750	.750	.750	.625	.688	.125	.125	.125	1.000	1.000	.750
M88	249	.150	.150	.175	.156	.188	.188	0.	.125	.094	0.	.125	.094	1.000	1.000	.750
M88	250	0.	0.	0.	.016	.063	0.	.031	0.	0.	.031	0.	0.	0.	0.	0.
M88	251	0.	0.	0.	.063	.063	0.	.094	.063	.125	.094	.094	.125	0.	.400	0.
M89	252	0.	.175	.150	.375	.313	.313	.313	.313	.250	.063	.125	.125	1.000	1.000	.750
M89	253	.250	.325	.325	.313	.313	.313	.313	.313	.250	.094	.125	.125	1.000	1.000	.750
M90	254	.100	.100	.950	1.000	1.000	1.000	1.000	1.000	1.000	.156	.125	.125	1.000	1.000	.750
M90	255	.400	.500	.350	.500	.563	.375	.500	.500	.500	.125	.125	.125	1.000	1.000	.750
M92	256	.500	.510	.500	.563	.563	.563	.553	.563	.500	.156	.125	.125	1.000	1.000	.750
M92	257	0.	.500	.500	.500	.500	.500	.500	.500	.500	.125	.125	.125	1.000	1.000	.750
M92	258	.325	.450	.400	.500	.500	.500	.375	.500	.500	.063	.125	.125	1.000	1.000	.750
M93	259	.400	.475	.450	.500	.500	.500	.500	.500	.500	.125	.125	.125	1.000	1.000	.750
M94	260	0.	.350	0.	.313	.313	.313	.313	.375	.250	.125	.125	.125	1.000	1.000	.750
M94	261	.300	.525	.175	.313	.313	.313	.313	.375	.250	.125	.125	.125	1.000	1.000	.750
M94	262	.275	.350	.250	.313	.313	.313	.375	.313	.313	.094	.125	.125	0.	1.000	.750
M95	263	.450	.475	.425	.500	.500	.500	.500	0.	.500	.125	0.	.125	1.000	1.000	.750
M96	264	.325	0.	0.	.313	.313	.313	.313	.313	.250	.125	.125	.125	1.000	1.000	.750
M96	265	.350	.375	.325	.500	.500	.313	.563	.500	.500	.125	.125	.125	1.000	1.000	.750
M97	266	0.	.250	.250	.313	.313	.313	.313	.250	.250	.125	.125	.125	1.000	1.000	.750
M97	267	.300	.325	.250	.313	.375	.313	.375	.250	.313	.125	.125	.125	1.000	1.000	.750
M97	268	.300	.325	.275	.313	.313	.313	.375	.313	.313	.125	.125	.125	1.000	1.000	.750
M98	269	0.	0.	0.	.156	.156	.125	.125	.125	.125	.094	.125	.125	1.000	.650	.750
M98	270	0.	0.	0.	0.	0.	0.	0.	0.	.125	0.	0.	.125	0.	0.	0.
M98	271	0.	0.	0.	.094	.063	.125	.094	.125	.125	.094	.125	.125	1.000	.650	.400
M98	272	0.	0.	0.	.094	.063	.125	.063	.063	.125	.063	.063	.125	1.000	.400	.650
M99	273	.550	.500	.500	.563	.500	.500	0.	0.	.500	0.	0.	.125	0.	1.000	.750
M99	274	.600	.575	.600	.625	.625	.625	0.	0.	.500	0.	0.	.125	1.000	1.000	.750
M99	275	.500	.425	.475	.500	.500	.500	0.	0.	.500	0.	0.	.125	0.	1.000	.750
M100	276	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M100	277	.125	.125	.300	.156	.188	.188	.188	.156	.094	.125	.125	.094	1.000	1.000	.750
M100	278	0.	0.	0.	.063	.063	.063	.063	.063	.094	.063	.063	.094	.400	0.	.650
M100	279	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M100	280	.075	0.	0.	0.	0.	0.	.094	.063	0.	.094	.063	0.	.400	.400	.100
M101	281	0.	.100	0.	.125	.125	.125	0.	0.	.125	0.	0.	.125	1.000	1.000	.650
M101	282	0.	0.	0.	.094	.125	.125	0.	0.	.125	0.	0.	.125	1.000	.650	.650
M101	283	0.	.175	.350	.156	.156	.188	0.	.188	.125	0.	.125	.125	1.000	1.000	.750
M101	284	0.	.175	.175	.156	.188	.188	0.	0.	.125	0.	0.	.125	1.000	1.000	.750
M102	285	.125	0.	0.	.125	.094	.094	.094	.125	.094	.094	.125	.094	1.000	.650	.400
M102	286	0.	0.	0.	.094	0.	.094	.063	.125	.094	.063	.063	.094	0.	.400	.750
M102	287	.200	.200	.200	.156	.156	.156	.188	.188	.188	.125	.125	.125	0.	1.000	.750
M103	288	0.	0.	0.	0.	.063	0.	.063	0.	.063	.063	0.	.063	0.	0.	.100
M103	289	0.	.575	0.	.125	.125	.125	.094	0.	.125	.094	0.	.125	0.	1.000	.750
M103	290	0.	0.	0.	.125	.125	.125	.125	.250	.125	.125	.125	.125	.400	1.000	.750
M104	291	.300	.175	.200	.188	.156	.188	.188	.188	.188	.094	.125	.125	1.000	1.000	.750

Table 14. - Continued

M104	292	0.	0.	0.	0.	.125	.063	.063	.125	.125	.063	.125	.125	1.000	1.000	.400
M105	293	.300	.250	.275	.313	.313	.313	.375	0.	.313	.125	0.	.125	1.000	1.000	.750
M105	294	.300	.275	.275	.375	.375	.375	.375	0.	.313	.125	0.	.125	1.000	1.000	.750
M105	295	.500	.425	.450	0.	.375	.375	.438	.125	.313	.125	.125	.125	1.000	1.000	.750
M106	296	.500	.575	.500	.563	.500	.500	.563	.500	.313	.125	.125	.125	1.000	1.000	.750
M106	297	.500	.600	.450	.500	.500	.500	.563	.500	.313	.094	.125	.125	1.000	1.000	.750
M107	298	0.	.075	.125	.156	.156	.188	.125	0.	.188	.094	0.	.188	1.000	1.000	.750
M108	299	.225	.300	.500	.500	.500	.500	.563	.563	.500	.125	.125	.125	0.	1.000	.750
M108	300	.500	.550	.600	.500	.500	.500	.563	.438	.500	.125	.125	.125	0.	1.000	.750
M108	301	.450	.475	.450	.500	.563	.500	.563	.500	.500	.094	.125	.125	0.	1.000	.750
M110	302	.225	.350	.300	.375	.375	.375	.188	.375	.250	.063	.125	.125	1.000	1.000	.750
M113	303	.350	.375	.400	.375	.375	.313	.313	0.	.313	.094	0.	.125	1.000	1.000	.750
M113	304	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M113	305	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M113	306	.300	.325	.325	.313	.313	.313	.063	.313	.313	.063	.125	.125	1.000	1.000	.750
M113	307	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M113	308	0.	.350	.275	.313	.375	.313	0.	.375	.313	0.	.125	.125	1.000	1.000	.750
M114	309	0.	0.	0.	.063	0.	.094	.063	0.	0.	.063	0.	0.	0.	.400	.400
M114	310	0.	0.	0.	0.	0.	0.	.063	0.	.094	.063	0.	.094	0.	.400	.100
M114	311	0.	0.	0.	.094	0.	.125	.078	.125	0.	.078	.125	0.	0.	1.000	.400
M114	312	0.	0.	0.	.156	0.	.125	.094	.063	.125	.094	.125	.125	1.000	1.000	.750
M114	313	0.	0.	0.	0.	0.	0.	.094	0.	.125	.094	0.	.125	0.	.400	.400
M114	314	.100	0.	0.	.156	.125	.094	.125	.125	0.	.063	.063	0.	1.000	.400	.750
M115	315	0.	0.	0.	.094	.063	.094	.031	.125	0.	.031	.125	0.	0.	0.	.100
M115	316	0.	.060	0.	.156	.188	.188	.063	.125	.125	.063	.063	.125	1.000	1.000	.750
M115	317	0.	0.	0.	.094	.094	.125	.063	.063	.125	.063	.063	.125	1.000	1.000	.750
M115	318	.125	.125	.100	.125	.094	.125	.031	0.	.125	.031	0.	.125	1.000	1.000	.750
M115	319	0.	0.	.100	.125	.125	.125	.063	.125	.125	.063	.125	.125	1.000	1.000	.750
M115	320	0.	0.	0.	.063	.063	0.	0.	0.	.125	0.	0.	.125	0.	.400	.400
M116	321	0.	.350	0.	.094	.063	.063	.063	.063	.094	.063	.063	.094	1.000	1.000	.400
M116	322	0.	.110	0.	0.	.125	.125	.094	.125	.094	.094	.125	.094	1.000	1.000	.750
M116	323	.125	.150	.125	.125	.125	.125	.094	.125	0.	.094	.125	0.	0.	.650	.750
M116	324	0.	0.	0.	.250	.188	.188	.125	.188	.063	.094	.125	.063	0.	1.000	.750
M117	325	0.	.150	0.	.156	.156	.156	.125	.125	.094	.094	.125	.094	0.	1.000	.750
M117	326	.200	.125	0.	.125	.156	.125	.094	.125	.094	.094	.125	.094	1.000	1.000	.750
M118	327	0.	0.	0.	.156	.188	.125	.094	.188	.188	.094	.094	.125	1.000	1.000	.750
M118	328	0.	0.	0.	.125	.125	.125	.094	.125	0.	.094	.125	0.	1.000	1.000	.750

Table 15.- Tabulation of Nondestructive Test Observations, Sequence 3 (Set 3)

PANEL NUMBER	CRACK NUMBER	X-radiography NO.1	X-radiography NO.2	X-radiography NO.3	Penetrant NO.1	Penetrant NO.2	Penetrant NO.3	Ultrasonic by Length NO.1	Ultrasonic by Length NO.2	Ultrasonic by Length NO.3	Ultrasonic by Depth NO.1	Ultrasonic by Depth NO.2	Ultrasonic by Depth NO.3	Eddy Current NO.1	Eddy Current NO.2	Eddy Current NO.3
M1	1	.250	.300	.375	.250	.250	.375	.250	.250	.250	.188	.125	.094	.650	1.000	.650
M1	2	.250	.300	.375	.750	.250	.375	.375	.250	.250	.156	.188	.094	.650	1.000	.650
M1	3	.250	.260	.375	.313	.250	.375	.375	.250	.250	.188	.188	.094	.400	1.000	.650
M2	4	.075	.075	.125	.125	.063	0.	.063	.125	0.	.063	.063	0.	.400	.400	.650
M2	5	.075	0.	.125	.063	.063	.125	.063	.125	.063	.063	.063	.031	.100	.400	.650
M2	6	.050	.040	.125	.063	.063	.125	.063	.063	.063	.063	.063	.031	.400	0.	.400
M3	7	.100	.100	.060	.063	.063	.063	.094	.063	.063	.125	.063	.063	.100	1.000	.650
M3	8	.100	.075	.060	.125	.094	.063	.125	.063	.125	.125	.063	.125	.400	1.000	.650
M3	9	.100	.075	.060	.063	.063	.063	.063	.063	.031	.063	.063	.031	.400	1.000	.400
M4	10	.250	.250	.250	.250	.250	.375	.250	.250	.250	.313	.125	.094	.400	1.000	1.000
M4	11	.275	.275	.250	.250	.250	.375	.250	.250	.250	.313	.125	.094	.650	1.000	1.000
M4	12	.275	.275	.250	.250	.250	.375	.250	.250	.250	.313	.125	.094	.650	1.000	1.000
M5	13	.100	.100	.060	.125	.125	.063	.063	.063	.063	.063	.063	.063	.400	1.000	.650
M5	14	.100	.100	.060	.125	.125	.063	.094	.063	.063	.063	.063	.063	.400	1.000	.650
M5	15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M5	16	.100	.100	.060	.063	.063	.063	.094	.063	.063	.063	.063	.063	.100	1.000	.650
M5	17	.100	0.	.060	.125	.125	.063	.094	.063	.063	.094	.063	.063	.400	1.000	.650
M6	18	.100	.125	.060	.063	.063	.063	0.	.125	.063	0.	.063	.031	.400	.400	.650
M6	19	0.	0.	0.	.031	.031	0.	0.	0.	0.	0.	0.	0.	.100	.400	0.
M7	20	.100	.100	.125	.125	.125	.063	.125	.188	.125	.125	.125	.063	.400	1.000	.400
M7	21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M8	22	0.	0.	0.	0.	0.	0.	.063	0.	0.	.031	0.	0.	0.	0.	.100
M8	23	.100	.100	.125	.063	.063	.063	.063	.125	.063	.063	.063	.031	.400	.400	.400
M8	24	.125	.135	0.	.125	.125	.125	.125	.063	.063	.125	.063	.031	.650	.750	.650
M8	25	0.	0.	0.	0.	.016	0.	.063	.063	0.	.031	.031	0.	0.	0.	0.
M8	26	0.	0.	.125	.063	.063	0.	0.	.063	0.	0.	.063	0.	.100	.400	.650
M8	27	0.	0.	.375	.063	.063	0.	0.	.063	.063	0.	.063	.063	0.	0.	0.
M9	28	.250	.260	.250	.250	.250	.375	.313	.250	.250	.125	.375	.094	.650	1.000	.650
M9	29	.250	.275	.250	.250	.250	.375	.313	.250	.250	.125	.375	.094	1.000	1.000	.650
M9	30	.250	.250	.250	.250	.250	.375	.313	.250	.250	.125	.250	.094	.650	1.000	.650
M10	31	0.	.050	0.	.063	.063	0.	.031	0.	0.	.031	0.	0.	0.	0.	0.
M10	32	.100	.150	.060	.125	.125	.125	.063	.125	0.	.063	.063	0.	.650	1.000	.650
M10	33	.100	0.	.060	.125	.125	.125	.063	.125	.031	.063	.063	.031	.400	.650	.650
M10	34	.075	.100	.060	.125	.125	.125	.063	.125	.063	.063	.125	.031	.650	.650	.650
M10	35	.075	.075	.060	.125	.125	.125	.063	.125	.031	.063	.063	.031	.400	.650	.650
M10	36	.075	.060	0.	.125	.125	.125	.063	.063	.031	.063	.063	.031	.650	.650	.650
M11	37	0.	.050	0.	0.	0.	0.	.313	.250	0.	.125	.375	0.	.650	1.000	.650
M11	38	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M12	39	0.	0.	0.	0.	.031	0.	.063	0.	0.	.031	0.	0.	0.	.100	.650
M12	40	0.	.125	.125	.125	.125	.125	.125	.125	.031	.125	.125	.031	.650	1.000	1.000
M12	41	.100	.075	0.	.063	.063	.063	.063	0.	0.	.031	0.	0.	0.	.400	.650

Table 15. - Continued

M13	42	.100	.075	.060	.125	.125	.125	.125	.125	.063	.125	.063	.125	.400	1.000	.400
M13	43	.100	.050	.060	.094	.094	.094	.125	.125	.063	.094	.063	.063	.650	1.000	0.
M13	44	.100	.100	.060	.063	0.	.063	.094	.063	.031	.094	.063	.031	.400	.400	0.
M14	45	0.	0.	0.	.063	.031	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M14	46	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M14	47	.100	.150	.060	.125	.125	.188	.125	.125	.063	.125	.063	.031	.400	1.000	.650
M15	48	.250	.275	.250	.313	.250	.375	.344	.250	.375	.188	.250	.094	1.000	1.000	.650
M15	49	.250	.300	.250	.250	.250	.375	.344	.250	.375	.125	.188	.094	1.000	1.000	.650
M15	50	.250	.350	.250	.375	.313	.375	.375	.434	.375	.156	.250	.094	.650	1.000	.650
M16	51	.250	.300	.250	.250	.250	.375	.313	.250	.375	.125	.125	.125	.650	1.000	.650
M16	52	.275	.300	.250	.375	.313	.375	.313	.250	.375	.125	.063	.094	.400	1.000	1.000
M16	53	.225	.225	.250	.250	.250	.375	.313	.250	.375	.125	.063	.094	1.000	1.000	1.000
M17	54	.075	.075	.060	.094	.094	.063	.094	.063	.125	.125	.063	.125	.650	1.000	.650
M21	55	0.	.075	0.	.063	.031	.063	.063	.125	.063	.063	.063	.063	0.	0.	.650
M21	56	.100	.075	0.	.125	.063	.063	.094	.063	.063	.094	.063	.063	.400	.400	.650
M21	57	.100	.075	0.	.125	.063	.063	.094	.125	.063	.063	.063	.063	.100	.650	.650
M21	58	.100	0.	0.	0.	.031	.063	.031	0.	.031	.094	0.	.031	0.	0.	0.
M22	59	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M22	60	.075	.075	.060	.125	.125	.063	.125	.125	.063	.125	.125	.031	.400	.650	.650
M22	61	0.	.125	0.	.063	0.	0.	.125	.063	.125	.063	.063	.063	0.	0.	0.
M22	62	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M22	63	0.	0.	0.	0.	0.	0.	0.	.125	0.	0.	.063	0.	0.	0.	0.
M23	64	.100	.100	.060	.125	.063	.063	.094	.125	.063	.094	.031	.063	.400	.650	.650
M23	65	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M23	66	0.	0.	0.	0.	0.	0.	0.	.188	0.	0.	.063	0.	0.	0.	0.
M23	67	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M24	68	.075	.075	.125	.125	.125	.125	.125	.063	.125	.125	.063	.063	.650	.650	1.000
M25	69	.100	.125	.125	.063	.063	.125	.125	.125	0.	.125	.063	0.	.650	.650	1.000
M26	70	0.	0.	0.	.063	.063	.063	.063	.063	.031	.063	.063	.031	.400	.400	.400
M26	71	.100	.150	.125	.125	.063	.125	.125	.125	.125	.125	.063	.063	.650	1.000	1.000
M27	72	.100	0.	0.	.125	.063	.125	.063	.125	0.	.063	.063	0.	0.	.650	.650
M27	73	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.400
M27	74	.050	.100	0.	.125	.063	.125	.125	.125	.063	.125	.063	.031	.400	.650	.650
M28	75	0.	.100	0.	.125	.125	.063	.125	.063	.063	.125	.063	.031	.400	.650	.650
M28	76	0.	0.	0.	.063	.031	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M28	77	.100	.100	0.	.063	.063	0.	.031	0.	0.	.031	0.	0.	.650	.650	.650
M29	78	0.	0.	0.	.031	.063	0.	.031	.063	.063	.031	.031	.031	0.	0.	0.
M29	79	.075	.100	.125	.125	.125	.125	.063	.063	.063	.063	.063	.031	.650	.400	0.
M29	80	.075	.100	.125	.063	.063	.063	.125	.063	.063	.125	.063	.031	.400	1.000	.650
M30	81	.275	.325	.375	.250	.250	.375	.313	.188	.375	.125	.063	.094	.650	1.000	1.000
M31	82	.250	.250	.250	.250	.250	.375	.313	.313	.250	.156	.313	.156	.650	1.000	.650
M31	83	.250	.275	.250	.250	.250	.375	.313	.313	.250	.125	.313	.156	.650	1.000	.650
M31	84	.250	.275	.250	.250	.250	.375	.313	.313	.250	.125	.313	.156	.650	1.000	.650
M32	85	0.	0.	0.	.063	.063	.063	.125	.063	0.	.125	.063	0.	.400	.400	.650
M32	86	0.	0.	0.	.063	.125	.063	.063	.063	.063	.063	.063	.063	.400	.400	.650
M32	87	0.	0.	0.	.125	.125	.063	.063	.063	.063	.063	.063	.063	.650	.650	.650
M33	88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M33	89	.100	.100	.125	.125	0.	0.	.094	.125	.063	.094	.125	.063	.400	1.000	.650
M33	90	0.	0.	0.	0.	0.	0.	.063	0.	0.	.094	0.	0.	0.	0.	0.
M33	91	.100	.050	0.	.063	.031	0.	.094	.094	.031	.094	.063	.031	0.	0.	.400
M33	92	.075	.100	0.	.063	0.	0.	.063	.063	.031	.063	.094	.031	.400	0.	.650
M34	93	.250	.250	.250	.250	.250	.375	.344	.313	.250	.125	.188	.156	1.000	1.000	.650
M34	94	.250	.250	.250	.250	.250	.375	.250	.250	.250	.094	.250	.156	.650	1.000	.650
M35	95	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M35	96	0.	0.	0.	.063	.031	.063	.063	.063	.063	.094	.063	.031	0.	0.	0.

Table 15.- Continued

M35	97	0.	0.	0.	.063	.031	.063	.063	.063	0.	.063	.063	0.	0.	0.	0.
M35	98	.100	.100	0.	.125	.125	.125	.125	.125	.063	.094	.125	.094	.400	1.000	.400
M35	99	.100	0.	0.	.063	.063	.063	.063	.125	.031	.094	.063	.063	0.	.650	.100
M35	100	0.	0.	0.	.063	.063	.125	.063	.063	.063	.094	.063	.063	.400	.400	.100
M36	101	.100	0.	0.	.125	.125	.125	.063	.063	.125	.063	.063	.063	.400	.400	0.
M36	102	0.	0.	0.	.125	.063	.063	.063	.063	.063	.063	.063	.031	.400	.400	0.
M36	103	0.	0.	0.	.063	.063	.063	.063	.063	0.	.063	.063	0.	.100	.400	0.
M36	104	.050	0.	0.	.063	.063	.063	.063	.063	0.	.063	.063	0.	.400	0.	0.
M36	105	0.	0.	.060	.063	.125	0.	.063	.125	.063	.063	.125	.031	.650	.650	1.000
M36	106	0.	.125	0.	.125	.125	.125	.063	.125	.125	.063	.125	.063	.650	.650	1.000
M37	107	.250	.275	.250	.250	.250	.313	.313	.313	.250	.125	.313	.125	.400	1.000	.650
M37	108	.250	.275	.250	.250	.250	.313	.313	.313	.250	.125	.375	.156	.650	1.000	.650
M37	109	.250	.275	.250	.250	.250	.313	.313	.313	.250	.125	.313	.125	.650	1.000	.650
M38	110	.075	0.	0.	.125	.125	.125	.125	.125	.188	.125	.063	.094	0.	1.000	1.000
M38	111	.075	0.	.060	.063	.063	.125	.125	.063	.125	.125	.063	.063	.400	.650	.650
M38	112	0.	0.	.050	.063	.063	0.	.063	.125	.063	.125	.063	.031	.650	.400	.650
M38	113	.075	0.	.060	.063	.063	.125	.063	.125	.063	.063	.125	.031	.650	.400	.650
M38	114	.075	.075	.075	.125	.125	.125	.063	.125	.125	.063	.125	.063	.400	.400	.400
M39	115	0.	.075	.125	.063	0.	.063	.063	.125	.031	.094	.125	.094	0.	.650	0.
M39	116	.075	.100	.125	.125	.125	.125	.188	.188	.063	.125	.125	.094	.650	1.000	.400
M39	117	.075	.075	.125	.094	.063	.063	.125	.125	.063	.094	.125	.063	.400	1.000	.400
M39	118	0.	0.	.125	.063	.063	.125	.094	.125	.063	.094	.125	.063	0.	.400	.100
M39	119	.025	.060	0.	.063	.031	.063	.094	.125	.031	.094	.188	.031	.100	.400	.100
M40	120	.075	0.	.125	.063	.063	.063	.063	.125	.031	.063	.125	.031	.400	1.000	1.000
M40	121	0.	.125	0.	.125	.125	.063	.125	.125	.063	.125	.125	.063	.400	1.000	1.000
M40	122	.075	.100	.125	.125	.125	.063	.125	.125	.125	.125	.125	.125	.650	1.000	1.000
M40	123	.050	.075	.125	.063	.063	.063	.063	.125	.063	.063	.063	.063	.550	1.000	1.000
M41	124	.100	.050	0.	.063	.063	.063	.094	.125	.063	.063	.063	.063	.400	.400	.100
M41	125	.075	.050	.060	.063	.063	.063	.063	.063	.063	.094	.063	.063	.400	.650	0.
M41	126	.025	.100	.060	.125	.094	.125	.156	.125	.094	.094	.063	.063	.650	.400	.650
M41	127	.025	.100	.060	.125	.094	.125	.125	.125	.094	.125	.063	.063	.100	1.000	.650
M42	128	.275	.300	.250	.375	.250	.250	.250	.250	.250	.125	.063	.156	.650	1.000	1.000
M43	129	.275	.275	.375	.250	.313	.313	.344	.313	.250	.156	.250	.125	.650	1.000	.650
M43	130	.275	.300	.375	.250	.313	.313	.313	.313	.250	.125	.250	.125	1.000	1.000	.650
M44	131	.150	.100	.125	.063	.125	0.	.063	.125	.063	.063	.063	.063	.400	.650	1.000
M44	132	0.	0.	0.	.063	.063	0.	.031	.063	.031	.063	.063	.063	0.	0.	.100
M45	133	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M45	134	0.	0.	.125	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M45	135	.175	.125	.125	.125	.094	.125	.094	.125	.063	.094	.063	.063	.400	1.000	.400
M49	136	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M49	137	.100	.125	0.	.125	.094	.125	.125	.125	.063	.094	.063	.063	.400	1.000	.650
M49	138	0.	0.	0.	0.	.063	.063	.063	.063	.031	.063	.063	.031	0.	0.	.100
M49	139	0.	0.	0.	.063	.063	.063	.063	.063	.031	.031	.063	.031	0.	0.	.100
M49	140	0.	0.	0.	.063	.063	.063	.031	.063	.031	.063	.031	.031	.100	0.	0.
M49	141	.100	.100	.125	.125	.125	.125	.125	.063	.063	.094	.063	.094	.650	1.000	.400

Table 15.- Continued

M50	142	.125	.125	.125	.125	.125	.125	.063	.125	.125	.063	.125	.063	.650	1.000	1.000
M50	143	.075	.100	.125	.063	.125	.063	.063	.125	.063	.063	.125	.063	.400	0.	.400
M50	144	.075	.075	.125	.063	.125	.063	.063	.125	.063	.063	.063	.063	.650	.650	.400
M50	145	.075	.100	.125	.063	.125	.063	.063	.125	.063	.063	.125	.063	.400	.650	.400
M50	146	0.	.100	.125	.063	.125	.063	.063	.125	.063	.063	.063	.063	.400	.400	0.
M50	147	.100	.125	.125	.125	.125	.125	.063	.125	.125	.063	.125	.094	.650	1.000	1.000
M51	148	.100	.100	.125	.063	.125	.063	.063	.125	.063	.063	.063	.031	.400	1.000	.400
M51	149	0.	0.	0.	0.	0.	0.	.031	0.	0.	.031	0.	0.	0.	0.	0.
M52	150	.100	.100	.060	.125	.125	.063	.031	.125	.125	.031	.125	.125	.650	1.000	1.000
M53	151	0.	0.	0.	0.	0.	0.	0.	0.	.031	0.	0.	.031	.400	0.	0.
M53	152	.100	.110	.125	.125	.094	.125	.125	.125	.063	.094	.063	.063	.400	1.000	.650
M53	153	0.	0.	0.	0.	0.	0.	.094	.063	0.	.063	.125	0.	.400	1.000	.650
M54	154	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M54	155	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.400	0.
M54	156	.100	.100	.060	.125	.125	.063	0.	.125	.063	0.	.063	.063	.650	.650	.650
M55	157	.100	0.	0.	.063	0.	0.	.063	.063	.063	.063	.063	.031	.650	1.000	1.000
M55	158	0.	0.	0.	0.	0.	0.	.031	.031	0.	.031	.031	0.	0.	0.	.400
M55	159	.100	0.	0.	.063	.125	.063	.063	.063	.063	.063	.063	.031	.400	1.000	0.
M56	160	.500	.500	.500	.500	.500	.500	.563	.563	.375	.125	.188	.188	.650	1.000	.650
M56	161	.500	.500	.500	.500	.500	.500	.563	.563	.500	.125	.313	.188	1.000	1.000	.650
M57	162	.350	.350	.375	.375	.313	.313	.375	.375	.250	.125	.250	.156	.650	1.000	.650
M57	163	.350	.350	.375	.375	.313	.313	.375	.375	.250	.125	.188	.156	.650	1.000	.650
M57	164	.350	.350	.375	.375	.313	.375	.375	.375	.375	.125	.250	.188	1.000	1.000	1.000
M58	165	.500	.500	.500	.500	.500	.500	.563	.563	.500	.188	.188	.125	.650	1.000	1.000
M58	166	.500	.575	.500	.563	.563	.500	.625	.625	.500	.156	.188	.125	1.000	1.000	1.000
M58	167	.500	.500	.500	.500	.500	.500	.594	.625	.500	.156	.188	.125	1.000	1.000	1.000
M59	168	.300	.350	.375	.375	.313	.313	.375	.375	.250	.125	.250	.188	1.000	1.000	.650
M59	169	.300	.350	.375	.375	.313	.313	.375	.375	.250	.125	.188	.188	1.000	1.000	.650
M59	170	.300	.375	.375	.313	.313	.313	.375	.313	.250	.125	.250	.188	1.000	1.000	.650
M60	171	0.	0.	0.	.063	.063	.094	.125	.094	.125	.094	.063	.125	0.	.400	.400
M60	172	0.	0.	0.	.125	.063	.094	.125	.125	.125	.125	.125	.125	.400	.650	.650
M60	173	.175	0.	.125	.063	.063	.094	.094	.094	.125	.125	.125	.125	.400	.650	1.000
M60	174	.200	.200	.375	.188	.156	.188	.188	.188	.125	.125	.125	.188	.650	1.000	1.000
M60	175	0.	0.	0.	.031	0.	0.	.063	.063	.063	.063	.125	.063	0.	0.	.400
M61	176	.275	.325	.375	.375	.313	.313	.375	.313	.250	.156	.125	.188	.650	1.000	.650
M61	177	.250	.325	.375	.375	.313	.313	.375	.313	.250	.125	.188	.188	.650	1.000	.650
M61	178	.250	.325	.375	.375	.313	.313	.375	.375	.250	.125	.188	.188	.650	1.000	.650
M62	179	.500	.500	.500	.500	.500	.500	.500	.563	.500	.125	.250	.250	1.000	1.000	1.000
M62	180	0.	0.	0.	.125	.125	.125	.188	.188	.125	.125	.188	.125	.400	1.000	1.000
M62	181	0.	0.	0.	.125	.094	0.	.313	.094	.125	.094	.063	.125	.400	1.000	1.000
M62	182	.150	0.	.125	.188	.188	0.	.313	.125	.125	.125	.125	.125	.650	1.000	0.
M62	183	0.	0.	0.	.063	.031	0.	.063	.094	.125	.094	.125	.125	.400	.400	.400
M62	184	0.	0.	0.	0.	.031	0.	.063	0.	.125	.094	0.	.063	.650	0.	1.000
M63	185	.325	.350	.375	.375	.375	.375	.375	.375	.250	.125	.188	.188	1.000	1.000	.650
M63	186	.275	.400	0.	.313	.313	.375	.375	.375	.250	.125	.250	.188	1.000	1.000	.650
M63	187	.325	.350	.375	.375	.313	.375	.375	.375	.250	.125	.250	.188	.650	1.000	.650
M64	188	.350	.350	.375	.375	.313	.375	.125	.188	0.	.125	.250	0.	.650	0.	1.000
M64	189	.300	.325	.375	.313	.313	.375	.125	.188	0.	.094	.250	0.	.650	0.	1.000
M65	190	.500	.500	.500	.500	.500	.500	.563	.500	.375	.125	.250	.188	1.000	1.000	.650
M65	191	.500	.525	.500	.500	.500	.563	.500	.500	.375	.125	.313	.188	1.000	1.000	.650

Table 15.- Continued

M65	192	.500	.500	.500	.500	.500	.500	.500	.563	.375	.125	.250	.188	.650	1.000	.650
M66	193	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M67	194	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M68	195	.150	.150	0.	.250	.188	0.	.188	.188	.188	.125	.125	.125	1.000	1.000	1.000
M68	196	0.	0.	0.	0.	.063	0.	.063	.063	.063	.063	.125	.063	0.	.400	0.
M68	197	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M68	198	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M68	199	0.	.150	0.	0.	0.	0.	0.	.063	0.	0.	.125	0.	0.	0.	0.
M69	200	.525	.550	.500	.500	.500	.500	.563	.563	.500	.125	.125	.313	.650	1.000	1.000
M70	201	.300	.275	.250	.375	.250	.375	.250	.313	.250	.125	.063	.188	1.000	1.000	1.000
M70	202	.500	.500	.500	.500	.500	.500	.500	.500	.500	.125	.063	.188	1.000	1.000	1.000
M71	203	.400	.375	.375	.375	.375	.500	.375	.375	.375	.125	.125	.125	.650	1.000	1.000
M71	204	.350	.375	.375	.375	.375	.375	.375	.375	.375	.125	.125	.156	.650	1.000	1.000
M71	205	.350	.325	.375	.375	.375	.375	.375	.375	.375	.125	.125	.250	.650	1.000	1.000
M72	206	0.	.150	0.	.125	.125	.250	.125	.188	.125	.125	.063	.063	1.000	1.000	1.000
M73	207	0.	.150	0.	.125	.125	.125	.125	.125	.125	.125	.063	.125	.650	1.000	1.000
M73	208	.125	.100	.125	.188	.188	.250	.188	.125	.188	.125	.063	.125	.650	1.000	1.000
M74	209	0.	0.	.250	.188	.125	.250	.125	.125	.188	.125	.125	.094	1.000	1.000	1.000
M74	210	0.	0.	0.	.125	.125	.188	.125	.125	.125	.125	.125	.094	1.000	1.000	1.000
M74	211	0.	0.	0.	.125	.125	.250	.125	.125	.125	.125	.125	.094	1.000	1.000	1.000
M75	212	.100	.100	0.	.125	.188	.250	.125	.125	.125	.125	.125	.125	.650	1.000	1.000
M76	213	0.	0.	0.	.125	.125	.063	.125	.063	.063	.125	.063	.063	1.000	1.000	1.000
M76	214	.150	0.	0.	.125	.125	.188	.125	.125	.125	.125	.063	.063	1.000	1.000	1.000
M76	215	0.	0.	0.	.125	.125	.063	.125	.125	.125	.125	.063	.063	1.000	1.000	1.000
M76	216	0.	0.	0.	.188	.188	.188	.125	.125	.188	.125	.063	.063	1.000	1.000	1.000
M77	217	0.	.450	.500	.500	.500	.500	.500	.500	.500	.125	.125	.125	.650	1.000	1.000
M77	218	.450	.525	.500	.500	.500	.500	.563	.500	.500	.125	.125	.125	.650	1.000	1.000
M77	219	.500	.500	.500	.500	.500	.500	.500	.563	.500	.125	.125	.156	.650	1.000	1.000
M81	220	0.	0.	0.	.063	.063	.031	.031	.063	0.	.031	.063	0.	0.	.400	0.
M81	221	0.	0.	0.	.063	.125	.063	.063	.063	.063	.063	.063	.063	0.	.650	.400
M81	222	0.	.050	0.	.063	.125	.063	.063	.063	.063	.063	.063	.063	.400	.650	.400
M81	223	.150	.125	0.	.125	.188	.125	.125	.125	.125	.125	.063	.094	.650	1.000	1.000
M81	224	0.	0.	0.	0.	.125	.063	.125	.125	.125	.125	.063	.094	.100	1.000	0.
M81	225	0.	0.	.125	0.	0.	.031	.063	0.	.063	.063	0.	.031	.100	.400	.400
M82	226	0.	0.	0.	.063	0.	.063	0.	0.	.031	0.	0.	.031	0.	0.	0.
M82	227	0.	0.	0.	.125	.063	.063	.063	.063	.063	.063	.063	.031	.400	0.	0.
M82	228	0.	0.	0.	.063	.063	0.	.063	.063	.063	.125	.063	.031	.650	0.	.650
M82	229	0.	0.	0.	.125	.125	.125	.125	.125	.125	.125	.063	.063	.650	1.000	1.000
M82	230	.175	0.	0.	.125	.188	.250	.125	.125	.188	.125	.063	.094	1.000	1.000	1.000
M82	231	0.	0.	0.	.125	.063	.125	.125	.125	.125	.063	.063	.063	1.000	1.000	1.000
M83	232	0.	.125	0.	.063	.125	.063	.125	.125	.063	.125	.125	.031	.400	1.000	1.000
M83	233	0.	0.	.375	.125	.188	.125	.188	.125	.125	.125	.125	.094	.650	1.000	1.000
M83	234	0.	0.	0.	.125	.188	.125	.125	.125	.125	.125	.125	.094	.650	1.000	1.000
M83	235	0.	0.	.375	.125	.188	.125	.125	.125	.188	.125	.125	.125	.650	1.000	1.000
M83	236	.100	0.	0.	.063	.125	.063	.063	.125	.063	.063	.125	.063	.400	1.000	1.000
M83	237	0.	0.	0.	.063	.125	.063	.125	.125	.125	.125	.063	.094	.400	1.000	1.000
M84	238	0.	.150	.125	.125	.125	.250	.188	.188	.125	.063	.125	.094	.650	1.000	1.000
M84	239	.150	.175	.125	.188	.188	.250	.125	.250	.188	.125	.125	.094	1.000	1.000	1.000
M85	240	0.	0.	0.	.063	.125	.063	.063	.125	.063	.063	.063	.031	.400	.650	.400
M85	241	0.	0.	.375	.188	.188	.188	.125	.125	.125	.125	.125	.094	.650	1.000	1.000

Table 15.- Continued

M85	242	0.	0.	.375	.031	.125	.125	.125	.125	.125	.125	.125	.063	.650	1.000	1.000
M86	243	0.	0.	0.	.125	.125	.125	.125	.125	.125	.031	.063	.031	1.000	1.000	1.000
M86	244	.150	0.	0.	.125	.125	.125	.125	.125	.125	.063	.063	.063	1.000	1.000	1.000
M86	245	0.	0.	0.	.063	.063	.063	.063	.125	.063	.063	.063	.063	1.000	1.000	.650
M86	246	0.	0.	0.	.125	.125	.250	.125	.125	.188	.125	.063	.094	1.000	1.000	1.000
M87	247	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M87	248	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M88	249	.175	.175	.125	.188	.125	.313	.125	.125	.250	.063	.125	.094	1.000	1.000	.650
M88	250	0.	0.	.375	0.	.031	0.	0.	0.	.031	0.	0.	.031	0.	0.	0.
M88	251	0.	0.	0.	.063	.063	.063	.063	.063	.063	.063	.063	.063	.650	1.000	.400
M89	252	.250	.300	.375	.375	.375	.031	.375	.375	.375	.125	.188	.125	.650	1.000	1.000
M89	253	.350	.325	.375	.375	.313	.313	.375	.375	.375	.125	.188	.125	1.000	1.000	1.000
M90	254	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M91	255	.500	.475	.500	.500	.500	.500	.500	.563	.500	.125	.125	.188	1.000	1.000	1.000
M92	256	.600	.500	.500	.500	.563	.500	.500	.500	.500	.125	.125	.125	1.000	1.000	1.000
M92	257	.400	.425	.375	.500	.500	.500	.500	.500	.500	.125	.125	.094	1.000	1.000	1.000
M92	258	.500	.450	.375	.500	.500	.500	.500	.500	.500	.125	.500	.094	1.000	1.000	1.000
M93	259	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M94	260	.300	0.	.375	.375	.313	.375	.313	.375	.375	.063	.125	.094	1.000	1.000	1.000
M94	261	0.	0.	.375	.375	.313	.775	.313	.375	.375	.063	.125	.094	1.000	1.000	1.000
M94	262	0.	0.	.375	.250	.313	.375	.313	.250	.375	.063	.125	.094	1.000	1.000	1.000
M95	263	.500	.500	.500	.625	.500	.750	.500	.563	.500	.125	.188	.094	1.000	1.000	1.000
M96	264	.375	.300	.375	.375	.313	.375	.500	.313	.375	.063	.125	.094	1.000	1.000	1.000
M96	265	.375	.275	.375	.500	.500	.500	.313	.500	.500	.063	.125	.094	1.000	1.000	1.000
M97	266	.325	.300	0.	.313	.313	.313	.375	.375	.250	.125	.188	.125	.650	1.000	1.000
M97	267	.250	.275	.375	.313	.313	.313	.313	.313	.375	.125	.188	.125	.650	1.000	1.000
M97	268	.325	.300	.375	.250	.313	.313	.344	.375	.375	.125	.188	.125	1.000	1.000	1.000
M98	269	.200	.225	0.	.125	.125	.156	.125	.125	.125	.094	.125	.125	.650	1.000	1.000
M98	270	0.	0.	0.	.063	.094	.094	.156	.063	.250	.125	.125	.125	.400	.650	1.000
M98	271	0.	0.	0.	.063	.094	.125	.125	.125	0.	.125	.125	0.	.400	1.000	1.000
M98	272	0.	0.	0.	.063	.094	.094	.094	.125	0.	.063	.125	0.	.400	1.000	1.000
M99	273	.550	.525	.500	.500	.500	.563	.563	.625	.500	.156	.188	.125	1.000	1.000	1.000
M99	274	.650	.600	.625	.625	.625	.625	.688	.625	.500	.125	.188	.125	.650	1.000	1.000
M99	275	.500	.490	.500	.500	.500	.500	.500	.563	.500	.125	.156	.125	.650	1.000	1.000
M100	276	0.	0.	0.	.063	.063	.094	0.	.125	.125	0.	.125	.125	.400	1.000	1.000
M100	277	.175	.175	.250	.188	.156	.188	.156	.188	.125	.063	.125	.125	.400	1.000	1.000
M100	278	0.	0.	0.	.063	.063	.063	.125	.125	.125	.031	.125	.125	.400	1.000	1.000
M100	279	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
M100	280	0.	0.	0.	.063	.063	.063	0.	.094	.125	0.	.063	.125	.100	.650	1.000
M101	281	0.	0.	0.	.125	.125	.063	.125	.125	.125	.125	.125	.125	.400	1.000	1.000
M101	282	0.	0.	.125	.094	.094	.063	.063	.125	.125	.063	.125	.125	.400	1.000	1.000
M101	283	.150	.200	.125	.063	.063	.125	.188	.188	.125	.125	.125	.125	.650	1.000	1.000
M101	284	.150	.200	.125	.063	.063	.125	.125	.250	.125	.125	.188	.125	.650	1.000	1.000
M102	285	0.	0.	0.	.125	.094	.125	.063	.125	.125	.063	.125	.125	.400	1.000	1.000
M102	286	0.	0.	0.	.063	.063	.125	.125	.063	.125	.094	.125	.125	.400	1.000	1.000
M102	287	.200	0.	.250	.250	.188	.188	.188	.188	.125	.125	.188	.125	.650	1.000	1.000
M103	288	.300	.350	.375	.313	.313	.375	.375	.375	.375	.125	.188	.125	1.000	1.000	1.000
M103	289	.300	.350	.375	.313	.313	.375	.094	.375	.375	.063	.188	.125	.650	1.000	1.000
M103	290	.300	.350	.375	.313	.313	.375	.375	.375	.375	.125	.188	.125	.650	1.000	1.000
M104	291	.175	.175	.375	.188	.188	.188	.250	.188	.125	.094	.125	.125	.650	1.000	1.000

Table 15.- Continued

M104	292	0.	.350	.125	.125	.094	.125	.125	.188	.125	.125	.125	.125	.400	1.000	1.000
M105	293	.325	.300	.375	.313	.313	.313	.313	.375	.375	.125	.188	.125	1.000	1.000	1.000
M105	294	.300	.375	.375	.375	.375	.375	.375	.375	.375	.125	.188	.125	.650	1.000	1.000
M105	295	.400	.400	.375	.438	.375	.375	.438	.438	.500	.125	.188	.125	.650	1.000	1.000
M106	296	.500	.525	.500	.500	.500	.625	.563	.625	.500	.125	.188	.125	1.000	1.000	1.000
M106	297	.500	.500	.500	.500	.500	.625	.563	.625	.500	.125	.188	.125	1.000	1.000	1.000
M107	298	0.	.100	.375	.125	.188	.250	.125	.188	.188	.063	.125	.094	1.000	1.000	1.000
M108	299	.500	.500	.500	.500	.500	.563	.563	.563	0.	.125	.188	0.	.650	1.000	1.000
M108	300	.500	.520	.500	.500	.500	.563	.563	.625	0.	.125	.188	0.	.650	1.000	1.000
M108	301	.500	.525	.500	.563	.500	.563	.625	.625	0.	.094	.125	0.	1.000	1.000	1.000
M110	302	.250	.300	.375	.313	.313	.375	.438	.375	.125	.125	.156	.125	.650	1.000	1.000
M113	303	0.	0.	0.	.063	.031	0.	.063	.125	.125	.063	.125	.063	0.	.650	0.
M113	304	0.	0.	0.	.031	.031	.063	0.	0.	.125	0.	0.	.063	0.	.650	0.
M113	305	0.	0.	0.	.063	.063	0.	.063	.094	.125	.094	.125	.125	.400	.650	1.000
M113	306	0.	0.	0.	.125	.125	.125	.125	.125	.125	.094	.188	.125	.400	.650	1.000
M113	307	0.	0.	0.	.125	.125	.125	.125	.125	.125	.094	.125	.125	.650	1.000	1.000
M113	308	0.	0.	0.	.125	.188	.125	.156	.250	.125	.125	.125	.125	1.000	1.000	1.000
M114	309	0.	0.	0.	.063	.031	.063	0.	.063	.125	0.	.094	.125	.400	.650	.400
M114	310	0.	0.	0.	.063	.031	.250	0.	.063	.125	0.	.063	.125	.100	.400	0.
M114	311	0.	0.	0.	.063	.063	.063	.094	.094	.125	.094	.125	.125	.400	1.000	1.000
M114	312	0.	0.	0.	.125	.125	.188	.188	.188	.125	.125	.125	.125	.400	1.000	1.000
M114	313	0.	0.	0.	.063	.063	.125	.125	.125	.125	.125	.125	.125	.400	1.000	1.000
M114	314	.100	.075	.060	.188	.125	.125	.125	.125	.125	.125	.125	.125	.650	1.000	1.000
M115	315	0.	0.	0.	.063	.063	.125	.063	.125	0.	.094	.063	0.	.400	.400	.650
M115	316	.100	0.	0.	.188	.125	.125	.063	.188	0.	.031	.125	0.	.400	1.000	1.000
M115	317	0.	0.	.125	.125	.125	.125	.094	.125	0.	.094	.094	0.	.650	1.000	1.000
M115	318	0.	0.	.125	.125	.125	.125	.125	.125	.125	.063	.125	.125	.650	1.000	1.000
M115	319	.100	.125	.125	.125	.094	.125	.125	.125	.125	.094	.125	.125	.400	1.000	1.000
M115	320	0.	0.	0.	.063	.063	0.	.063	.094	.125	.125	.125	.125	.100	.650	1.000
M116	321	0.	0.	0.	.125	.063	.125	.094	.125	.063	.094	.094	.125	.400	1.000	1.000
M116	322	.075	0.	0.	.188	.125	.188	.188	.125	0.	.125	.156	0.	.650	1.000	1.000
M116	323	0.	-.100	0.	.125	.125	.125	.125	.094	0.	.125	.125	0.	.650	1.000	1.000
M116	324	.125	.100	.125	.188	.188	.188	.219	.188	0.	.125	.125	0.	.400	1.000	1.000
M117	325	.150	0.	.375	.125	.125	.250	.125	.125	.125	.125	.063	.094	1.000	.650	1.000
M117	326	0.	0.	0.	.125	.125	.125	.125	.125	.063	.125	.063	.063	1.000	.650	1.000
M118	327	.100	.100	.060	.125	.125	.188	.125	.125	.063	.094	.125	.063	.400	1.000	1.000
M118	328	0.	0.	0.	.125	.094	.125	.125	.125	.375	.125	.188	.125	.650	1.000	1.000

Table 16.- Actual Crack Data, General Dynamics Panels

PANEL NO.	CRACK NO.	CRACK LENGTH	CRACK DEPTH	INITIAL FINISH	INITIAL THICKNESS	FINAL FINISH	FINAL THICKNESS	CRACK POSITION X	CRACK POSITION Y	FAILURE LOAD	A/T INIT	A/T FINAL	A/2C	LINE
A1	401	.022	.007	55	.0860	55	.0860	2.00	7.50	0	.081	.081	.318	1
A1	402	.111	.034	55	.0860	55	.0860	3.00	6.00	0	.395	.395	.306	2
A2	403	.034	.007	62	.0807	62	.0807	3.00	10.50	0	.087	.087	.206	3
A2	404	.288	.034	62	.0807	62	.0807	2.00	8.50	0	.421	.421	.118	4
A2	405	.290	.036	62	.0807	62	.0807	1.50	7.00	0	.446	.446	.124	5
A3	406	.068	.016	32	.0827	32	.0827	2.50	5.50	0	.193	.193	.235	6
A5	407	.352	.042	21	.0872	21	.0872	1.50	9.50	0	.482	.482	.119	7
A5	408	.362	.044	21	.0872	21	.0872	2.50	8.00	0	.505	.505	.122	8
A5	409	.098	.036	21	.0872	21	.0872	1.50	6.00	0	.413	.413	.367	9
A5	410	.086	.029	21	.0872	21	.0872	3.00	5.00	0	.333	.333	.337	10
A4	411	.090	.024	44	.0816	44	.0816	1.50	10.00	0	.294	.294	.267	11
A4	412	.173	.022	44	.0816	44	.0816	2.50	7.50	0	.270	.270	.127	12
A6	413	.084	.021	243	.0812	243	.0812	3.00	11.00	0	.259	.259	.250	13
A6	414	.104	.021	243	.0812	243	.0812	1.00	8.50	0	.259	.259	.202	14
A6	415	.064	.014	243	.0812	243	.0812	3.00	8.50	0	.172	.172	.219	15
A6	416	.352	.042	243	.0812	243	.0812	2.00	7.50	0	.517	.517	.119	16
A6	417	.334	.040	243	.0812	243	.0812	2.50	6.00	0	.493	.493	.120	17
A7	418	.059	.015	92	.0834	92	.0834	1.50	10.00	0	.180	.180	.254	18
A8	419	.048	.008	247	.0834	247	.0834	1.00	11.00	0	.096	.096	.167	19
A8	420	.069	.018	247	.0834	247	.0834	2.50	10.00	0	.216	.216	.261	20
A8	421	.372	.046	247	.0834	247	.0834	2.50	7.50	0	.552	.552	.124	21
A8	422	.089	.020	247	.0834	247	.0834	2.00	5.00	0	.240	.240	.225	22
A9	423	.075	.023	17	.0849	17	.0849	1.50	11.00	0	.271	.271	.307	23
A9	424	.362	.046	17	.0849	17	.0849	2.50	8.50	0	.542	.542	.127	24
A9	425	.078	.021	17	.0849	17	.0849	3.00	5.00	0	.247	.247	.269	25
A10	426	.080	.022	47	.0826	47	.0826	1.50	8.50	0	.266	.266	.275	26
A11	427	.085	.029	250	.0846	250	.0846	1.00	10.50	0	.343	.343	.341	27
A11	428	.356	.054	250	.0846	250	.0846	1.50	8.50	0	.638	.638	.152	28
A11	429	.069	.021	250	.0846	250	.0846	3.00	5.50	0	.248	.248	.304	29
A12	430	.085	.019	237	.0826	237	.0826	2.50	5.50	0	.230	.230	.224	30
A14	431	.027	.005	16	.0796	16	.0796	0.	0.	0	.063	.063	.185	31
A14	432	.318	.036	16	.0796	16	.0796	3.00	8.00	0	.452	.452	.113	32
A15	433	.075	.021	16	.0870	16	.0870	3.00	11.00	0	.241	.241	.280	33
A15	434	.085	.024	16	.0870	16	.0870	1.00	10.00	0	.276	.276	.282	34
A15	435	.094	.027	16	.0870	16	.0870	1.50	8.50	0	.310	.310	.287	35
A15	436	.384	.046	16	.0870	16	.0870	2.50	6.50	0	.529	.529	.120	36
A16	437	.081	.026	43	.0849	43	.0849	1.00	11.00	0	.306	.306	.321	37
A16	438	.091	.036	43	.0849	43	.0849	2.50	11.00	0	.424	.424	.396	38
A16	439	.036	.014	43	.0849	43	.0849	1.00	8.50	0	.165	.165	.389	39
A16	440	.372	.046	43	.0849	43	.0849	2.50	7.50	0	.542	.542	.124	40
A16	441	.326	.044	43	.0849	43	.0849	2.50	6.00	0	.518	.518	.135	41
A18	442	.096	.025	37	.0864	37	.0864	1.50	11.00	0	.289	.289	.260	42
A18	443	.065	.017	37	.0864	37	.0864	1.50	9.00	0	.197	.197	.262	43
A18	444	.064	.013	37	.0864	37	.0864	2.00	7.00	0	.150	.150	.203	44
A18	445	.089	.022	37	.0864	37	.0864	3.00	5.00	0	.255	.255	.247	45
A20	446	.197	.012	170	.0734	170	.0734	1.50	8.50	0	.163	.163	.061	46
A21	447	.129	.040	77	.0871	77	.0871	1.00	10.50	0	.459	.459	.310	47
A21	448	.370	.046	77	.0871	77	.0871	2.50	9.00	0	.528	.528	.124	48
A21	449	.081	.019	77	.0871	77	.0871	2.00	8.00	0	.218	.218	.235	49
A21	450	.370	.048	77	.0871	77	.0871	2.00	6.50	0	.551	.551	.130	50
A21	451	.067	.024	77	.0871	77	.0871	1.50	5.50	0	.276	.276	.358	51
A23	452	.342	.044	92	.0872	92	.0872	2.50	5.50	0	.505	.505	.129	52
A24	453	.062	.013	41	.0798	41	.0798	2.00	9.50	0	.163	.163	.210	53
A24	454	.340	.036	41	.0798	41	.0798	2.50	9.00	0	.451	.451	.106	54
A24	455	.069	.015	41	.0798	41	.0798	1.50	8.00	0	.188	.188	.217	55
A24	456	.296	.025	41	.0798	41	.0798	2.00	7.00	0	.326	.326	.088	56

Table 16. - Continued

B1	501	.478	.128	35	.2098	35	.2098	2.00	9.50	0	.610	.610	.268	57
B1	502	.510	.094	35	.2098	35	.2098	2.00	7.50	0	.448	.448	.184	58
B1	503	.116	.030	35	.2098	35	.2098	3.00	5.50	0	.143	.143	.259	59
B2	504	.118	.031	192	.2150	192	.2150	1.00	11.00	0	.144	.144	.263	60
B2	505	.109	.027	192	.2105	192	.2105	3.00	11.00	0	.128	.128	.248	61
B2	506	.472	.124	192	.2105	192	.2105	2.00	9.50	0	.589	.589	.263	62
B2	507	.504	.094	192	.2105	192	.2105	1.50	7.50	0	.447	.447	.187	63
B2	508	.512	.090	192	.2105	192	.2105	3.00	6.00	0	.428	.428	.176	64
B3	509	.512	.094	43	.2064	43	.2064	2.00	12.00	0	.455	.455	.184	65
B3	510	.134	.037	43	.2064	43	.2064	3.00	10.50	0	.179	.179	.276	66
B3	511	.458	.084	43	.2064	43	.2064	3.00	9.00	0	.407	.407	.183	67
B3	512	.458	.090	43	.2064	43	.2064	1.00	8.00	0	.436	.436	.197	68
B3	513	.498	.088	43	.2064	43	.2064	2.50	4.50	0	.426	.426	.177	69
B4	514	.444	.080	230	.2113	230	.2113	2.50	10.50	0	.379	.379	.180	70
B4	515	.465	.096	230	.2113	230	.2113	1.00	8.50	0	.454	.454	.206	71
B4	516	.506	.094	230	.2113	230	.2113	3.00	6.00	0	.445	.445	.186	72
B5	517	.522	.108	45	.2202	45	.2202	2.00	9.00	0	.490	.490	.207	73
B6	518	.426	.054	63	.2108	63	.2108	1.50	10.00	0	.256	.256	.127	74
B6	519	.474	.114	63	.2108	63	.2108	2.50	8.50	0	.541	.541	.241	75
B6	520	.123	.033	63	.2108	63	.2108	1.00	7.50	0	.157	.157	.268	76
B6	521	.143	.043	63	.2108	63	.2108	2.50	5.50	0	.204	.204	.301	77
B7	522	.490	.144	82	.2237	82	.2237	1.50	8.50	0	.644	.644	.294	78
B7	523	.149	.054	82	.2237	82	.2237	3.00	7.00	0	.241	.241	.362	79
B9	524	.534	.110	153	.2254	153	.2254	2.00	10.00	0	.488	.488	.206	80
B9	525	.190	.064	150	.2254	150	.2254	2.00	7.50	0	.284	.284	.337	81
B9	526	.470	.098	153	.2254	153	.2254	3.00	7.00	0	.435	.435	.209	82
B9	527	.157	.058	153	.2254	153	.2254	1.50	5.50	0	.257	.257	.369	83
B10	528	.460	.064	50	.2235	50	.2235	2.50	8.50	0	.286	.286	.139	84
B10	529	.478	.080	50	.2235	50	.2235	1.50	7.50	0	.358	.358	.167	85
B11	530	.520	.114	54	.2248	54	.2248	2.00	9.00	0	.507	.507	.219	86
B12	531	.478	.085	193	.2243	193	.2243	1.50	8.50	0	.383	.383	.180	87
B13	532	.144	.052	66	.2224	66	.2224	2.00	7.00	0	.234	.234	.361	88
B13	533	.526	.105	66	.2224	66	.2224	3.00	6.50	0	.477	.477	.202	89
B14	534	.124	.034	37	.2102	37	.2102	3.00	11.00	0	.162	.162	.274	90
B14	535	.508	.092	37	.2102	37	.2102	1.50	10.00	0	.438	.438	.181	91
B14	536	.492	.130	37	.2102	37	.2102	2.50	9.00	0	.618	.618	.264	92
B14	537	.474	.128	37	.2102	37	.2102	1.50	8.00	0	.609	.609	.270	93
B14	538	.524	.092	37	.2102	37	.2102	1.00	6.00	0	.438	.438	.176	94
B15	539	.145	.053	27	.2199	27	.2199	3.00	7.00	0	.241	.241	.366	95
B17	540	.121	.035	34	.2126	34	.2126	3.00	10.50	0	.165	.165	.289	96
B17	541	.482	.136	34	.2126	34	.2126	1.50	9.00	0	.640	.640	.282	97
B17	542	.442	.056	34	.2126	34	.2126	2.50	8.00	0	.263	.263	.127	98
B17	543	.506	.092	34	.2126	34	.2126	2.00	6.00	0	.433	.433	.182	99
B18	544	.530	.108	35	.2223	35	.2223	2.50	10.00	0	.486	.486	.204	100
B18	545	.512	.104	35	.2223	35	.2223	2.00	7.50	0	.468	.468	.203	101
B18	546	.496	.116	35	.2223	35	.2223	3.00	7.00	0	.522	.522	.234	102
B18	547	.144	.050	35	.2223	35	.2223	1.50	6.00	0	.225	.225	.347	103
B20	548	.534	.108	30	.2196	30	.2196	2.50	11.00	0	.492	.492	.202	104
B20	549	.478	.126	30	.2196	30	.2196	1.50	9.50	0	.574	.574	.264	105
B20	550	.530	.106	30	.2196	30	.2196	2.00	8.00	0	.483	.483	.200	106
B20	551	.143	.043	30	.2196	30	.2196	1.50	7.00	0	.196	.196	.301	107
B20	552	.124	.038	30	.2196	30	.2196	3.00	5.50	0	.173	.173	.306	108
B21	553	.534	.106	90	.2959	90	.2959	2.50	10.00	0	.358	.358	.199	109
B21	554	.140	.053	90	.2959	90	.2959	2.00	7.50	0	.179	.179	.379	110
B21	555	.520	.106	90	.2959	90	.2959	2.00	6.00	0	.358	.358	.204	111
B22	556	.135	.045	27	.2228	27	.2228	1.50	10.00	0	.202	.202	.333	112
B22	557	.550	.110	27	.2228	27	.2228	2.50	8.00	0	.494	.494	.200	113
B22	558	.137	.048	27	.2228	27	.2228	1.00	5.50	0	.215	.215	.350	114
B24	559	.538	.112	223	.2263	223	.2263	1.00	9.00	0	.495	.495	.208	115
B24	560	.144	.055	223	.2263	223	.2263	2.00	7.50	0	.243	.243	.382	116

Table 17.- Tabulation of Nondestructive Test Observations, General Dynamics Panels

X-RAY MEASUREMENTS

A 1	401	.300	.330	.275	A 1	402	0.	0.	0.
A 2	403	0.	0.	0.	A 2	404	.200	.175	.200
A 2	405	.250	.250	.225	A 3	406	0.	0.	0.
A 5	407	.250	.200	.250	A 5	408	.275	.300	.225
A 5	409	0.	0.	0.	A 5	410	0.	0.	0.
A 4	411	0.	0.	0.	A 4	412	0.	0.	0.
A 6	413	0.	0.	0.	A 6	414	0.	0.	0.
A 6	415	0.	0.	0.	A 6	416	0.	0.	.275
A 6	417	0.	0.	0.	A 7	418	0.	0.	0.
A 8	419	0.	0.	0.	A 8	420	0.	0.	0.
A 8	421	0.	.250	0.	A 8	422	0.	0.	0.
A 9	423	0.	0.	0.	A 9	424	.200	0.	0.
A 9	425	0.	0.	0.	A10	426	0.	0.	0.
A11	427	0.	0.	0.	A11	428	.350	.300	.300
A11	429	0.	0.	0.	A12	430	0.	.075	0.
A14	431	0.	0.	0.	A14	432	.300	.250	.275
A15	433	0.	0.	0.	A15	434	0.	0.	0.
A15	435	0.	.125	0.	A15	436	0.	.250	.085
A16	437	0.	0.	0.	A16	438	0.	0.	0.
A16	439	0.	0.	0.	A16	440	0.	.250	.300
A16	441	.275	0.	.275	A18	442	0.	0.	0.
A18	443	0.	0.	0.	A18	444	0.	0.	0.
A18	445	0.	0.	0.	A20	446	.200	.175	.200
A21	447	0.	0.	.100	A21	448	.250	.300	.300
A21	449	0.	0.	0.	A21	450	0.	.325	.350
A21	451	.350	0.	0.	A23	452	.300	.300	.250
A24	453	0.	0.	0.	A24	454	0.	0.	.175
A24	455	0.	0.	.300	A24	456	.125	0.	.125

ULTRASONIC MEASUREMENTS LENGTH

A 1	401	.250	.313	.250	A 1	402	.125	.125	.125
A 2	403	0.	0.	0.	A 2	404	.250	.250	.250
A 2	405	.250	.250	.313	A 3	406	.125	.063	.063
A 5	407	.125	.063	.094	A 5	408	.375	.125	.250
A 5	409	.125	.125	.063	A 5	410	.125	.094	.063
A 4	411	.125	.063	.094	A 4	412	.125	.063	.094
A 6	413	.125	.063	.063	A 6	414	.125	.125	.125
A 6	415	.125	.063	.063	A 6	416	.250	.125	.250
A 6	417	.250	.125	0.	A 7	418	.063	.063	.032
A 8	419	0.	0.	0.	A 8	420	0.	0.	0.
A 8	421	.375	.375	.313	A 8	422	0.	0.	0.
A 9	423	.125	.063	.188	A 9	424	.375	.375	.375
A 9	425	.125	.063	.188	A10	426	.125	.063	.500
A11	427	.125	.063	.063	A11	428	.375	.375	.375
A11	429	.125	.063	.063	A12	430	.063	.063	.063
A14	431	0.	0.	0.	A14	432	.375	.375	.313
A15	433	.125	.094	.063	A15	434	.125	.094	.063
A15	435	.125	.094	.125	A15	436	.375	.375	.313
A16	437	.125	.094	.094	A16	438	.125	.125	.094
A16	439	.125	.063	.063	A16	440	.375	.375	.313
A16	441	.375	.375	.250	A18	442	.125	.094	.063
A18	443	.125	.063	.032	A18	444	.125	.063	.063
A18	445	.125	.094	.125	A20	446	.125	.188	.375
A21	447	.125	.125	.063	A21	448	.375	.375	.375
A21	449	.125	.063	.063	A21	450	.375	.375	.375
A21	451	.125	.063	.063	A23	452	.375	.375	.375
A24	453	0.	0.	0.	A24	454	.375	.375	.375
A24	455	.063	0.	.063	A24	456	.250	.250	.313

PENETRANT MEASUREMENTS

A 1	401	.375	.344	.375	A 1	402	.125	.125	.063
A 2	403	0.	0.	0.	A 2	404	.375	.250	.313
A 2	405	.375	.250	.313	A 3	406	.063	.063	0.
A 5	407	.375	.313	.313	A 5	408	.375	.313	.313
A 5	409	.125	.094	.063	A 5	410	.125	.063	.063
A 4	411	.125	.094	.063	A 4	412	.125	.094	0.
A 6	413	0.	0.	.125	A 6	414	0.	.063	.063
A 6	415	0.	.063	.125	A 6	416	0.	.313	.313
A 6	417	0.	.313	.313	A 7	418	.063	.063	0.
A 8	419	0.	0.	0.	A 8	420	.063	.063	.063
A 8	421	.375	.375	.375	A 8	422	.125	.063	.125
A 9	423	.125	.094	.063	A 9	424	.375	.375	.375
A 9	425	.125	.063	.063	A10	426	.125	.094	.094
A11	427	.125	.094	.063	A11	428	.375	.313	.375
A11	429	0.	0.	0.	A12	430	.125	.063	.125
A14	431	0.	0.	0.	A14	432	.375	.250	.313
A15	433	.125	.063	.063	A15	434	.125	.063	.063
A15	435	.125	.063	.063	A15	436	.375	.313	.375
A16	437	.125	.063	.063	A16	438	.125	.063	.125
A16	439	.125	.032	.063	A16	440	.375	.375	.313
A16	441	.375	.250	.313	A18	442	0.	.094	0.
A18	443	0.	.094	0.	A18	444	0.	.063	0.
A18	445	0.	.063	0.	A20	446	.375	.250	.188
A21	447	0.	.063	.125	A21	448	0.	.250	.313
A21	449	0.	.032	0.	A21	450	0.	.313	.313
A21	451	0.	.032	.063	A23	452	.375	.250	.313
A24	453	.375	.063	0.	A24	454	0.	.375	.313
A24	455	0.	.063	0.	A24	456	0.	.313	.313

ULTRASONIC MEASUREMENTS DEPTH

A 1	401	.125	.094	.125	A 1	402	.125	.063	.125
A 2	403	0.	0.	0.	A 2	404	.125	.094	.125
A 2	405	.125	.125	.125	A 3	406	.125	.063	.063
A 5	407	.125	.375	.125	A 5	408	.125	.375	.125
A 5	409	.125	.094	.063	A 5	410	.125	.094	.063
A 4	411	.125	.125	.094	A 4	412	.125	.063	.094
A 6	413	.125	.063	.063	A 6	414	.125	.125	.125
A 6	415	.125	.063	.063	A 6	416	.125	.375	.188
A 6	417	.125	.375	0.	A 7	418	.063	.063	.032
A 8	419	0.	0.	0.	A 8	420	0.	0.	0.
A 8	421	.125	.125	.125	A 8	422	0.	0.	0.
A 9	423	.125	.063	.188	A 9	424	.125	.125	.125
A 9	425	.125	.063	.188	A10	426	.125	.063	.063
A11	427	.125	.063	.063	A11	428	.125	.125	.125
A11	429	.125	.063	.063	A12	430	.063	.063	.063
A14	431	0.	0.	0.	A14	432	.125	.125	.125
A15	433	.125	.094	.063	A15	434	.125	.094	.063
A15	435	.125	.094	.125	A15	436	.125	.125	.125
A16	437	.125	.094	.094	A16	438	.125	.094	.094
A16	439	.125	.063	.063	A16	440	.125	.125	.125
A16	441	.125	.125	.125	A18	442	.125	.094	.063
A18	443	.125	.063	.032	A18	444	.125	.063	.063
A18	445	.125	.094	.125	A20	446	.125	.125	.125
A21	447	.125	.125	.063	A21	448	.125	.125	.125
A21	449	.125	.063	.063	A21	450	.125	.125	.125
A21	451	.125	.063	.063	A23	452	.125	.125	.125
A24	453	0.	0.	0.	A24	454	.125	.125	.125
A24	455	.063	0.	.063	A24	456	.125	.125	.125

Table 17.- Continued

EDDY CURRENT MEASUREMENTS

A 1	401	.650	.750	.650	A 1	402	0.	.650	.650
A 2	403	0.	0.	0.	A 2	404	.650	.750	.650
A 2	405	0.	.750	.650	A 3	406	.650	0.	.400
A 5	407	.650	.750	.650	A 5	408	.650	.750	.650
A 5	409	.650	.750	.650	A 5	410	.650	.650	.650
A 4	411	0.	.100	1.000	A 4	412	.650	.100	1.100
A 6	413	.650	0.	0.	A 6	414	.650	.750	.650
A 6	415	0.	0.	0.	A 6	416	.650	.750	.650
A 6	417	.650	.750	.650	A 7	418	.650	0.	0.
A 8	419	0.	0.	0.	A 8	420	.650	.400	.650
A 8	421	.650	.750	.650	A 8	422	.650	.650	.650
A 9	423	.650	.400	.650	A 9	424	.650	.750	.650
A 9	425	0.	.400	.650	A10	426	.650	.400	.650
A11	427	.650	.750	.650	A11	428	.650	.750	.650
A11	429	0.	0.	0.	A12	430	.650	.750	.650
A14	431	0.	0.	0.	A14	432	.650	.750	.650
A15	433	.650	0.	.650	A15	434	.650	.750	.650
A15	435	.650	.750	.650	A15	436	.650	.750	.650
A16	437	.650	.750	.650	A16	438	.650	.750	.650
A16	439	.650	.750	.650	A16	440	.650	.750	.650
A16	441	.650	.750	.650	A18	442	.650	.750	.650
A18	443	.650	.750	.650	A18	444	0.	.650	.650
A18	445	.650	.750	.650	A20	446	.650	.650	.650
A21	447	.650	.750	.650	A21	448	.650	.750	.650
A21	449	.650	0.	.650	A21	450	.650	.750	.650
A21	451	.650	.750	.650	A23	452	.650	.750	.650
A24	453	0.	.400	.650	A24	454	.650	.750	.650
A24	455	.650	.750	.650	A24	456	0.	.750	.650

X-RAY MEASUREMENTS

B1	501	.450	.350	.375	B1	502	.325	.500	0.
B1	503	0.	0.	0.	B2	504	0.	0.	0.
B2	505	0.	0.	0.	B2	506	.425	.250	.350
B2	507	.325	0.	0.	B2	508	.375	.375	.350
B3	509	.375	0.	.200	B3	510	0.	0.	0.
B3	511	0.	0.	0.	B3	512	.400	0.	.275
B3	513	0.	0.	0.	B4	514	0.	0.	0.
B4	515	.300	.350	.250	B4	516	0.	.350	.350
B5	517	.475	.400	.475	B6	518	0.	0.	0.
B6	519	.425	.350	.325	B6	520	0.	0.	0.
B6	521	0.	0.	.325	B7	522	.375	.400	.425
B7	523	0.	0.	0.	B9	524	0.	0.	.060
B9	525	0.	0.	0.	B9	526	.275	0.	0.
B9	527	0.	0.	0.	B10	528	0.	0.	.325
B10	529	.350	.275	.400	B11	530	.425	.350	.450
B12	531	.375	0.	.425	B13	532	0.	0.	.375
B13	533	0.	.250	0.	B14	534	0.	0.	0.
B14	535	.350	.325	0.	B14	536	.450	.400	.400
B14	537	.450	.350	.375	B14	538	0.	0.	.150
B15	539	0.	0.	0.	B17	540	0.	0.	0.
B17	541	.425	.425	.425	B17	542	.200	0.	.300
B17	543	0.	0.	0.	B18	544	.475	.450	.325
B18	545	0.	0.	0.	B18	546	0.	0.	0.
B18	547	.450	.350	.375	B20	548	0.	0.	.325
B20	549	.325	.275	.375	B20	550	.450	.375	.400
B20	551	0.	0.	0.	B20	552	0.	0.	0.
B21	553	.325	.375	.250	B21	554	0.	0.	0.
B21	555	.425	.375	.450	B22	556	0.	0.	0.
B22	557	.425	.425	.425	B22	558	0.	0.	0.
B24	559	.385	.400	.350	B24	560	0.	0.	0.

Table 17. - Continued

PENETRANT MEASUREMENTS

B1	501	.500	.500	.500	B1	502	.500	.500	.500
B1	503	.125	.094	.125	B2	504	.125	.063	0.
B2	505	.125	.063	.125	B2	506	0.	.500	.500
B2	507	.375	.500	.500	B2	508	.375	.500	.500
B3	509	0.	.438	.500	B3	510	0.	.063	0.
B3	511	.500	.438	.500	B3	512	.500	.500	.500
B3	513	.500	.500	0.	B4	514	.500	.438	.500
B4	515	.500	.438	.500	B4	516	.500	.438	.500
B5	517	.500	.500	.500	B6	518	.125	.250	.375
B6	519	0.	.438	.500	B6	520	.125	.125	.125
B6	520	0.	.125	0.	B7	522	0.	.438	.500
B7	523	0.	0.	.125	B9	524	0.	.250	.500
B9	525	0.	.188	.188	B9	526	0.	.250	.500
B9	527	0.	.125	.094	B10	528	.500	.500	.500
B10	529	.500	.500	.500	B11	530	.500	.500	.500
B12	531	.500	.500	.500	B13	532	.500	0.	.125
B13	533	.500	.500	.500	B14	534	.125	.125	0.
B14	535	.500	.500	.500	B14	536	.500	.500	.500
B14	537	.500	.500	.500	B14	538	.500	.500	.500
B15	539	.125	0.	.125	B17	540	0.	.188	0.
B17	541	.500	.500	.500	B17	542	0.	.313	.500
B17	543	.500	.500	.500	B18	544	.500	.500	.500
B18	545	0.	.188	.125	B18	546	.500	.500	.500
B18	547	.500	.500	.500	B20	548	.500	.500	.500
B20	549	.500	.500	.500	B20	550	.500	.500	.500
B20	551	.125	.188	0.	B20	552	.125	.125	.125
B21	553	.375	.500	.500	B21	554	0.	.125	0.
B21	555	.375	.500	.125	B22	556	0.	.125	.125
B22	557	0.	.500	.500	B22	558	.125	.125	.125
B24	559	.500	.500	.500	B24	560	.125	.125	.125

ULTRASONIC MEASUREMENTS DEPTH

B1	501	.125	.125	.125	B1	502	.125	.125	.125
B1	503	.125	.063	.125	B2	504	.125	.063	.063
B2	505	.125	.063	.063	B2	506	.063	.125	.125
B2	507	.063	.125	.125	B2	508	.063	.125	.125
B3	509	.063	.063	.125	B3	510	0.	0.	.063
B3	511	.063	.063	.125	B3	512	.063	.063	.125
B3	513	.063	.125	.125	B4	514	.063	.063	.125
B4	515	.063	.125	.125	B4	516	.063	.125	.125
B5	517	.063	.063	.094	B6	518	.063	.063	.125
B6	519	.063	.063	.125	B6	520	.063	.063	.063
B6	521	.063	.063	.063	B7	522	.063	.063	.125
B7	523	.063	.063	.094	B9	524	.063	.094	.125
B9	525	.125	.063	.063	B9	526	.063	.094	.125
B9	527	.125	.063	.094	B10	528	.063	.125	.125
B10	529	.063	.125	.125	B11	530	.063	.063	.125
B12	531	.063	.063	.125	B13	532	0.	0.	.125
B13	533	.063	.125	.125	B14	534	.125	.125	.094
B14	535	.063	.125	.125	B14	536	.063	.063	.125
B14	537	.063	.125	.125	B14	538	.063	.125	.125
B15	539	.125	.094	.094	B17	540	.063	.125	.063
B17	541	.063	.125	.125	B17	542	.063	.094	.125
B17	543	.063	.125	.125	B18	544	.125	.094	.125
B18	545	.125	.094	.063	B18	546	.125	.094	.125
B18	547	.125	.063	.125	B20	548	.125	.094	.125
B20	549	.125	.125	.125	B20	550	.125	.125	.125
B20	551	.125	.094	.063	B20	552	.125	.125	.063
B21	553	.125	.125	.125	B21	554	.125	.063	.063
B21	555	.125	.094	.125	B22	556	.125	.094	.063
B22	557	.063	.094	.125	B22	558	.063	.094	.063
B24	559	.063	.094	.125	B24	560	0.	0.	.125

ULTRASONIC MEASUREMENTS LENGTH

B1	501	.500	.500	.500	B1	502	.500	.500	.500
B1	503	.125	.063	.125	B2	504	.125	.063	.063
B2	505	.125	.063	.063	B2	506	.500	.500	.500
B2	507	.500	.500	.500	B2	508	.500	.500	.500
B3	509	.500	.500	.500	B3	510	0.	0.	.063
B3	511	.500	.500	.500	B3	512	.500	.313	.500
B3	513	.500	.500	.500	B4	514	.500	.375	.500
B4	515	.500	.500	.500	B4	516	.500	.375	.500
B5	517	.375	.375	.438	B6	518	.500	.500	.500
B6	519	.500	.500	.500	B6	520	.063	.094	.063
B6	521	.063	.094	.063	B7	522	.500	.500	.500
B7	523	.125	.125	.094	B9	524	.500	.500	.500
B9	525	.250	.125	.188	B9	526	.500	.500	.500
B9	527	.125	.125	.094	B10	528	.500	.500	.500
B10	529	.500	.500	.500	B11	530	.500	.500	.500
B12	531	.500	.438	.500	B13	532	0.	0.	.500
B13	533	.500	.500	.500	B14	534	.125	.125	.094
B14	535	.500	.500	.500	B14	536	.500	.500	.500
B14	537	.500	.500	.500	B14	538	.500	.500	.500
B15	539	.125	.125	.094	B17	540	.125	.125	.125
B17	541	.500	.500	.500	B17	542	.500	.375	.500
B17	543	.500	.500	.500	B18	544	.500	.500	.500
B18	545	.125	.125	.063	B18	546	.500	.500	.500
B18	547	.500	.438	.500	B20	548	.500	.500	.500
B20	549	.500	.500	.500	B20	550	.500	.500	.500
B20	551	.125	.125	.063	B20	552	.125	.125	.063
B21	553	.500	.500	.500	B21	554	.125	.125	.063
B21	555	.500	.500	.500	B22	556	.125	.125	.063
B22	557	.500	.500	.500	B22	558	.125	.125	.063
B24	559	.500	.438	.500	B24	560	0.	0.	.125

EDDY CURRENT MEASUREMENTS

B1	501	.650	.750	.650	B1	502	.650	.750	.650
B1	503	0.	0.	.650	B2	504	.650	.750	.650
B2	505	.650	.750	.650	B2	506	.650	.750	.650
B2	507	.650	.750	.650	B2	508	.650	.750	.650
B3	509	0.	0.	.650	B3	510	.650	.750	.650
B3	511	.650	.750	.650	B3	512	.650	0.	.650
B3	513	.650	.750	.650	B4	514	.650	.750	.650
B4	515	.650	.750	.650	B4	516	.650	.750	.650
B5	517	.650	.750	.650	B6	518	.650	.750	.650
B6	519	.650	.750	.650	B6	520	.650	.750	.650
B6	521	0.	0.	.650	B7	522	.650	.750	0.
B7	523	.650	.750	.650	B9	524	.650	.750	.650
B9	525	.650	.750	.650	B9	526	.650	.750	.650
B9	527	.650	.750	.650	B10	528	.650	.750	.650
B10	529	.650	.750	.650	B11	530	.650	.750	.650
B12	531	.650	.750	.650	B13	532	0.	0.	0.
B13	533	.650	0.	.650	B14	534	.650	.750	.650
B14	535	.650	.750	.650	B14	536	.650	.750	.650
B14	537	0.	0.	.650	B14	538	.650	0.	.650
B15	539	.650	.750	.650	B17	540	.650	.750	.650
B17	541	.650	0.	.650	B17	542	.650	0.	1.000
B17	543	.650	0.	1.000	B18	544	.650	.750	.650
B18	545	0.	.750	.650	B18	546	.650	.750	.650
B18	547	.650	.750	.650	B20	548	.650	.750	.650
B20	549	.650	.750	.650	B20	550	.650	.750	.650
B20	551	.650	.750	.650	B20	552	.650	.750	.650
B21	553	.650	.750	.650	B21	554	.650	0.	.650
B21	555	.650	.750	.650	B22	556	.650	.750	.650
B22	557	.650	.750	.650	B22	558	.650	.750	.650
B24	559	.650	.750	.650	B24	560	.650	.750	.650

Table 18.- Tabulation of Holographic Test Observations

PANEL NUMBER	CRACK NUMBER	NO.1	NO.2
M1	1	.420	.100
M1	2	.170	.100
M1	3	.280	.100
M3	7	.100	0.
M3	8	0.	0.
M3	9	0.	0.
M5	13	.050	0.
M5	14	.050	0.
M5	15	0.	0.
M5	16	.050	0.
M7	20	.100	0.
M7	21	0.	0.
M9	28	.100	.100
M9	29	.100	.100
M9	30	.100	.100
M11	37	.100	.100
M11	38	.100	0.
M13	42	.050	0.
M13	43	.050	0.
M13	44	.050	0.
M15	48	.100	.100
M15	49	.120	.100
M15	50	.900	.100
M17	54	.100	0.
M21	55	.050	0.
M21	56	.050	0.
M21	57	.050	0.
M21	58	0.	0.
M23	64	0.	0.
M23	65	0.	0.
M23	66	0.	0.
M23	67	0.	0.
M31	82	.100	.100
M31	83	.100	.100
M31	84	.100	0.
M33	88	.050	0.
M33	89	.050	0.
M33	90	.050	0.
M33	91	0.	0.
M33	92	0.	0.
M34	93	.100	.100
M34	94	.100	.110
M35	95	0.	0.
M35	96	0.	0.
M35	97	0.	0.
M35	98	.050	0.
M35	99	.050	0.
M35	100	.050	0.
M37	107	.100	.100
M37	108	.100	.100
M37	109	.100	.100
M39	115	0.	0.
M39	116	.100	0.
M39	117	0.	0.
M39	118	0.	0.
M39	119	0.	0.
M41	124	0.	0.
M41	125	0.	0.
M41	126	.100	0.
M41	127	0.	0.
M43	129	.100	.100
M43	130	.100	.100
M45	133	.050	0.
M45	134	0.	0.
M45	135	.050	0.
M49	136	0.	0.
M49	137	.050	0.
M49	138	.050	0.
M49	139	0.	0.
M49	140	.050	0.
M49	141	.050	0.
M53	151	0.	0.
M53	152	.100	.100
M53	153	0.	0.
M56	160	.100	.100
M56	161	.100	.100
M57	162	.100	.100
M57	163	.100	.100
M57	164	.100	0.
M58	165	.100	.100
M58	166	.100	.150
M58	167	.100	.100
M59	168	.100	.100
M59	169	.100	.100
M59	170	0.	0.
M61	176	.100	.100
M61	177	.100	.100
M61	178	.100	0.
M62	179	.100	.100
M62	180	0.	0.
M62	181	0.	0.
M62	182	0.	0.
M62	183	0.	0.
M62	184	0.	0.
M63	185	.100	0.
M63	186	.100	0.
M63	187	.100	.100
M64	188	.100	.100
M64	189	.100	.100
M65	190	.100	.100
M65	191	.100	.100
M65	192	.100	.100
M66	193	.100	.100
M68	195	0.	0.
M68	196	0.	0.
M68	197	0.	0.
M68	198	0.	0.
M68	199	0.	0.
M87	247	.100	.100
M87	248	.100	.100
M89	252	.100	.100
M89	253	.100	0.
M97	265	.100	.100
M97	267	.100	0.
M97	268	.100	0.
M99	273	.100	.100
M99	274	.100	.100
M99	275	.100	.100
M101	281	0.	0.
M101	282	0.	0.
M101	283	.100	.050
M101	284	.100	0.
M103	288	.100	.100
M103	289	.100	.100
M103	290	.100	0.
M105	293	.100	0.
M105	294	.100	.100
M105	295	.100	0.
M108	299	.100	.100
M108	300	.100	.100
M108	301	.100	.100
M113	303	0.	0.
M113	304	0.	0.
M113	305	0.	0.
M113	306	.050	0.
M113	307	.050	0.
M113	308	0.	0.
M115	315	0.	0.
M115	316	0.	0.
M115	317	0.	0.
M115	318	0.	0.
M115	319	0.	0.
M115	320	0.	0.

Data Ordering

Actual crack data.- The data were ordered by panel and crack numbers in Table 12. Initial and final (after chemical milling) thicknesses and finishes, panel failure loads, the crack that initiated failure, initial and final crack depth-to-panel thickness (a/t) ratios, and crack depth-to-length ratios were calculated. The ordered actual values were then used as bases for all NDT analyses. Actual crack data were then divided into four groups:

1) Panels 1 thru 29 - Thin, smooth surface specimens;

2) Panels 30 thru 55 - Thin, rough surface specimens;

3) Panels 56 thru 86 - Thick, smooth surface specimens;

4) Panels 87 thru 118 - Thick rough surface specimens.

Actual values were then ordered by group according to the crack length and crack depth. These values were then used as bases for NDT analyses with respect to specimen thickness and surface finish.

Statistical Analysis of All Data

Analysis of data was oriented to demonstrate that current state-of-the-art NDT methods are capable of reliably detecting small, tightly closed cracks and to evaluate the influences of various surface finishes and proof stress loading on crack detection by NDT methods. The parameters of primary importance in the use of NDT detection data for fracture mechanics analysis are crack length, crack depth, crack depth-to-panel thickness ratio (size), and crack depth-to-crack length values for these parameters. Analysis was then directed to determine the flaw size that would be detected by NDT inspection with a high probability and confidence.

To establish the correct probability from the data available, traditional reliability methods were applied. Reliability is concerned with the probability that a failure will not occur when an inspection method is applied. One of the ways to measure reliability is to measure the number of chances for failure versus the number of successes. This ratio times 100% gives us the best estimate of reliability. This estimate is termed a point estimate and is independent of sample size.

For an operation such as nondestructive detection fatigue cracks, the reliability for large crack sizes would be expected to be high, while the reliability for small crack sizes would be expected to be low. To establish reasonable sample sizes to evaluate such cases, confidence limits may be applied to provide a basis for comparison of detection successes. Confidence limits are statistical determinations based on sampling theory and are values within which we expect the true reliability value to lie. For a given sample size, the higher our confidence level, the wider our confidence limits.

Application to fatigue crack data.- The 984 NDT observations taken using each NDT technique are repeated with each inspection sequence. This sample base provides an opportunity for evaluation at high confidence levels. A reliability of 95% at a 95% confidence level was selected for processing all combined data, and analysis was based on these conditions. At large crack lengths, no failures in crack detection were detected. We may use standard reliability tables to select a sample size. For a 95% reliability and 95% confidence, 60 observations are required to establish a data point. Combined NDT data were then analyzed using a sampling size of 60 observations. When failure to detect occurs at shorter crack sizes, this basis is no longer valid and much larger sample sizes would be required to maintain the 95% reliability and 95% confidence limits. If the sampling size is held constant, confidence limits may be applied to these data to establish the true reliability values. A Chi-squared (χ^2) distribution analysis was applied to the data to find confidence intervals or boundaries based on the proportion of successes.

If we assume that a proportion P of an infinite set of NDT observations would result in success at a given crack size, and if we assume that 1 degree of freedom, m = 1 (i.e., detection or failure to detect) in data values is possible, then the χ^2 distribution is applicable for data samples where S and n - S are as large as 10:

$$\chi^2 = \frac{(S - np)^2}{npq}$$

where $q = 1 - p$,
n is the number of observations,
S is the number of successes in n trials.

Confidence simply means that the more we know about anything the better our chances are of being right. For an infinitely large sample size, 100% confidence can be gained in determining that a measurement coincides with the true value. For smaller sample sizes, confidence levels are established in terms of actual sample size and the success or failure rate within that sample. A confidence level is then based on history repeating itself and therefore specifies the percentage of the time we expect to be correct.

At an assumed confidence level ε, χ^2 may be obtained from statistical tables* corresponding to the level a/2 and m = 1. If ${\chi_1}^2$ and χ^2 and the observed values of S and n are substituted, the equation may be rewritten as

$$(n + {\chi_1}^3)P^2 - (2S + {\chi_1}^2)P + S^2/N = 0$$

and the two solutions for P are the bounds P_1 and P_2 of a confidence interval at a confidence level ε. A typical plot of data at 95% probability and 95% confidence might be as shown in Figure 24. Calculated probability values are plotted as [0] points. Upper probability limits are plotted as [+] points and lower probability limits are plotted as [-] points.

Plotting combined fatigue crack data.- The data point of most interest for the NDT analysis is the largest crack size that could be missed at 95% reliability and 95% confidence. For purposes of this study we have termed this point the threshold of detection or D_{TH}. We have plotted all combined data based on 60 observations (95% reliability and 95% confidence) to enable determination of the D_{TH} value and have applied the χ^2 distribution analysis to all data points to calculate and plot confidence limits for all data.

Figures 25 through 32 are the resultant respective plots for combined NDT data for the four inspection methods based on crack length (2c), crack depth (a), a/t, and a/2c values. For inspection Sequence 2, data obtained from General Dynamics panel inspections were combined to increase the data base. All data points were biased by starting at the largest crack size observed and counting down 60 observations (in decreasing actual crack size) to establish the data sample. The data point is plotted at the lowest crack length observed.

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*Burlington, Richard S.; and May, Donald C. Jr.: Handbook of Probability and Statistics with Tables. Handbook Publishers Inc., Sandusky, Ohio, 1953.

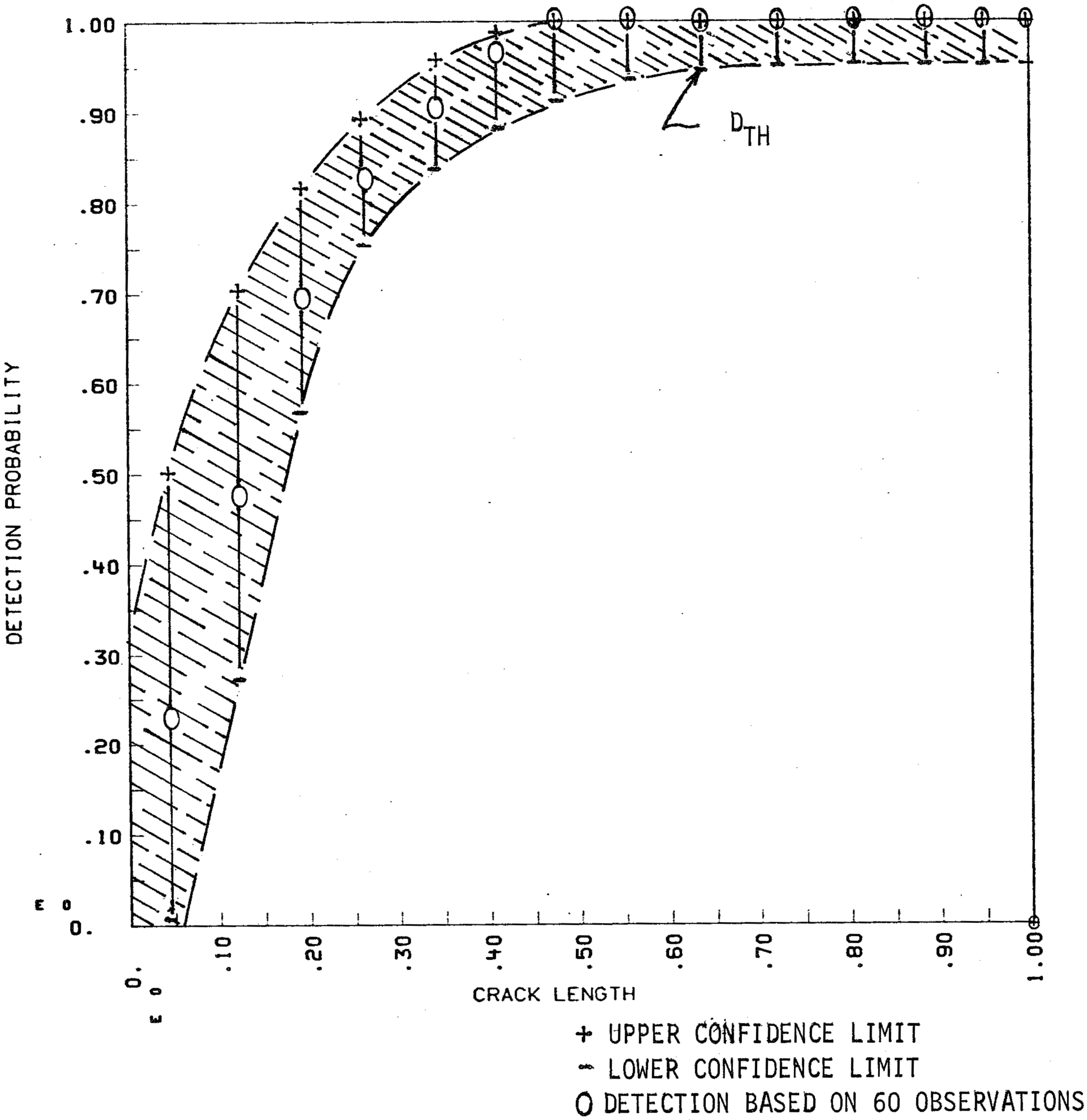
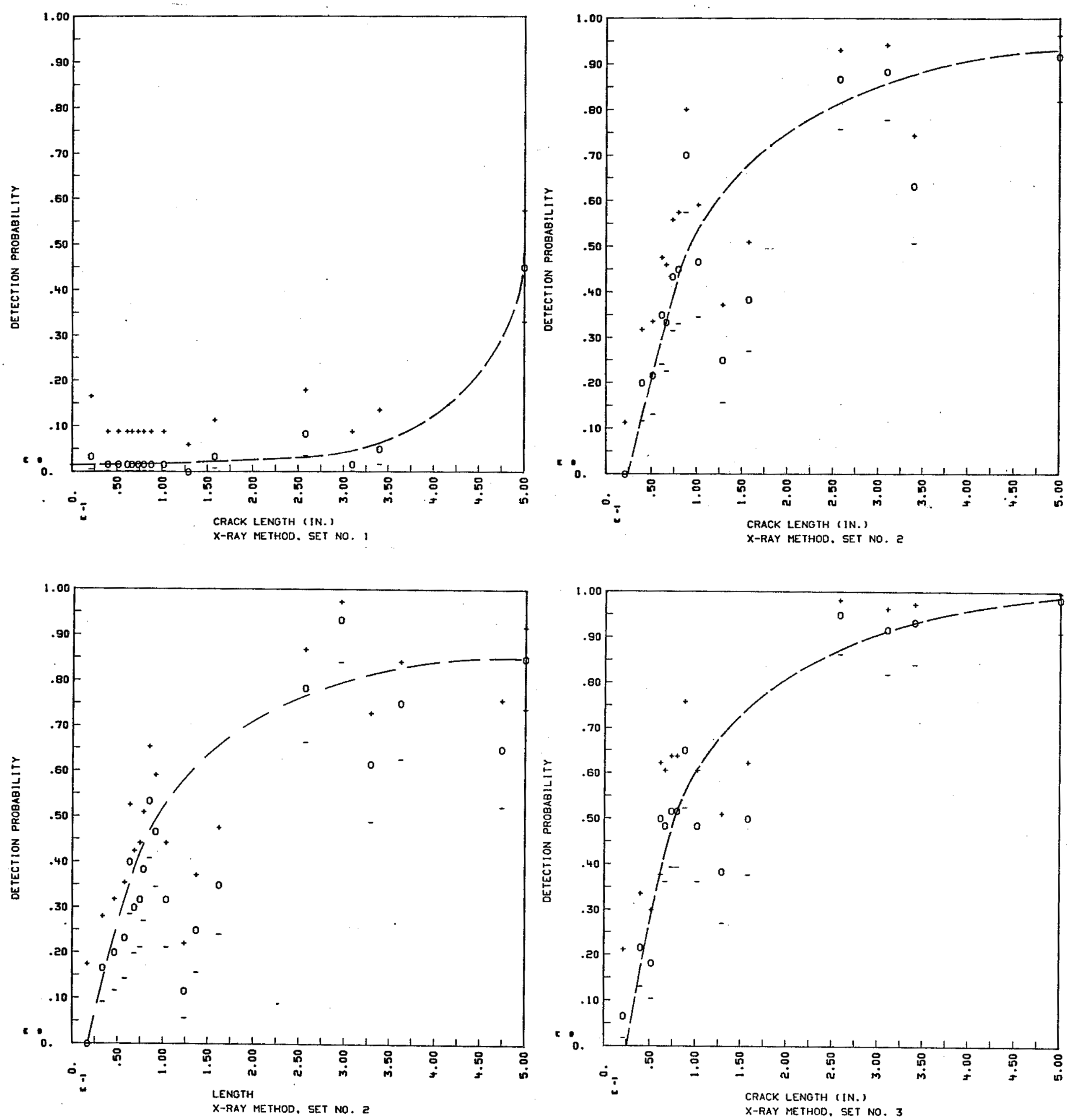


Figure 24.- Typical Plot of Crack Detection Probability Data



COMBINED MARTIN MARIETTA AND GENERAL DYNAMICS DATA

Figure 25.- Crack Detection Probability of the X-Radiographic Inspection Method Plotted by Actual Crack Length at 95% Probability and 95% Confidence Level (All Length Values x10)

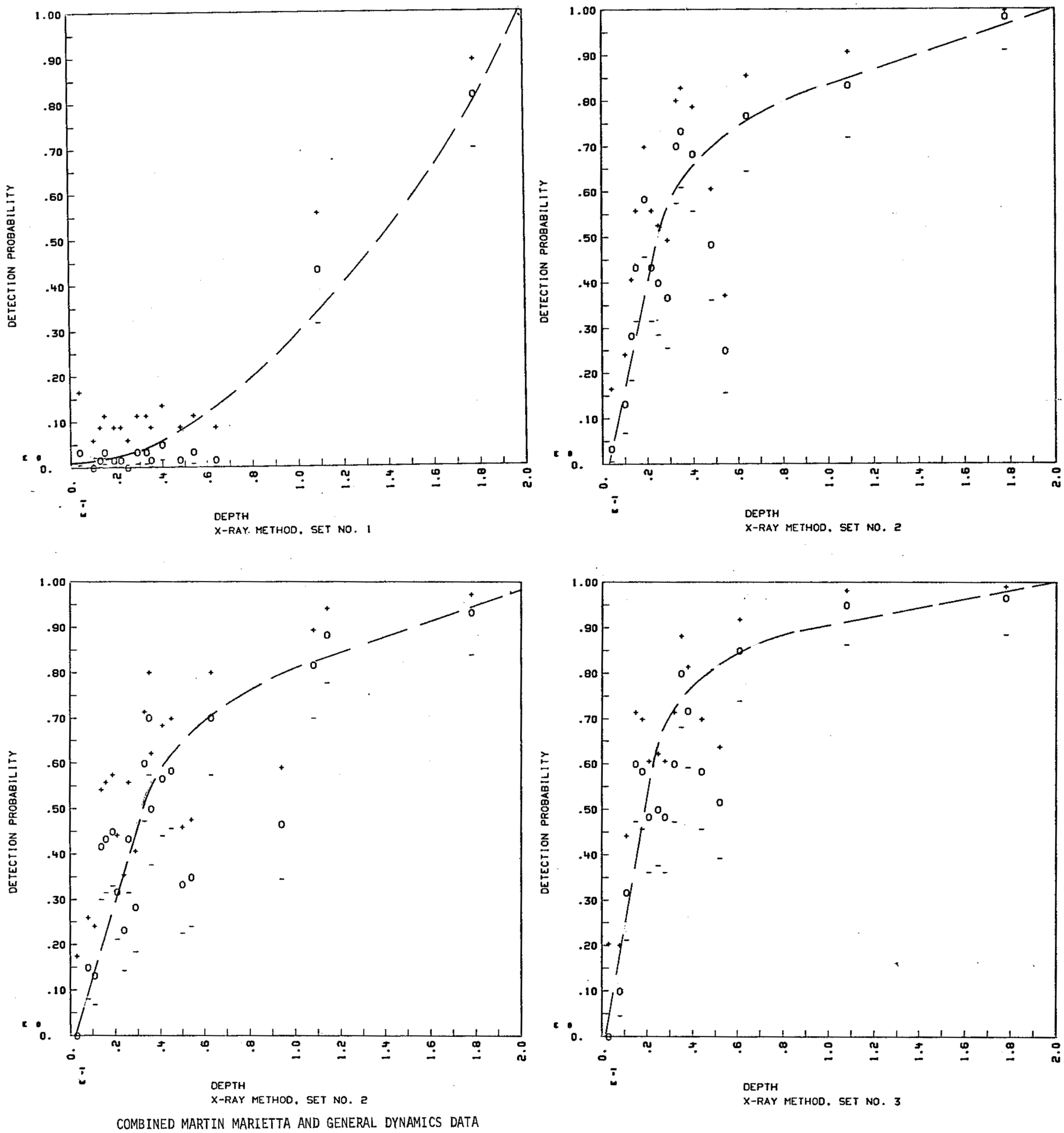


Figure 26.- Crack Detection Probability of the X-Radiographic Inspection Method Plotted by Actual Crack Depth at 95% Probability and 95% Confidence Level (All Depth Values x10)

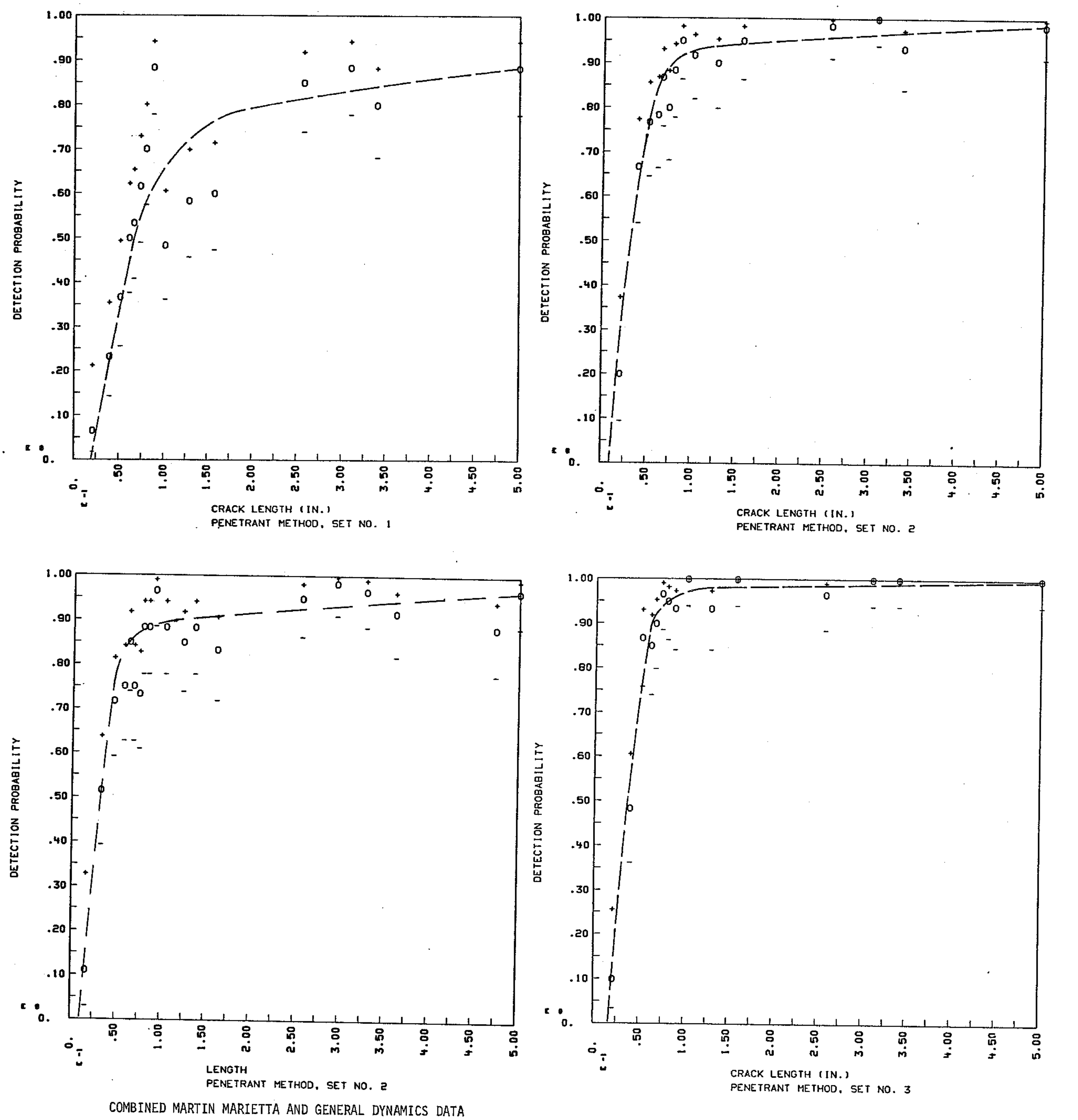


Figure 27.- Crack Detection Probability of the Penetrant Inspection Method Plotted by Actual Crack Length at 95% Probability and 95% Confidence Level (All Length Values x10)

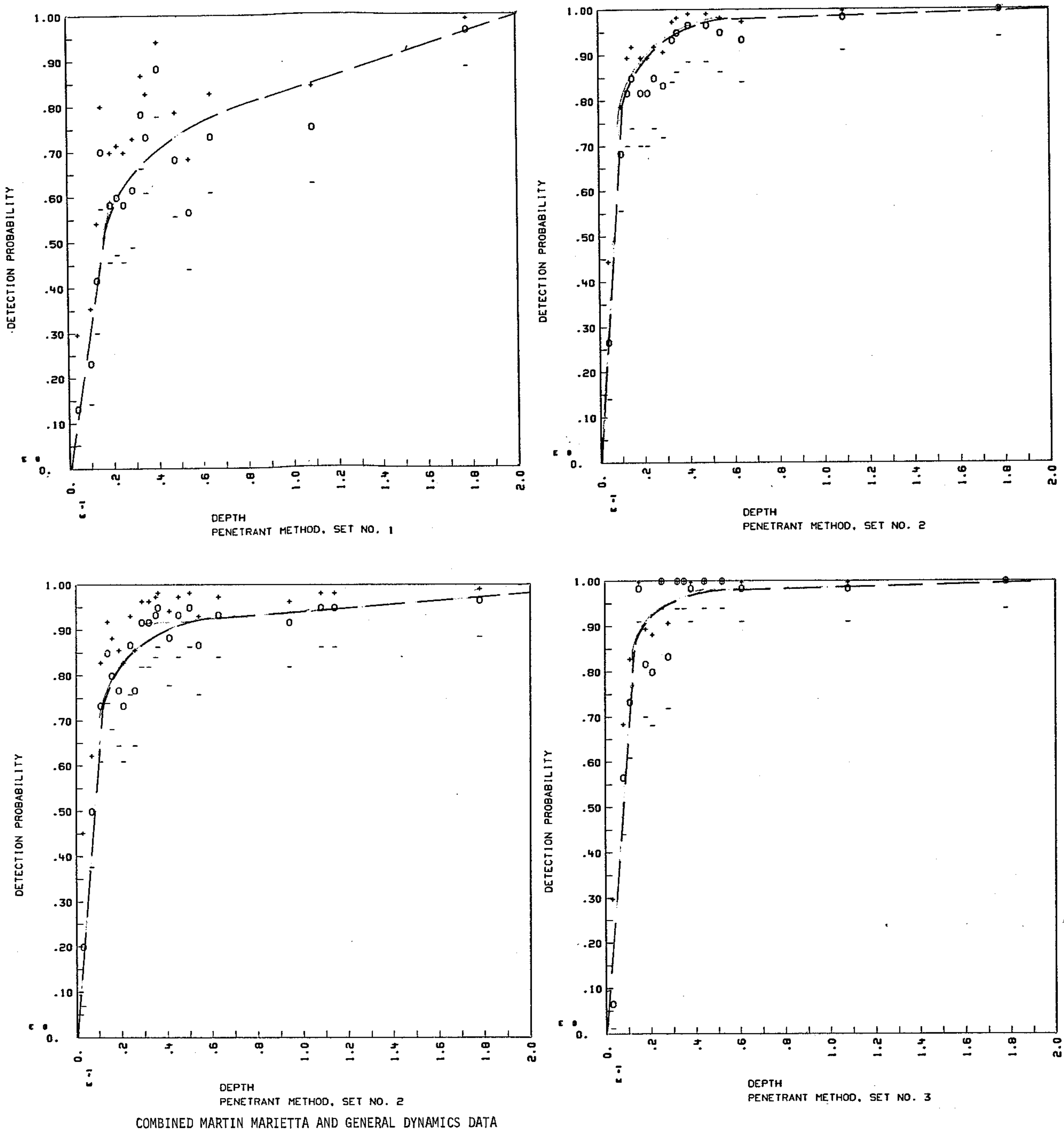


Figure 28. - Crack Detection Probability of the Penetrant Inspection Method Plotted by Actual Crack Depth at 95% Probability and 95% Confidence Level (All Depth Values x10)

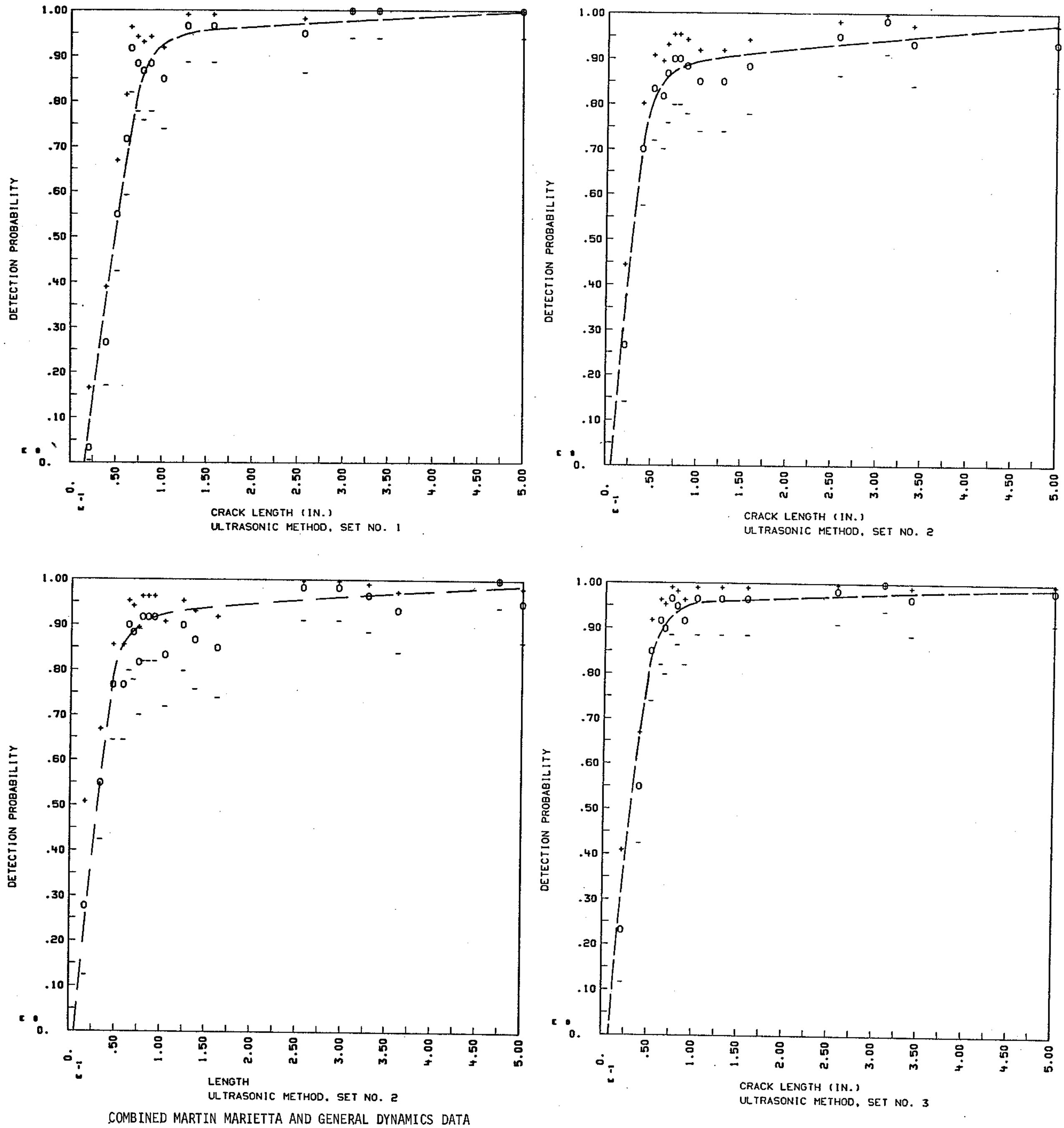
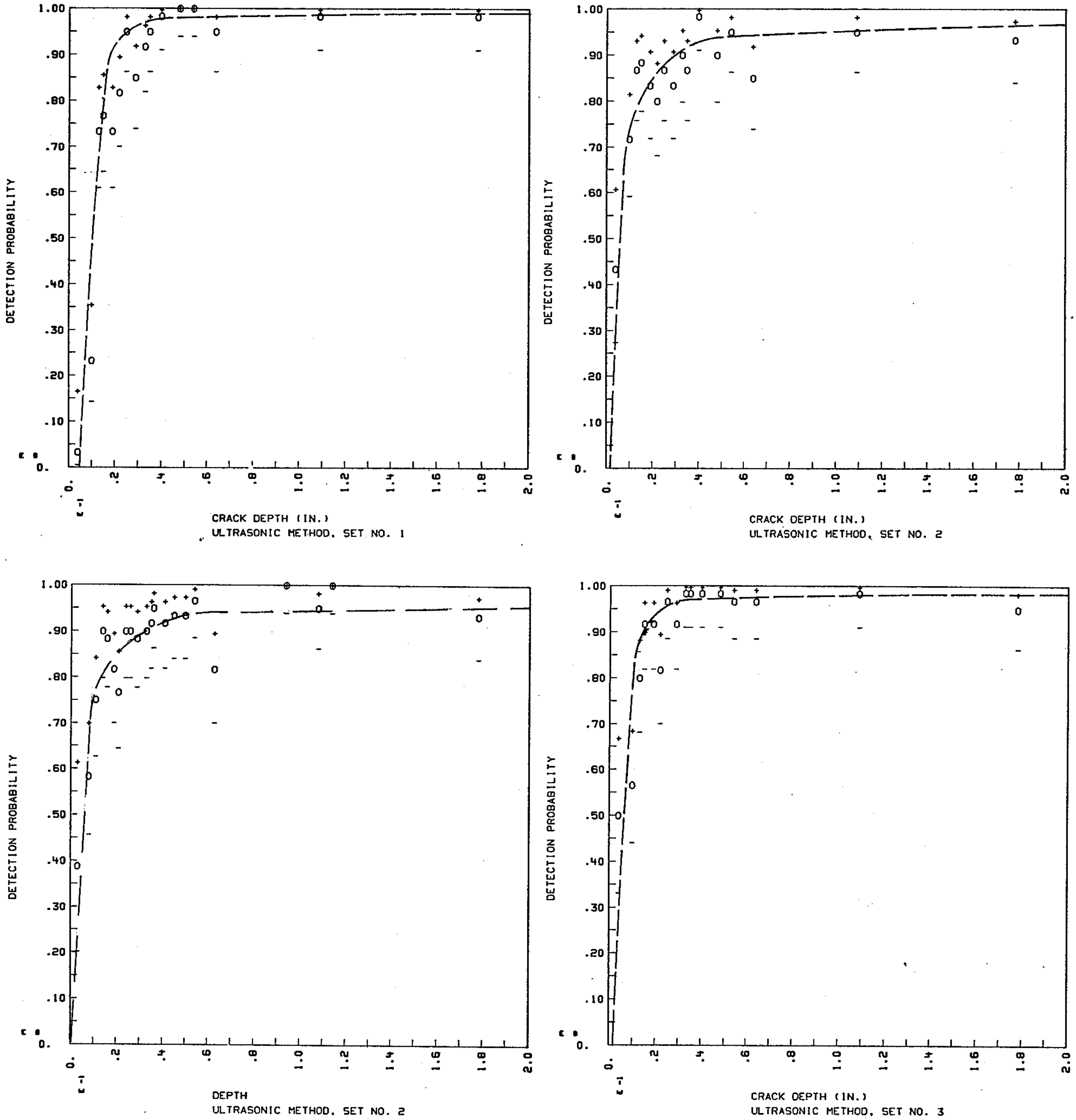


Figure 29. - Crack Detection Probability of the Ultrasonic Inspection Method Plotted by Actual Crack Length at 95% Probability and 95% Confidence Level (All Length Values x10)



COMBINED MARTIN MARIETTA AND GENERAL DYNAMICS DATA

Figure 30.- Crack Detection Probability of the Ultrasonic Inspection Method Plotted by Actual Crack Depth at 95% Probability and 95% Confidence Level (All Depth Values x10)

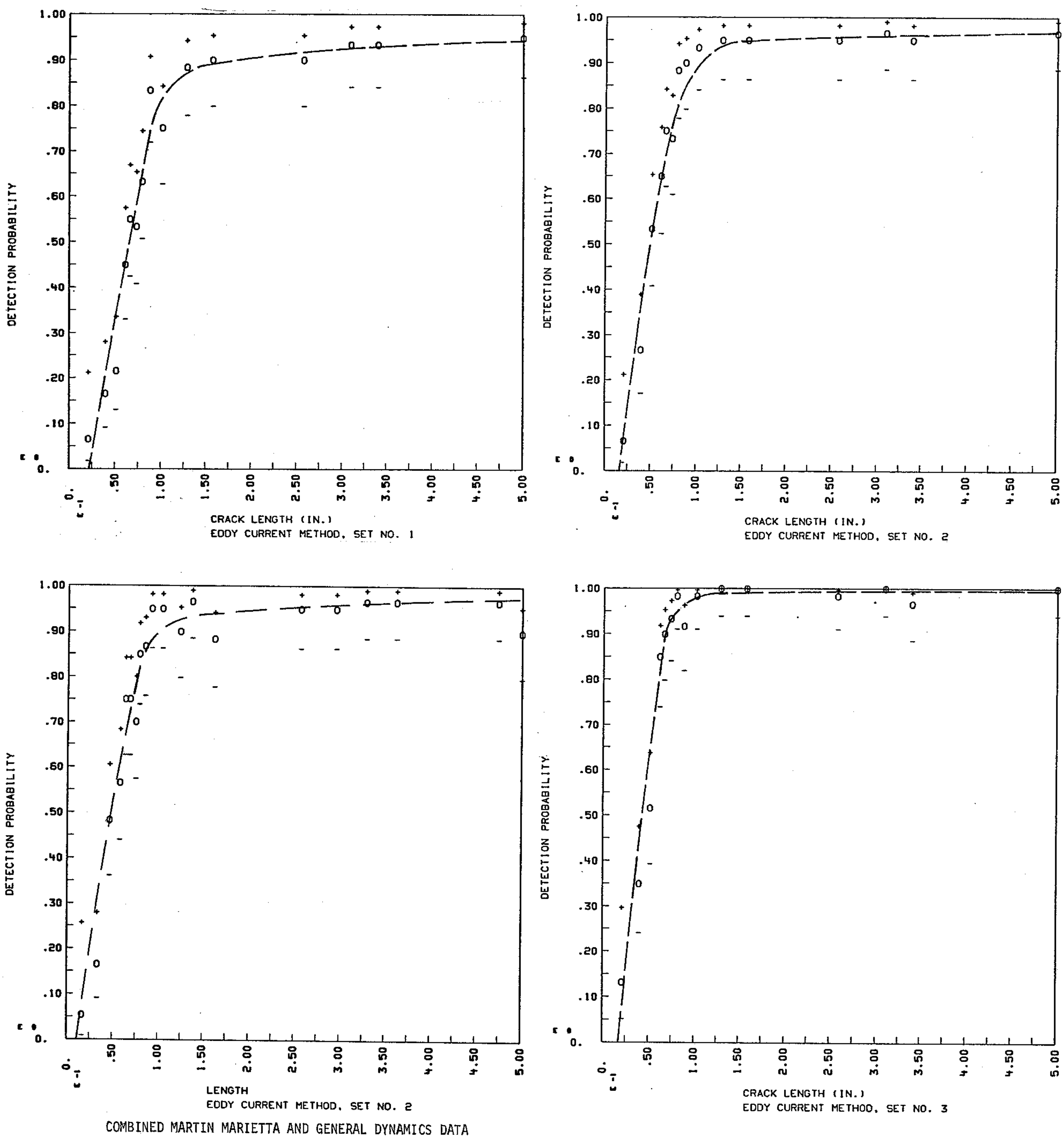


Figure 31. - Crack Detection Probability of the Eddy Current Inspection Method Plotted by Actual Crack Length at 95% Probability and 95% Confidence Level (All Length Values x10)

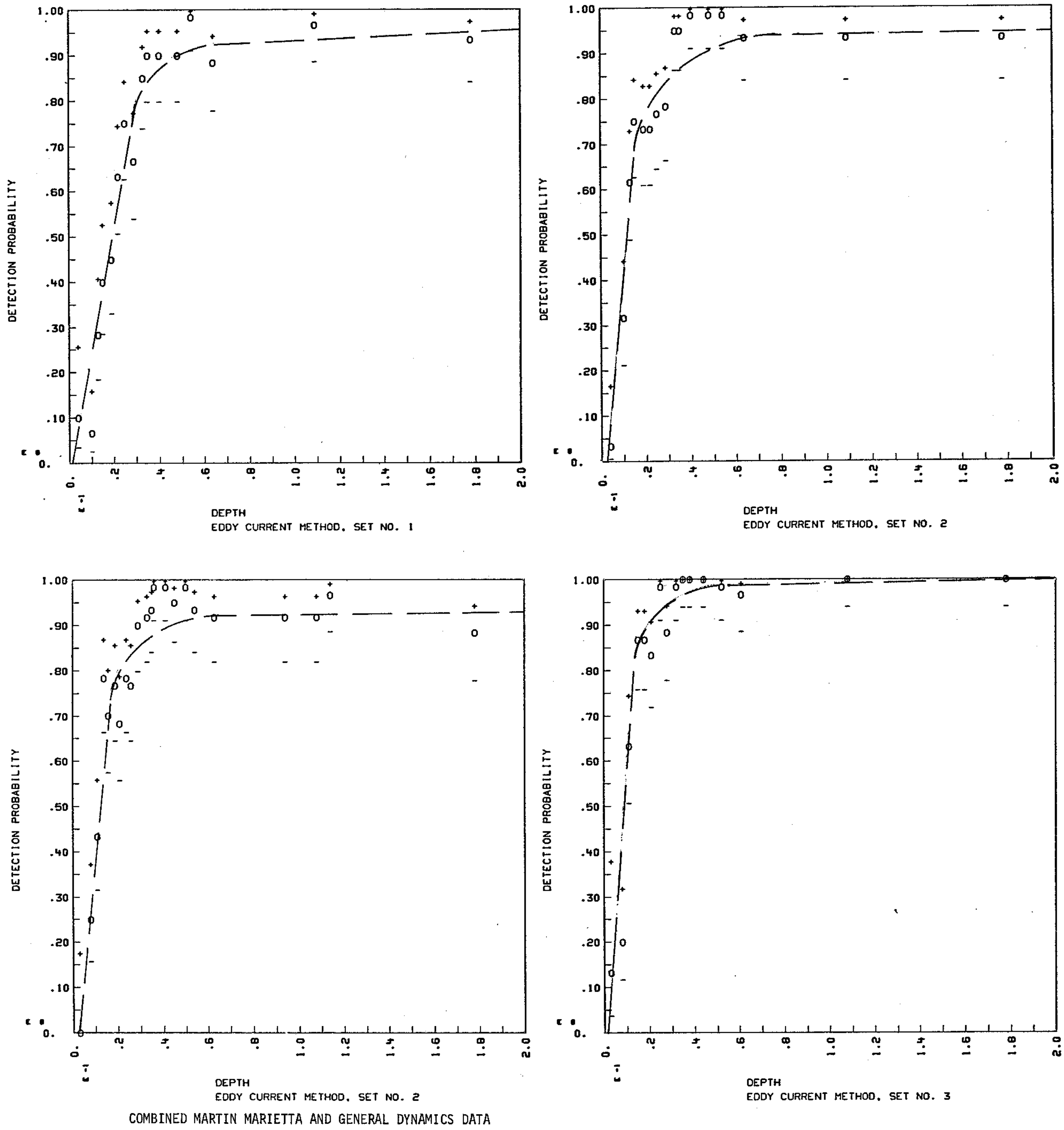


Figure 32.- Crack Detection Probability of the Eddy Current Inspection Method Plotted by Actual Crack Depth at 95% Probability and 95% Confidence Level (All Depth Values x10)

Figures 33 and 34 are the plots of detection probabilities by crack length and depth for the General Dynamics panels. Figure 35 is the detection probabilities by crack length and depth for th the holographic evaluation. The sample size for Figures 33 thru 35 was reduced to 30 observations (90% reliability at 95% confidence) due to the reduced number of overall observations.

Plotting fatigue crack data by groups.- The effects of surface finish and thickness on detection were evaluated by separating the data into appropriate groups for analysis. To provide a better sample base, the sample size for these data was reduced to 30 observations, which corresponds to a 90% reliability at 95% confidence based on no failure. The confidence limits were calculated and the data plotted in the same manner.

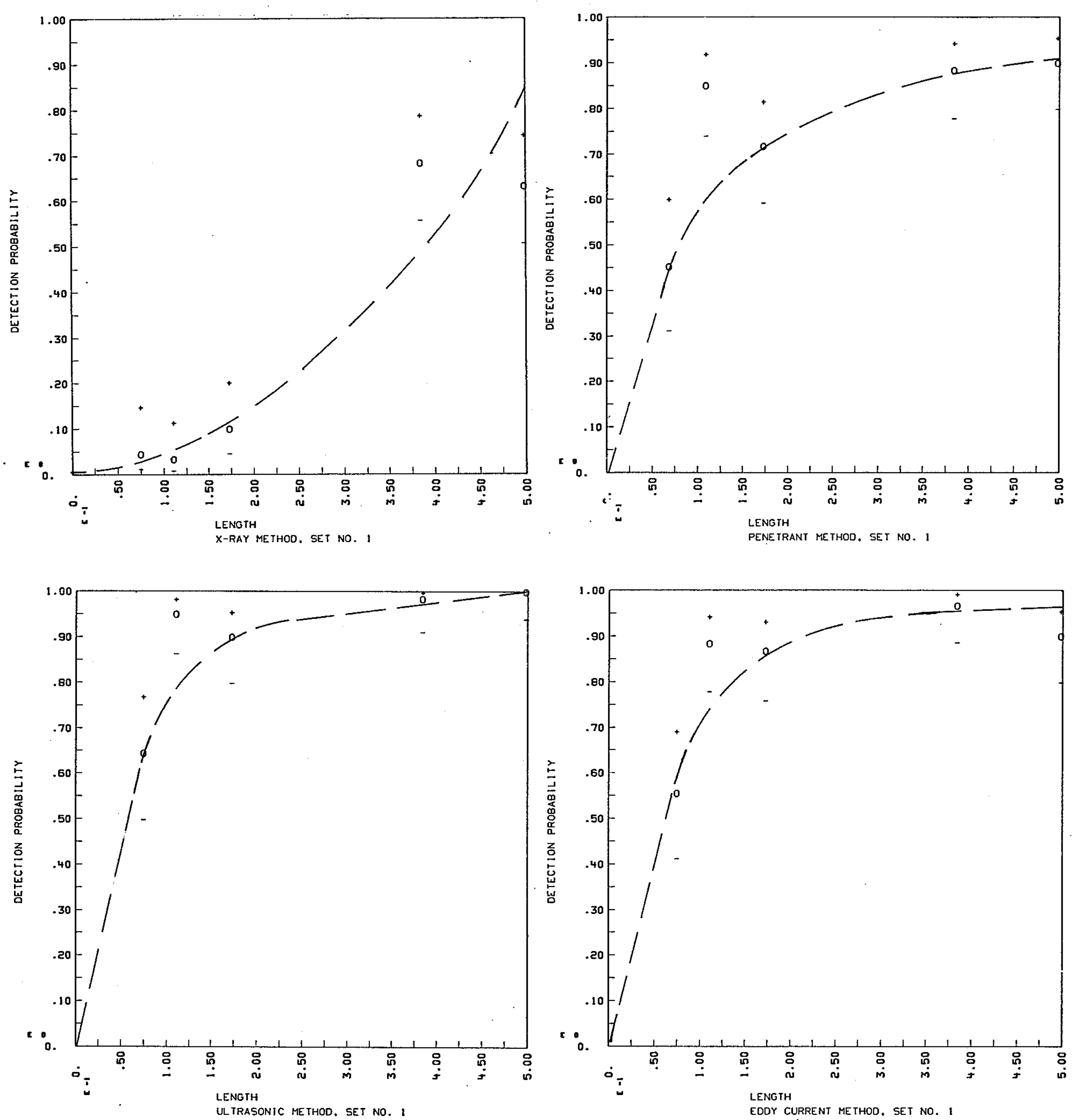


Figure 33.- Crack Detection Probability Plotted by Actual Crack Length at 90% Probability and 95% Confidence Level, General Dynamics Panels (All Length Values x10)

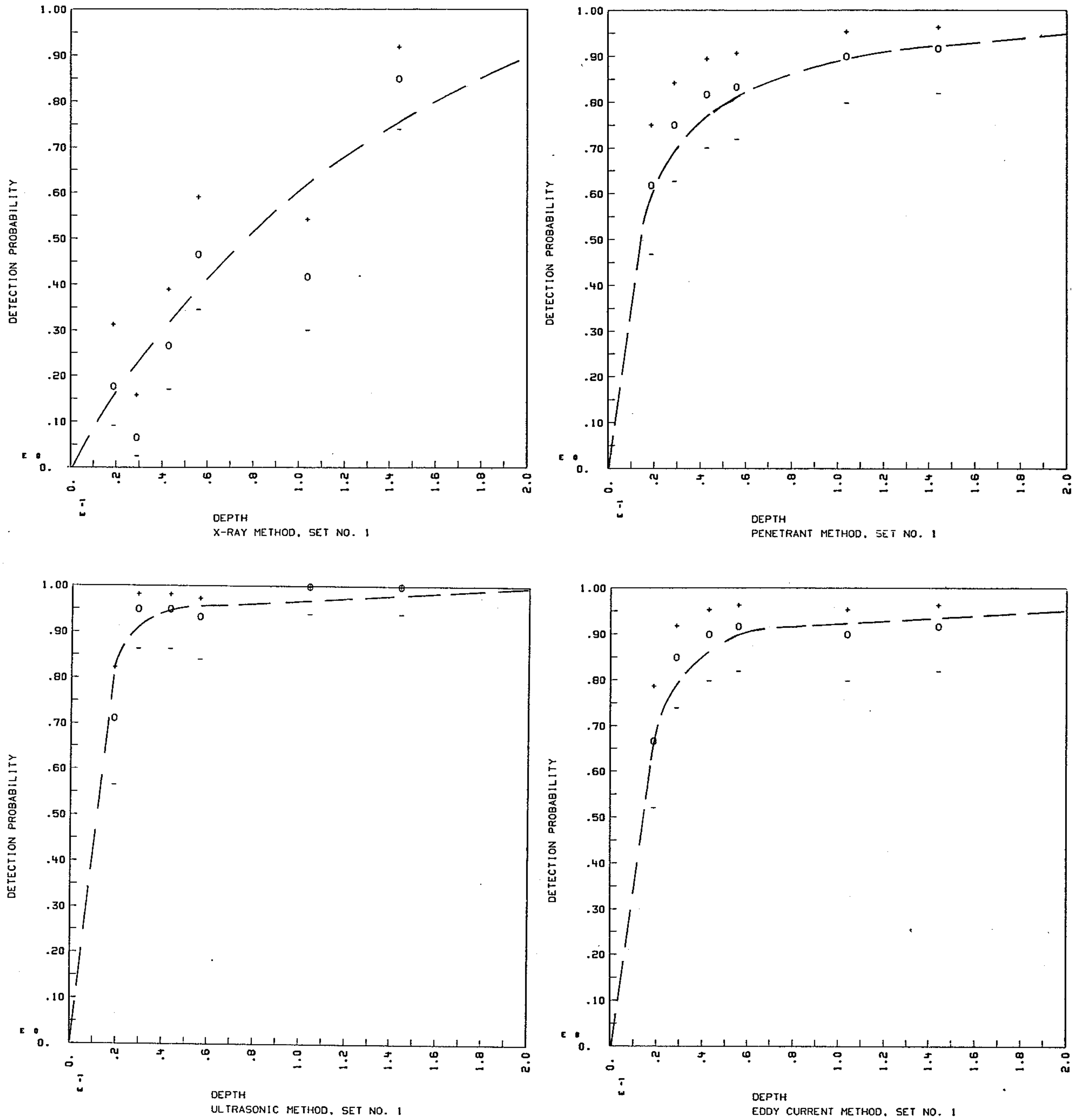


Figure 34.- Crack Detection Probability Plotted by Actual Crack Depth at 90% Probability and 95% Confidence Level, General Dynamics Panels. (All Depth Values x10)

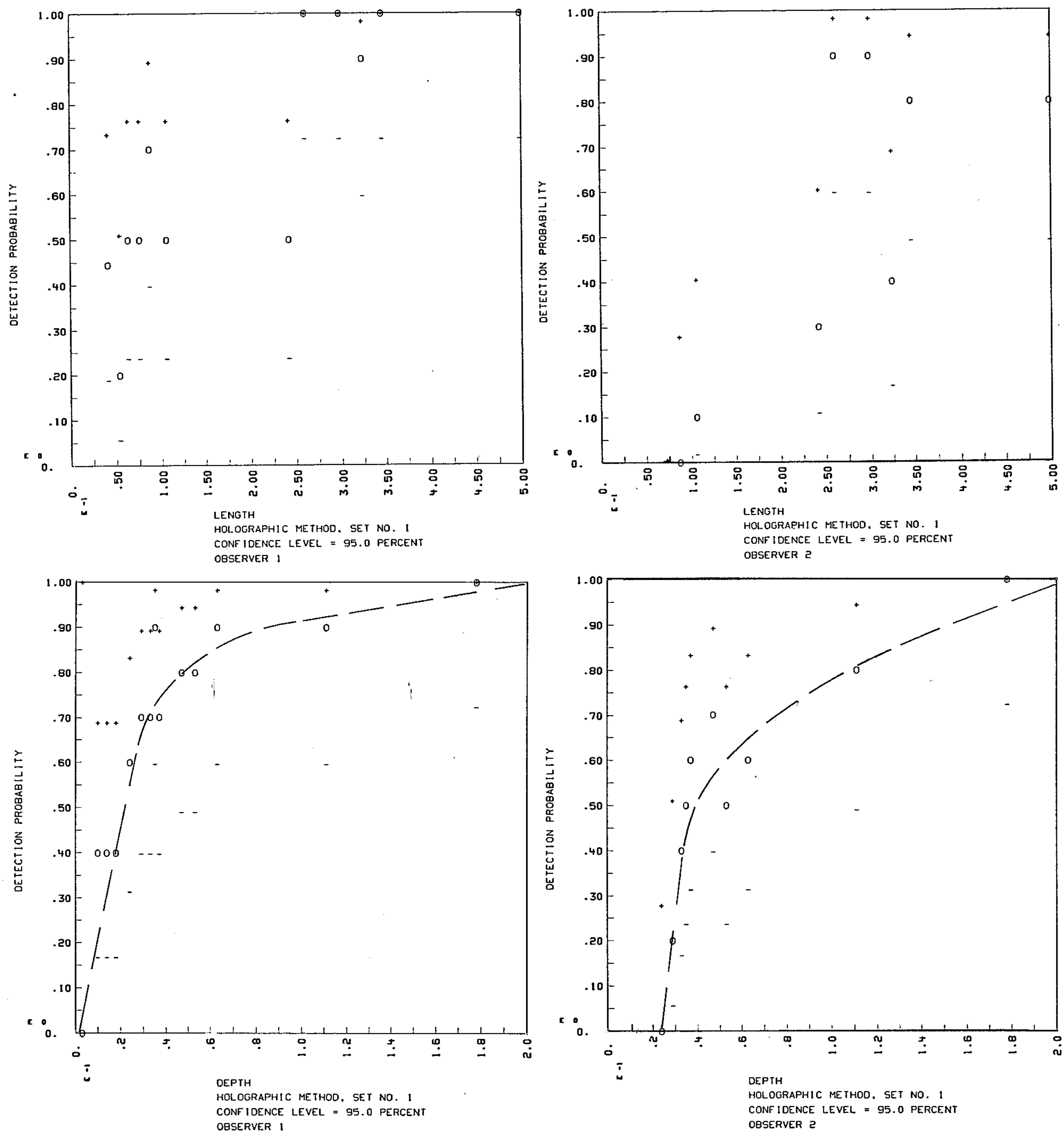


Figure 35. - Crack Detection Probability of the Holographic Inspection Method Plotted by Actual Crack Length and Depth at 90% Probability and 95% Confidence Level (All Length and Depth Values x10)

DISCUSSION OF RESULTS

Detection Probabilities

The results of all inspections are shown in Figures 25 thru 35. The results of X-radiographic inspections are shown in Figures 25, 26, 33, and 34. A large increase in inspection sensitivity was observed between inspection of panels in the "as-milled" condition and inspection after chemical milling. This increase is attributed to attack of cracks at the edges with resultant selective material removal. This analysis is supported by the lower detection probabilities obtained with the General Dynamics panels that had been lightly etched by a metallographic preparation method*. An increase in detection probability was obtained after proof testing. Threshold detection probabilities were:

Sequence 1, 45% (32%, worst-case) for 0.500-in. (1.27-cm) long cracks;

Sequence 2, 90% (80% worst-case) for 0.500-in. (1.27-cm) long cracks;

Sequence 3, 97.5% (90) worst-case) for 0.500-in. (1.27-cm) long cracks.

Penetrant inspection results are shown in Figures 27, 28, 33, and 34. The effects of chemical milling and etching are also evident by the improved detection after chemical milling and the lower detection obtained on General Dynamics panels. Lower detection probabilities were obtained during initial (Set 1) evaluation for cracks approximately 0.100 inch (0.254 cm) in length. This is attributed to tighter cracks produced in this dimensional range. Threshold detection probabilities were:

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*Detection of Fatigue Cracks by Nondestructive Testing Methods. NASA CR-128946. General Dynamics, March 1973, p. 4-1.

Sequence 1, 70% (45% worst-case) for 0.125-in. (0.318-cm) long cracks;

Sequence 2, 92.5% (78% worst-case) for 0.125-in. (0.318-cm) long cracks;

Sequence 3, 97.5% (93% worst-case for 0.125-in. (0.318-cm) long cracks.

Ultrasonic test results are shown in Figures 29, 30, 33, and 34. Chemical milling decreased ultrasonic inspection probabilities, which is attributed to the increased surface roughness. The slight increase in detection obtained on General Dynamics panels is attributed to the change in grain direction for these panels. Threshold detection probabilities were:

Sequence 1, 90% (73% worst-case) for 0.100-in. (0.254-cm) long cracks;

Sequence 2, 88% (73% worst-case) for 0.100-in. (0.254-cm) long cracks;

Sequence 3, 95% (88% worst-case) for 0.100-in. (0.254-cm) long cracks.

Eddy current inspection results are shown in Figures 31, 32, 33, and 34. Eddy current detection improved with each inspection sequence. Threshold detection probabilities were:

Sequence 1, 80% (63% worst-case) for 0.100-in. (0.254-cm) long cracks;

Sequence 2, 90% (83% worst-case) for 0.100-in. (0.254-cm) long cracks;

Sequence 3, 97.5% (90% worst-case) for 0.100-in. (0.254-cm) long cracks.

The increased detection from Sequence 1 to Sequence 2 is attributed, in part, to a modification of eddy current inspection technique.

Holographic inspection results are shown in Figure 35. These data show the holographic method to be more sensitive to the crack depth parameter than to crack length. It ranks above penetrant and X-radiography and lower than ultrasonic and eddy current methods in detection probability. An improvement in detection would be expected for panel loadings to high levels.

Acoustic emission results during proof loading were as predicted by fracture mechanics analyses. Larger cracks grew subcritically and resultant emission was detected, while smaller cracks were sustained and produced no emissions.

Effects of Thickness and Surface Finish

Analyses of data by groups according to thickness and surface finish revealed no large changes. A slight increase in X-radiographic detection was observed for thin, smooth panels. Penetrant results were slightly better for both thick and thin smooth panels. Eddy detection was slightly better for thick, smooth panels. Ultrasonic detection was better for thin, smooth panels and better for both thin sets than for the thick sets. Chemical milling resulted in an increase in noise for all ultrasonic inspections but was approximately equal in effect for all panels.

Effects of Crack Growth Mode

Sixteen cracks were grown at higher stress levels as noted in the actual data (Table 12). No change in detection was attributed to this change. Comparison of nondestructive test observations may be made by referring to Table 13.

Correlation of Data to a/t and a/2c Ratios

All nondestructive test data were analyzed and plotted by a/t and a/2c ratios. The a/t correlation to detection probability obtained approximates that obtained for crack depth correlations. No meaningful relation of a/2c to detection probability was obtained. The usefulness of the values for nondestructive test analysis is not evident and plots of these data are not included in this report.

CONCLUSIONS AND RECOMMENDATIONS

Ultrasonic, eddy current, and penetrant inspection methods were demonstrated to be applicable and sensitive to detection of small tight cracks. Holography was demonstrated to be sensitive to flaw depth and is worthy of further consideration and analysis. Acoustic emission was shown to be sensitive to subcritical crack growth and to be a useful tool in locating growing flaws under load. X-radiography was demonstrated to be the least reliable of available nondestructive test methods for crack detection and should not be seriously considered as a sensitive, reliable technique for detection of tight cracks.

Results show that surface roughness and thickness had little effect on inspection results. Likewise, a high stress mode of crack growth did not affect crack detection. Chemical etching was shown to have variable effects on inspection results and was beneficial for X-radiographic and penetrant inspections. Proof load improved detection for all methods.

Human variations in this program were minimized by the large number of observations made. Although qualified personnel performed these inspections, human errors did occur as is noted by failures to detect some of the larger cracks by some observers. The data are thought to be representative of a production operation where inspection schedules increase chances for error. Ultrasonic inspection was the only automated technique used and exhibited the least data scatter.

Holographic inspection results provide two interesting observations. The first is the sensitivity of holography to crack depth, which would indicate that it has applicability as an analytical tool in fracture mechanics technology for evaluating and analyzing plane-strain and mixed-mode flaw behavior in materials. The second is the local residual stress around a crack exhibited under decreased loading.

The quantitative inspection results obtained and presented herein are scarce in nondestructive test engineering technology. The data may be used as a design guide for establishing engineering acceptance criteria. This use should, however, be tempered by considerations of material type, condition, and configuration, and by the inspection methods and controls maintained in the inspection process. For critical items or special applications, qualification of the inspection methods is an essential element of design qualification and must be satisfied to assure design reliability.

This program is one of the first devoted to generation of quantitative nondestructive evaluation data. In addition to establishing such data for other materials and fabrication processes, several elements are recommended for consideration in future studies:

1) Further automation in whole or part of nondestructive evaluation techniques;

2) Evaluation of the effects of compressive loading on crack detection probabilities;

3) Determination of thickness boundaries, thin and thick, for reliable application of NDT techniques;

4) Determination of the influences of prior fabrication processes on reliability of a technique. For example, if a part has been in service or has been stored in a modifying environment, crack detection by the penetrant method may be poor;

5) Both holographic and acoustic emission techniques need to be further developed and qualified.

To measure these and other promising techniques, standard test and reference specimens need to be developed and used in testing laboratories and inspection operations.

APPENDIX.-A

RADIOGRAPHY OF PRODUCTION FATIGUE
CRACKED PANELS

1.0 SCOPE

To establish the technique for performing X-radiography of production fatigue cracked panels using a selected optimum and reasonable production technique.

2.0 REFERENCES

2.1 Quality Directive 0620-011, Detection of Fatigue Cracks by Nondestructive Methods and Nondestructive Methods/Materials Evaluation

2.2 Military Standard 453 - Inspection, Radiographic

2.3 Quality Standard 10110 - Radiographic Inspection

3.0 EQUIPMENT AND MATERIALS

3.1 Norelco X-ray Machine, 150 KV 24 MA

3.2 Kodak Industrial Automatic Processor Model B

3.3 MacBeth Quantalog Transmission Densitometer, Model TD - 100A

3.4 Viewer, High Intensity, General Electric Model BY - Type I or equivalent

3.5 Penetrameters - In accordance with Military Standard 453 and wire type construction DIN 101S016

3.6 Magnifiers, 5X-Pocket Comparator or equivalent

3.7 Lead numbers, lead tape, and lead shot accessories

3.8 Form X-21 (Figure 2), Fatigue Crack Panel Inspection Report

4.0 PERSONNEL

Personnel performing radiographic inspection shall be qualified in accordance with Military Standard 453 and Quality Standard 10110

5.0 PROCEDURE

5.1 An optimum and reasonable production technique using Kodak, Type M Industrial X-ray Film shall be used to perform the radiography of Production Fatigue Cracked Panels (Table 1)

The rationale for this technique is based on the results as demonstrated by the radiographs and techniques employed for the radiography of twelve Calibration Panels.

5.2 Refer to Table 1 to determine the correct setup data necessary to produce the proper exposure except:

Paragraph (h) Radiographic Density shall be:

.060 - 2.5 to 3.5

.205 - 2.5 to 3.5

Paragraph (i) Focal Spot Size shall be:

2.5 mm

Collimation 1 1/8" diameter lead diaphragm at the tube head

5.3 Place the film in direct contact with the surface of the panel being radiographed.

5.4 Prepare and place the required film identification on the film and panel. (Figure #1)

NOTE: A lead shot shall be placed near the corner formed by machining, nearest the drilled hole which has the panel number tag inserted. (Figure #1)

5.5 The appropriate penetrameter (Military Standard 453, .06 for the thin panels, .25 for the thick panels and wire penetrameter DIN 62 AL 101S016) shall be radiographed with each panel for the duration of the exposure.

5.6 The penetrameters shall be placed upon the upper surface of a block of metal of the same alloy composition and approximately the same thickness as the panel being radiographed.

5.7 The radiographic density of the machined area of the panel shall not vary more than ± 15 percent from the density at the Military Standard 453 penetrameter location.

5.8 Align the direction of the central beam of radiation perpendicular and to the center of the panel being radiographed.

5.9 Expose the film at the selected technique obtained from Table 1.

5.10 Process the exposed film through the Automatic Processor. (Table 1)

5.11 The radiographs shall be free from blemishes or film defects which may mask defects or cause confusion in the interpretation of the radiograph for fatigue cracks.

5.12 The density of the radiographs shall be checked with a densitometer (Ref. 3.3) and shall be within a range of 2.5 to 3.5 as measured over the machined area of the panel.

5.13 Using a viewer with proper illumination (Ref. 3.4) and magnification (5X - Pocket Comparator or equivalent) interpret the radiographs to determine the number, location, and length of fatigue cracks in each panel radiographed.

5.14 The radiographic interpreter will record the number, location, and length of fatigue cracks in each panel radiographed on Form X-21 (Figure 2), Fatigue Crack Panel Inspection Report

5.14.1 Determine the location of the crack by measuring from the corner formed by machining which is identified by a lead shot placed on the panel (Figure #2).

5.14.2 Determine the X, Y dimension and number each crack (Figure #2).

5.14.3 Record the X, Y dimension, number and length of each crack on Form X-21. Sketch in the approximate location of each crack (Figure #2).

6.0 SAFETY

6.1 The use of radiographic equipment shall be in accordance with the safety provisions specified in Martin Marietta Corporation, Denver Division, Radiological Safety Manual.

6.2 Radiographic personnel shall wear a film badge at all times while operating the X-ray Equipment.

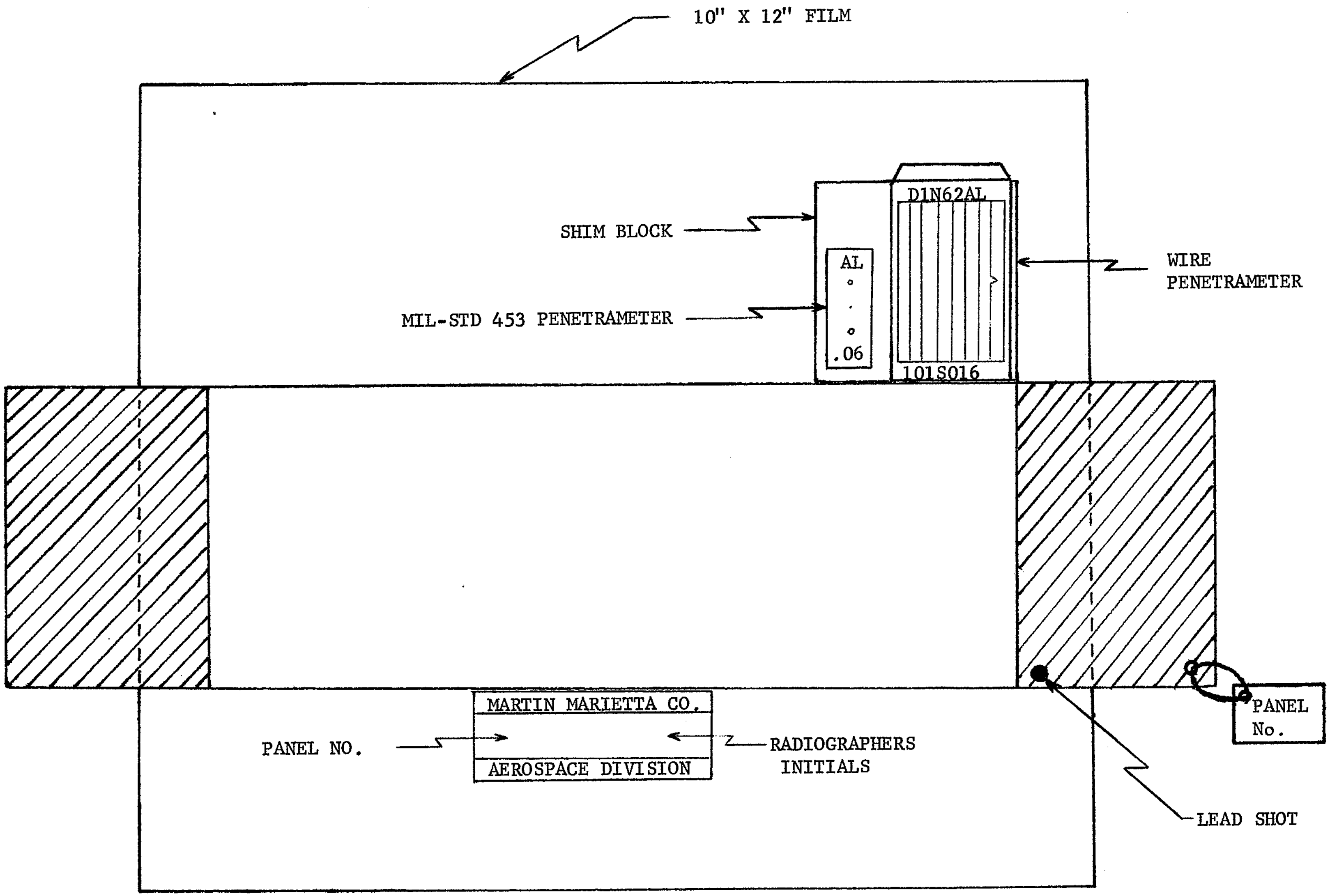

10" X 12" FILM
SHIM BLOCK
MIL-STD 453 PENETRAMETER
AL
.06
D1N62AL
101S016
WIRE PENETRAMETER
MARTIN MARIETTA CO.
AEROSPACE DIVISION
PANEL NO.
RADIOGRAPHERS INITIALS
PANEL No.
LEAD SHOT

FIGURE #1

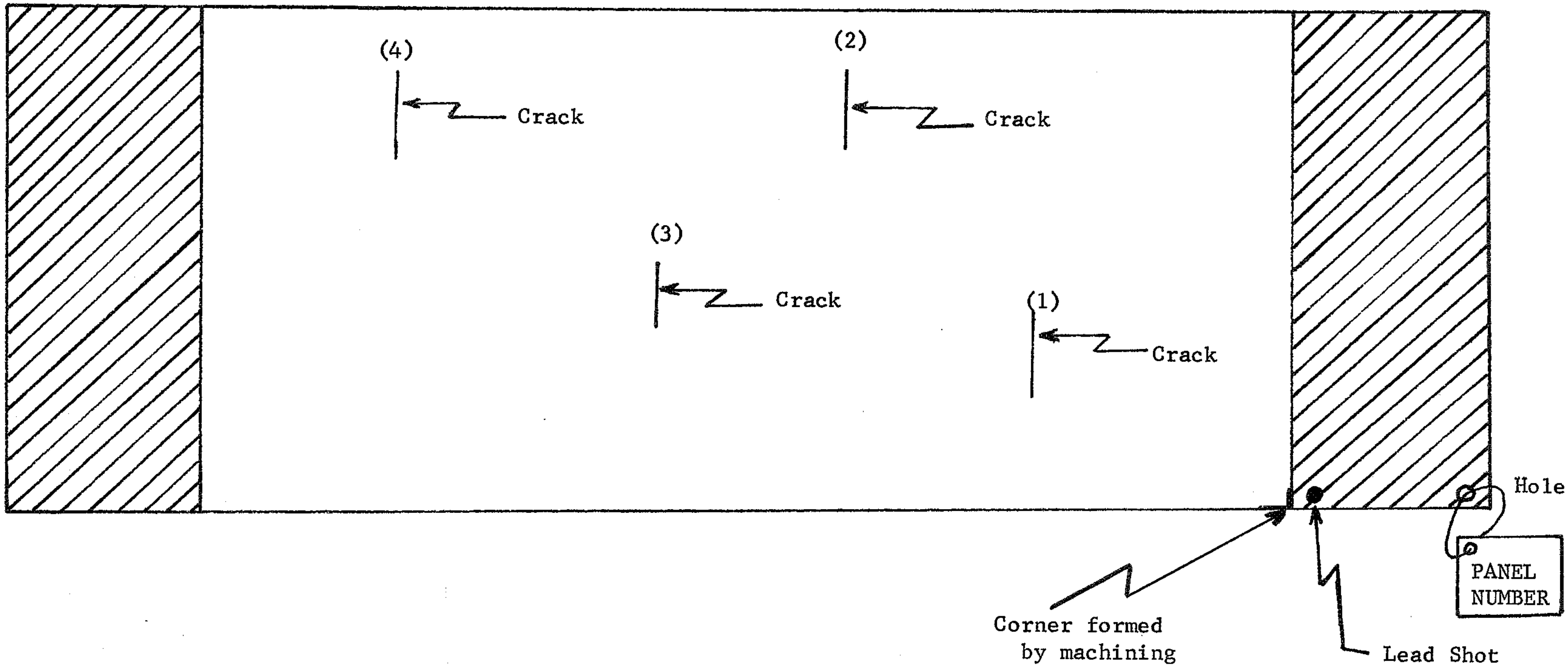


FIGURE #2:

NOTE: The X, Y dimension shall be measured from the machined corner (lead shot) to the end of the crack nearest to the Y axis.

Table 1

Detection of Fatigue Cracks -- X-Ray

Contract No. NAS9-12276

Type of Film: Eastman Kodak Type M

Exposure Parameters: Optimum Technique

(a) Kilovoltage:
  .060 - 30 KV
  .205 - 40 KV

(b) Milliamperes:
  .060 - 20 MA
  .205 - 20 MA

(c) Exposure Time:
  .060 - 7 Minutes
  .205 - 15 Minutes

(d) Target/Film Distance:
  46 Inches

(e) Geometry or Exposure:
  Perpendicular

(f) Film Holders/Screens:
  Ready Pack/No Screens

(g) Development Parameters:
  Kodak Model B Automatic Processor
  Development Temperature of 78°F

(h) Radiographic Density:
  .060 - 3.0
  .205 - 3.0

(i) Other Pertinent Parameters/Remarks:
  Radiographic Equipment
  Norelco 150 KV 24 MA
  Beryllium Window
  .7 and 2.5 Focal Spot

APPENDIX.-B

ULTRASONIC INSPECTION FOR FATIGUE CRACK PROGRAM PANELS

1.0 SCOPE

1.1 This procedure covers ultrasonic inspection for detecting fatigue cracks in thin aluminum plate.

2.0 REFERENCES

2.1 Manufacturer's instruction manual for the UM-715 Reflectoscope instrument.

2.2 Nondestructive Testing Training Handbook, P1-4-4, Volumes I, II and III, Ultrasonic Testing, General Dynamics 1967.

2.3 Nondestructive Testing Handbook, McMasters, Ronald Press, 1959, Volume II, Sections 43-48.

3.0 EQUIPMENT

3.1 UM-715 Reflectoscope, Automatic Industries

3.2 10N Pulser/Receiver, Automation Industries

3.3 E-550 Transigate, Automation Industries

3.4 J394, 10 MHz transducer, Automation Industries

3.5 SR 150 Budd, Ultrasonic Bridge

3.6 319DA Alden, Recorder

3.7 Calibration Panel and Reference Panels

4.0 PERSONNEL

4.1 The ultrasonic inspection shall be performed only by technically qualified personnel.

5.0 PROCEDURE

5.1 Set up equipment per attached set up sheet.

5.2 Submerge the calibration panel (page 9) in a tank of water and position the transducer to produce a maximum peak from the front surface of the small vertical hole in this panel.

5.3 Adjust the sensitivity control for a signal amplitude of one inch plus or minus two tenths with a sensitivity setting at times one (X1)

5.3 continued

(See reference photograph #1). Switch sensitivity to times ten (X 10) and check against photograph #2.

5.4 Submerge and scan reference panels 1D5T4R and 105T6S at the sensitivity setting established in paragraph 5.3, but with sensitivity setting at times 10 (X 10).

5.5 Submerge and scan the first five test panels inspecting both sides of each panel and record.

5.6 Repeat Step 5.2. Make adjustments in the sensitivity for a signal amplitude of one inch plus or minus two tenths at a sensitivity of times one (X 1).

5.7 Submerge and scan next five panels.

5.8 Repeat Step 5.7.

5.9 Submerge and scan remaining panels.

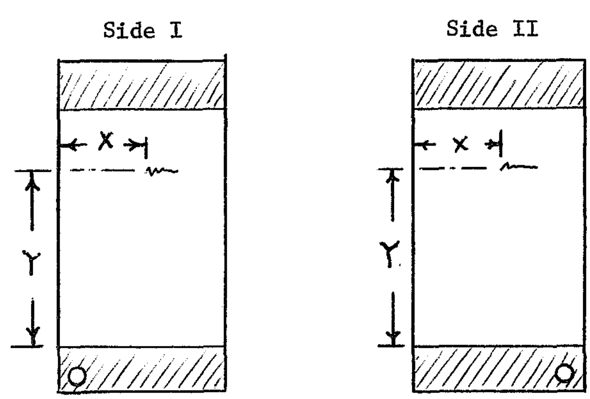
5.10 Repeat Step 5.4.

5.11 When removing panels from water, thoroughly dry by wiping with cheese cloth.

5.12 Locate the panel over the corresponding ultrasonic recording and outline the panel on the recording noting the mill cut edges.

5.13 On data sheet X 21, note the locations of each crack giving "X" and "Y" coordinates and the length and width of the crack indications.

5.14 Panel Orientation and Dimensioning of the Cracks

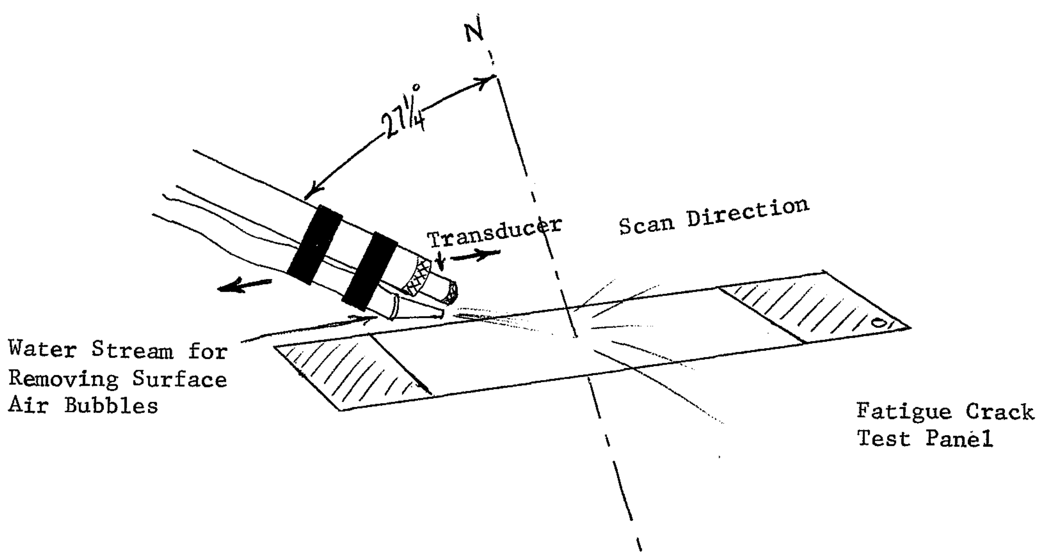


5.15 Put date, inspection number, sequence nomenclature (US-1 before chem mill; US-3 after post proof) Panel number, and side on each sheet of form X 21.

ULTRASONIC SET-UP SHEET

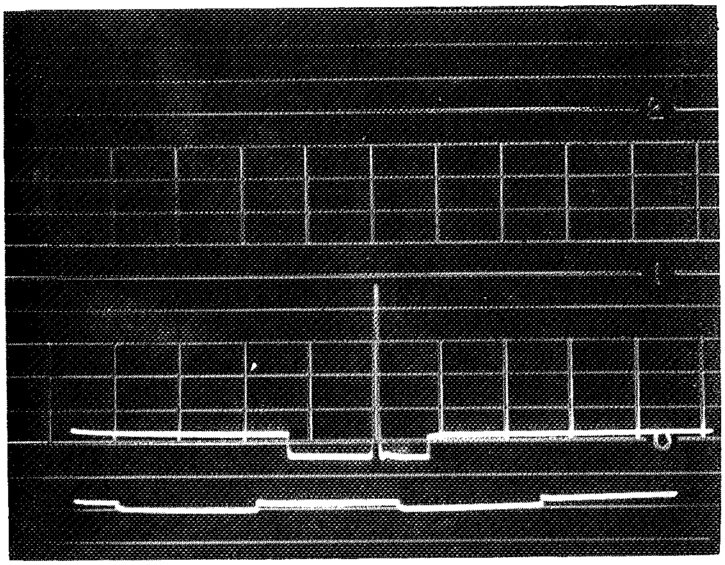
DATE:	06/20/72
METHOD:	Pulse/Echo @ 27 1/4° incident angle
OPERATOR:	
INSTRUMENT:	UM715 Reflectoscope with 10N Pulser/Receiver
PULSE LENGTH:	Min.
PULSE TUNING:	max. response
REJECT:	(dial symbol)
SENSITIVITY:	1.0 to 6.0 X 10.0 (after all other settings are made, this control should be adjusted to produce an "A" scan as shown in ref. photo's 1 and 2)
FREQUENCY:	10 MHz
GATE START:	4 (dial symbol)
GATE LENGTH:	3 (dial symbol)
TRANSDUCER:	J394, SIL, 10.0 MHz, F.S., .37, SN24776
WATER PATH:	1 3/8" (adjust for max. response)
WRITE LEVEL:	+ Auto Reset (dial symbol)
PART:	Fatigue Crack Test Panels

SET-UP GEOMETRY:

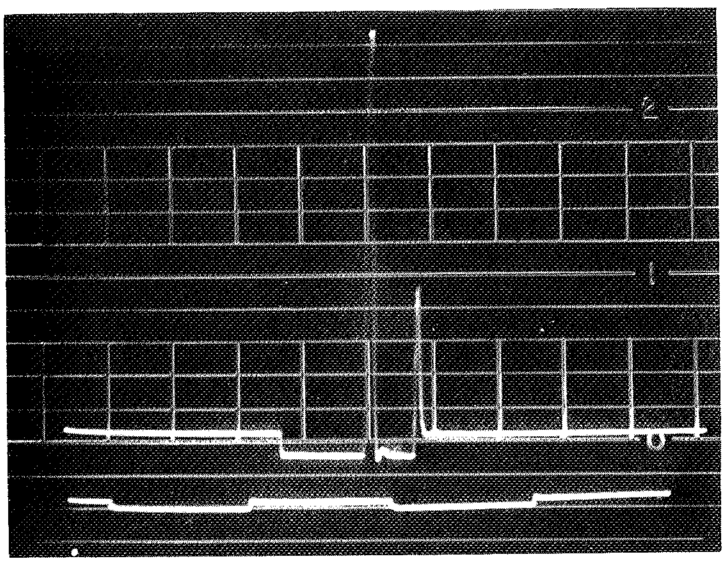


CALIBRATION PANEL

SMALL HOLE RESPONSE



X 1



X 10

ATTACHMENT #1

I. After Chem Mill

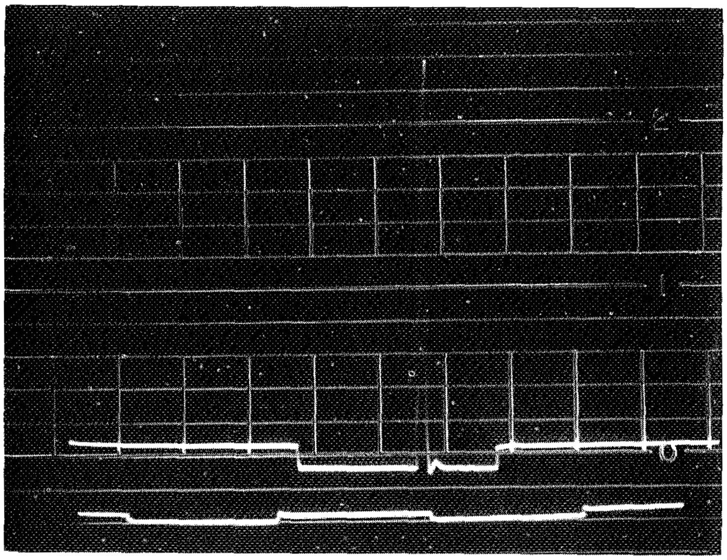
When inspecting panels 1C - 10C, 16C - 24C and 28C, the sensitivity must be reduced because of the etched pits.

The procedure will be:

1. Set-upon small hole in calibration panel per 5.1 thru 5.3.
2. Reduce sensitivity for an amplitude of 2.4" with sensitivity on times ten (X 10). (See photograph #3)
3. Submerge and scan reference panels 105T4R and 105T6S. Retain these recordings with test panel recordings.
4. Scan panels 1C - 10C.
5. Check amplitude of signal response on small calibration panel. Adjust to 2.4".
6. Scan panels 16C - 24C and 28C.
7. Repeat Number 3.
8. Scan remaining panels following 5.1 thru 5.15.

ATTACHMENT

CALIBRATION PANEL
SMALL HOLE RESPONSE



Reference Photograph #3

ATTACHMENT # 2

The incident angle for the General Dynamics Panels and the Martin Marietta Panels after Proof Testing shall be inspected at 30° incident angle instead of the 27 ¼° angle.

The sensitivity shall be adjusted so that the response from the hole in the calibration panel measures 1.4 inches with the coarse sensitivity on times one (X 1). The coarse sensitivity will then be switched to times ten (X 10).

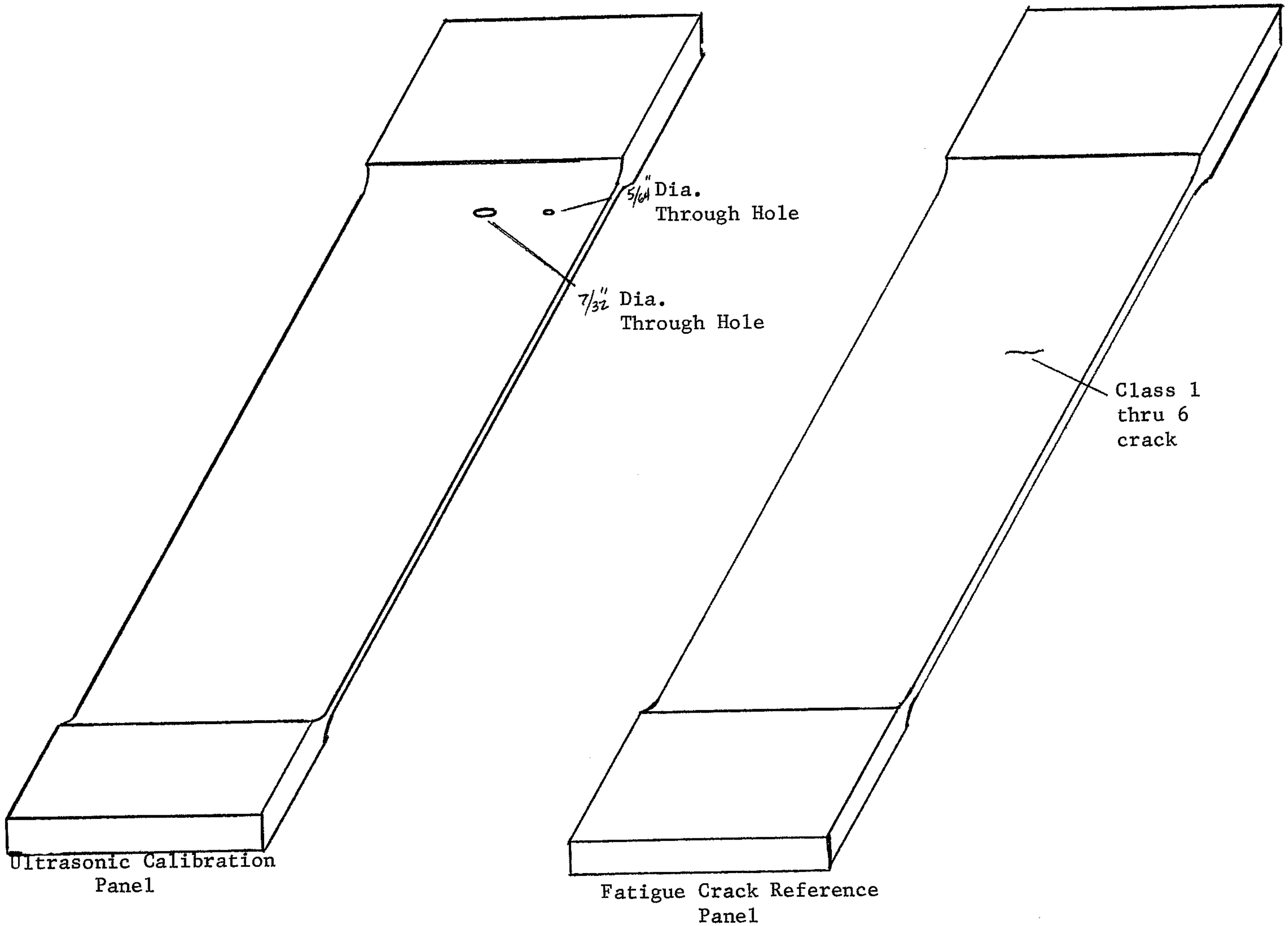

5/64" Dia.
Through Hole
7/32" Dia.
Through Hole
Class 1
thru 6
crack
Ultrasonic Calibration
Panel
Fatigue Crack Reference
Panel

FIGURE I

APPENDIX.-C

EDDY CURRENT INSPECTION FOR FATIGUE CRACK PROGRAM PANELS

1.0 SCOPE

1.1 This procedure covers eddy current inspection for detecting fatigue cracks in thin aluminum plate.

2.0 REFERENCES

2.1 Manufacturer's instruction manual for the Nortec Model NDT-3 Eddy Current Instrument.

2.2 Nondestructive Testing Training Handbooks, P1-4-5 Volumes I and II, Eddy Current Testing, General Dynamics, 1967.

2.3 Nondestructive Testing Handbook, McMasters, Ronald Press, 1959, Volume II, Sections 35-41.

3.0 EQUIPMENT

3.1 Nortec NDT-3 Eddy Current Instrument

3.1.1 100 KHz Plug-in Module for NDT-3

3.1.2 100 KHz Probe for NDT-3

3.2 NDE Fatigue Crack Reference Panels 105T6S and 117U6R

3.3 Special Plexiglas shoe for Probe

3.4 Special Probe Manual Scanning Fixture

3.5 Vinyl Tape

4.0 PROCEDURE

4.1 Connect 100 KHz Plug-in Module and 100 KHz Probe to NDT-3 instrument.

4.2 Turn instrument power on by turning Coarse Gain control to position #1.

4.3 Check batteries by push button switches. (These should be checked every hour of use.)

4.3.1 Meter should read 66.0 + 1.0 - 6.0 microamperes.

4.4 Adjust R-1 to a voltage between TP-1 and TP-2 of 1.0 volts peak to peak.

4.5 Place one layer of vinyl tape over the end of the probe.

4.5.1 Replace vinyl tape as needed

4.6 Set instrument controls as follows:

Level	- 8.50	Balance "X"	- 3.20
Fine Gain	- 5.00	Balance "R"	- 7.00
Coarse Gain	- 1		

4.7 Place reference panel on manual probe scanning fixture. (To detect cracks in rough surfaced panels, use reference panel 117U6R; to detect cracks in smooth surfaced panels, use reference panel 105T-6S)

4.8 Place the probe on the referenced panel and adjust the level control until meter reads mid scale.

4.9 Adjust the Balance "X" control and level control so that the meter reads the same value (within $\pm$ 5 units) with and without a sheet of note paper between probe and the panel.

4.10 Move Coarse Gain control to position 2.

4.10.1 Repeat steps 4.8 and 4.9.

4.11 Move Coarse Gain control to position 3.

4.11.1 Repeat steps 4.8 and 4.9.

4.12 Using level control adjust meter to read 70.

4.13 Scan probe over the known crack in the appropriate reference panel and note meter deflection.

Panel: 105T6S - Crack Location X = 1.23" Y = 5.83"

Panel: 117U6R - Crack Location X = 0.97" Y = 6.51"

4.14 Replace reference panel with the inspection test panel to be checked.

4.14.1 Place inspection test panel into special fixture with tag in the upper right corner. Align machined edge with rule "Y".

4.15 Scan the probe in the "Y" direction over the test panel indexing the scanning fixture in the "X" direction in 1/8" increments until the entire panel has been covered.

4.16 Repeat 4.15 for opposite side of test panel.

4.16.1 Place inspection test panel into special fixture with tag in upper right corner. Align machined edge with rule "Y".

NOTE: A CRACK IS INDICATED BY A RELATIVELY QUICK DEFLECTION OF THE METER.

4.17 Crack indications are to be noted on fatigue crack panel inspection report Form X-21 (see attached sample).

4.18 The magnitude of the crack will be noted on Form X-21 as follows:

A meter deflection of 10 uA or less = weak magnitude (W)

A meter deflection of 10 uA to 40 ua = moderate magnitude (M)

A meter deflection of 40 uA to 65 ua = strong magnitude (S)

A meter deflection of 65 uA and up = very strong magnitude (VS)

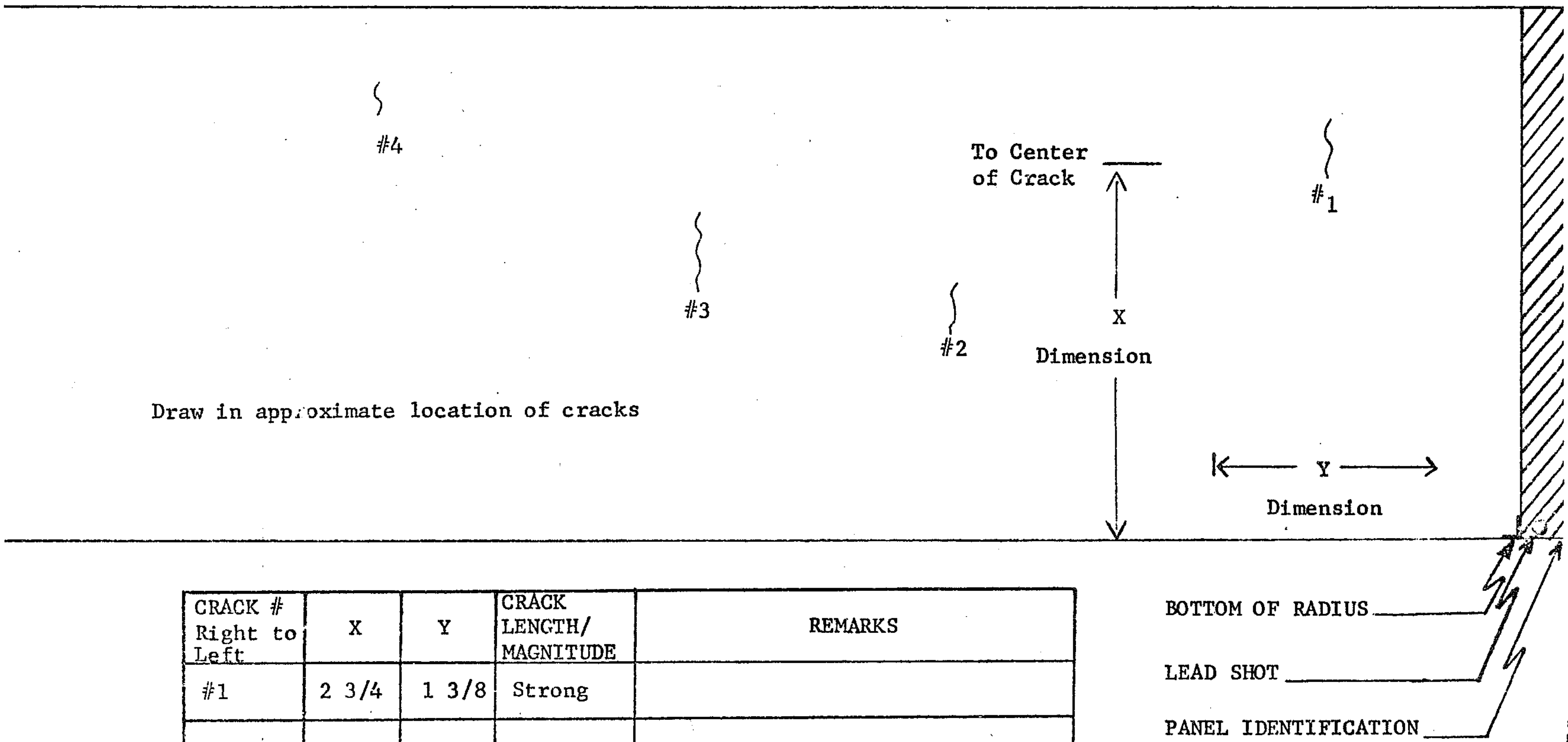
5.0 SAFETY

5.1 Operation should be in accordance with standard safety procedure used in operating any electrical device.

FATIGUE CRACK PANEL
INSPECTION REPORT

Side One
or
Side Two

SEQUENCE 1	PANEL NUMBER 1
OPERATOR Todd, P.H.	DATE 06-10-72



CRACK # Right to Left	X	Y	CRACK LENGTH/ MAGNITUDE	REMARKS
#1	2 3/4	1 3/8	Strong	
#2	1 11/16	3 3/4	Moderate	
#3	2 1/16	5 3/8	Very Strong	
#4	3	7 7/16	Weak	

ATTACHMENT I

EDDY CURRENT INSPECTION FOR FATIGUE CRACK PROGRAM PANELS

1.0 SCOPE

1.1 This procedure covers eddy current inspection for detecting fatigue cracks in thin aluminum plate.

2.0 REFERENCES

2.1 Manufacturer's instruction manual for the Nortec Model NDT-3 Eddy Current Instrument.

2.2 Nondestructive Testing Training Handbooks, P1-4-5, Volumes I and II, Eddy Current Testing, General Dynamics, 1967

2.3 Nondestructive Testing Handbook, by McMasters, Ronald Press, 1959, Volume II, Sections 35-41.

3.0 EQUIPMENT

3.1 Nortec NDT-3 Eddy Current Instrument

3.1.1 100 KHz Plug-in Module for NDT-3

3.1.2 100 KHz Probe for NDT-3

3.2 NDE Fatigue Crack Reference Panels 105T6S and 117U6R

3.3 Special Plexiglas Shoe for Probe

3.4 Beckman 10" Recorder, Model 1005

3.5 Special Probe Manual Sanning Fixture

3.6 Vinyl Tape

4.0 PERSONNEL

4.1 Only technically qualified personnel shall perform inspections.

5.0 PROCEDURE

5.1 Connect 100 KHz Plug-in Module and 100 KHz Probe to NDT-3 instrument.

5.2 Turn instrument power on by turning Coarse Gain Control to position #1.

5.3 Check batteries by push button switches. (These should be checked once every hour of use.)

5.4 Adjust R-1 to a voltage between TP-1 and TP-2 of 1.0 volts peak to peak.

5.5 Disconnect meter at the meter terminals and connect Beckman Recorder in its place and turn recorder on.

5.6 Place one layer of vinyl tape over the end of the probe and plexiglas shoe.

5.7 Set instrument controls as follows:

NDT-3

Level	- 7.00	Balance "X" - 3.10
Fine Gain	- MAX	Balance "Y" - 7.00
Course Gain	- 1	

RECORDER

Range - 100 MV

5.8 Place reference panel on manual probe scanning fixture. (To detect cracks in rough surfaced panels, use reference panel 117U6R: to detect cracks in smooth surfaced panels, use reference panel 105T6S)

5.9 Place the probe on the reference panel and adjust the level control until recorder reads zero scale.

5.10 Adjust the Balance "X" Control and level control so that the Recorder reads the same value (within $\pm$ 5 units) with and without a single sheet of note paper between the probe and the panel.

5.11 Move Coarse Gain Control to position #2.

5.11.1 Repeat Steps 5.9 and 5.10.

5.12 Using level control adjust Recorder to Zero.

5.13 Scan probe over the known crack in the appropriate reference panel and note Recorder deflection.

5.13.1 Turn Recorder ON and record length and depth of crack.

Panel 105T6S - Crack location X = 1.23" Y = 2.71", Side I

Panel 117U6R - Crack loaction X = 0.97" Y = 3.50", Side I

5.14 Replace reference panel with the inspection test panel to be checked.

5.14.1 Place inspection test panel into special fixture with tag in lower left corner (side I). Align machined edge with rule "Y".

5.15 Scan the probe in the "Y" direction over the test panel indexing the scanning fixture in the "X" direction in 1/8" increments until the entire panel has been covered.

5.15.1 Record length and depth of all cracks detected.

5.16 Repeat 5.15 for opposite side of test panel.

5.16.1 Place inspection test panel into special fixture with tag in lower right corner. Align machined edge with rule "Y".

NOTE: A CRACK IS INDICATED BY A RELATIVELY QUICK DEFLECTION OF THE RECORDER.

5.17 Crack indications are to be noted on Fatigue Crack Panel Inspection Report, Form X-21.

5.18 The magnitude of the crack will be noted on Form X-21 as follows:

A meter deflection of 10 mv or less = weak magnitude (W)

A meter deflection of 10 mv to 40 mv = moderate magnitude (M)

A meter deflection of 40 mv to 65 mv = strong magnitude (S)

A meter deflection of 65 mv and up = very strong magnitude (VS)

6.0 SAFETY

6.1 Operation should be in accordance with Standard Safety Procedure used in operating any electrical device.

LIQUID PENETRANT INSPECTION PROCEDURE FOR

FATIGUE CRACK DETECTION

1.0 SCOPE

1.1 This procedure describes liquid penetrant inspection of aluminum plate for detecting fatigue cracks.

2.0 REFERENCES

2.1 Uresco Corporation Data Sheet No. PN-100

2.2 Nondestructive Testing Training Handbooks P1-4-2, Liquid Penetrant Testing, General Dynamics Corporation, 1967

2.3 Nondestructive Testing Handbook, McMasters Ronald Press, 1959, Volume I, Sections 6, 7 and 8

3.0 EQUIPMENT

3.1 Uresco P-151 Ultra-Sensitive Fluorescent Penetrant

3.2 Uresco K-410 Spray Remover

3.3 Uresco D499C Spray Developer

3.4 Cheese Cloth

3.5 Ultraviolet light source (Magnaflux Black-Ray B-100 with General Electric H-100, FL4, Projector flood lamp and Magnaflux 3901 filter.

3.6 Two inch paint brush

3.7 1,1,1 - Trichloroethane

3.8 Isopropyl Alcohol

3.9 Rubber Gloves

3.10 Assorted dip pans, trays and holding racks

3.11 Light Meter, Weston Model 703, Type 3A

4.0 PERSONNEL

4.1 The liquid penetrant inspection shall be performed by technically qualified personnel.

5.0 PROCEDURE

5.1 Clean panels to be penetrant inspected by wiping each side of the panel with cheese cloth dampened in Isopropyl Alcohol and air dry for one hour.

5.2 Clean penetrant pan and brush with Isopropyl Alcohol.

5.3 Fill pan to 1/8th capacity with Uresco P-151 penetrant.

5.4 Holding the panel over the pan, brush the penetrant onto the panel covering both sides (machined areas only).

5.5 Allow the excess penetrant to drain off the panel into the pan.

5.6 Place the panel in the rack and allow a dwell time of 30 minutes.

5.7 Turn on the ultraviolet light and allow a warm up of 15 minutes.

5.7.1 Measure the intensity of the ultraviolet light and assure a minimum reading of 125 foot candles at 15" from the filter. (or 1020 micro watts per cm^2)

5.8 After the 30 minute penetrant dwell time, remove the excess penetrant remaining on the panel as follows:

5.8.1 With dry cheese cloth, remove as much penetrant as possible from the surfaces of the panel.

5.8.2 With cheese cloth, dampened with K-410, wipe remainder of surface penetrant from the panel.

5.8.3 Inspect the panel under ultraviolet light. If surface penetrant remains on the panel, repeat step 5.8.2.

NOTE: The check for cleanliness shall be done in a dark room with no more than two foot candles of white ambient light.

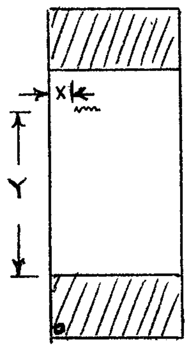
5.9 Allow 30 minutes bleed out time for the panels.

NOTE: After proof testing, panels are to be sprayed with D499c Uresco developer.

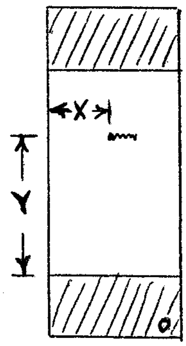
5.10. After the 30 minute bleed out time, inspect the panels for cracks under black light. This inspection will again be done in a dark room.

5.11 On data sheet X-21, record the location of the crack giving "X" and "Y" coordinates and the length of the cracks.

5.12 Panel orientation and dimensioning of the cracks.



Side I



Side II

5.13 Record date, inspection number, sequence nomenclature, (P-1 before milling; P-2 after chemical milling; P-3 after proof testing), panel number and side on each sheet of form X-21.

APPENDIX.-E

PENETRANT REMOVAL FOR FATIGUE CRACKS IN SMALL PANELS

1.0 SCOPE

1.1 This procedure covers the post cleaning methods developed for removal of penetrant material from fatigue cracks.

2.0 REFERENCE

2.1 Uresco Corporation Data Sheet No. PN-100

2.2 Nondestructive Testing Training Handbooks, P1-4-2, Liquid Penetrant Testing, General Dynamics Corporation, 1967

3.0 EQUIPMENT

3.1 Cleaning Materials

3.1.1 Isopropyl Alcohol (Industrial Grade)

3.1.2 1,1,1 - Trichloroethane

3.1.3 Uresco K-410 Spray Cleaner, Uresco Corporation

3.1.4 Tap Water

3.2 Cleaning Equipment

3.2.1 Ultrasonic Bath (Delta Sonics Model UT35H with Ultrasonic Generator Model 2000 or equivalent.

3.2.2 Ultraviolet light source (Magnaflux Black-Ray, B-100 with General Electric H-100 projector flood lamp and Magnaflux 3901 filter.

3.2.3 White light source (Standard incandescent or fluorescent light)

3.2.4 Pan (12" x 18" x 8") plastic, Stainless Steel, etc.

4.0 PERSONNEL

The fatigue crack cleaning procedure shall be performed by technically qualified personnel.

5.0 PROCEDURE

5.1 Three Cleaning Procedures have been developed for the three basic penetrant types.

5.2 Penetrant Types

5.2.1 Solvent Removable

5.2.2 Water Washable

5.2.3 Post Emulsifier

5.3 Cleaning Procedure for Solvent Removable Penetrants

5.3.1 Spray clean panel thoroughly using K-410.

5.3.2 Remove excess cleaner with paper towels.

5.3.3 Place panel in a bath of Isopropyl Alcohol for a 1 hour soak.

5.3.4 Place panel in ultrasonic cleaner containing 70% 1,1,1 - trichloroethane and 30% isopropyl alcohol; clean for 1 hour.

5.3.5 Dry panel with warm forced air for approximately 5 minutes.

5.3.6 Inspect panel under ultraviolet light for fluorescent penetrants or white light for visible penetrant. If _any_ traces of penetrants remain, repeat step 5.3.4.

5.4 Cleaning of Water Washable Penetrants

5.4.1 Soak panel in a bath of Isopropyl Alcohol for 1 hour.

5.4.2 Place panel in ultrasonic cleaner using Isopropyl Alcohol. Clean for 1 hour (See 5.3.4).

5.4.3 Dry panel with warm forced air for approximately 5 minutes.

5.4.4 Inspect panel under ultraviolet light for fluorescent penetrants or white light for visible penetrants. If _any_ traces of penetrant remain, repeat step 5.4.2.

5.5 Cleaning of Post Emulsifier Penetrants

5.5.1 Do not emulsify. Clean as a solvent Removable Penetrant. (see 5.3)

APPENDIX.-F

HOLOGRAPHIC INSPECTION OF FATIGUE CRACKED PANELS

1.0 SCOPE

To establish the optimized technique for evaluation of fatigue cracked panels under Contract NAS 9-12276.

2.0 EQUIPMENT

2.1 50 MW Helium-Neon Laser

2.2 Optical components as noted.

2.3 Specimen loading fixture.

2.4 Hologram holder and positioner.

2.5 Agfa-Gevaert 10E75 high resolution holographic plates.

3.0 PERSONNEL

3.1 Only technically qualified personnel shall perform inspection.

4.0 PROCEDURE

4.1 Position the test specimen in the loading fixture.

4.2 Apply a tension load

4.2.1 600 pounds (5100 psi) for 0.060 inch (0.15 cm) specimens.

4.2.2 2500 pounds (5950 psi) for 0.210 inch (0.531 cm) specimens.

4.3 Expose a holographic plate.

4.4 Develop hologram.

4.5 Reposition hologram in the focal plane holder.

4.6 Increase tension load

4.6.1 800 pounds (6850 psi) for 0.060 inch (0.152 cm) specimens.

4.6.2 3000 pounds (7100 psi) for 0.210 inch (0.531 cm) specimens.

4.7 Examine the specimen for presence of cracks by viewing through the initial hologram. A crack will appear as a break in the fringe pattern.

4.8 Record

4.8.1 Location of cracks.

4.8.2 The overall background fringe density (fringes per inch).

4.8.3 The number of fringes affected by the crack.

4.8.4 The magnitude of the fringe shift around the crack.

5.0 SAFETY

5.1 Avoid direct or prolonged exposure of unprotected eyes to the laser beam.

ATTACHMENT 1

Live Fringe Compressive Load (Hysteresis) Method

4.0 PROCEDURE

4.1 Position the test specimen in the loading fixture.

4.2 Apply a tension load.

4.2.1 800 pounds (6850 psi) for 0.060 inch (0.152 cm) specimens.

4.2.2 3000 pounds (7100 psi) for 0.210 inch (0.531 cm) specimens.

4.3 Expose a holographic plate.

4.4 Develop hologram.

4.5 Reposition hologram in the focal plane holder.

4.6 Decrease tension load to

4.6.1 600 pounds (5100 psi) for 0.060 inch (0.152 cm) specimens.

4.6.2 2500 pounds (5950 psi) for 0.210 inch (0.531 cm) specimens.

4.7 Examine the specimen for presence of cracks by viewing through the initial hologram. A crack will appear as a light or dark line in a contrasting dark or light fringe field.

4.8 Record

4.8.1 Location of cracks.

APPENDIX.-G

ACOUSTIC EMISSION INSPECTION PROCEDURE FOR FATIGUE CRACK DETECTION/LOCATION IN ALUMINUM PLATE

1.0 SCOPE

1.1 This procedure describes acoustic emission inspection of aluminum plate for detecting and locating fatigue cracks.

2.0 REFERENCES

2.1 Dunegan, H. L., Tatro, C. A.; "Passive Pressure Transducer Utilizing Acoustic Emission," Lawrence Radiation Lab, The Review of Scientific Instruments, August 1967.

2.2 Pracht, E. M.; "Acoustic Emission - Phase II A Nondestructive Test For Detection of Crack Growth," Martin Marietta Aerospace, December 1970.

2.3 Pracht, E. M.; "Acoustic Emission Monitoring For Detection of Cracks in Advanced Fibrous Composite Materials," Martin Marietta Aerospace, October 1971.

3.0 EQUIPMENT

3.1 Endevco Model 2222B Accelerometers, 3 each;

3.2 Kistler Model 504A Charge Amplifiers, 3 each;

3.3 Tektronic Model 564B Storage Oscilloscope;

3.4 Ampex Model FR1300 Tape Recorder;

3.5 Dana Model 2860 D.C. Amplifier;

3.6 Hewlett Packard Model 650A Test Oscillator;

3.7 Astatic Model 335H Microphone;

3.8 Martin Audio Amplifier;

3.9 Honeywell Model 1912 Oscillograph;

3.10 MTS Model 661-22 Tension Test Machine;

3.11 Dana Model 5600 Digital Voltmeter;

3.12 Assorted electrical power and connecting cables;

3.13 Eastman 910 Contact Cement.

3.14 Cheese cloth;

3.15 Methyl Ethyl Keotone (MEK).

4.0 PERSONNEL

4.1 The acoustic emission inspection shall be performed by technically qualified personnel.

5.0 PROCEDURE

5.1 Clean the aluminum plates to be inspected by acoustic emission in areas of accelerometer attachment with cheesecloth dampened in MEK.

5.2 Mark the accelerometer location on the aluminum plate as follows:

5.2.1 No. 1 accelerometer in center of plate and 1 inch from upper machined area.

5.2.2 No. 2 accelerometer in center of plate and 1/4 inch from right-hand edge.

5.2.3 No. 3 accelerometer 1 inch from lower machined area and 1/4" from left-hand edge.

5.3 Attach a small ¼" X ¼" X ¼" wide, 90 degree angle, aluminum bracket to each accelerometer with a drop of Eastman 910 contact cement and press together.

5.4 Mount the ¼" aluminum brackets, with the attached accelerometers, to the areas marked on the aluminum plate by applying a drop of Eastman 910 contact cement to the aluminum plate and the aluminum brackets and pressing together. The accelerometers should be at right angles to the aluminum plate surface with the accelerometer base toward the center of the aluminum bracket.

5.5 Place the aluminum plate, with the attached accelerometers, in the tension test machine. Adjust the ramp rate of the tension test machine to pull at the rate of .25 in/in/min.

5.6 Connect the electronic equipment per schematic diagrams 1 and 2.

5.7 Allow a few minutes for equipment to warm up and stabilize.

5.8 Start tension test machine to pulling aluminum plate and start recorder and oscillograph at the same time.

5.9 The oscilloscope and the audio amplifier should be monitored for flaw growth indication and the event coordinated with the digital voltmeter reading (indicating applied pressure) at that time. This should be recorded on the tape recorder by means of the microphone and a notation made with a pad and pencil also. This is useful in locating the emission during playback.

5.10 Set the tape recorder to run at 60 IPS tape speed during tension testing.

5.11 Set the oscillograph paper speed to .2 IPS during tension testing.

5.12 Narration of Events

The three accelerometers (Endevco Model 2222B) generate signals up to 8000 hertz which drive the 504A charge amplifiers. The charge amplifiers provide 1 volt peak output for a full scale (5G) input signal. The charge amplifier output signal is FM recorded into the magnetic tape recorder which is running at 60 IPS ± 25%. The frequency response of the tape recorder is 20,000 hertz ± .5 decibel. A timing signal and the data from 3 accelerometers are recorded at 60 IPS tape speed and later reproduced at 1-7/8 IPS, thus providing a time base change of 32:1.

"On line" monitoring of the system, at time of recording, is accomplished by running both the oscillograph and the oscilloscope. The oscillograph is operated at a slow paper speed (.2 IPS) during testing. The high speed galvanometer (5000 H_z) in the oscillograph is utilized during "on line" recording. The frequency response of the Dana amplifiers (between the tape recorder and the oscillograph) are good up to 50,000 H_z. The limiting factor on frequency response is therefore the accelerometer itself. Tape speed errors of the tape recorder and paper speed errors of the oscillograph are not significant factors providing that a stable timing frequency is recorded on tape. The time base error could otherwise be off by as much as 2%, due to paper speed variations of the oscillograph.

5.13 After testing is complete, play back the data on the tape recorder at 60 IPS.

5.14 Monitor the data play back on the storage oscilloscope.

5.14.1 Set the storage oscilloscope to sweep (trigger) at a voltage spike just above background noise level (approximately 1½ times background noise).

5.15 After the voltage spike has been located on the magnetic tape, set the tape recorder to run at 1-7/8 IPS.

5.16 Set the oscillograph to record at 160 IPS.

5.17 Start the tape recorder and the oscillograph simultaneously and monitor the oscilloscope for a visual indication of the voltage spike.

5.18 Stop the oscillograph and the tape recorder as soon as a voltage spike is observed.

5.19 To locate the flaw that propagated:

5.19.1 Determine the elapsed time of the pressure pulse from the time it reached the first accelerometer to the time it reached the other two accelerometers by utilizing the 32000 cycles/sec timing pulse (Ref. Fig. 2). Accel. #3 to Accel. #2 = $0.2 \times 3.2 \times 10^{-4} = .64 \times 10^{-4}$ secs.

Accel. #3 to Accel. #1 = $0.4 \times 3.2 \times 10^{-4} = 1.28 \times 10^{-4}$ secs.

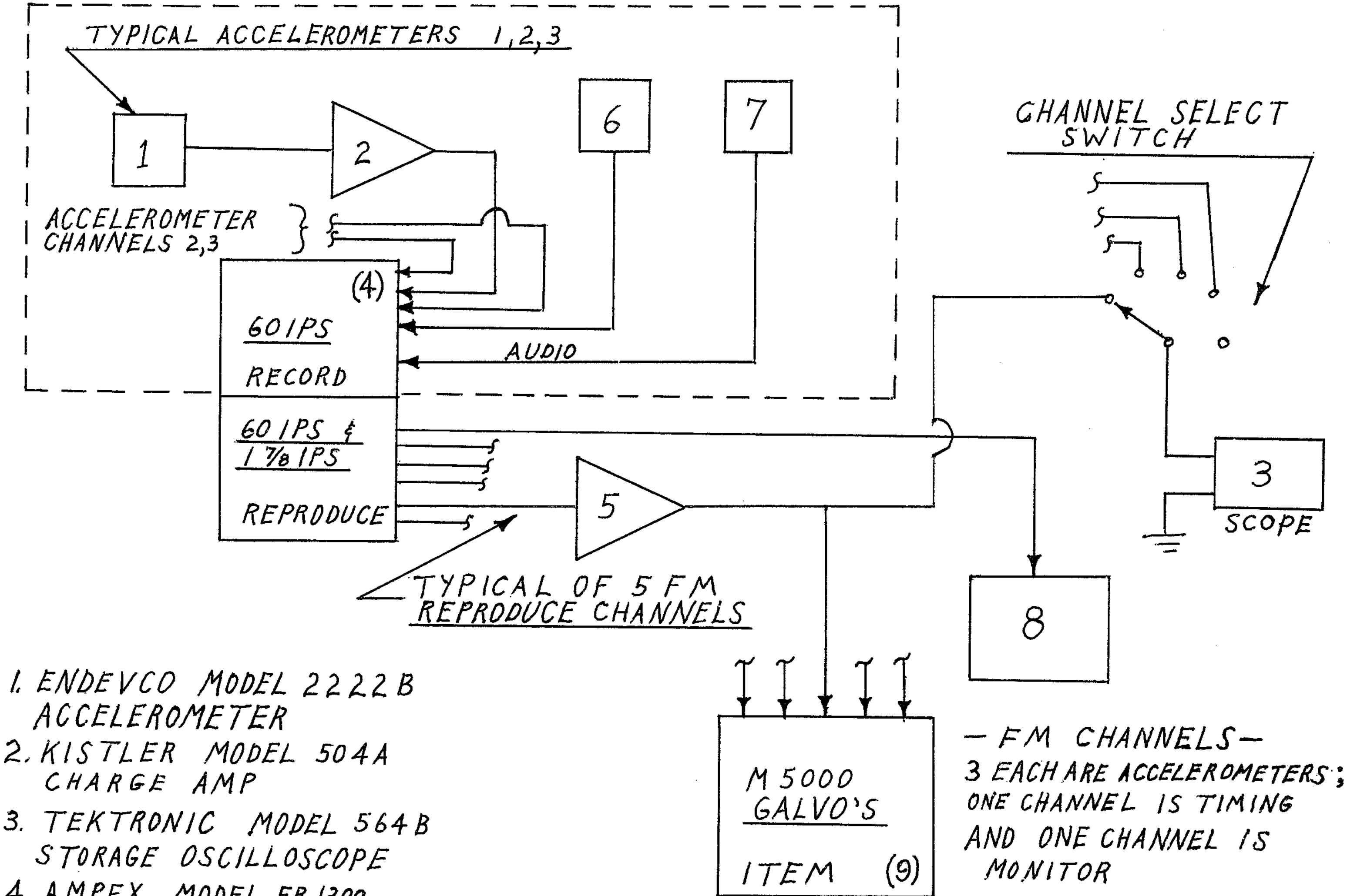
5.19.2 Determine the distance the pressure pulse traveled;

Accel #3 to Accel. #2 = $.64 \times 10^{-4} \times 11.6 \times 10^{4} = 7.4$ inches

Accel. #3 to Accel. #1 = $1.28 \times 10^{-4} \times 11.6 \times 10^{4} = 14.9$ inches.

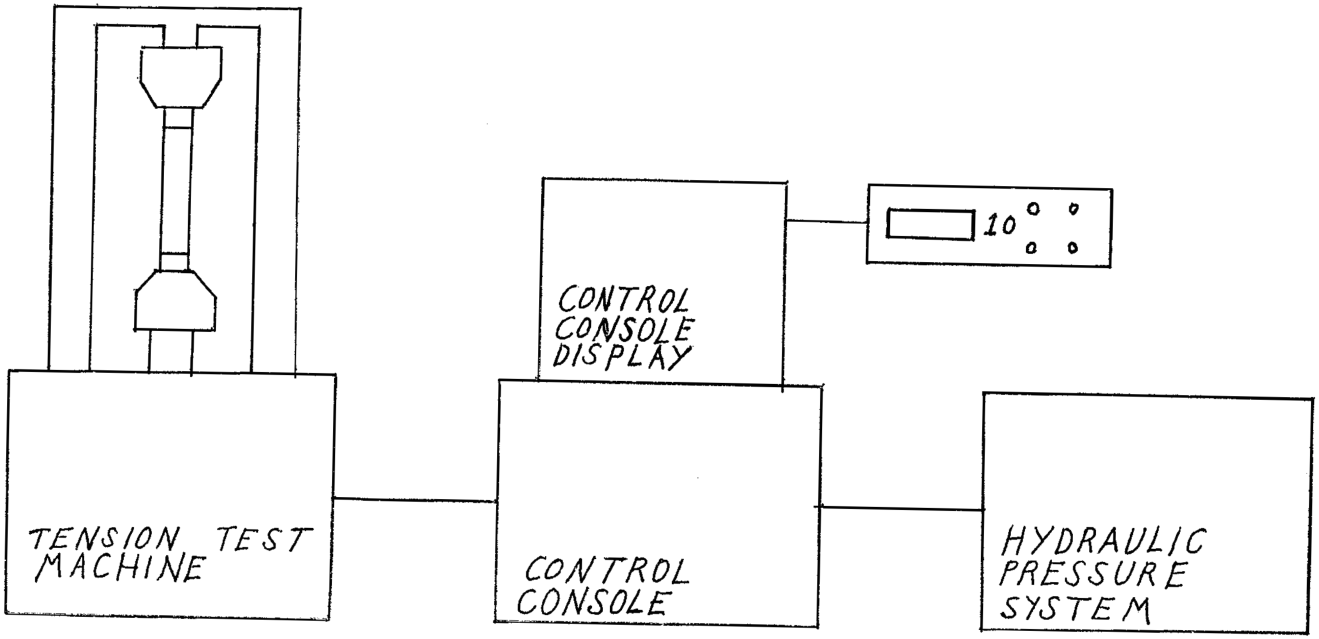
5.19.3 Determine the distance the pressure pulse traveled after it passed Accel. #1 by drawing a circle with a radius of 7.4 inches around Accel. #2 and drawing another circle with a radius of 14.9 inches around Accel. #1.

5.19.4 Locate the origin of the pressure pulse by drawing a circle that is tangent to the two circles constructed in the previous step and that passes through Accel. #3. The center of this circle is the origin of the pressure pulse (the propagating flaw).



1. ENDEVCO MODEL 2222 B ACCELEROMETER
2. KISTLER MODEL 504 A CHARGE AMP
3. TEKTRONIC MODEL 564 B STORAGE OSCILLOSCOPE
4. AMPEX MODEL FR 1300 TAPE RECORDER
5. DANA MODEL 2860 DC AMP

Fig. 1 (a)



6	HEWLETT PACKARD	MODEL 650A	TEST OSCILLATOR
7	ASTATIC	MODEL 335H	MICROPHONE
8	MARTIN		AUDIO AMPLIFIER
9	HONEYWELL	MODEL 1912	OSCILLOGRAPH
10	DANA	MODEL 5600	DIGITAL VOLTMETER

Fig. 1 (b)

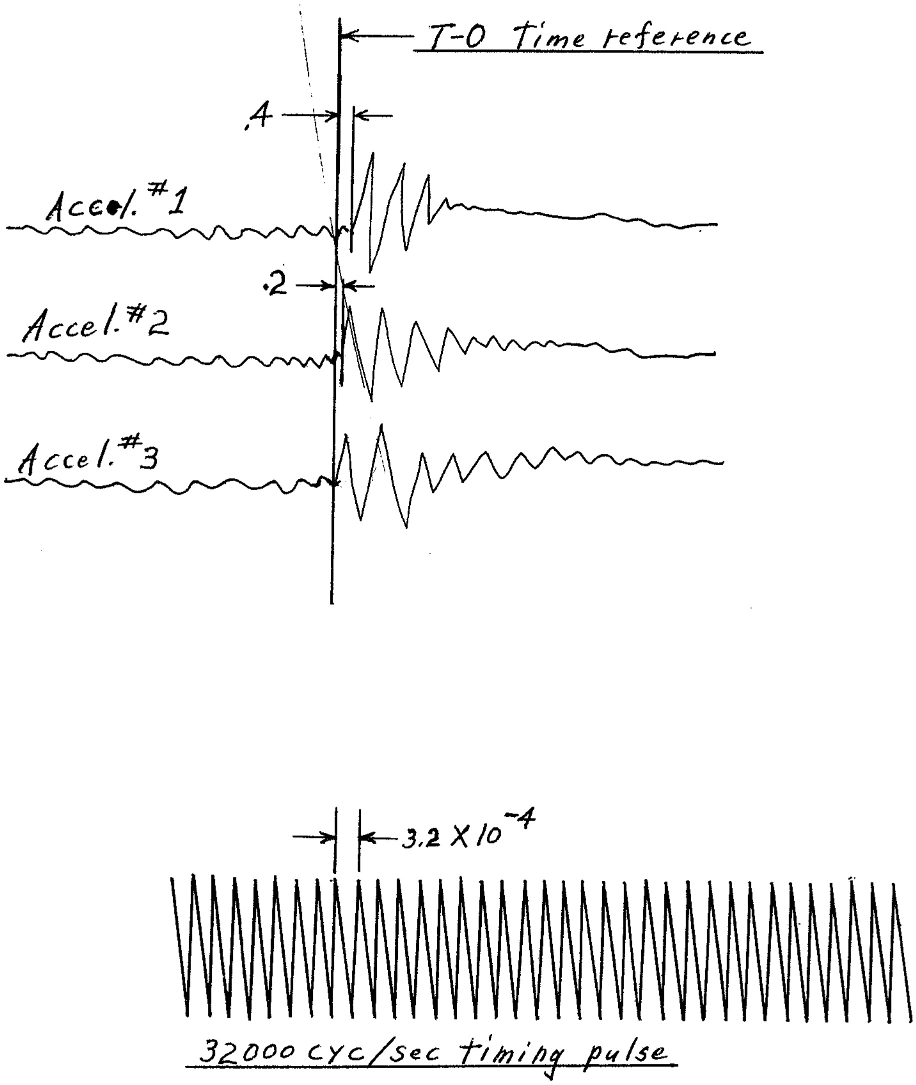

T-0 Time reference
.4
Accel. #1
.2
Accel. #2
Accel. #3
3.2 X 10^-4
32000 cyc/sec timing pulse

Fig. 2

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