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DIVISION OF AUTOMATION INDUSTRIES, INC.

Sperry

DANBURY, CONNECTICUT

FINAL REPORT

ON

DEVELOPMENT OF A RING BEAM WHEEL SURFACE WAVE SEARCH UNIT

Prepared for:

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA
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Modification 2

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1.0 TABLE OF CONTENTS

2.0 INTRODUCTION

2.1 General

Sheet and plate metal form an essential and integral part of major structural components and assemblies in space vehicle stages. Use of unsound material could seriously jeopardize flights because of unreliable strength assumptions. Lack of soundness becomes more acute, or actually begins to exist, as a result of working the material. Therefore, methods for detecting and locating surface defects are required in the preassembly phases of stage fabrication.

Methods presently used include fluorescent dye penetrant, visual inspection, and others of lesser popularity. All of these methods are time consuming and are quite subject to human error. Further, the dye penetrant method, although comparatively accurate, adds a clean-up problem in the removal of the dye; this is especially difficult in small cracks and becomes critical where "lox" cleanliness is involved.

Ultrasonic methods of inspection have become fairly common in recent years. Work has been done at MSFC which demonstrates the accuracy and the reliability of weld inspection by ultrasonic methods, and also demonstrates unique capabilities not possible by other means. Generally, these techniques use a shear wave approach. An angle beam shear wave method has the characteristic of probing through the material of a plate in a zig-zag path along the plate, alternately reflecting from its two sides. Thus, both sides may be scanned in one operation. A shallow crack at one side would form a corner reflector; the material surface acting as one face, and the crack as the other face of the corner reflector. Both flat plate and contoured plate may be inspected by this method. However, the operation of this method may be seriously complicated by irregular geometry of the opposite side, or by attachments made to the opposite side. It is in such cases that the use of a surface wave method has a distinct advantage.

Unlike shear wave propagation as described above, surface waves penetrate only to a very limited depth into the material, and travel along the contour of the material until interrupted by a sharp change in surface direction. A natural edge of the material or a very shallow discontinuity in the material would present such a change in direction.

Surface wave propagation requires a material thickness of at least one wavelength of the surface wave. Thinner material will not support surface waves; instead, the thinner material would cause Lamb waves to be generated. Propagation of surface waves is only slightly attenuated in aluminum having smooth faces. These characteristics make the use of a surface wave method especially suitable for the inspection of large areas of a single surface of either flat or gently contoured aluminum plate.

2.2 Prior Development Work

The use of Variable Angle Wheel Search Units, Type SOB, Size 1/2" x 1", Styles 50D403, 50D340 and 50D404 in operating frequencies of 1.0 Mc., 2.25 Mc., and 5.0 Mc. for the detection of surface discontinuities in specimen aluminum materials by surface wave techniques has been investigated in detail.

Results of this investigation are given in a final report entitled "Ultrasonic Surface Wave Probing Techniques for Determining Material Soundness", Reference 3.1.

Test results indicate that the Variable Angle Wheel Search Unit, Style 50D340 at 2.25 Mc., is the most effective in surface inspection of specimen material.

Results of further tests show that its ultrasonic beam, as used in a pulse-echo method, is very directional. Turning the beam 0.5 degree from the normal to a test notch 12" away reduces signal amplitude 10%. Turning 2.0 degrees from the normal reduces signal amplitude 75%.

In consideration of such high directivity, the use of Variable Angle Wheel 50D340 would in practice require inspection scans at about 1^{o} intervals in orientation to provide complete coverage for the detection of straight notches on specimen materials. Counting both sides of a notch to be equally detectable, full coverage would therefore require scans at a minimum of 180 orientations.

2.3 Ring Beam Wheel Surface Wave Search Unit

The design and development of a ring beam wheel surface wave search unit was proposed for the purpose of reducing the number of scanning angles needed for reliable detection of randomly oriented surface cracks.

The performance expected of such a search unit was based to a large degree on results obtained and reported in "Ultrasonic Surface Wave Probing Techniques for Determining Material Soundness", Reference 3.1.

3.0 REFERENCE

3.1 Final Report, "Ultrasonic Surface Wave Probing Techniques for Determining Material Soundness", March 25, 1965, Contract No. NAS8-11454.

4.0 SCOPE OF WORK

4.1 Design, develop and deliver a special ultrasonic wheel type transducer which will radiate surface waves in a 360° pattern from its contact position on material to be scanned.

4.2 Perform necessary testing to define an ultrasonic surface wave flaw detection system.

4.3 Utilize ultrasonic frequencies necessary to scan plate aluminum material of thickness range .091" to 1.00" for surface discontinuities. Prepare new or use existing reference standards in performance of evaluation of the ring beam wheel.

4.4 Perform study of waves generated by the ring beam wheel. Prepare distance amplitude curves from reference plates to simulate surface defects at different test distances. Prepare recordings of all scans of reference or other test plates.

4.5 Determine with the use of a distance amplitude correction method the most efficient scanning pattern and number of scan passes necessary for complete coverage of a plate. Perform additional research and testing as required to define a basic ultrasonic surface wave test system.

4.6 Prepare surface wave system layout drawing incorporating all new features not previously presented.

5.0 DETAILED WORK PROGRAM

5.1 STEP I - Design and Procurement

5.1.1 Determine the effect of tire contact spot shape on inspection sensitivity.

5.1.2 Determine incident angle required in wheel fluid to produce a surface wave in specimen material.

5.1.3 Devise several methods of generating a conical beam within the tire at the angle determined in 5.1.2.

5.1.4 Of the several methods devised in 5.1.3, select two for development. Prepare drawings for the construction of a single search unit utilizing each of the two selected methods through the use of demountable reflector kits to be installed alternately.

5.1.5 Procure parts and materials for the construction of the search unit.

5.2 STEP II - Experimental Assembly

5.2.1 Assemble two (2) crystal-facings backings.

5.2.2 Compare operation of the two assemblies in simple immersion system.

5.2.3 Determine whether match network would improve operation. If so, design and construct network.

5.2.4 Complete assembly of Wheel Unit using the better of the two assemblies as found in Paragraph 5.2.2 and Reflector Kit "A" - 50B1413.

5.2.5 After experimental data has been obtained for STEP III using Reflector Kit "A", disassemble the Unit and reassemble using Reflector Kit "B" - 50B1414.

5.3 STEP III - Study of Waves

5.3.1 With Reflector Kit "A" - 50B1413 installed in the Wheel Unit, perform the following tests:

5.3.1.1 Show that Unit generates a ring beam of surface waves on specimen material. Determine whether internal beam angle is proper, check for presence of other modes on thick specimen material.

5.3.1.2 Obtain Amplitude/Notch Angle data in 22 1/2° intervals at a distance of 5", and in intervals of 30° at a distance of 10".

Use Test Plate "D", both sides. (See Figures 12 and 13.)

5.3.1.3 Obtain Amplitude/Notch Depth data using scan "Tire Roll A", on Test Plate "E". (See Figure 14.)

5.3.1.4 Obtain Distance/Amplitude data using scan "Tire Roll A", on Test Plate "E". (See Figure 14.)

5.3.1.5 Set up DAC. Operate DAC to correct for distance in above tests.

With DAC properly adjusted, take several slant scans such as "Tire Roll B", Sketch 14 on Test Plate "E". Show that results are the same as those for "Tire Roll A".

5.3.2 Install Reflector Kit "B" and repeat above paragraphs 5.3.1.1 through 5.3.1.5.

5.4 STEP IV - System Layout

5.4.1 Design Automatic Scanning and Recording System. Determine values for the following to provide best scanning system:

- Gate Start, time
- Gate Length, time
- Index Interval, inches
- Scanning Speed, feet/minute
- Indexing Speed, inches/second

5.4.2 Make mechanical layout for complete scanning system.

6.0 WORK PERFORMED AND RESULTS OBTAINED

6.1 STEP I - Design and Procurement

6.1.1 Design of a Ring Beam Wheel Search Unit

The first consideration in design was given to the shape of the spot made by the tire on the test material and its effect on inspection sensitivity.

Prior surface wave work performed with a Variable Angle Wheel Search Unit (Style 50D340) indicated that reflected signal amplitude is highly dependent on the width of the tire surface contact spot. Results of this work are reproduced in Figure 1. Here, the surface wave path is only at one side of the tire.

From this, it follows that the desired uniform testing sensitivity throughout a 360° range of a ring beam search unit requires a round spot shape, unless internal compensation is provided.

Tests were conducted using the existing tire on Search Unit Style 50D340 to compare the width and length of the contact spot as the tire was compressed. Results are plotted in Figure 2 (upper graph).

Hypothetical signal amplitudes were then calculated for the width and length directions by using the Signal Amplitude/Contact Width data of Figure 1 together with Spot Size/Post Height data of Figure 2 to obtain the calculated Signal Amplitude/Post Height plots in Figure 2.

The signal Amplitude/Post Height plots indicate that wide and irregular spread of inspection sensitivity throughout a 360° range would result if the present tire were used in a ring beam search unit. A decision was therefore made to construct a new tire having a spherical tread so that its contact spot would be round.

The second design consideration was given to the incident angle of the ultrasonic beam within the tire necessary to produce a surface wave in aluminum. Prior work showed that the Variable Angle Wheel Search Unit generated surface waves in specimen material when its side angle control was at a dial setting of 19.80 (see Page 9, Final Report, Reference 3.1), corresponding to an incident angle of 35°

(see Figure 7, Final Report, Reference 3.1). This agrees with the angle computed by substitution in Snell's Law:

$$\frac{V_1}{V_2} = \frac{\sin \phi_1}{\sin \phi_2}$$

where V_1 = 1.66×10^5 cm/sec., longitudinal velocity, wheel fluid.
See Figure 7, Reference 3.1

V_2 = 2.90×10^5 cm/sec., surface wave velocity, specimen material.
See Figure 17, Reference 3.1

ϕ_1 = Incident angle in wheel fluid

ϕ_2 = 90° (for surface wave in specimen material)

$$\phi_1 = \arcsin \frac{V_1}{V_2}$$

$$\phi_1 = 35^\circ$$

Therefore, a surface wave ring beam wheel search unit requires a conical beam in its wheel fluid at 35° from the normal.

The third design consideration was given to methods of generating such a 35° conical beam in a tire having a spherical tread.

The concept originally planned about a year ago to obtain this has a flat doughnut type transducer and a funnel reflector as shown laid out with beam paths in Figure 4. Recently, several alternate methods, as shown in Figures 3, 5, 6, and 7 have been proposed.

In all five layouts, a tire diameter of 6 1/4 inches and a contact spot diameter of 2 inches are used. Principal constructional and operational qualities are given below for comparison:

Figure 3	a)	Beam angle may be changed by changing angle of reflector insert
	b)	Crystal has very small area
	c)	Base of reflector too near tire for safety
Figure 4	a)	Beam angle may be changed by changing angle of reflector insert
	b)	Crystal has large area
Figure 5	a)	Beam angle fixed
	b)	Crystal has large area
Figure 6	a)	Beam paths use a large part of available height, leaving too little space for necessary backing
	b)	Beam angle may be changed by changing angle of reflector insert
	c)	Crystal has small area
Figure 7	a)	Beam angle may be changed by changing angles of reflector inserts
	b)	Crystal has small area

On the basis of the above listed qualities, the original concept, as shown in Figure 4, was chosen for development, with the concept in Figure 7 to be used as an alternate. Final design of these is given in Figures 8 and 9. Both systems use the same Transducer and Shaft Assembly. In the single "funnel" reflector system, the central part of the transducer's beam is masked by a baffle to prevent transmission directly through the orifice of the reflector. To change to the double reflector system, the funnel reflector and the central baffle are removed, and Reflector Kit "B" is installed. With this, Baffle 50B1412 masks the outer area of the transducer to prevent direct transmission to the tire.

Such construction also permits future installation of modified reflector and baffle kits for use in testing materials other than the specimen aluminum.

6.1.2 Procurement

Parts and materials required for the construction of the Ring Beam Wheel Search Unit, but not available in Sperry stores were purchased through outside vendors.

6.2 STEP II - Experimental Assembly

6.2.1 Transducer Test

Considering the fragility of Crystal 50A3618 and of the associated Facing 50A3617, and considering the critical operation of assembling these on Backing 50C1005 and Spacer 50A3621, these parts had been ordered in quantities of two each.

Two of each were received, and two assemblies, designated "A" and "B", were made.

Comparative ultrasonic tests of the two assemblies were made using an immersion system as shown in Figure 15.

In this, a steel ball reflector was set in the lower part of a tank; and a crystal backing assembly, supported by a mounting bolt, was partly immersed in water in the tank.

When the crystal leads were connected to a Reflectoscope switched to 2.25 Mc., a reflection from the steel ball was observed on the screen. The amplitude of this reflection was monitored as the assembly was rotated on the mounting bolt. Tests were repeated with the steel ball at several distances from the axis of the mounting bolt.

Representative results obtained, shown plotted on polar coordinates in Figure 16 indicate that Assembly "A" has a more uniform but somewhat lower ultrasonic amplitude output than Assembly "B". Since it is considered that uniformity of output is a more important quality than higher level output, Assembly "A" was chosen for installation in the Wheel Unit. Assembly "B" was kept as a spare.

The doughnut crystal 50A3618 has an electrical capacity of approximately 0.02 mfd. which is much larger than is found in search units commonly used with the Reflectoscope.

When the crystal was connected through a 6'4" cable to the "R" jack of the Reflectoscope, and when the frequency control of the Reflectoscope was set at 2.25 Mc., detuning was so severe that the initial pulse frequency, as observed on a Test Oscilloscope, dropped to 0.25 Mc.

The Pulser/Receiver 5N of the Reflectoscope was modified, and a match network was designed and installed in the Wheel Search Unit as shown in Figure 15. Pulse length and Pulse tuning controls were not used. With these changes made, the operating frequency of the system returned to 2.25 Mc.

Reflector Kit "A" 50B1413 (see Item 26 on Drawing 50D440; Figure 8) was installed on the Crystal Backing Assembly "A".

When partially immersed in a tank of water as shown in Figure 17 and when connected to a Reflectoscope, a clear reflection was obtained from a Test Reflector tilted at the 35° angle as it was rotated about the center line. This indicated that the required conical beam at 35° from the vertical was produced.

Reflector Kit "A" was removed from the backing and Reflector Kit "B" (see Figure 9) was installed.

Similar tests made on Reflector Kit "B" indicated that it also produced a conical beam at 35°. However, its amplitude was lower than that of Kit "A". In addition to the conical beam, Reflector Kit "B" produced a high amplitude beam almost axial in direction.

6.2.2 Assembly of Search Unit.

The Ring Beam Search Unit was first assembled with Reflector Kit "A" installed.

Principal parts of the Search Unit are illustrated in Figure 10. The completed search unit is illustrated in Figure 11.

6.3 STEP III - Study of Waves

6.3.1 Preparation of Test Plates

Test Plates "A" through "G" had been used to develop results given in Final Report - "Ultrasonic Surface Wave Probing Techniques for Determining Material Soundness" (Reference 3.1).

Plates "D" and "E" were chosen from this group for use in performing tests of the Ring Beam Wheel Search Unit.

Additional test notches at various angles on two sides of Test Plate "D" were prepared as shown on Figures 12 and 13. These were used to obtain Amplitude Angle data for the Ring Beam Wheel Search Unit at distances of 5 inches and 10 inches respectively.

Prior tests have indicated that when testing an aluminum plate 0.210" thick with 2.25 Mc surface waves, no interference results from notches on opposite sides of the plate.

Notch 19 is not a test notch, but is cut through the plate to eliminate reflections from plate edges which would interfere with tests to Notches 10 and 8..

Additional notches at depths of 0.005", 0.010", 0.020", and 0.030" on plate "E" were prepared as shown on Figure 14 to obtain Amplitude/Depth, Amplitude/Distance, and Amplitude/Angle data.

6.3.2 Search Unit Adjustment

With Reflector Kit "A" installed, the Ring Beam Wheel Search Unit was mounted on the laboratory test stand as shown in Figure 11, and was placed on an aluminum plate 1/4 inch in thickness as shown in Figure 20.

The "Shaft and Transducer Angle Adjustment" was set so that surface waves were transmitted simultaneously toward edges "A" and "B". Shims were placed at either S1 or S2 as required between the Mounting Bracket (50D444) and the test stand to align the search unit so that surface waves were also transmitted simultaneously toward edges "C" and "D".

Surface wave transmission was recognized by the following tests:

a) The wave could be damped (reduced in amplitude by absorption of energy) by placing one's hand along the beam on the upper surface.

b) The wave could not be damped from the bottom surface.
c) The measured velocity of the wave (2.9×10^5 cm/sec taken from Paragraph 3.3) agreed with the value established in prior work. (See Reference 3.1 Figure 17).

6.3.3 Analysis of Screen Patterns

Since the search unit radiates surface waves in all directions on the upper surface of specimen material, placing it on a rectangular test plate as shown in Figure 19 results in reflected signals from each of the four sides and from each of the four corners.

As an aid to identification of reflected signals, the testing time was measured from the initial pulse to signals reflected from plate edges at known distances and in four directions from the contact spot.

For the measurement of time intervals the following steps were taken:

a) A search unit Type SAQ was placed on an aluminum bar 6.31 inches long which produced multiple back reflections at regular time intervals of 50 microseconds.
b) Markers were displayed on the screen starting with the initial pulse. These were adjusted in length so that marker cycles matched the 50 microsecond back reflection intervals.
c) Testing times were then read directly from the calibrated marker cycles, as shown in Figures 18 and 19.

Testing times were read as the Wheel Search Unit was rolled toward or away from edges "A" and "B" in Figure 20; or slid sidewise toward or away from "C" and "D". Data obtained is plotted in Figure 20.

The plot indicates that the first 110 microseconds are taken by the search unit itself for transmission through the fluid. It also shows, as would be expected, that testing velocities are the same for the four different directions.

The velocity of the wave V_R is determined from the distance travelled in a known time. The plot shows that the wave makes a round trip in 22 inches of aluminum, during a 390 microsecond interval.

$$V_R = \frac{22 \times 2 \times 2.54 \text{ cm}}{390 \times 10^{-6} \text{ sec}}$$

$$V_R = 2.86 \times 10^5 \text{ cm/sec}$$

This measurement closely agrees with the velocity of 2.90×10^5 cm/sec for the surface wave in specimen material obtained by the precision method reported in Reference 3.1.

Some of the signals appearing on the screen originate within the Wheel Search Unit and are due to reflections from internal interfaces. Grouped together, these are called "wheel noise". As shown on Figure 18, the Wheel Search Unit placed on a wooden board takes the same physical shape as when placed on an aluminum plate but transmits nothing into the board. The reflections appearing are therefore all due to "wheel noise". High amplitudes wheel noise is shown to extend from 100 to 150 microseconds with another spike appearing at 215 microseconds. Transferring to testing distance, this indicates high interference in the range from 0 to 6 inches. To be reliably clear of such interference, testing should start 250 microseconds after the initial pulse, which corresponds to a distance of 8 inches from the center of the tire contact spot.

A typical screen pattern for a test to edges and corners of a 24 inch by 30 inch plate is shown in Figure 19. Both operating sensitivity and sweep length have been increased above settings used in Figure 18.

The following signals are shown:

Description	Time Usec	Distance Inches	Remarks
Wheel Noise	100 to 250	-	Same as Fig. 18
Edges			
A	200	5	In wheel noise
B	365	14	Clear
D	400	16	Clear
F	455	19	Clear
Corners			
C	375	14.9	Clear
E	410	16.8	Clear

Note: Screens displays 21" of material. Corner reflections G and H are off screen.

In rolling the tire along the plate, certain reflectors may remain fixed in distance, whereas others either increase or decrease in distance. It follows that their corresponding screen signals move along the baseline accordingly; some remaining fixed in position, some moving toward the initial pulse, other moving away from it.

As an example, if the search unit were moved from its position shown in Figure 19 along path "B" and "D" toward "D", the following shift of signals would result:

SCREEN PATTERN CHANGES AS WHEEL SEARCH UNIT IS MOVED TO THE RIGHT FROM POSITION SHOWN IN FIGURE 19

Description	Change in Baseline Position
Wheel Noise	No Change
Edges	
A	No Change
B	Moves to right
D	Moves to left
F	No Change
Corners	
C	Moves to right
E	Moves to left
H	Comes on SCREEN at right end and moves to left

Note: Corner reflection G remains offscreen.

6.3.4 Signal Amplitude/Notch Depth

A study was made of the relation of signal amplitude to notch depth as the wheel search unit was moved on Test Plate "E" at a fixed distance from notches of various depths.

A typical case is illustrated in Figure 21. In this, the search unit was moved by hand from "A" to "B" along a path 8 inches from the four notches in depths of 0.005", 0.010", 0.020", and 0.030". As the search unit came directly in front of each notch, a reflected signal appeared on the Reflectoscope screen at the 8 inch distance position.

A Transigate Module Style 50E550, was plugged into the Reflectoscope, with its output connected to a Tape Recorder (Brush - Mark II Model RD-2522-20). The Transigate was adjusted to start the display of its gate at the 7 inch testing position on the Reflectoscope screen, and to end its gate at the 9 inch position. With this, only signals appearing on the screen within the 7 to 9 inch testing range were sent to the Recorder. Furthermore, voltages of these signals were in direct proportion to their screen amplitudes, providing recorder in deflections also in proportion to screen signal amplitude. See Figure 23.

The Tape Record produced by the scan of the four notches is illustrated in Figure 22. This shows the shallowest notch (0.005" deep) clearly recorded, and increasing deflections for deeper notches.

6.3.5 Signal Amplitude/Notch Angle

A second study was made to determine the relative signal amplitude obtained from notches having various orientations but of constant depth and distance.

For this, the search unit was positioned as at "A" on Figure 24 and was moved by hand from Notch 19 to Notch 14 on Test Plate "D". During this run, signals successively appeared on the screen at the 5 inch testing position reflected from notches 10, 18, 11, 17, 12, 16, 13, 15, and 14 in that order. Their amplitudes were noted and recorded. This covered one 180° range at intervals of 22 1/2°. For the other 180° range the search unit was then turned around to position "B" and was again moved from 19 to 14. Tape recordings of the two runs are shown in the lower part of Figure 24.

Similar tests were run using notches at 10 inches away at intervals of 30° on the opposite side of Test Plate "D". Results are shown on Figure 25.

A summarization of signal amplitudes obtained in the above tests on the two sides of Plate "D" at both 5 inches and 10 inches away is given in Figure 26.

6.3.6 Distance Amplitude Correction (DAC)

A third study was conducted to:

a) Investiage the effect of notch distance on reflected signal amplitude.

b) Demonstrate the use of a Distance - Amplitude - Correction Module to remove the effect of notch distance on reflected signal amplitude.

For this, the search unit was placed on Test Plate "E" as shown in Figure 27 and the amplitude of the signal reflected from the 0.013" notch was monitored as distance "D" was varied.

A plot of the observed signal amplitude variation is given on the lower half of Figure 27. See the curve marked "DAC OFF"

A Distance Amplitude Correction (DAC) Module was then plugged into the Reflectoscope chassis and was adjusted for proper correction of the DAC-OFF curve.

With DAC turned on, the reflected signal amplitude remained between 1.0 and 1.2 inches for any distance "D" in the range of 2.5 to 25 inches.

A practical demonstration is given in Figure 28 of the use of the search unit and a DAC module in the Reflectoscope to maintain constant the amplitude of signals reflected from a given notch with both distance and orientation as variables.

Tire roll path "A" was set 3 inches away from, and parallel to, the group of four notches in various depths. Tire roll path "B" was arbitrarily laid out at 35° to "A" so that distances to the notches ranged from 4 to 14 inches.

The close approximation of the data obtained as plotted indicates an excellent correlation of signal amplitude and notch depth without regard to either notch distance or notch orientation.

6.3.7 Operation of Reflector Kit "B"

Following the performance of tests using Reflector Kit "A" as described in Paragraphs 6.3.2 through 6.3.6, the Wheel Search Unit was disassembled. Reflector Kit "A" was removed from the backing. Reflector Kit "B" was installed, and the Wheel Search Unit was reassembled.

Tests were then conducted using Reflector Kit "B".

After alignment of the Search Unit to test material by the same method described in Paragraph 6.3.2 for Reflector Kit "A", the Search Unit was placed on Test Plate "E" as shown in Figure 29.

A small screen signal appeared representing a surface wave reflection from the plate edge 6 inches away. If one placed an oiled finger along the test path, as at position "A", surface wave energy was absorbed and the screen signal disappeared. Reflectograms for the two conditions are shown in Figure 29.

Further tests were performed by positioning the Search Unit on Test Plate "E" to provide a tire roll path 14 inches away from, and parallel to, the four notches in depths of 0.005", 0.010", 0.020", and 0.030".

As they were scanned, all four notches were detected in succession. One Reflectogram on Figure 30 shows the detection of the 0.020" notch; another shown for comparison the screen pattern remaining immediately after passing by the 0.020" notch.

An analysis of the high-amplitude interference distributed generally along the baseline, as shown on all four Reflectograms, indicated that the major part was due to transmission of wave modes other than surface waves in the test plate. This interference is presumed to be due to the extraneous high amplitude beam almost axial in direction within the tire. The presence of such a beam is reported in Paragraph 6.2.1.

In consideration of the difficulty of observing and identifying small surface wave signals in the presence of a wide range of large interfering signals, further tests using Reflector Kit "B" in its present form were suspended.

6.4 System Layout

6.4.1 Principles of Scanning and Gating

When the Ring Beam Wheel Search Unit is placed on a test specimen, surface waves are produced as shown in Figure 31 radiating from the contact spot throughout a full 360° range.

An electronic gate is adjusted to start at a time corresponding to a small test distance away from the contact spot, and to end at another time corresponding to a longer distance at which testing sensitivity has not dropped to too low a level. The interval of gating therefore describes a doughnut pattern on the specimen also shown in Figure 31. Reflected signals received from surface discontinuities within this doughnut area are sent to an alarm and recording system. Signals occurring outside the gated time, such as the initial pulse and any wheel "noise", and reflections from distant edges are not sent to the alarm and recorder system.

The gate appears on the screen as shown in Figure 32, "Final Report" of Reference 31.

As the wheel moves along a test piece, the travelling doughnut describes an inspection pattern as shown in Figure 32.

Figure 33 shows how three round holes are detected in two parallel scans. Each scan position represents a tire track. Since round holes reflect equally well from all angles, they are detected whenever the "travelling doughnut" passes over them; or in other words, whenever the distance from wheel to hole falls between Gate Start "S" and Gate End "E".

Unlike drilled holes, straight surface notches are detected only when the ultrasonic beam is perpendicular to their orientation, and distances to them fall within the gated interval.

Figure 34 shows eight such notches in various orientations and at various distances from a tire roll track (Scan 1). Gate Start and Gate End settings are the same as those used in Figures 31, 32, and 33. Notches 1, 2, 3, and 4 are detected because:

a) A perpendicular to each notch intersects the tire roll track; and,
b) Ultrasonic beam length "L" measured on its perpendicular falls within the gated interval.

Notches 5, 6, 7, and 8 are not detected by Scan #1 for the following reasons:

Notch	
5	Distance "L" too long
6	Perpendicular does not cross tire roll track
7	Distance "L" too short
8	Distance "L" too long

Figure 35 illustrates how four successive parallel scans indexed at regular intervals detect all eight notches shown in Figure 34.

Figures 36 and 36-A show the relationship of detectable-notch orientation to notch distance from the tire roll path for given GATE START and GATE END distance values.

6.4.2 Practical Values for Gating, Scanning Indexing

GATE START - 250 microseconds after the initial pulse corresponding to 8 inches from the center of the tire contact spot. This avoids interference from Wheel Noise. See Figure 18, 19, and 20.

GATE END - 475 microseconds after the initial pulse corresponding to 20 inches from the center of the tire contact spot. Operation of DAC is effective in the range 8 through 20 inches. Refer to Figures 20 and 27.

INDEXING - Applying a GATE START of 8 inches and a GATE END of 20 inches to expressions given in Figures 36 and 36-A, we derive the graph in Figure 37 showing orientations of detectable notches plotted against notch distances.

This indicates that notches falling between -50° and $+50^{\circ}$ in orientation are detectable when in the distance range of 8 to 13 inches.

Indexing is therefore set at 5 inches so that all notches must in successive scans fall within the 8 to 13 inch interval.

Detection of the remaining 40° in each quadrant requires scanning at right angles to the first scan direction.

SCANNING PATTERN - For a rectangular piece, start the first of one series of scans 21 inches from an edge and run parallel to that edge as in Scan 1-1, Figure 38.

Index at 5 inch intervals to produce Scans 1-2, 1-3, etc. until 21 inches from the opposite edge.

Turn the system 90° and repeat in a similar manner to produce Scans 2-1, 2-2, 2-3, etc.

SCANNING LIMITATIONS - In each scan, the material edge left and the edge approached produce a signal within the gate when in the range of 8 to 20 inches away from the contact spot.

A margin 8 inches in from each edge of the rectangular piece is not tested for defects in all orientations (21 inch scanning margin minus 13 inch distance for -50° to +50° detection). The extent of detected orientations within this 8 inch margin varies with distance as plotted in Figure 37.

6.4.3 Equipment

The surface wave scanning system described in the Final Report, Reference 3.1 has been modified for use in the present system by substituting an automatic indexing component for the manual indexing operation.

In all other respects the modified equipment, as shown in Figure 39, is suited to properly accommodate the Ring Beam Wheel Search Unit.

Instrumentation consists of the following components:
Reflectoscope UM-50B721 with Pulser/Receiver 5N and Transigate 50E550.

<u>2nd deck</u> - UM710 with DAC and "S" Chassis
<u>3rd deck</u> - Single channel strip chart recorder and system control

The proposed Calibration Test Plate, Figure 40, contains Test notches suitable for the field adjustment of sensitivity, gating and Distance-Amplitude-Correction (DAC).

7.0 CONCLUSIONS

7.1 The "Proposed System for Surface Wave Inspection" described in Paragraph 6.4.3 of this report is suitable for scanning aluminum plate or formed panels of smooth contour approximately 16 feet by 16 feet in the thickness range of 0.091 to 1 inch and contoured to approximately 33-foot spherical diameter; or specifically the convex surface of a GORE, APEX-UPPER HEAD OXIDIZER TANK for the Saturn S-1C-T assembly. (See MSFC Drawing J-60E12102.)

7.2 The time required for inspection of a 16 ft. by 16 ft. specimen with a surface wave beam in a single direction is determined by the automatic carriage scan rate of 30 ft./min., the indexing interval of 5 inches, and the period for each indexing operation of 5 seconds.

Time per scan . . . . 32 seconds
Number of scans . . . 31
Scanning time . . . . 992 seconds
Indexing time . . . . 155 seconds

Total 1147 seconds

Total Inspection Time (two scanning directions) 2294 seconds, or 38.2 minutes

7.3 Surface notches in all orientations may be detected throughout the area of a test plate, excepting a margin of 8 inches from each edge.

Within this margin, notches in only a limited range of orientation are detectable.

8.0 RECOMMENDATIONS

The feasibility of using a Ring Beam Ultrasonic Surface Wave System for the inspection of SATURN structural components has been demonstrated in a series of tests on small area specimens containing controlled simulated defects.

The following steps are now recommended:

8.1 Complete design of the automatic ultrasonic inspection system illustrated in "Proposed System for Surface Wave Inspection", Sperry Products Drawing 52D443.

8.2 Construct the "System" in accordance with final design. Install instrument package as described on Sperry Products Drawing 52D443.

8.3 Prepare "Rotating Support Member".

8.4 Prepare ultrasonic reference plate as shown in Figure 40.

8.5 Use completed "System for Surface Wave Inspection" in performing the following tests:

a) Detect and record simulated defects in full size specimens in static tests (automatic drive turned off).

b) Detect and record simulated defects in full size specimens in dynamic tests (automatic drive turned on).

c) Compare results of (a) and (b).

d) Detect and record natural defects in both static and dynamic tests. Compare results.

e) Measure size of natural defects by means other than ultrasonic. (Note: This may use a destructive method.)

f) Establish correlation between recorded ultrasonic signals from both natural and simulated defects and their location and size.

g) Establish standard of ultrasonic operating sensitivity in testing through the use of a reference plate. See Figure 40.

9.0 ILLUSTRATIONS

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO	FILE REF
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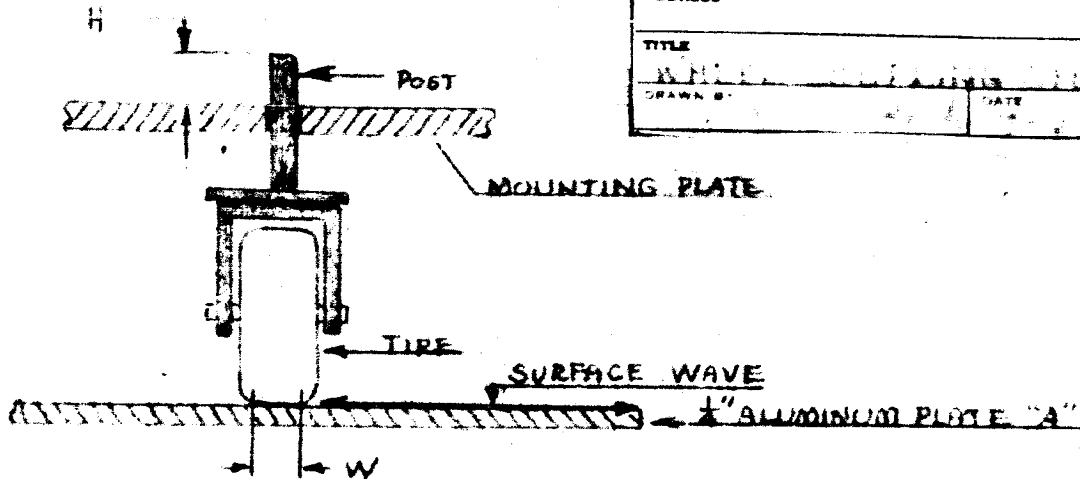
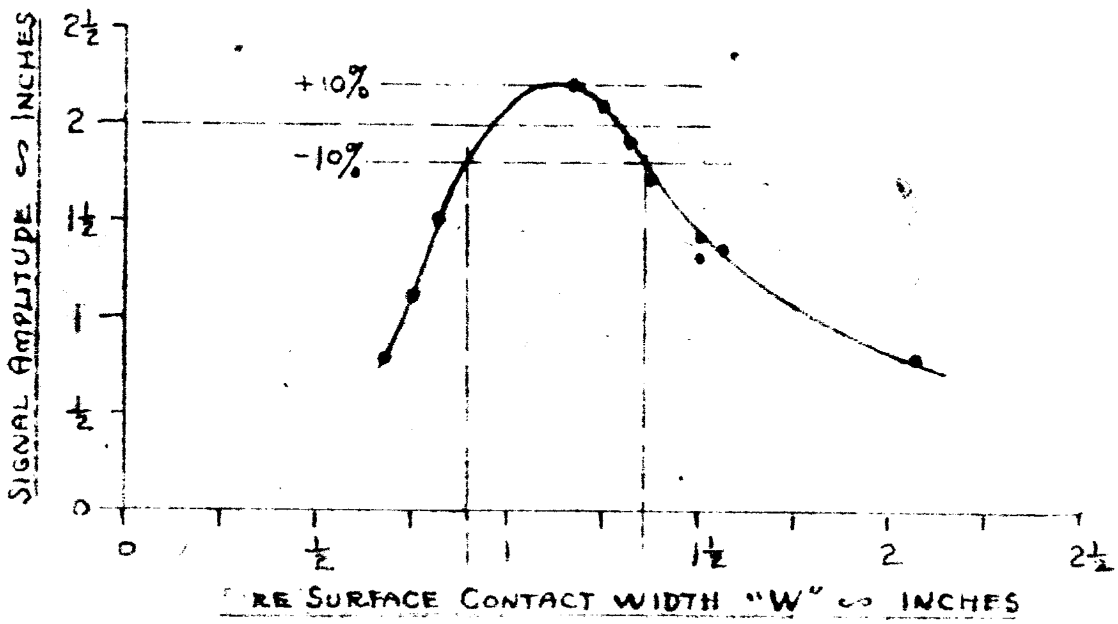
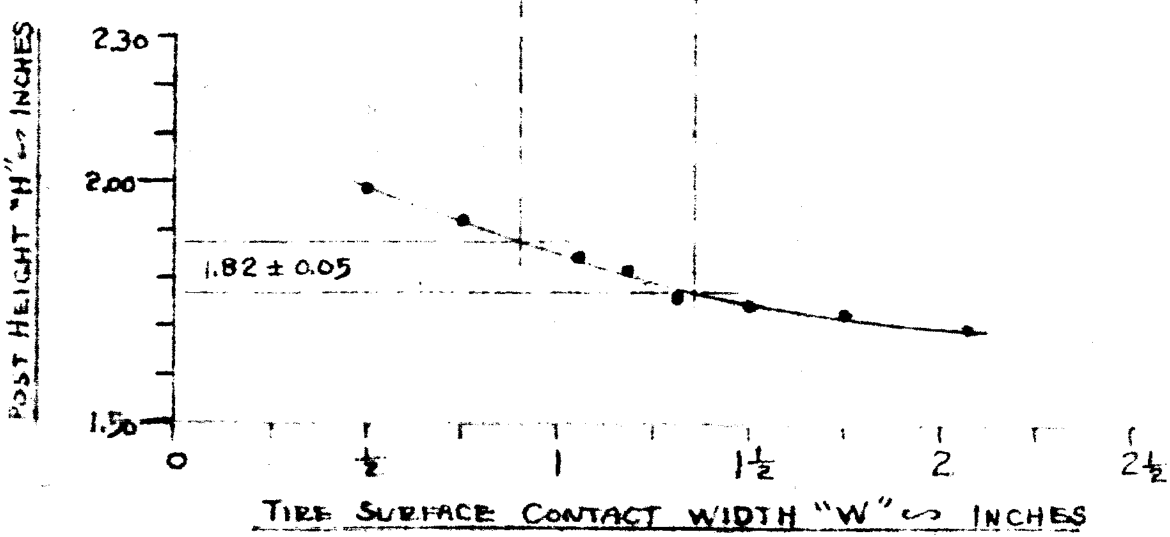
CUSTOMER NASA	
ADDRESS	
TITLE [illegible]	
DRAWN BY	DATE





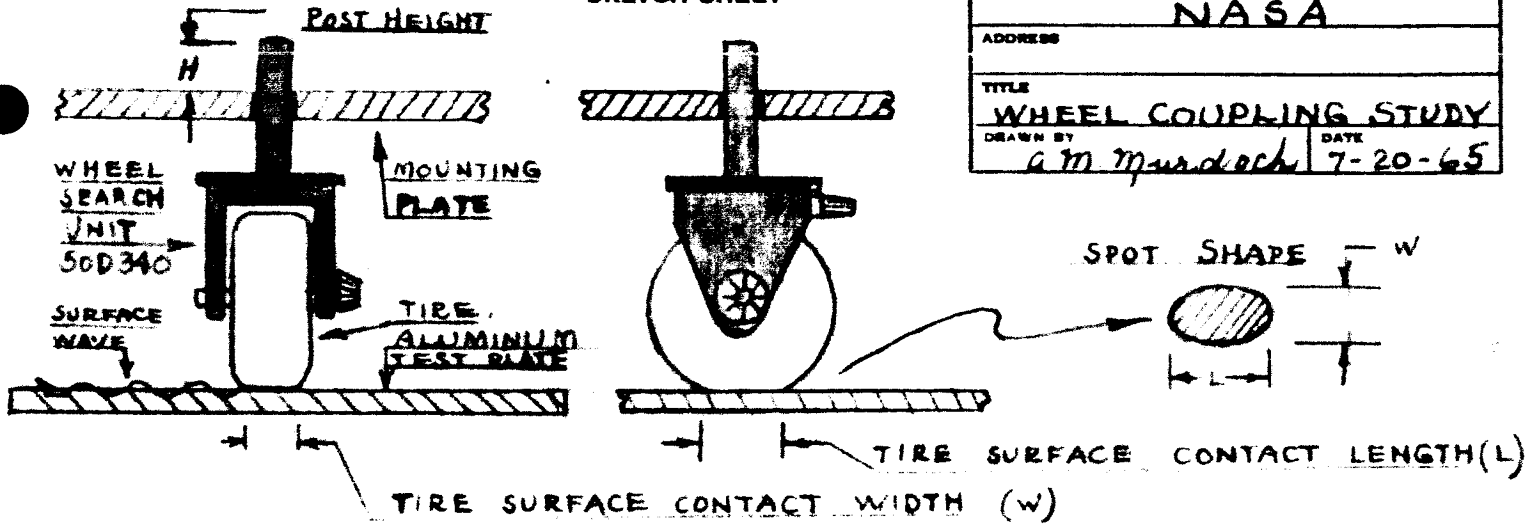


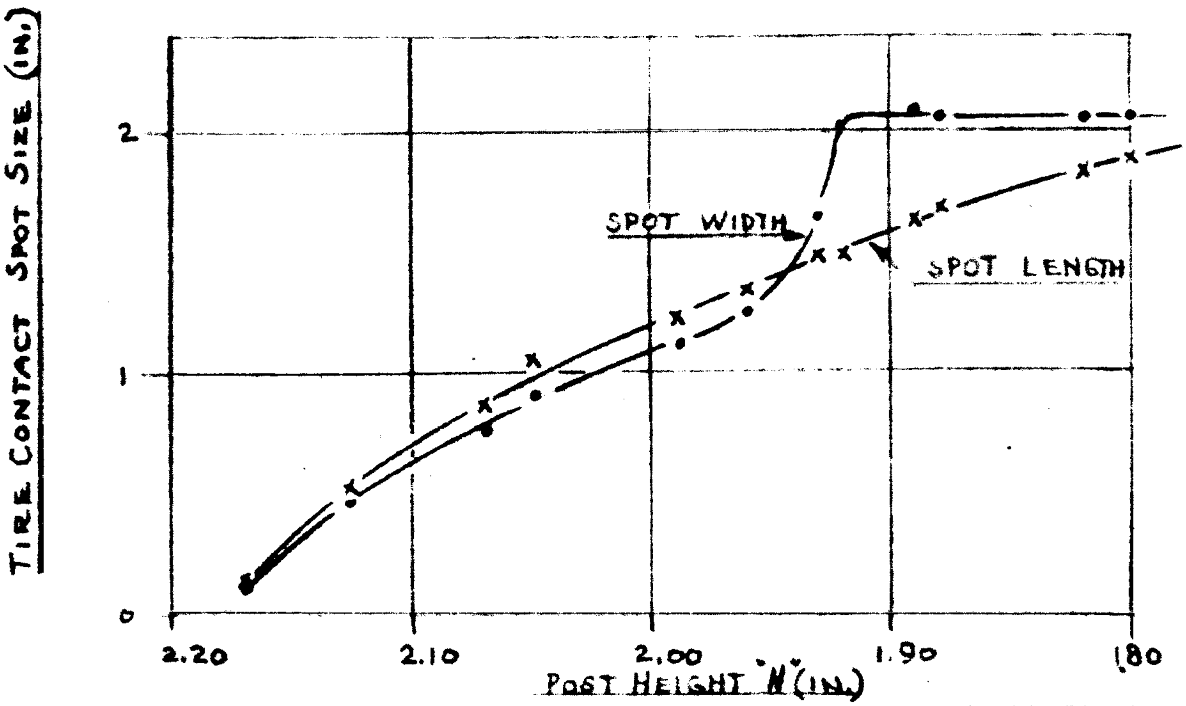
SEARCH UNIT TYPE SOB ; 2.25 mc/½"x1"
STYLE 50D340 ; SERIAL T-1723

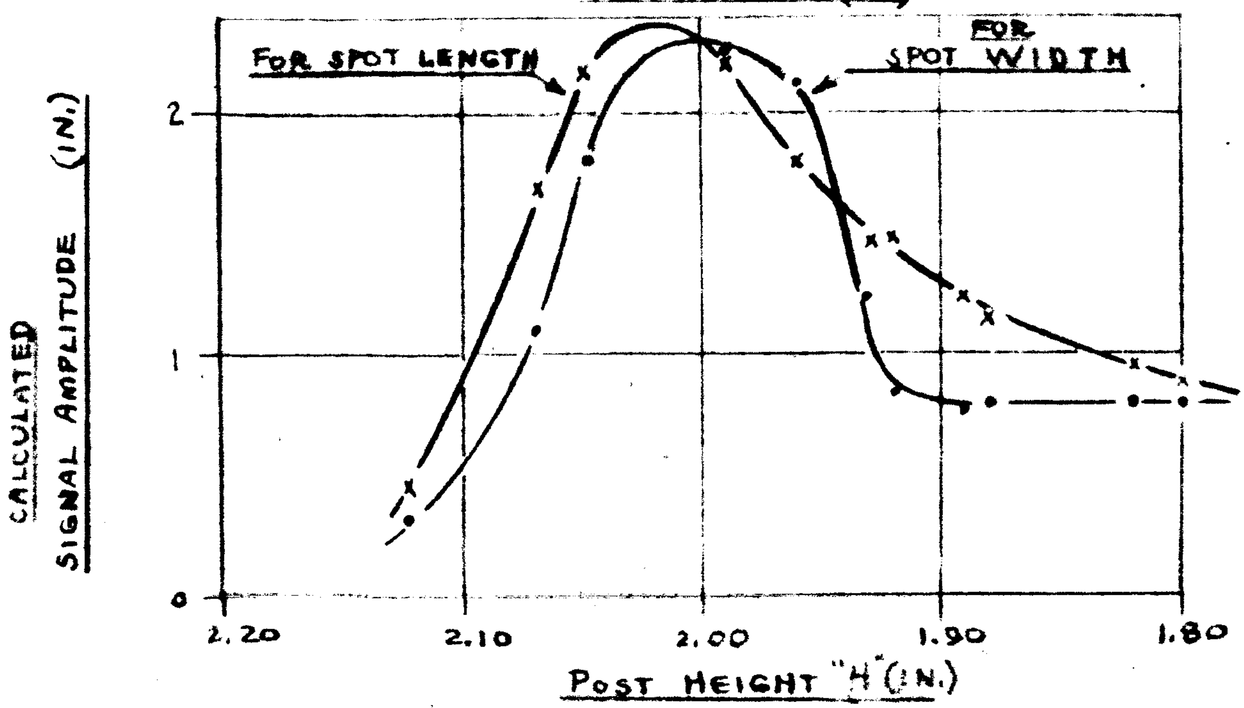
FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 2	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE WHEEL COUPLING STUDY	
DRAWN BY a m Murdoch	DATE 7-20-65

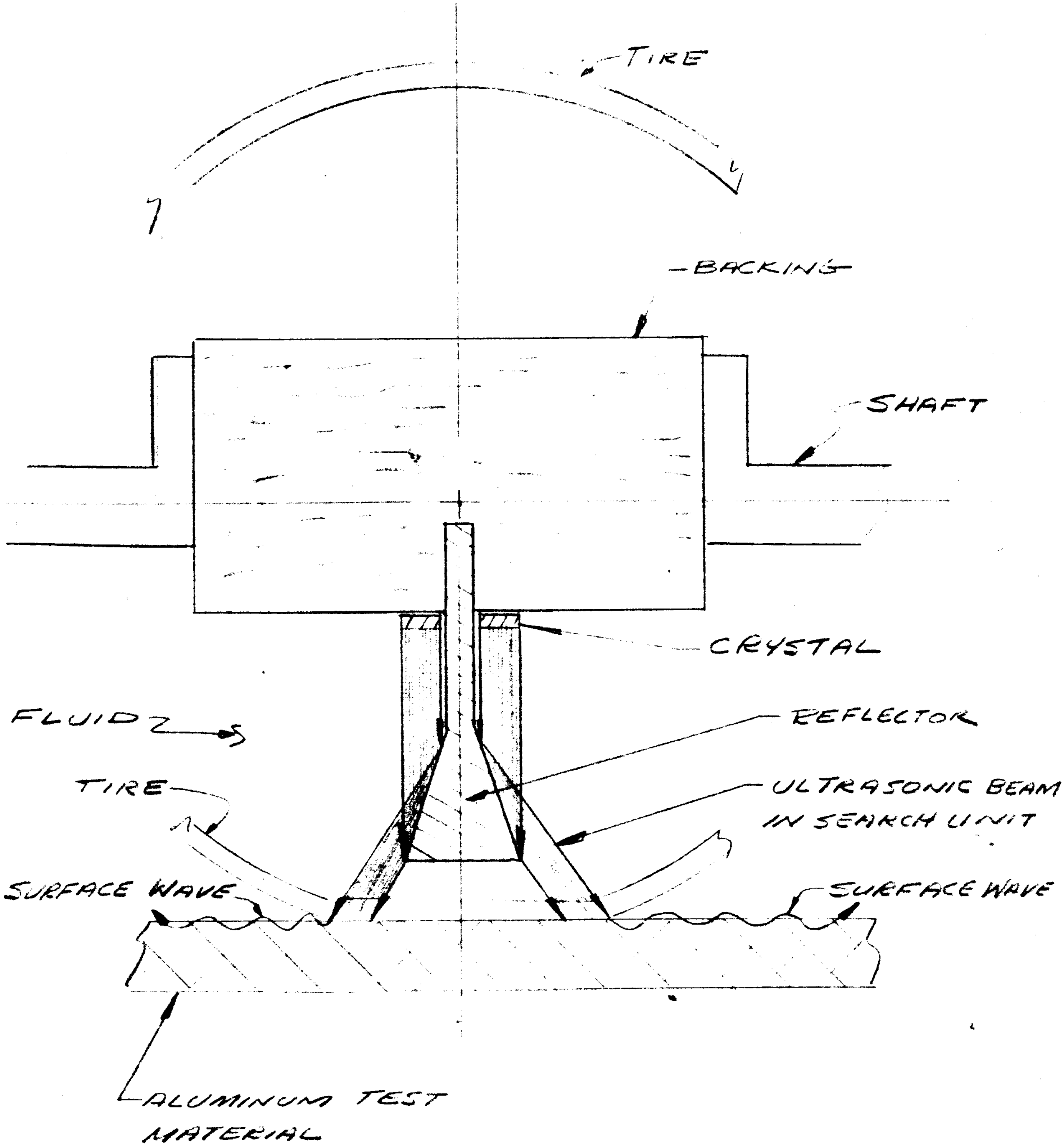






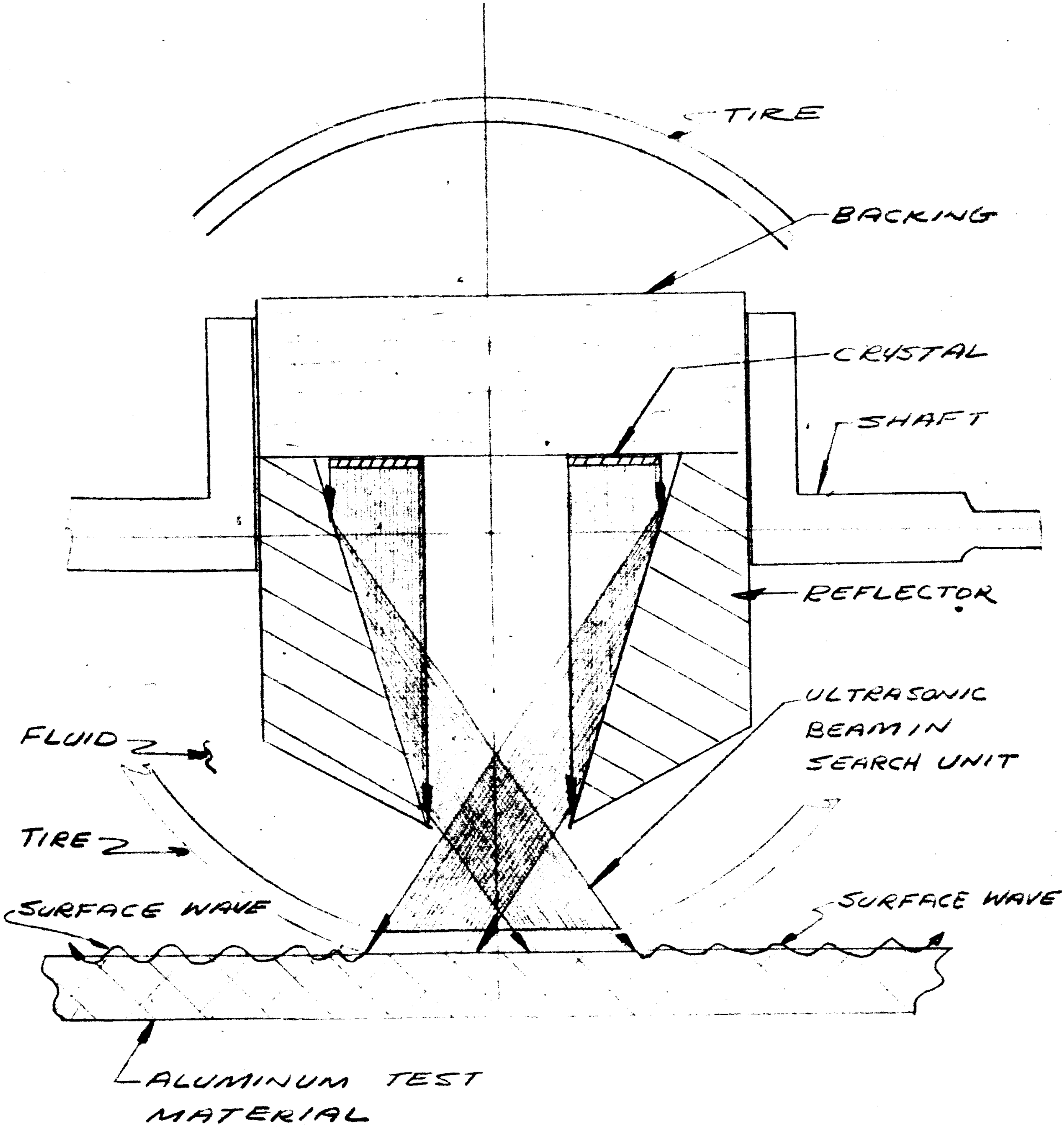
SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 3	FILE REF. C 30370
CUSTOMER NASA	
ADDRESS	
TITLE SURFACE WAVE S.U.	
DRAWN BY G CHABER	DATE 7-23-65



SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 4	FILE REF. C30370
CUSTOMER NASA	
ADDRESS	
TITLE SURFACE WAVE S.U.	
DRAWN BY G. CHABER	DATE 7-23-65



SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 5	FILE REF. E 30370
CUSTOMER NASA	
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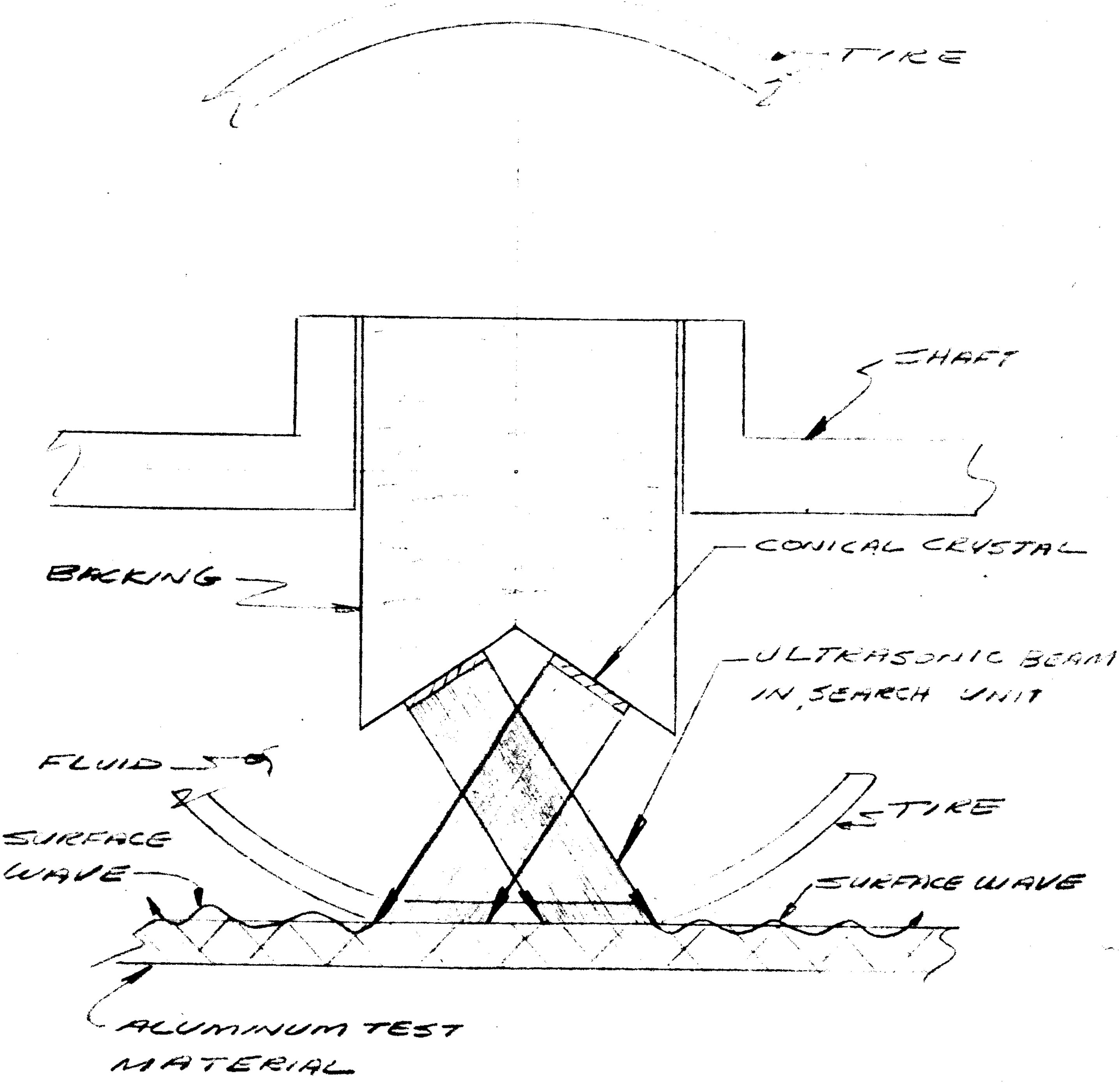
TITLE SURFACE WAVE S.U.	
DRAWN BY G CHABER	DATE 7-23-65



FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

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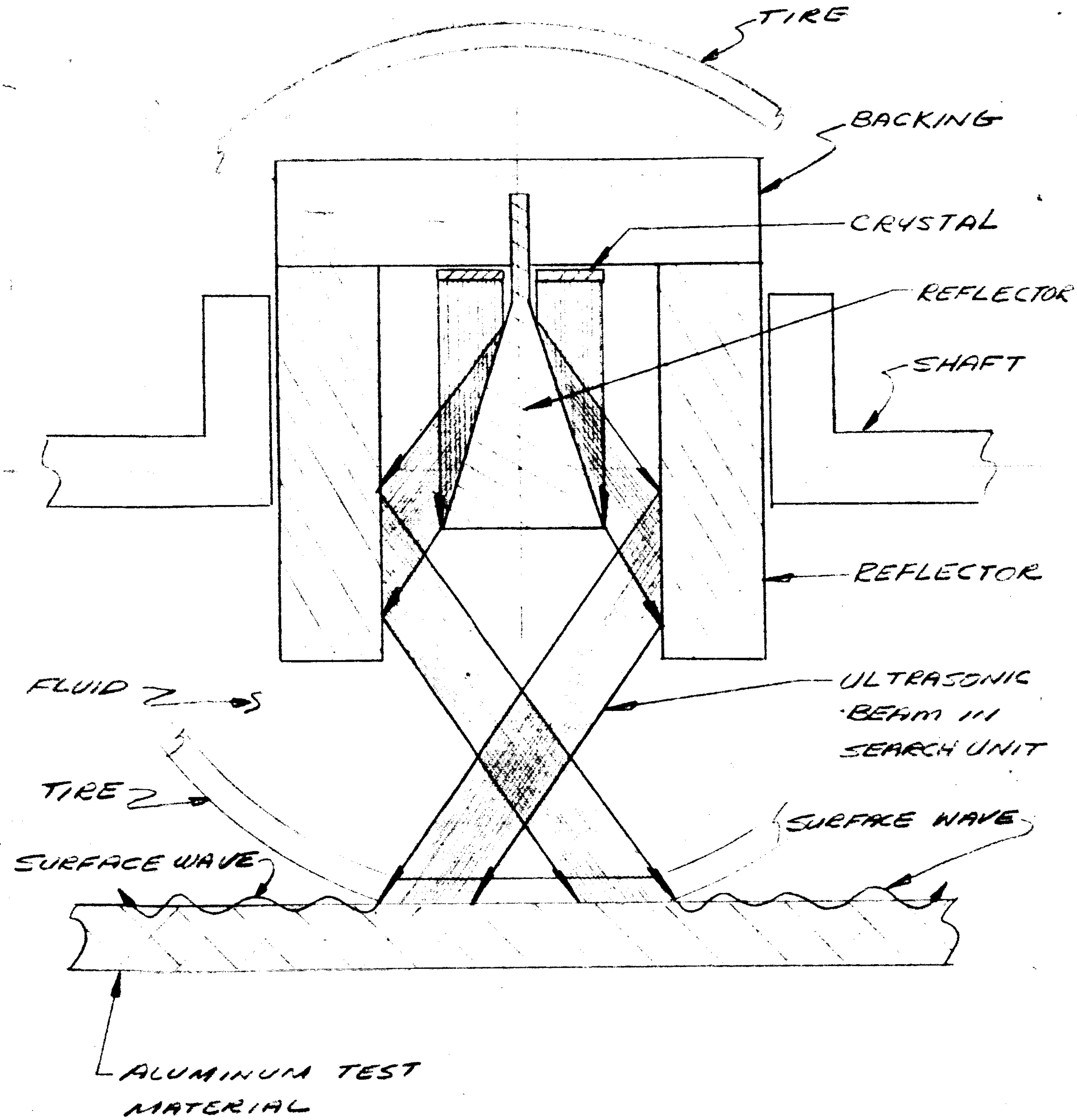
CUSTOMER NASA	
ADDRESS	
TITLE SURFACE WAVE S.U.	
DRAWN BY G CHABER	DATE 7-23-65



SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

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CUSTOMER NASA	
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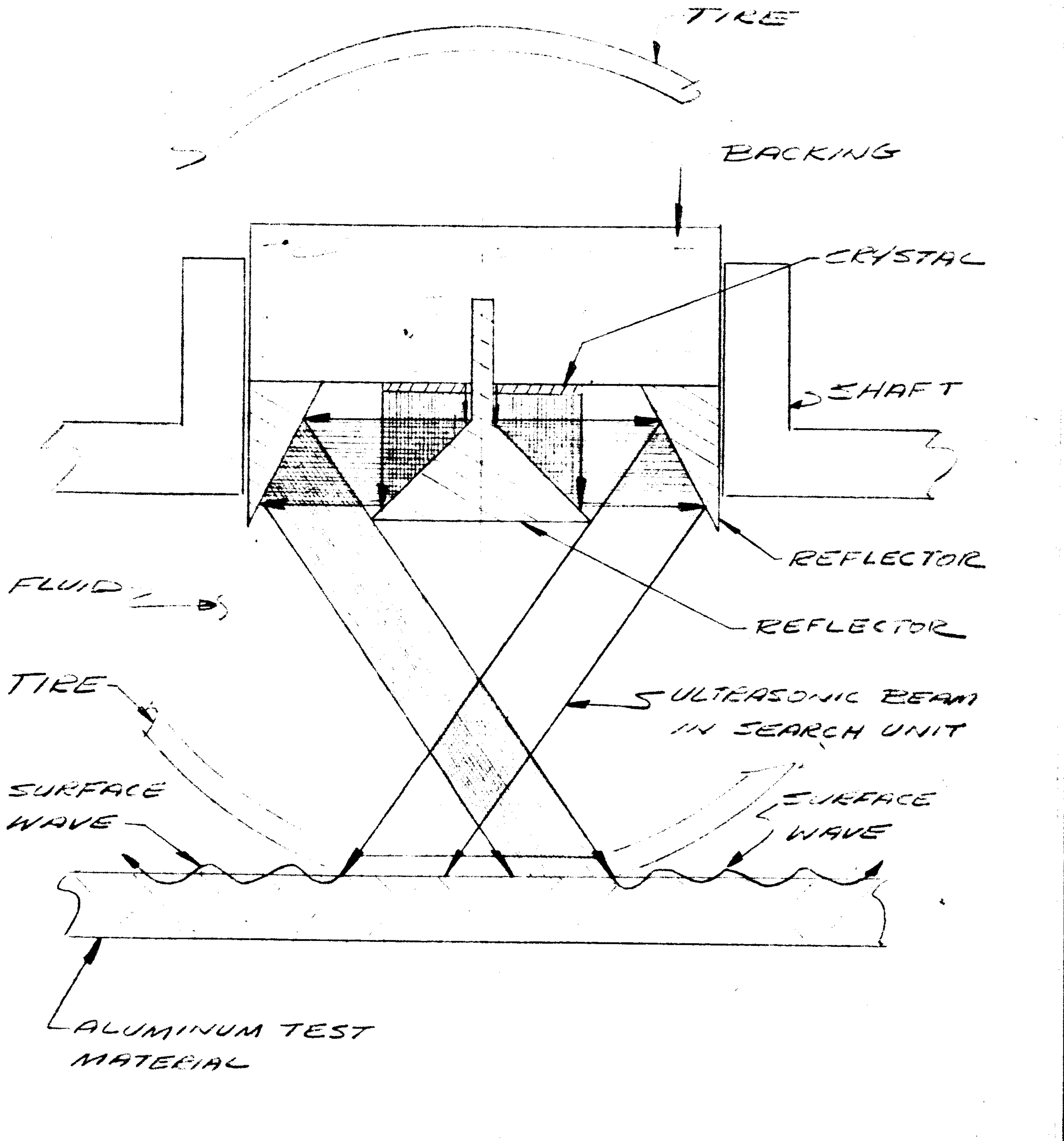
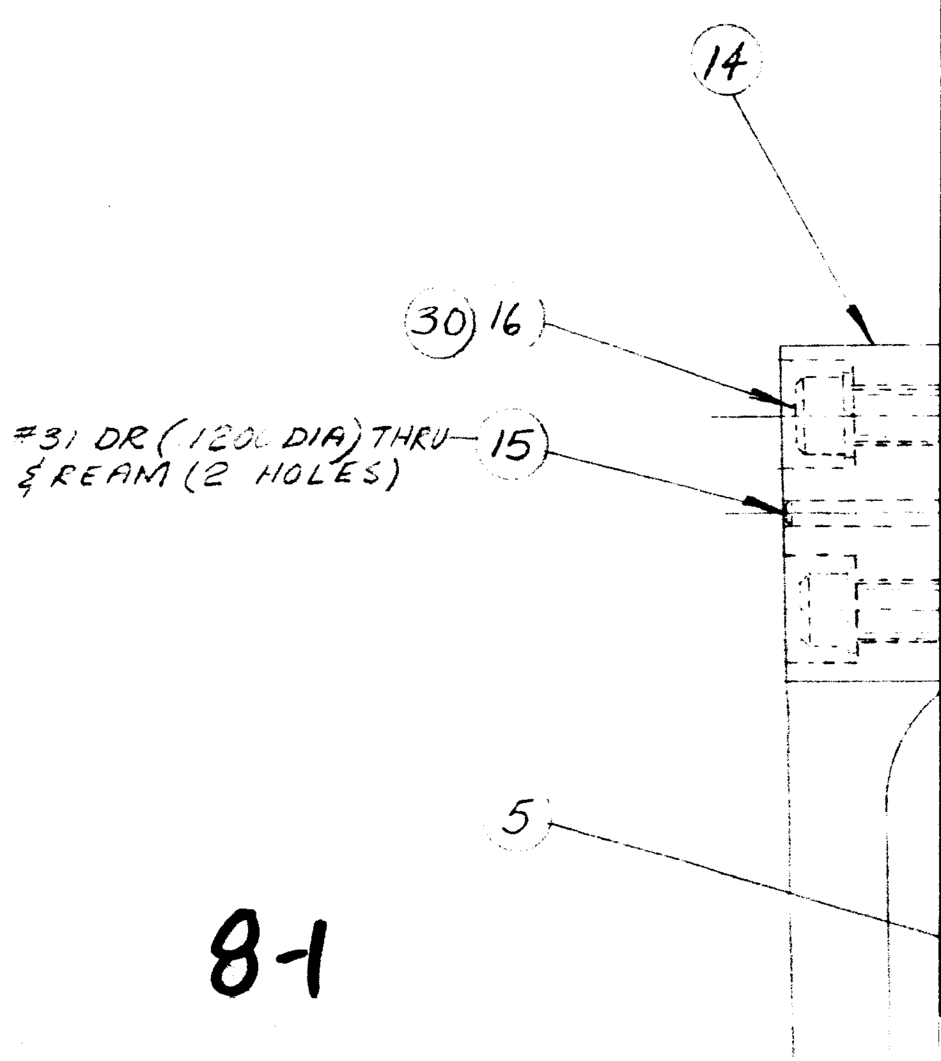
TITLE SURFACE WAVE S.U.	
DRAWN BY G CHABER	DATE 7-23-65





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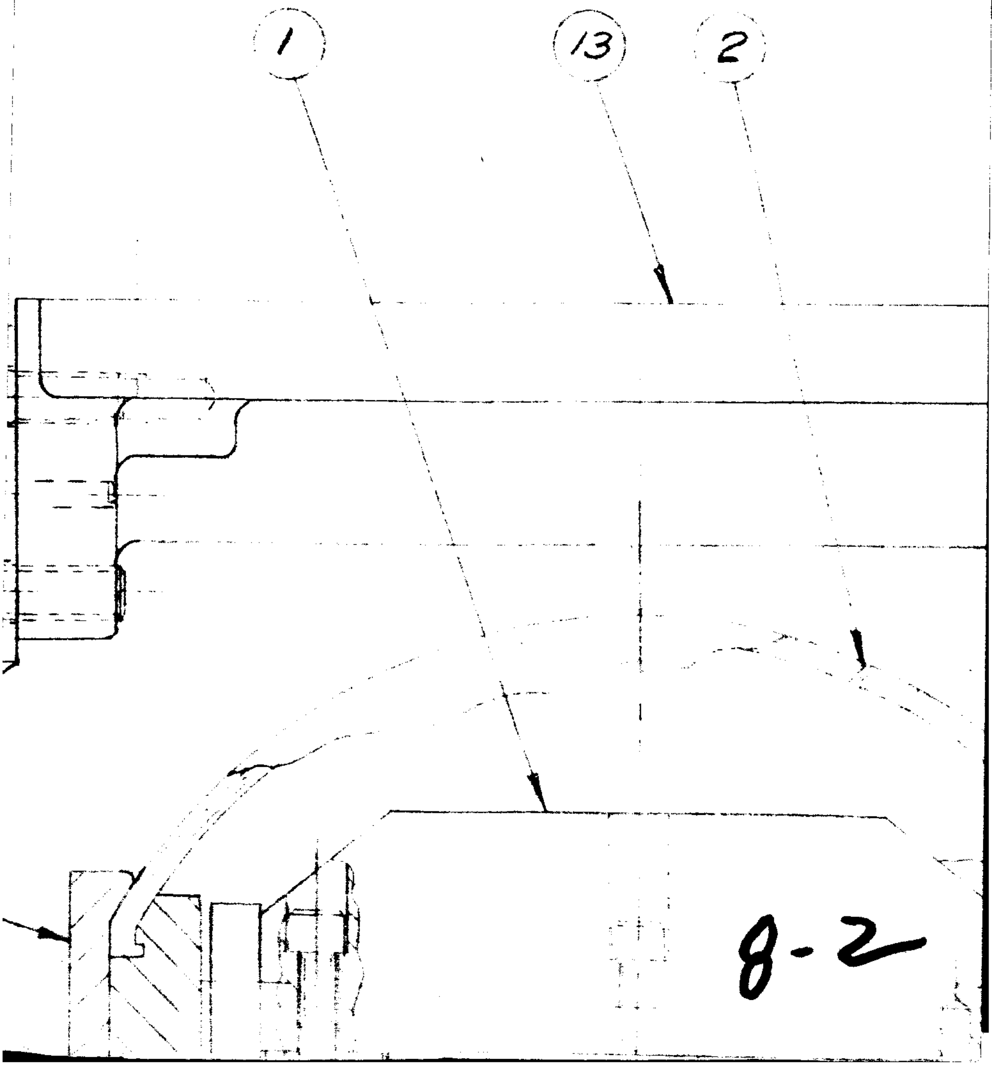
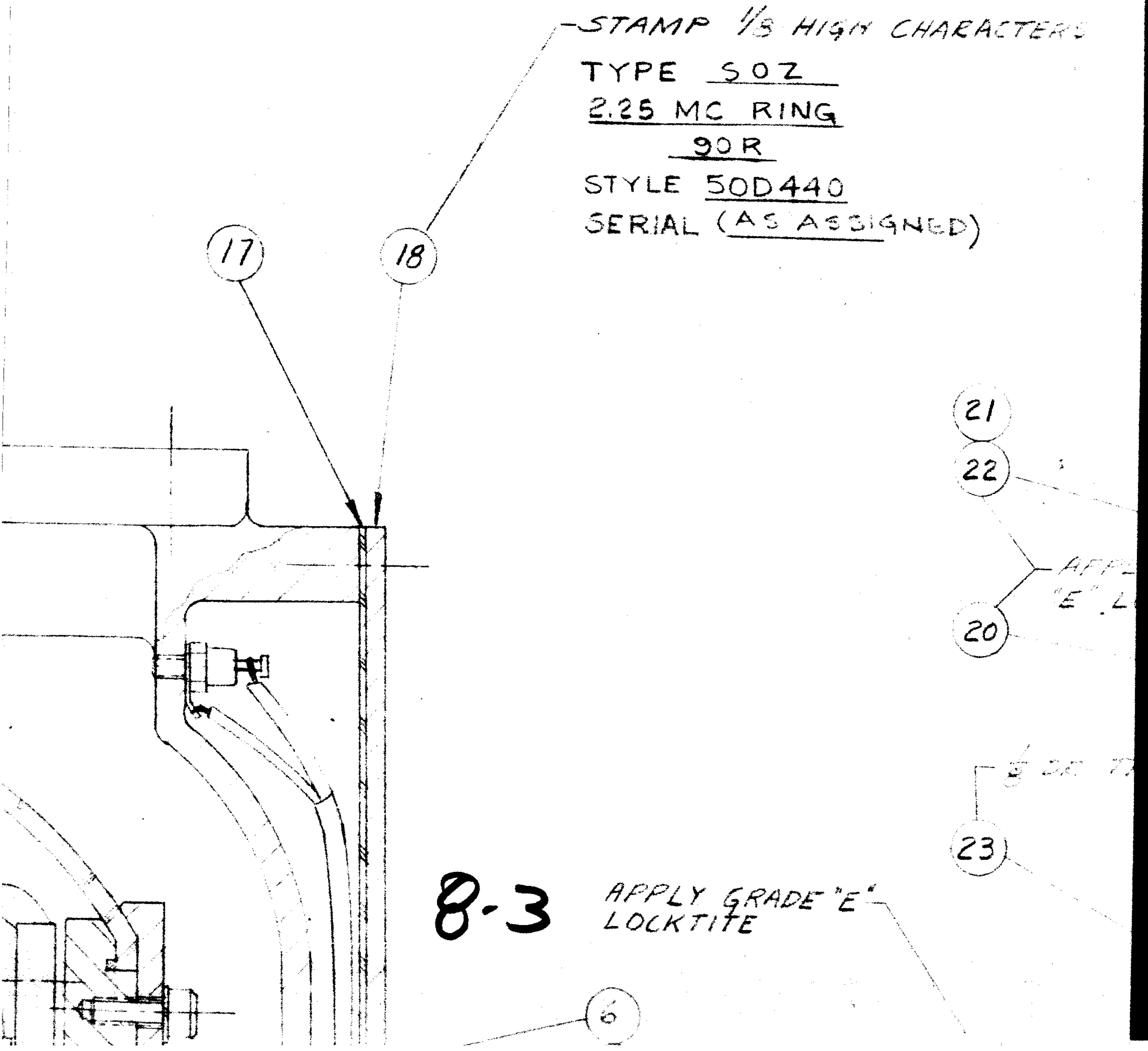
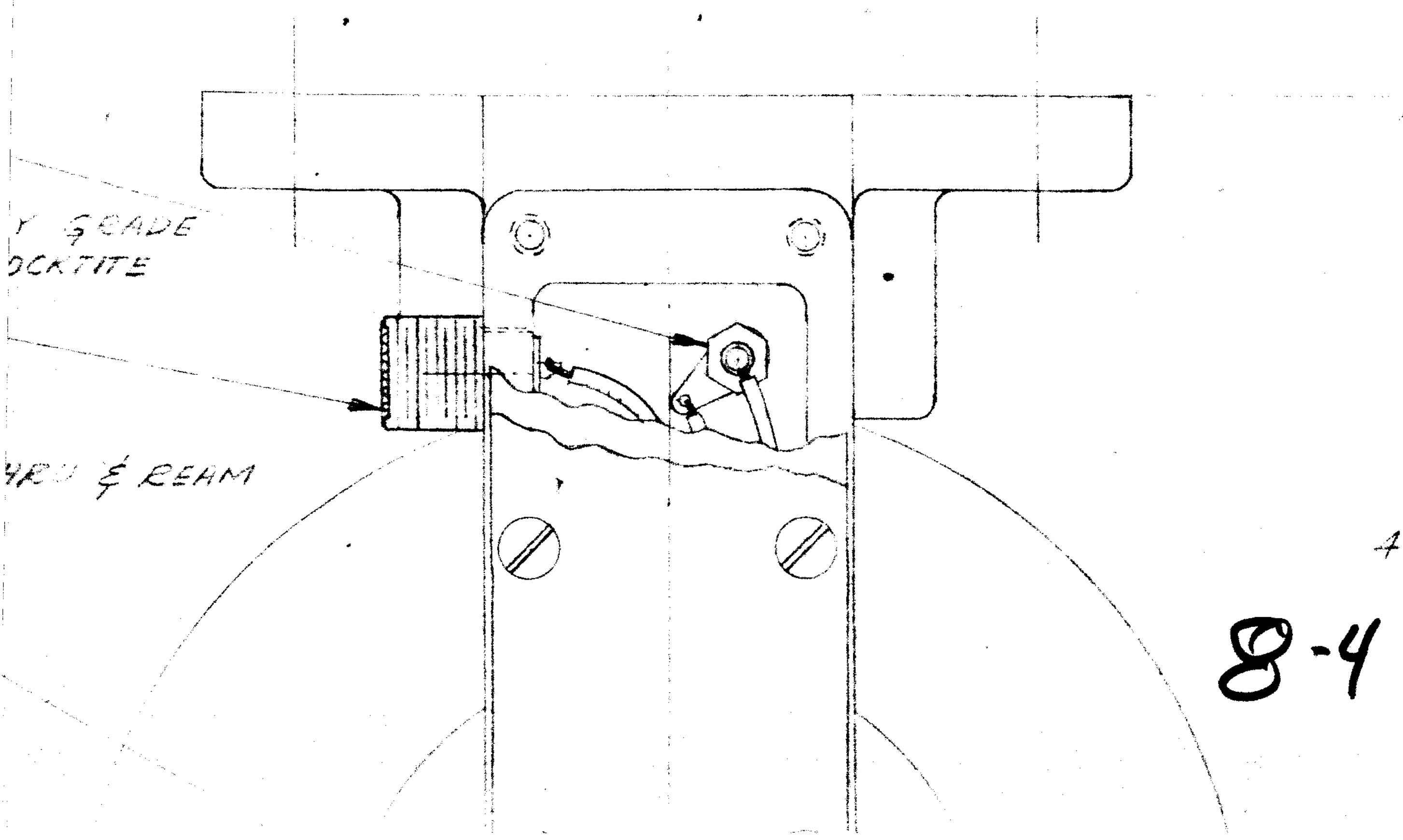


8-2


STAMP 1/8 HIGH CHARACTERS
TYPE SOZ
2.25 MC RING
90R
STYLE 50D440
SERIAL (AS ASSIGNED)
17
18
21
22
20
23
8-3
APPLY GRADE "E" LOCKTITE
6

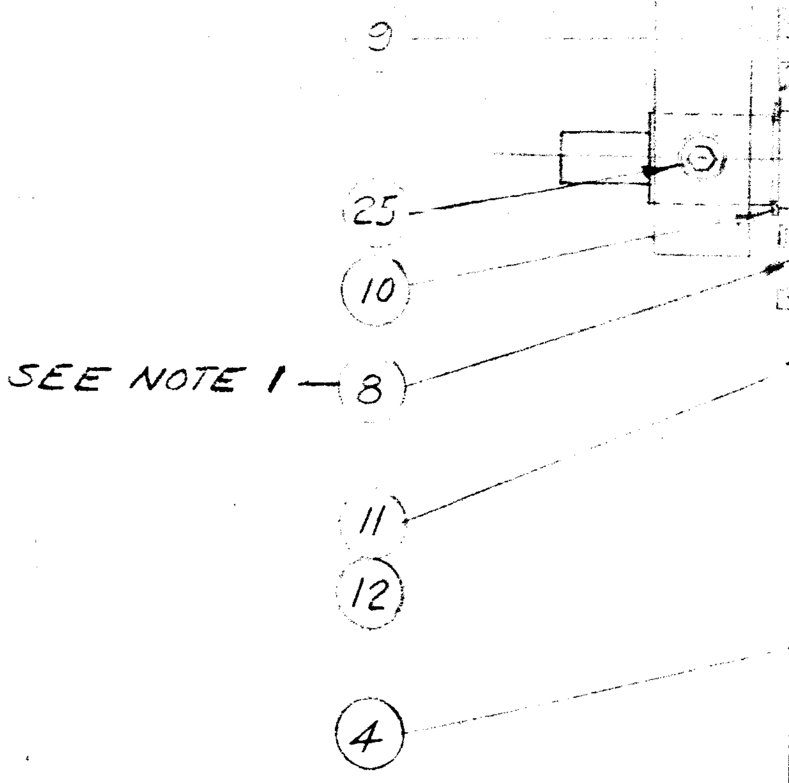


8-4

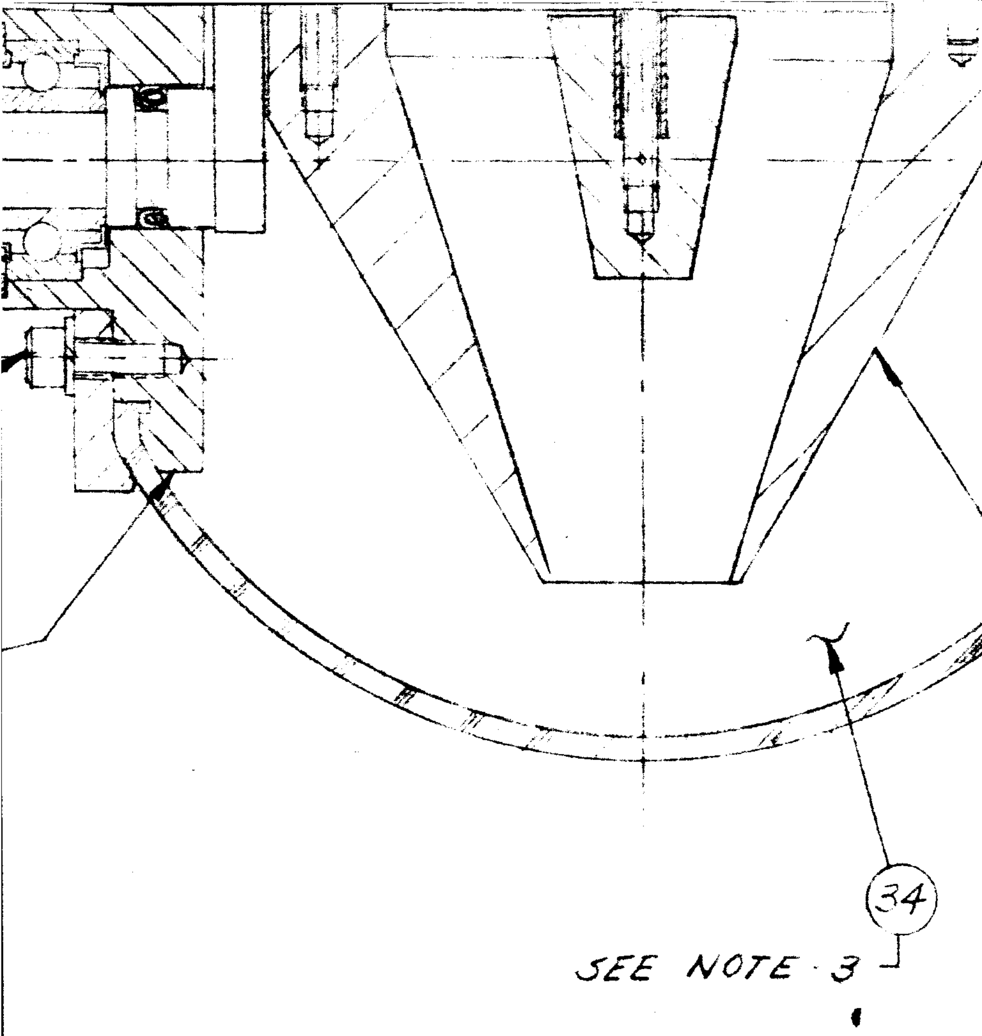
35	50A2955	TIRE CHANGE INSTRUCTION	1 REF
34	50A2804	WHEEL S. U. SOLUTION	A/R
33	————	LOCTITE SEALANT GRADE E AMERICAN SEALAND CO.	A/R
32	————	LOCTITE SEALANT GRADE A-A AMERICAN SEALANT CO.	A/R
31	————	LOCQUIC PRIMER AMERICAN SEALANT CO.	A/R
30	W21A09C	LOCKWASHER - 1/4 ST. ST.	3
29		WIRING DIAGRAM	REF
28	50B1398	TORQUE SPEC	REF
27	50B1414	REFLECTOR KIT "B"	1
26	50B1413	REFLECTOR KIT "A"	1
25	[illegible]	SET SCREW #10-32 x 1/4 [illegible]	1

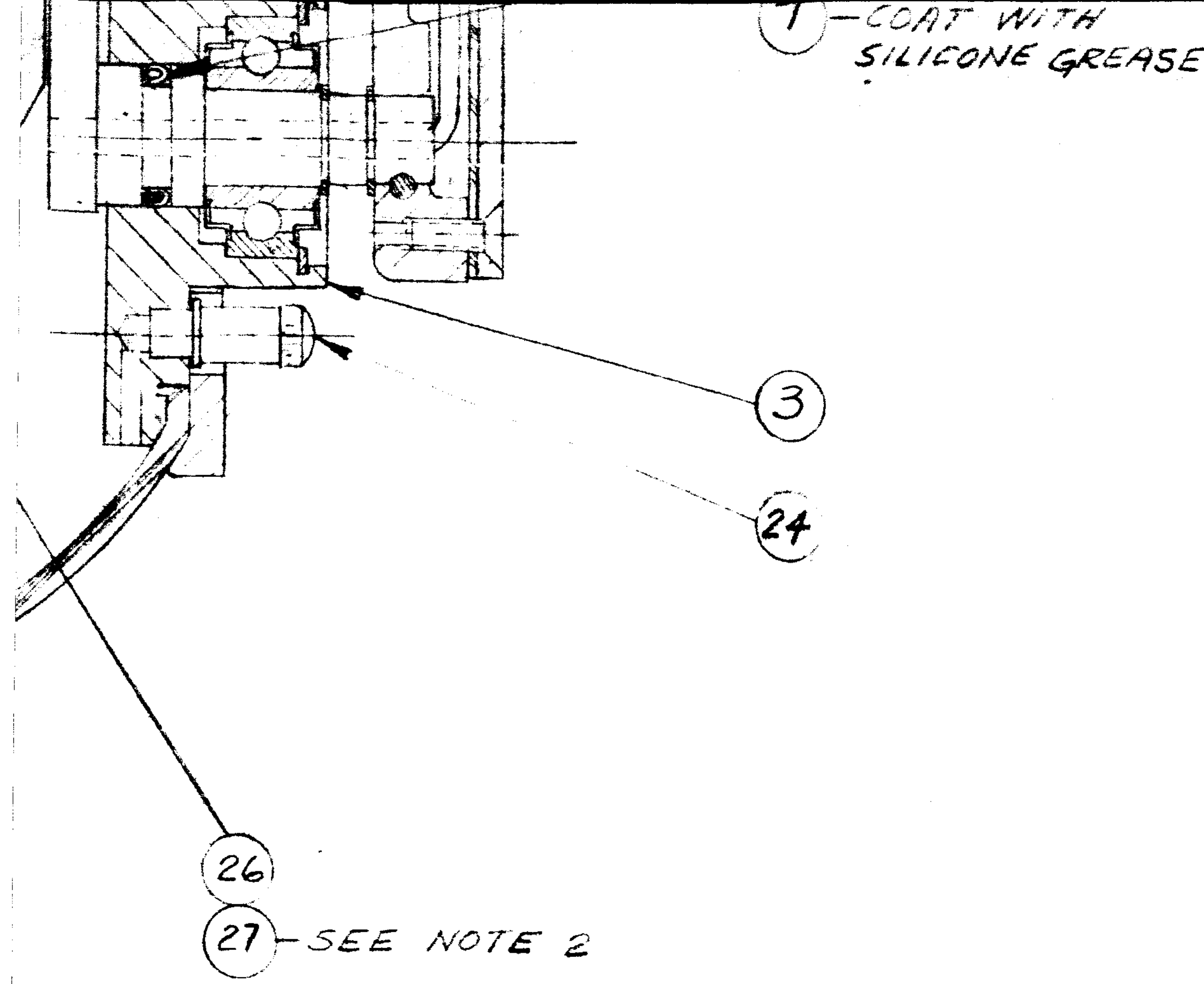
REF

85



8A6

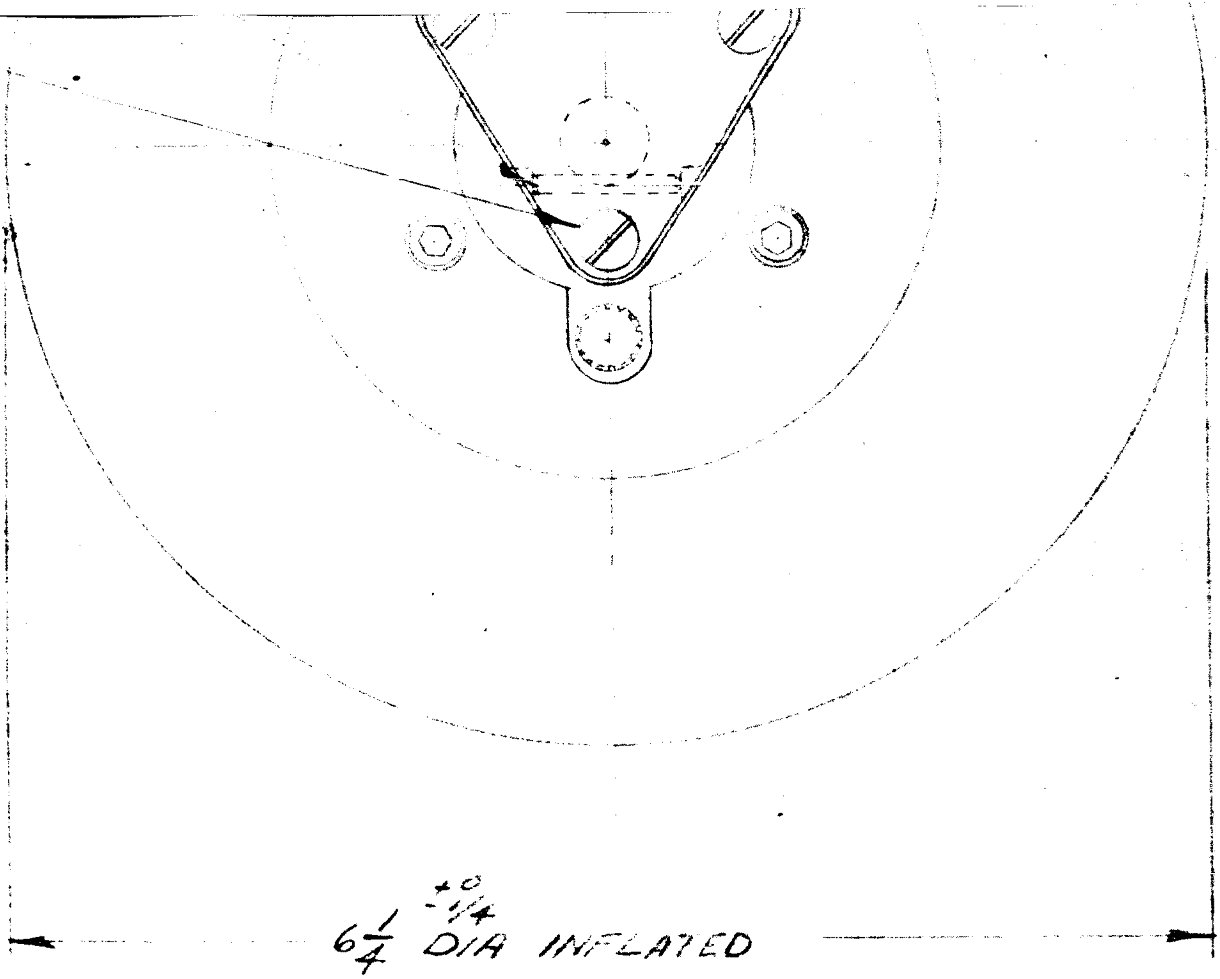

34
SEE NOTE 3



NOTES:

1. CLEAN I.D.
SHAFTS W
GRADE A-
2. ITEM #27
3. INFLATE T

FIG 8



OF BEARINGS (ITEM #8) & BEHRING AREA OF
TH LOCQUIC, THEN COAT THESE AREAS WITH
A LOCTITE & ASSEMBLE.
TO BE PACKAGED SEPARATELY & SHIPPED WITH UNIT.
RE TO 6 1/4" DIA WITH ITEM #34.

8-9

ITEM NO.	DWG. OR PART NO.	NAME	QUAN. REQ.
24	PURCH.	VALVE CAP, SCHRADER #7572V	2
23	P02E12C	TAPER PIN	1
22	CQA008C01	TERMINAL	1
21	CQA016A06	SOLDER LUG	1
20	PURCH	RECEPTACLE, GREMAR #6804	1
19	H01JD8C	SCREW, #8-32 × 1/2 LG FL. HD ST. ST.	7
18	50B943	COVER	1
17	50B942	GASKET	1
16	H42M16C	SCREW, # 1/4-20 × 1" LG ST. ST. HEX SOC HD	3
15	P03B20A	DOWEL PIN 1/8 DIA × 1 1/4 LG	2
14	50B834	SUPPORT	1
13	50D441	BRACKET	1
12	W21A07C	LOCKWASHER #10	6
11	H43K07C	SCREW #10-32 × 7/16 ST. ST. HEX SOC HD	6
10	ALM002X18	RET. RING WALDES #5100-50-MF	3
9	ALM004B10	RET. RING WALDES #5008-131-H	2
8	PURCH.	BALL BRG. NEW DEPARTURE #SS88013	2
7	PURCH.	U-CUP PACKING - HOUGHTON VIX-SYN #S-6-47 70 SHORE DURO	2
6	50A2923	SPREADER RING	2
5	50B1409	RING	2
4	50B1405	HUB	1
3	50B1407	HUB & VALVE ASSY	1
2	50B1408	TIRE	1
1	50C1004	TRANSDUCER & SHAFT ASSY	1

BILL OF MATERIAL

LTR.	E.C.N. NO.	DATE	CHK.

ENG. REF. | TIMES USED

SCALE FULL

EXCEPT AS NOTED

DEC. ± .005

FRAC. ± 1/64

ANGLES ± —

MACH. 63/√

DEBURR & BREAK SHARP EDGES & CORNERS .016.

50D440

REF. ASS'Y. NO.

MAT. OR P. SPEC.

FINISH

AUTOMATION INDUSTRIES, INC.
SPERRY PRODUCTS DIVISION
DANBURY, CONNECTICUT • U.S.A.

WHEEL SEARCH UNIT ASSY

2.25 MC

Sperry 50D440

E.L. 7/21/65 DRAWN BY DATE

RLG 7-23-65 MFG. CHECK BY DATE

[illegible] 7-23-65 CHECKED BY DATE

[illegible] 7-23-65 APPROVED BY DATE

50D440

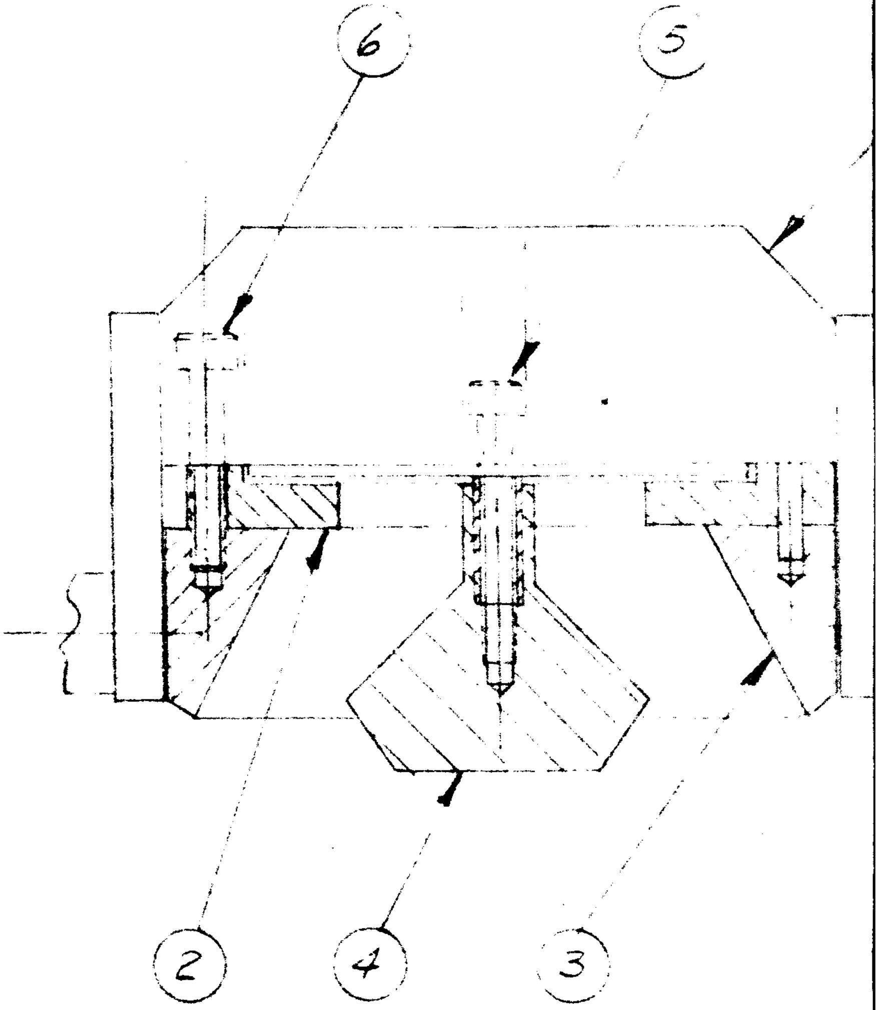


FIG. 9-1

(1) — SHOWN FOR REF ONLY
(NOT PART OF THIS KIT)

ITEM NO.	DWG. OR PART NO.	NAME	QUAN. REQ.
7	50B1414	REFLECTOR KIT "B"	1BP
6	H43K16C	SCR #10-32 x 1" LG SOC HD ST. ST.	REF
5	H44H20C	SCR #6-32 x 1 1/4 LG SOC HD ST. ST.	REF
4	50A3619	REFLECTOR	1
3	50B1411	REFLECTOR	1
2	50B1412	BAFFLE	1
1	50C1004	TRANSDUCER & SHAFT ASSY	REF

BILL OF MATERIAL

9-2

SCALE FULL

50D440

REF. ASSY. NO.

AUTOMATION INDUSTRIES, INC.
SPERRY PRODUCTS DIVISION
DANBURY, CONNECTICUT • U.S.A.

REFLECTOR KIT "B"

Sperry 50B1414

E.L. 7/21/65 — 7-23-65

DRAWN BY — DATE — MFG. CHECK BY — DATE

CHECKED BY — DATE 7-23-65

APPROVED BY — DATE 7-23-65

50D440 — 1

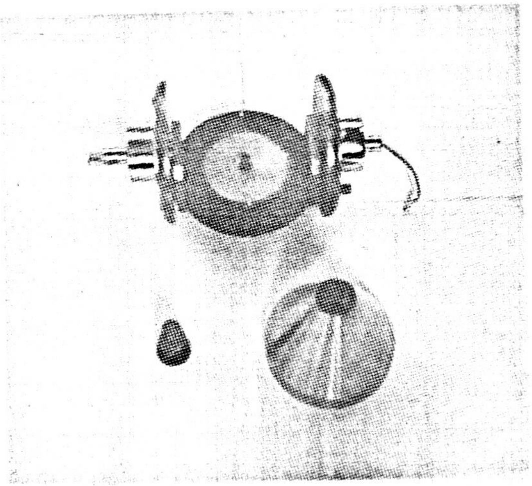
ENG. REF. — TIMES USED

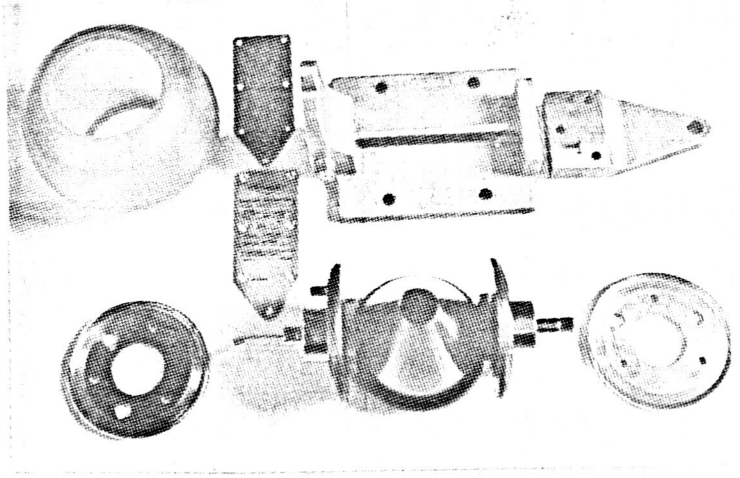
50B1414

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

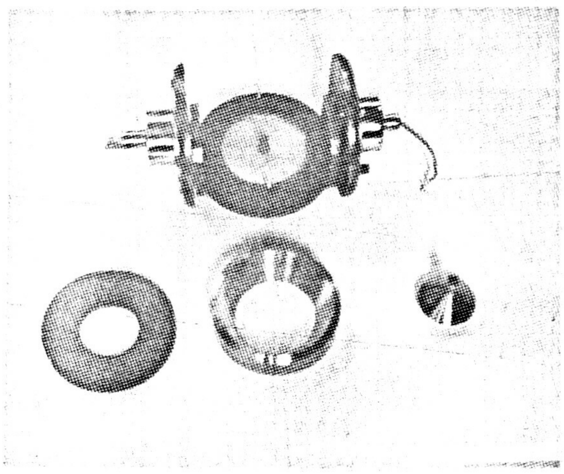
SKETCH NO.	FILE REF.
10	C-3037-11
CUSTOMER NASA	
ADDRESS	
TITLE PHOTOGRAPHS, EQUIPMENT	
DRAWN BY A.M. MURDOCH	DATE 3-21-66

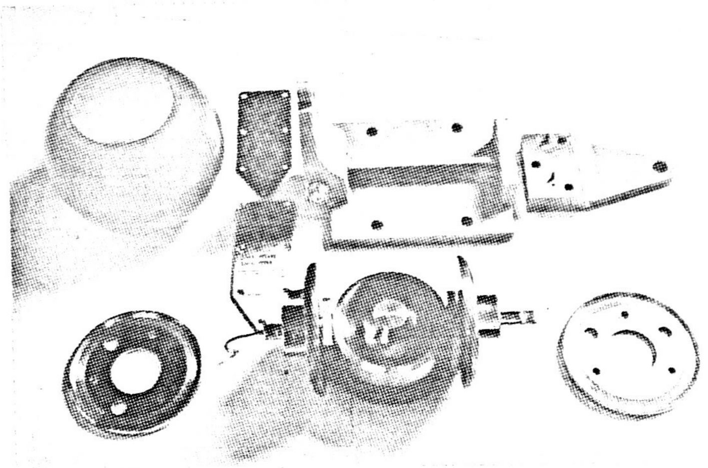
PRINCIPAL PARTS OF RING BEAM WHEEL SEARCH UNIT





WITH REFLECTOR KIT "A"



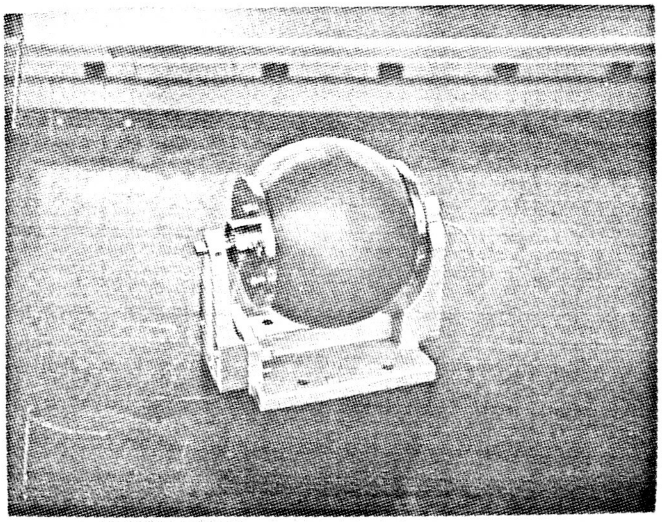


WITH REFLECTOR KIT "B"

FORM 1.41

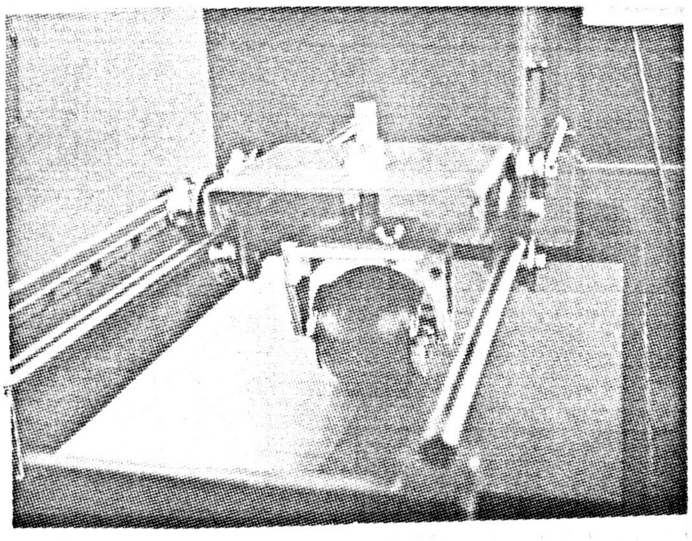
SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 11	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE SEARCH UNIT	
DRAWN BY A.M. Murdoch	DATE MAR. 1, 1966



RING BEAM WHEEL SURFACE WAVE SEARCH UNIT

STYLE 50D440

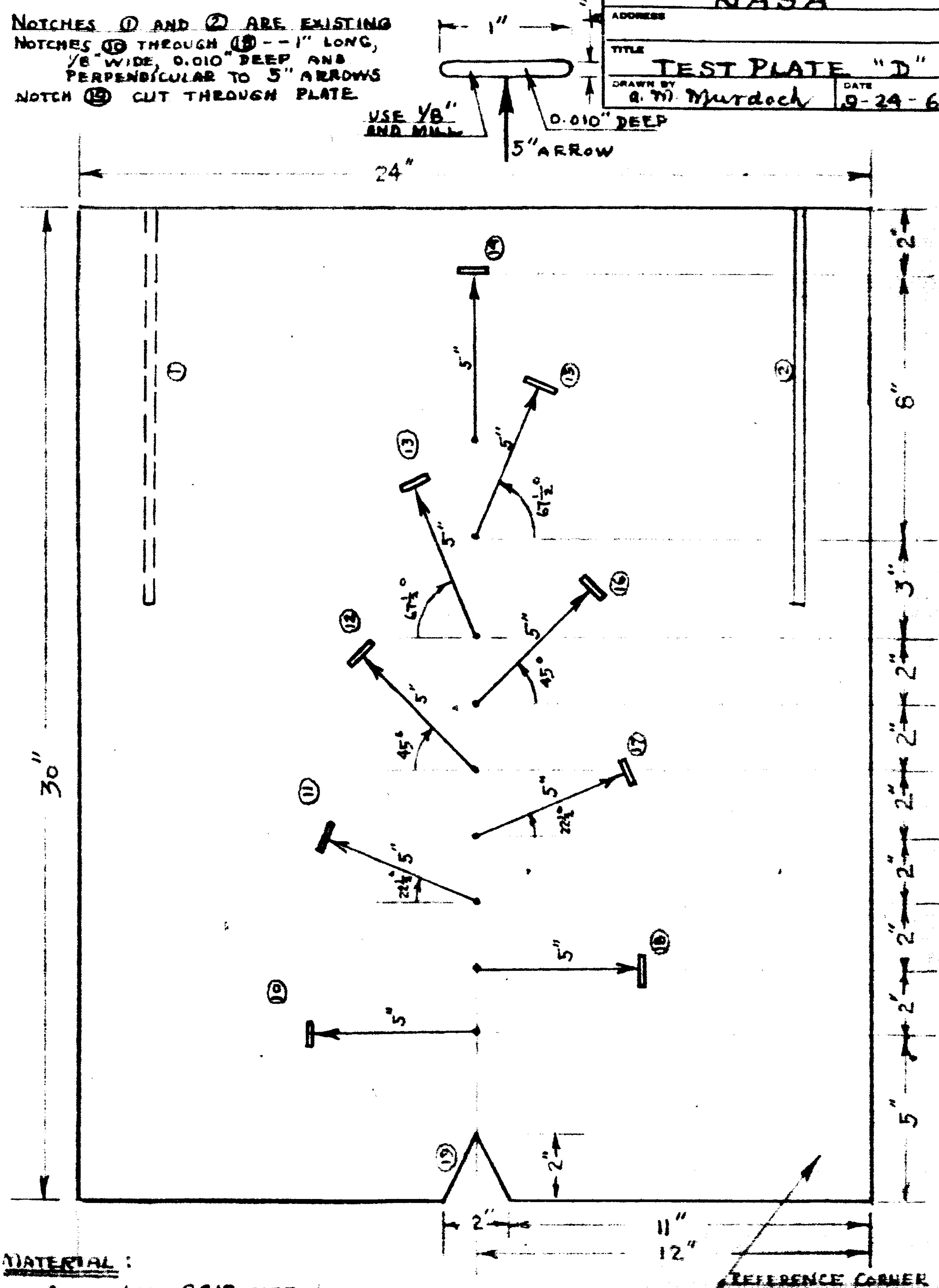


WHEEL SEARCH UNIT MOUNTED IN TEST STAND AND ON TEST PLATE "E"

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 12	FILE REF. C-3037-11
CUSTOMER NASA	
ADDRESS	
TITLE TEST PLATE "D"	
DRAWN BY A. M. Murdoch	DATE 9-24-65

NOTCHES ① AND ② ARE EXISTING
NOTCHES ⑩ THROUGH ⑱ -- 1" LONG, 1/8" WIDE, 0.010" DEEP AND PERPENDICULAR TO 5" ARROWS
NOTCH ⑲ CUT THROUGH PLATE



MATERIAL:
ALUMINUM 2219-T37
0.210" THICK

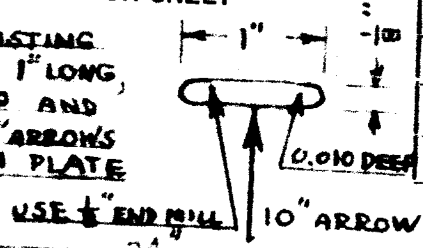
REFERENCE CORNER MARKED "C-2998-T--D" ON UNDER SIDE

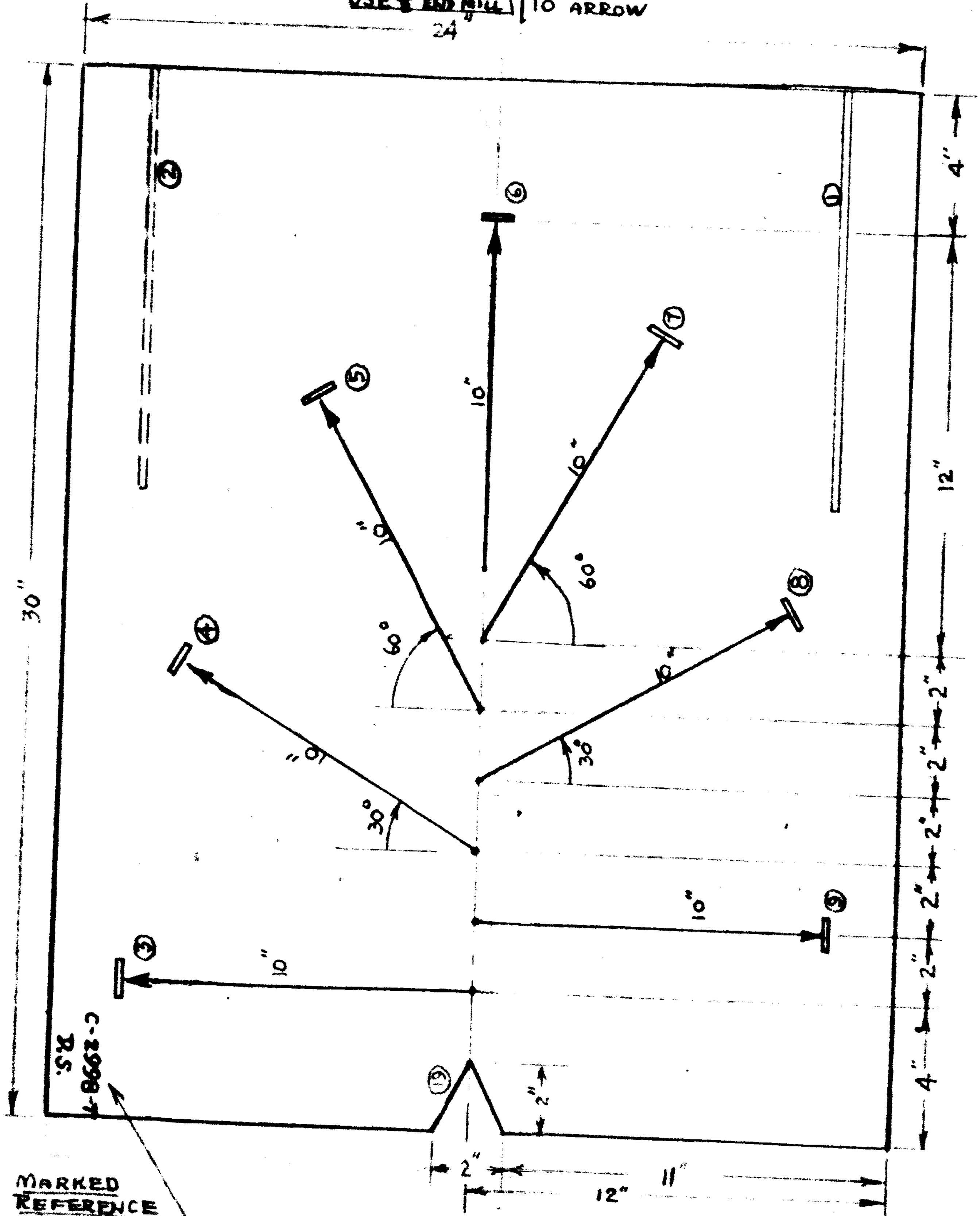
FORM 1 41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 13	FILE REF. C-3037-U
CUSTOMER: NASA	
ADDRESS	
TITLE: TEST PLATE "D"	
DRAWN BY: G. M. Murdock	DATE: 9-24-65

NOTCHES ① & ② ARE EXISTING
NOTCHES ③ THROUGH ⑨ -- 1" LONG, 1/8" WIDE, 0.010" DEEP AND PERPENDICULAR TO 10" ARROWS
NOTCH ⑲ -- CUT THROUGH PLATE





MARKED REFERENCE CORNER

MATERIAL: ALUMINUM -- 2219-T37
0.210" THICK

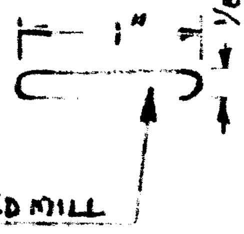
FORM 1.41

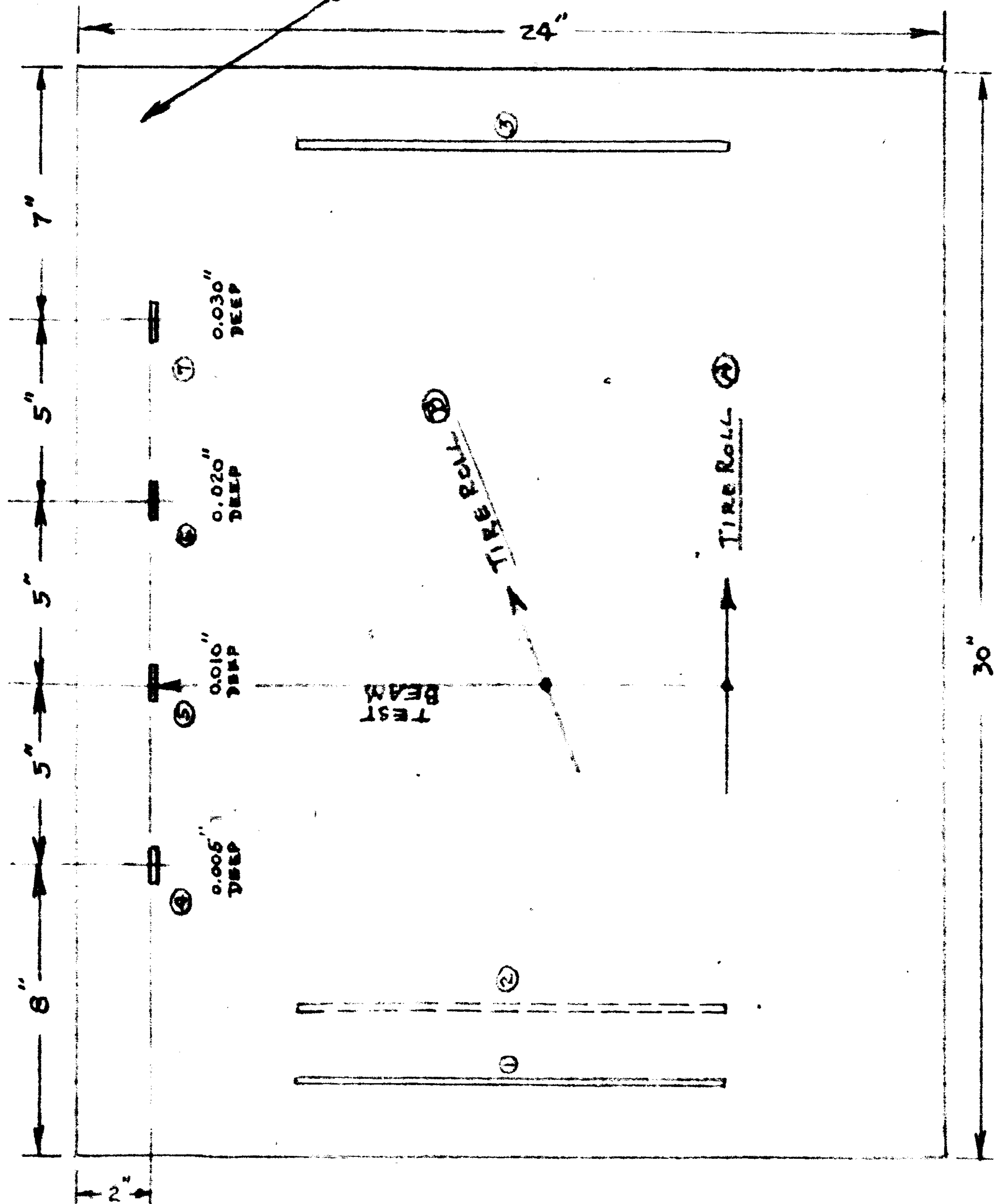
SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 14	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE TEST PLATE "E"	
DRAWN BY G.M. Murdock	DATE 9-23-65

NOTCHES ①, ② & ③ ARE EXISTING.
NOTCHES ④, ⑤, ⑥ & ⑦ ARE 1" LONG 1/8" WIDE AND IN DEPTHS AS SHOWN

REFERENCE CORNER MARKED "C-299B-T--E" ON UNDER SIDE

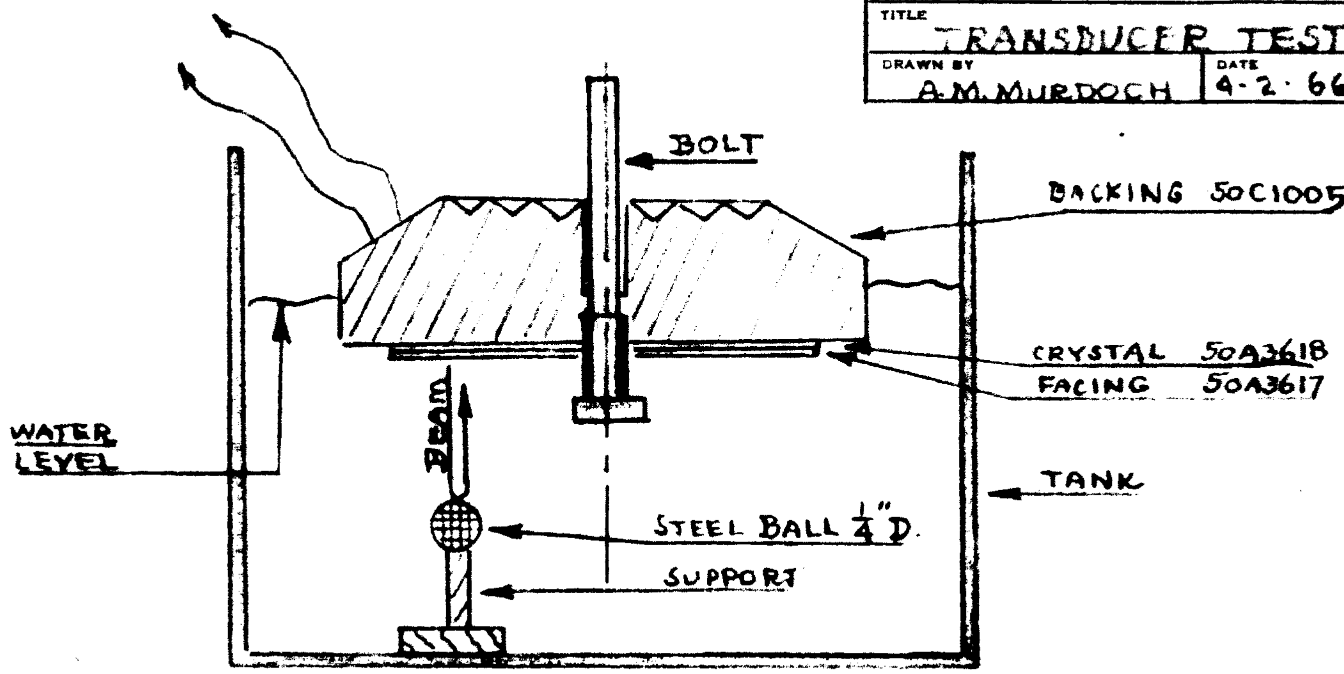


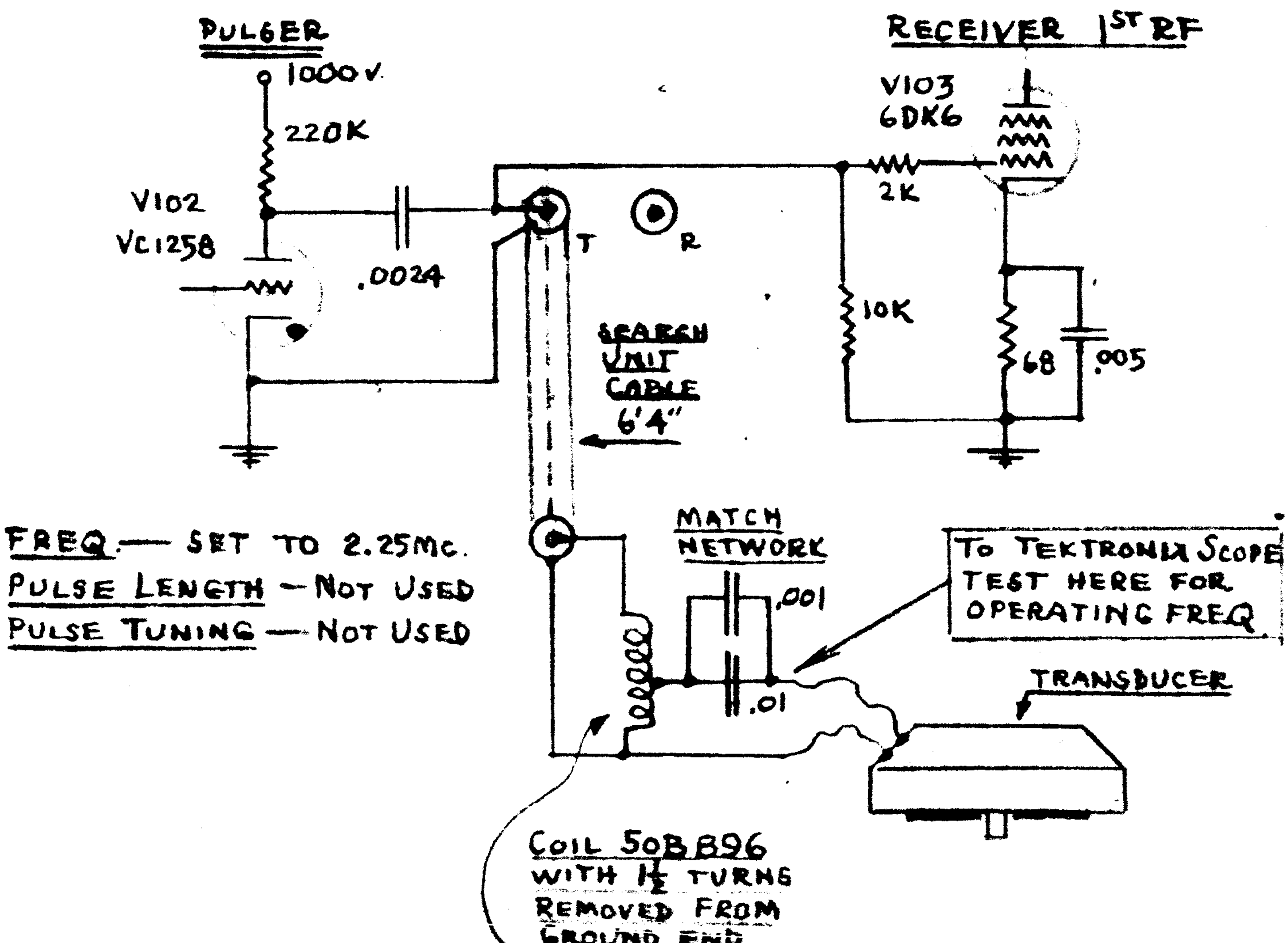


FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO.	FILE REF.
15	C-3037-U
CUSTOMER	NASA
ADDRESS	
TITLE	TRANSDUCER TEST
DRAWN BY A.M. MURDOCH	DATE 4-2-66



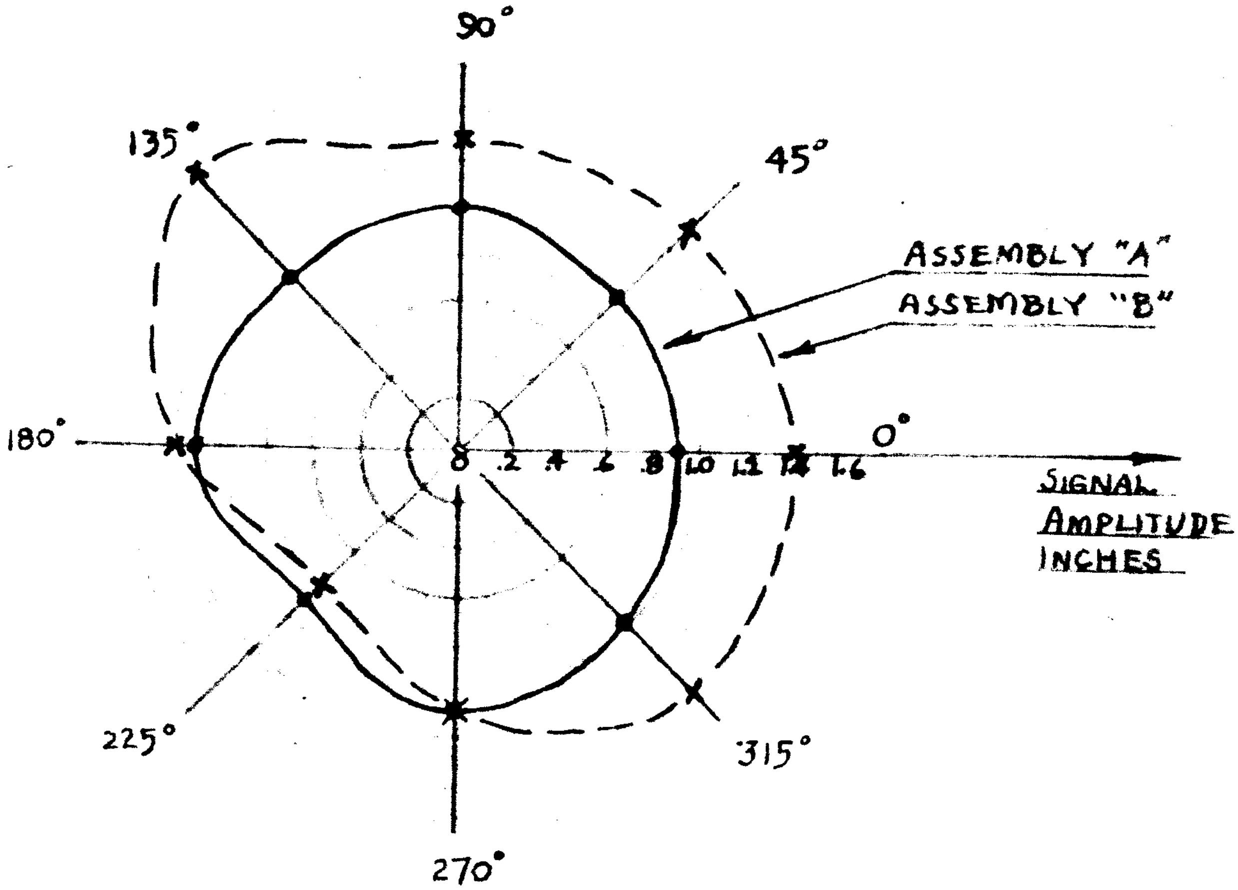


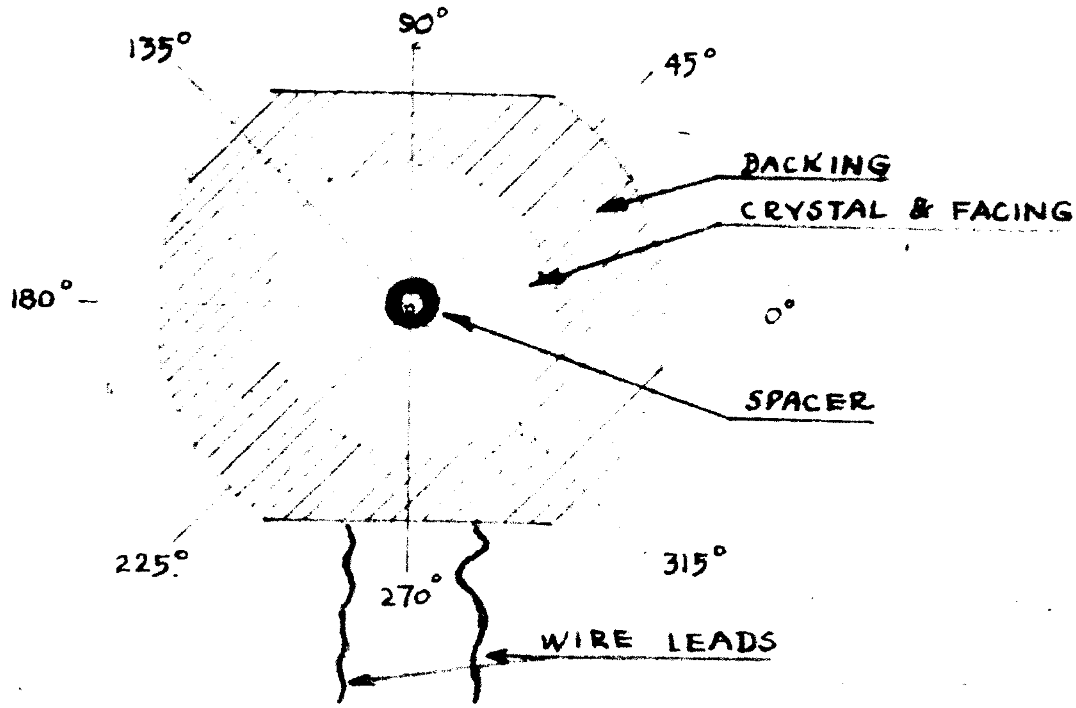
SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO.	16	FILE REF.	C-3037-U
CUSTOMER	NASA		
ADDRESS			
TITLE	TRANSDUCER TEST		
DRAWN BY	A. M. MURDOCH	DATE	JAN. 31, 1966

SIGNAL AMPLITUDE / POSITION

TEST SET-UP AS SHOWN IN FIG. 18

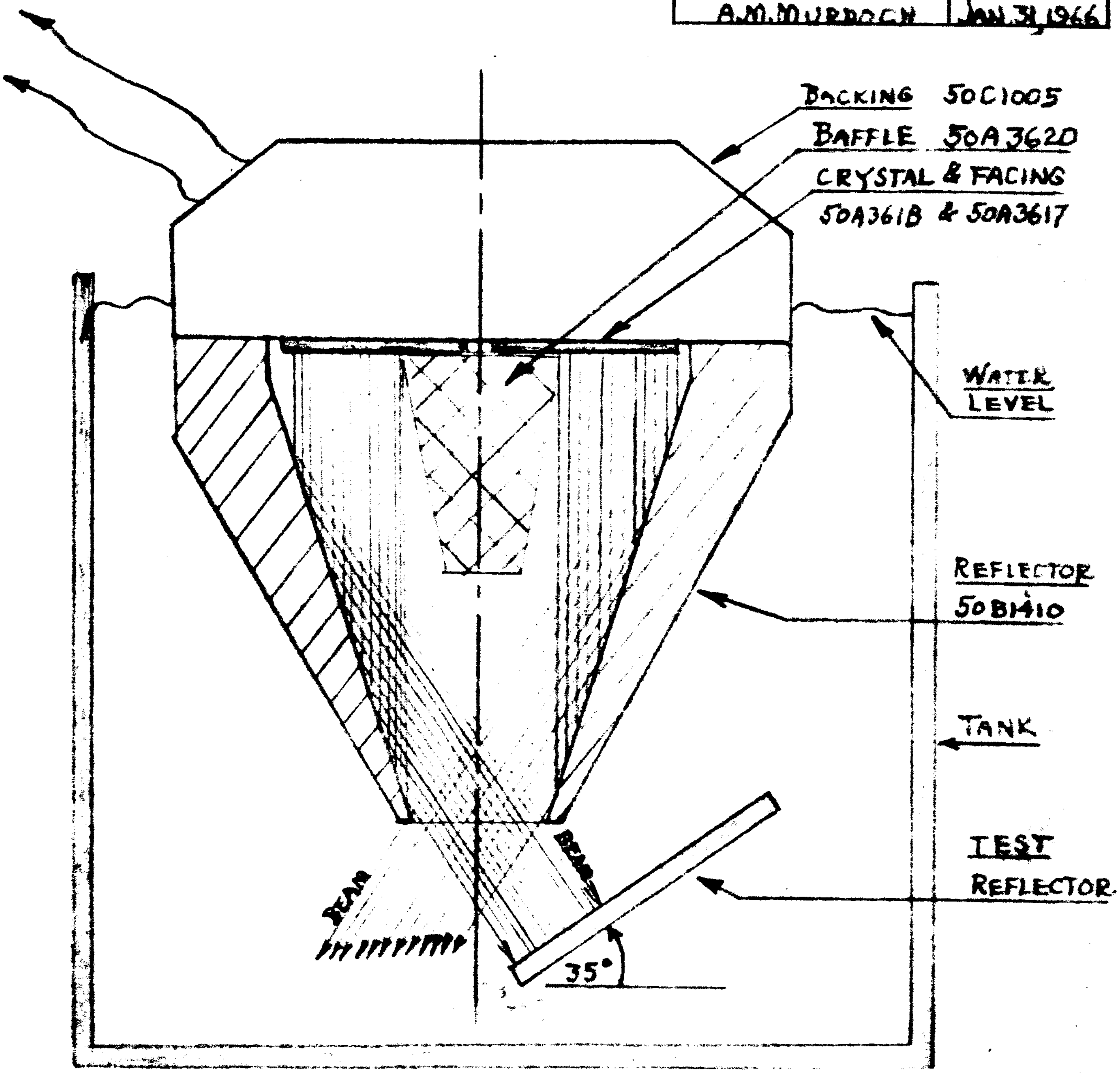




FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 17	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE TEST OF REFLECTOR KIT "A"	
DRAWN BY A.M. MURDOCH	DATE JAN 31, 1966

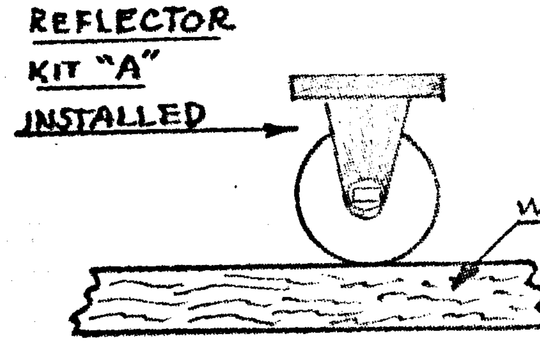


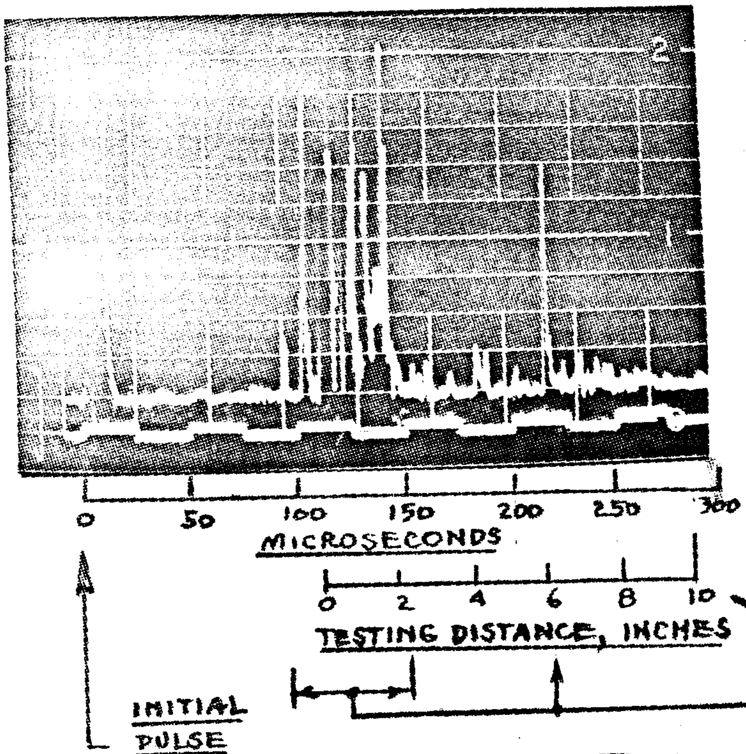
FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO.	FILE REF.
—	C-3037-U
CUSTOMER	NASA
ADDRESS / TITLE	ANALYSIS OF TEST PATTERNS
DRAWN BY A.M. MURDOCH	DATE 3-21-66

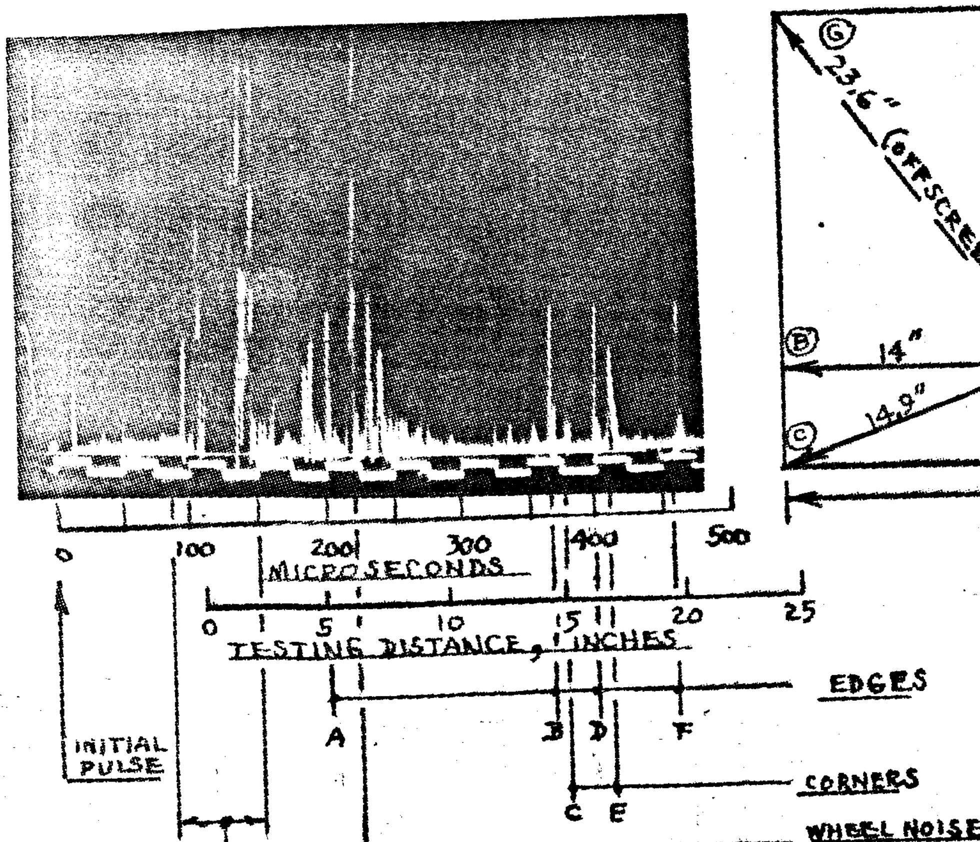
ANALYSIS OF TYPICAL TEST PATTERNS

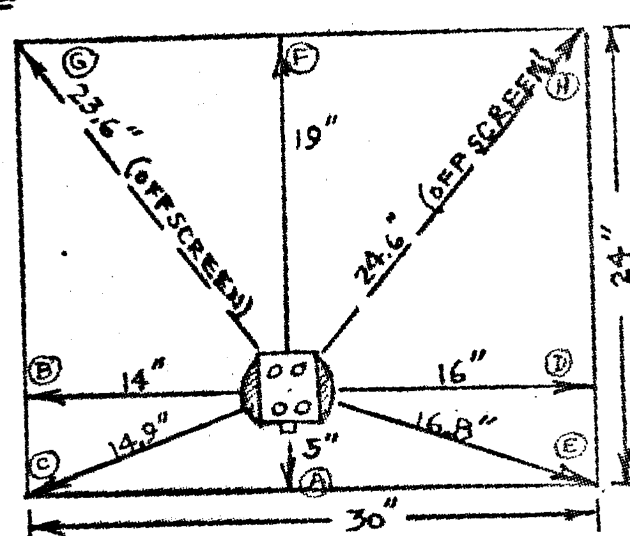




SEARCH UNIT PLACED ON WOODEN BOARD TO SHOW "WHEEL NOISE" WITHOUT SURFACE WAVE TRANSMISSION ON MATERIAL.
MARKERS: 1 CYCLE = 50 μSec.
TAKEN FROM FIG. 20
HIGH AMPLITUDE WHEEL NOISE

FIG. 18



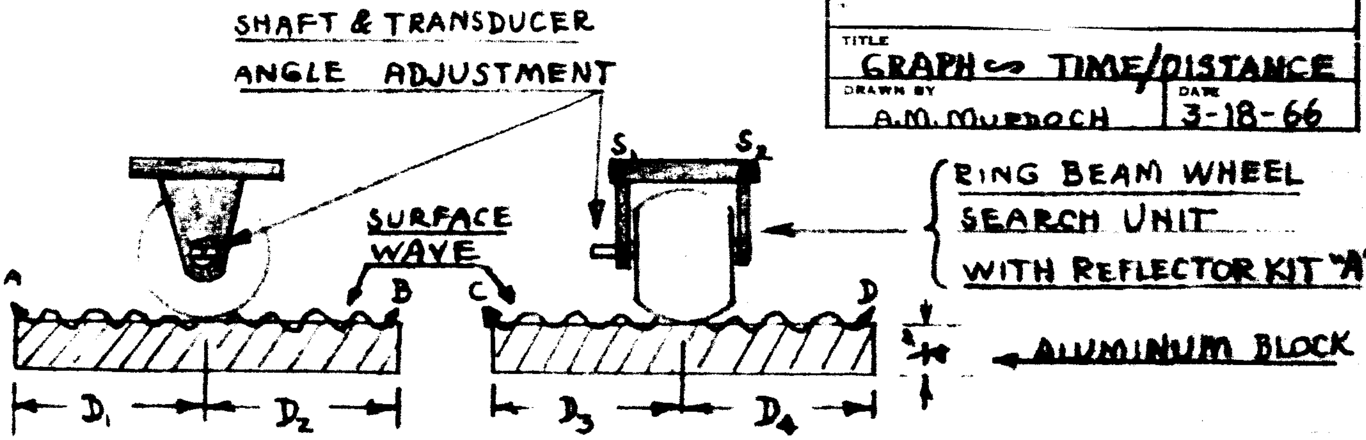


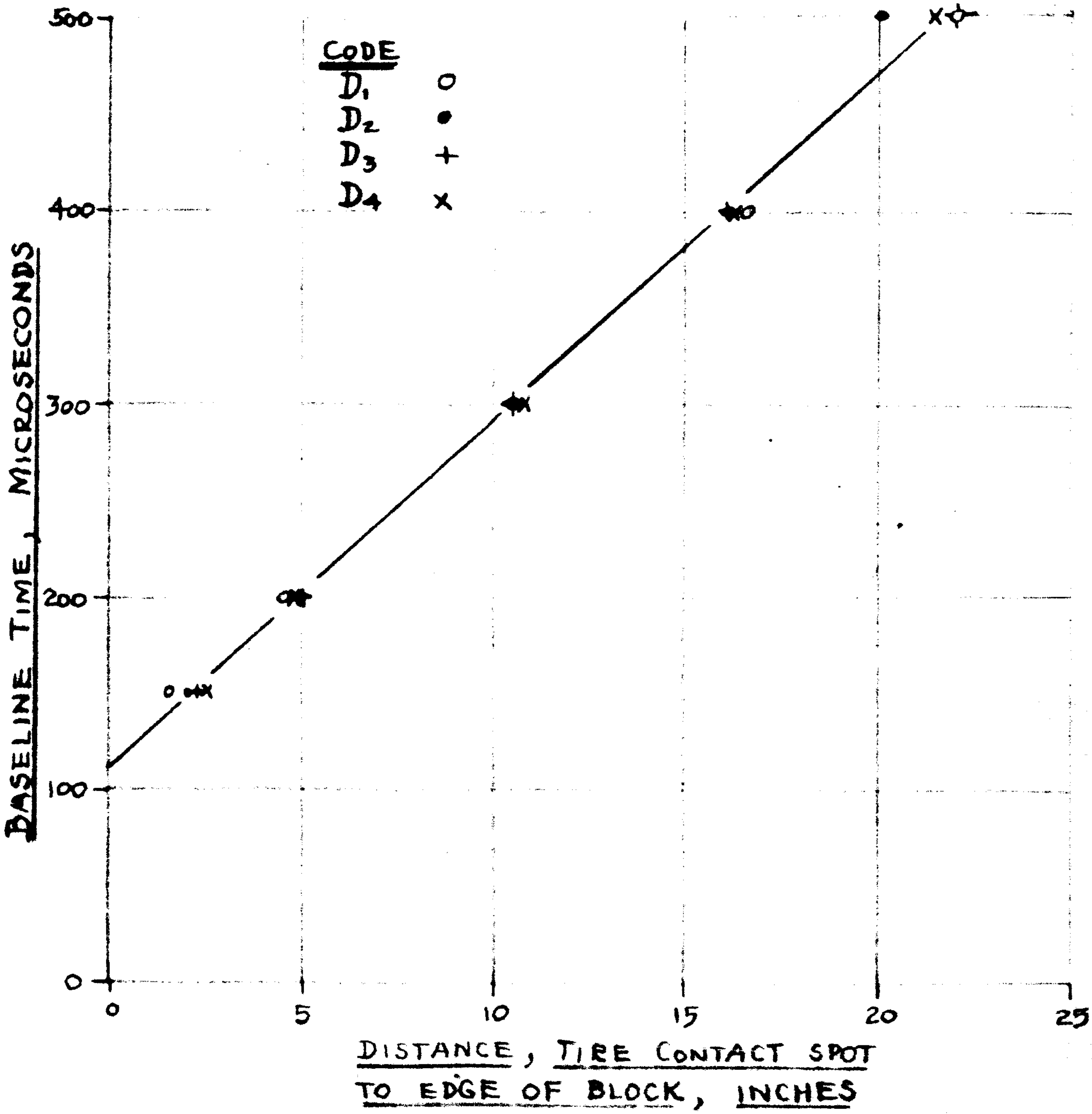
SEARCH UNIT PLACED ON ALUMINUN PLATE 1/4" X 24" X 30"

FIG. 19

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 20	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE GRAPH — TIME/DISTANCE	
DRAWN BY A.M. MURDOCH	DATE 3-18-66



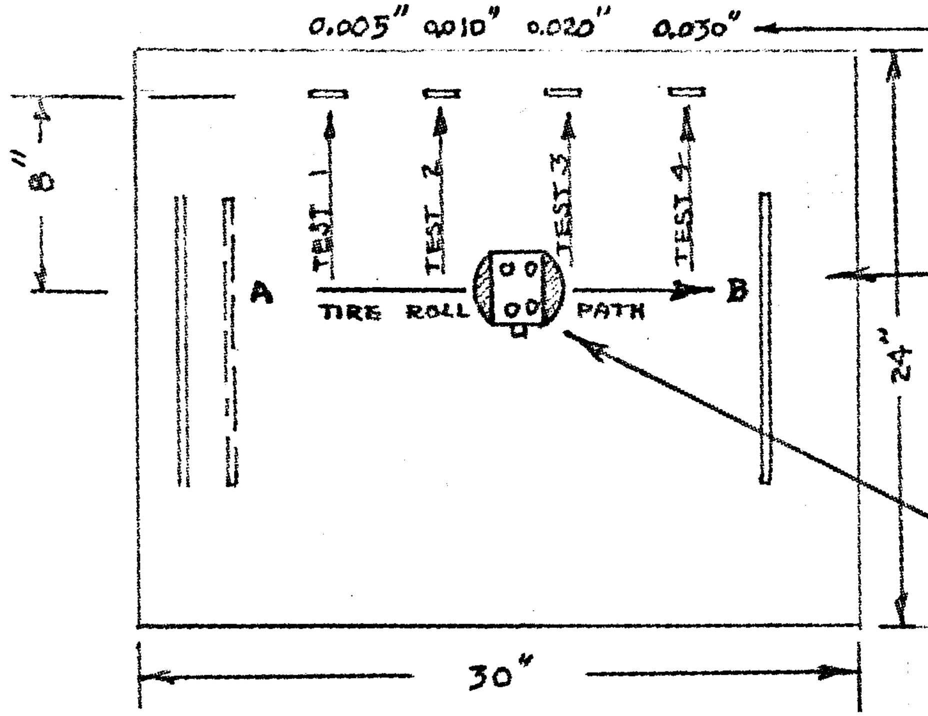


FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO.	FILE REF. C-3037-U
CUSTOMER	NASA
ADDRESS	SIGNAL AMP. / NOTCH DEPTH
TITLE	TAPE RECORDING
DRAWN BY A M MURDOCH	DATE 3-21-66

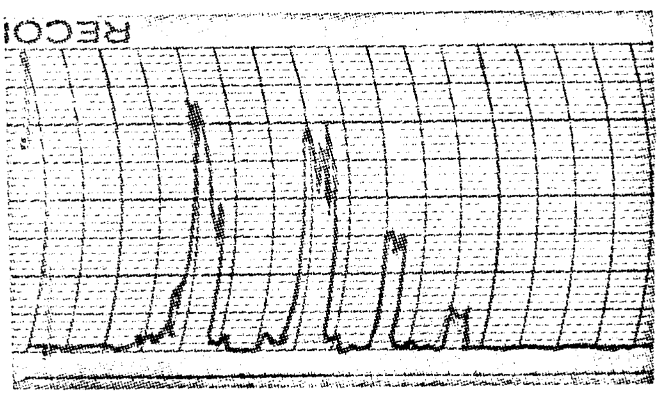
SIGNAL AMPLITUDE/NOTCH DEPTH



ALUMINUM TEST PLATE "E"

WHEEL SEARCH UNIT WITH REFLECTOR KIT "A"

FIG. 21



TAPE RECORD
RECORDER BRUSH MARK II
MODEL RD-2522-20

REFLECTOSCOPE
REJECT - OFF
SENSITIVITY - 1X1

ZERO

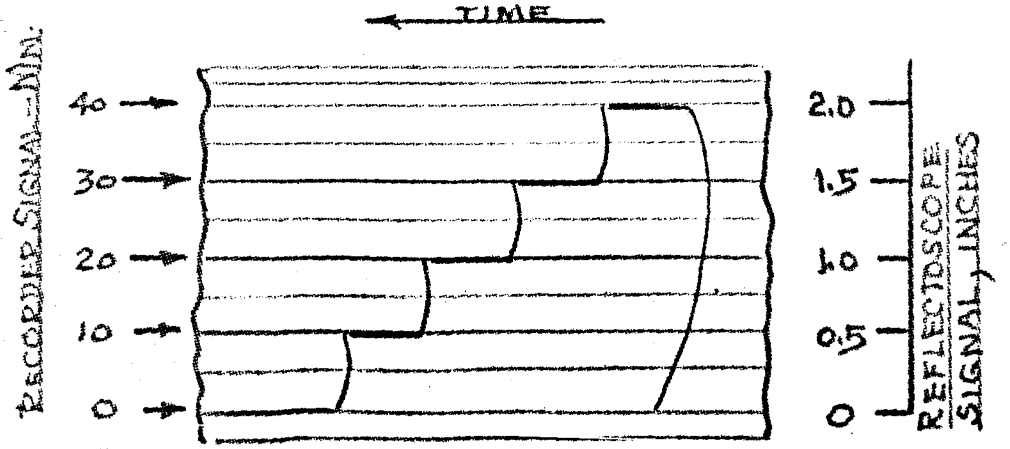
0.030" 0.020" 0.010" 0.005" ← NOTCH DEPTH

4 3 2 1 ← TEST NO.

DIRECTION OF TAPE →

← TIME

FIG. 22



COMPARISON OF REFLECTOSCOPE AND RECORDER SIGNAL AMPLITUDES

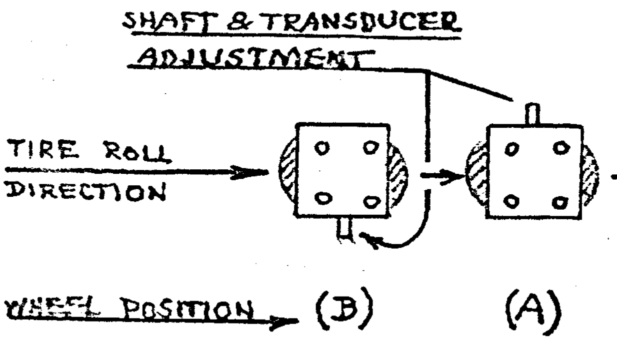
FIG. 23

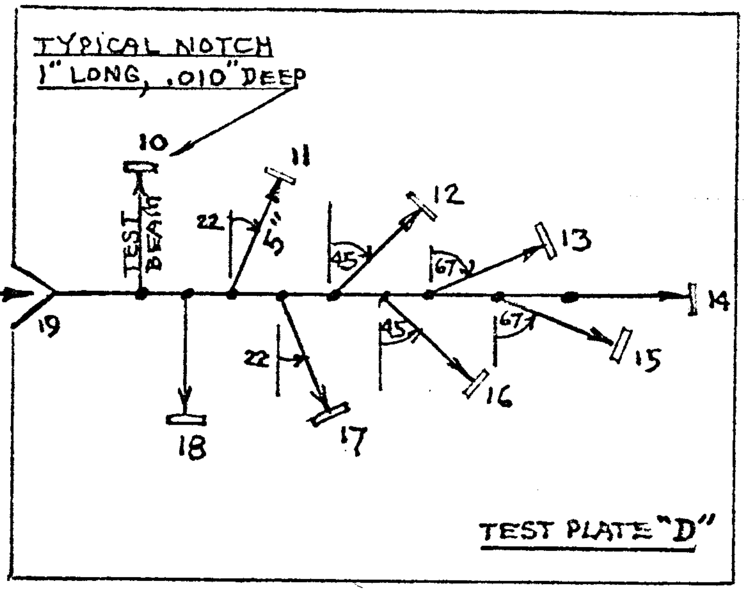
FORM 1.41

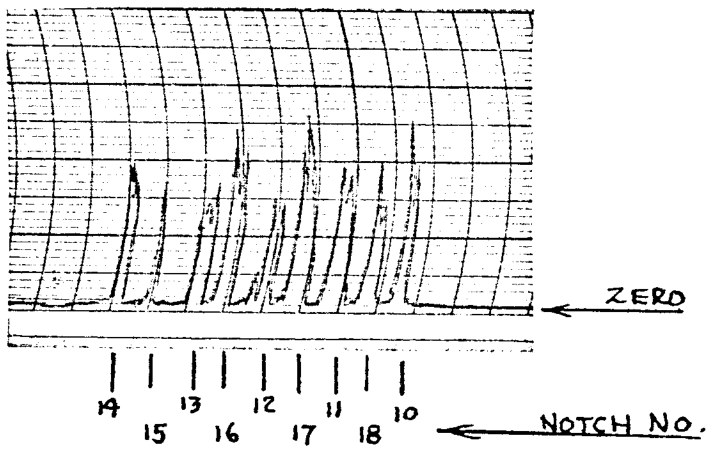
SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

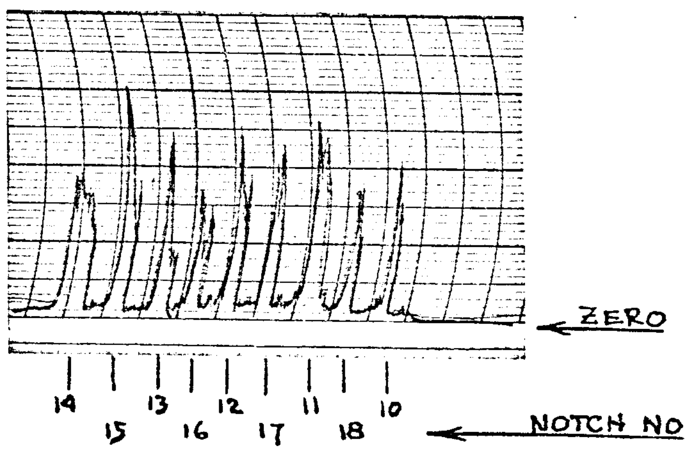
SKETCH NO. 24	FILE REF. C-3037-12
CUSTOMER NASA	
ADDRESS SIGNAL DIS/NOTCH ANGLE	
TITLE TAPE RECORDINGS	
DRAWN BY A.M. MURDOCH	DATE 3-22-66

DETECTION OF NOTCHES 5" AWAY AND AT VARIOUS ANGLES









DIRECTION OF TAPES →

← TIME

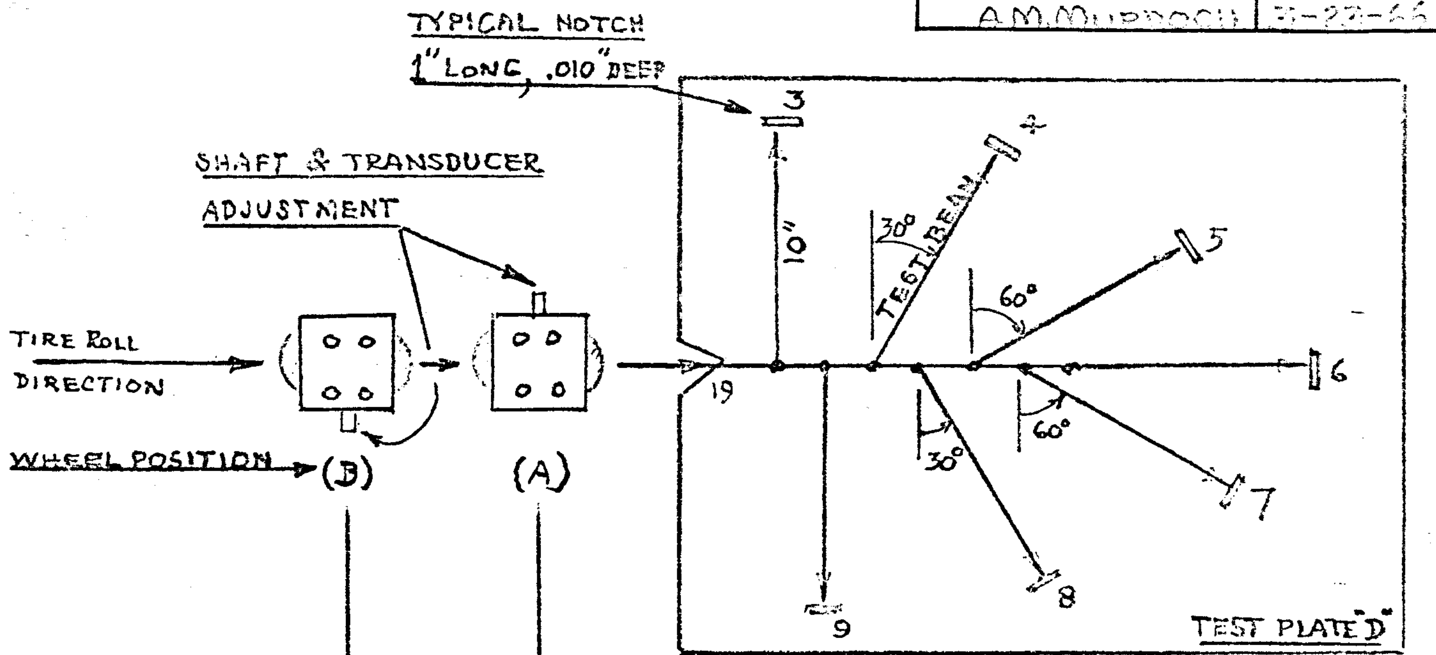
REFLECTOR KIT – "A"
REFLECTOSCOPE
SETTINGS

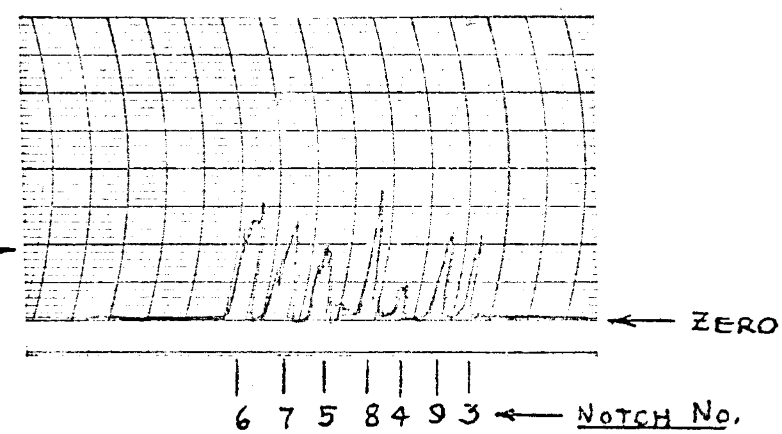
SENSITIVITY — 1X1
REJECT — OFF
D.A.C. — OFF
TRANSIGATE – GATE START – $3\frac{1}{2}$"
GATE END – $6\frac{1}{2}$"

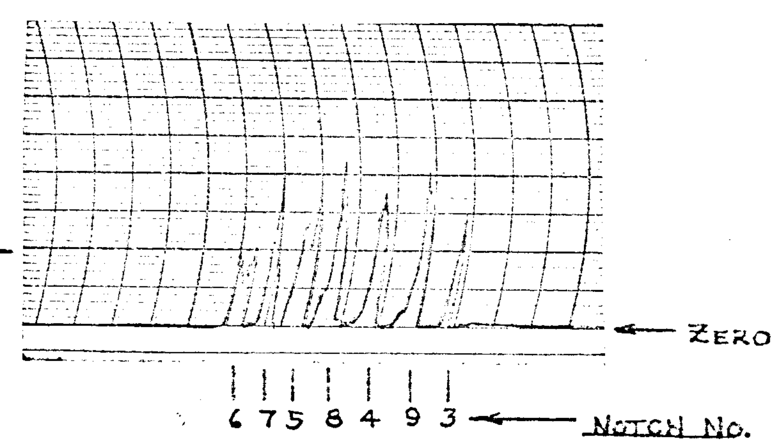
SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 25	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS SIGNAL AMP/NOTCH ANGLE	
TITLE TAPE RECORDINGS	
DRAWN BY A.M. MURDOCH	DATE 3-22-66

DETECTION OF NOTCHES 10" AWAY AND AT VARIOUS ANGLES







REFLECTOR KIT - "A"

REFLECTOSCOPE SETTINGS
- SENSITIVITY - 1x1
- REJECT --- OFF
- D.A.C. --- OFF
- TRANSIGATE
  - GATE START 8"
  - GATE END 12"

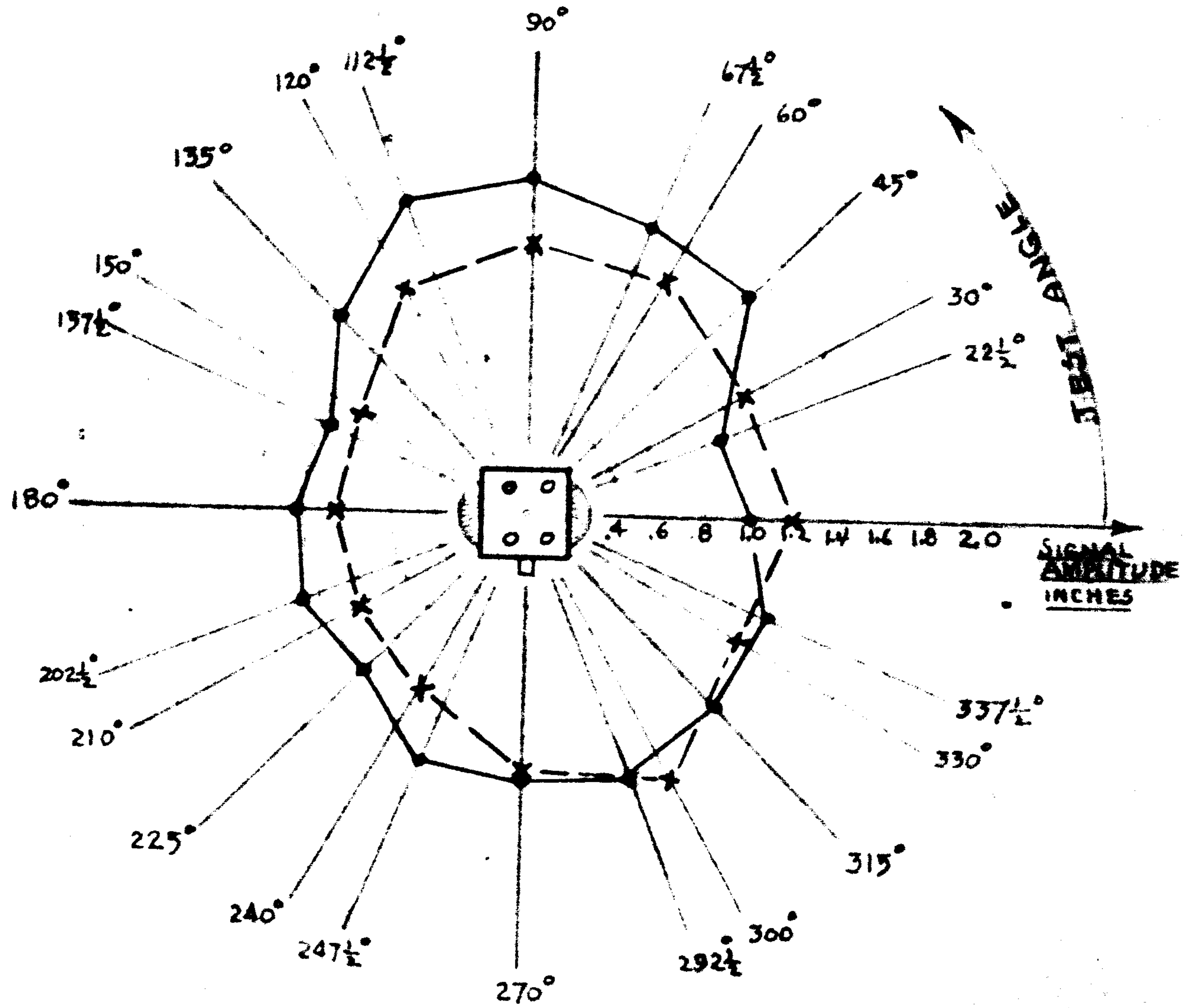
DIRECTION OF TAPES →

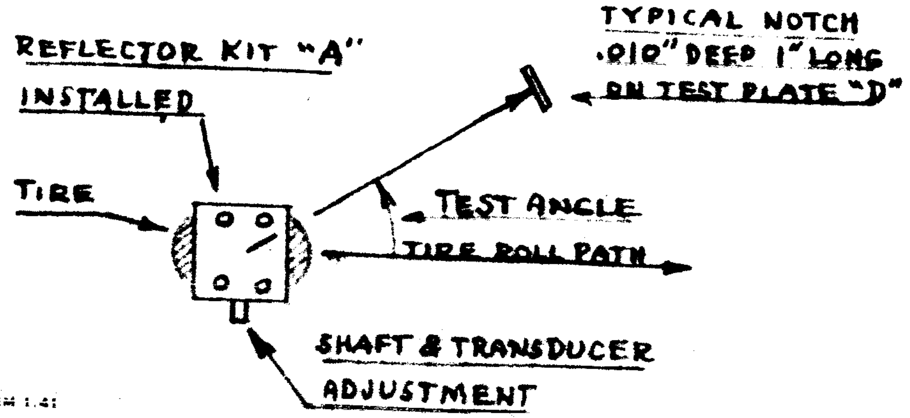
← TIME

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 26	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE GRAPH – SIG. AMP./NOTCH ANGLE	
DRAWN BY A.M.MURDOCH	DATE 3-22-66

SIGNAL AMPLITUDE/NOTCH ANGLE





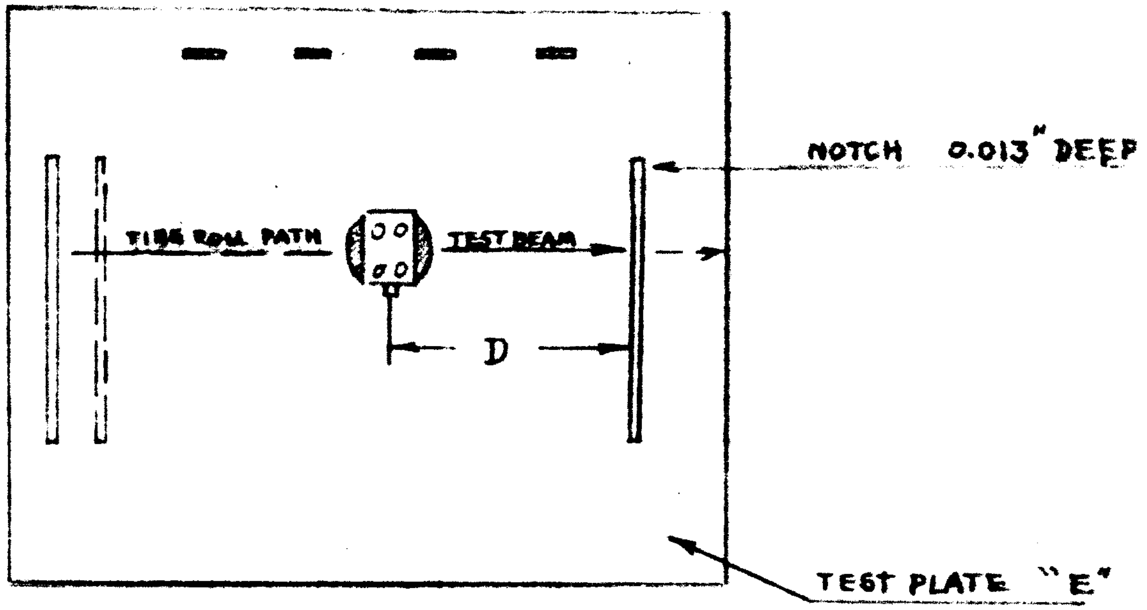
SYMBOL	DISTANCE TO NOTCH
——•——	5"
— —×—	10"

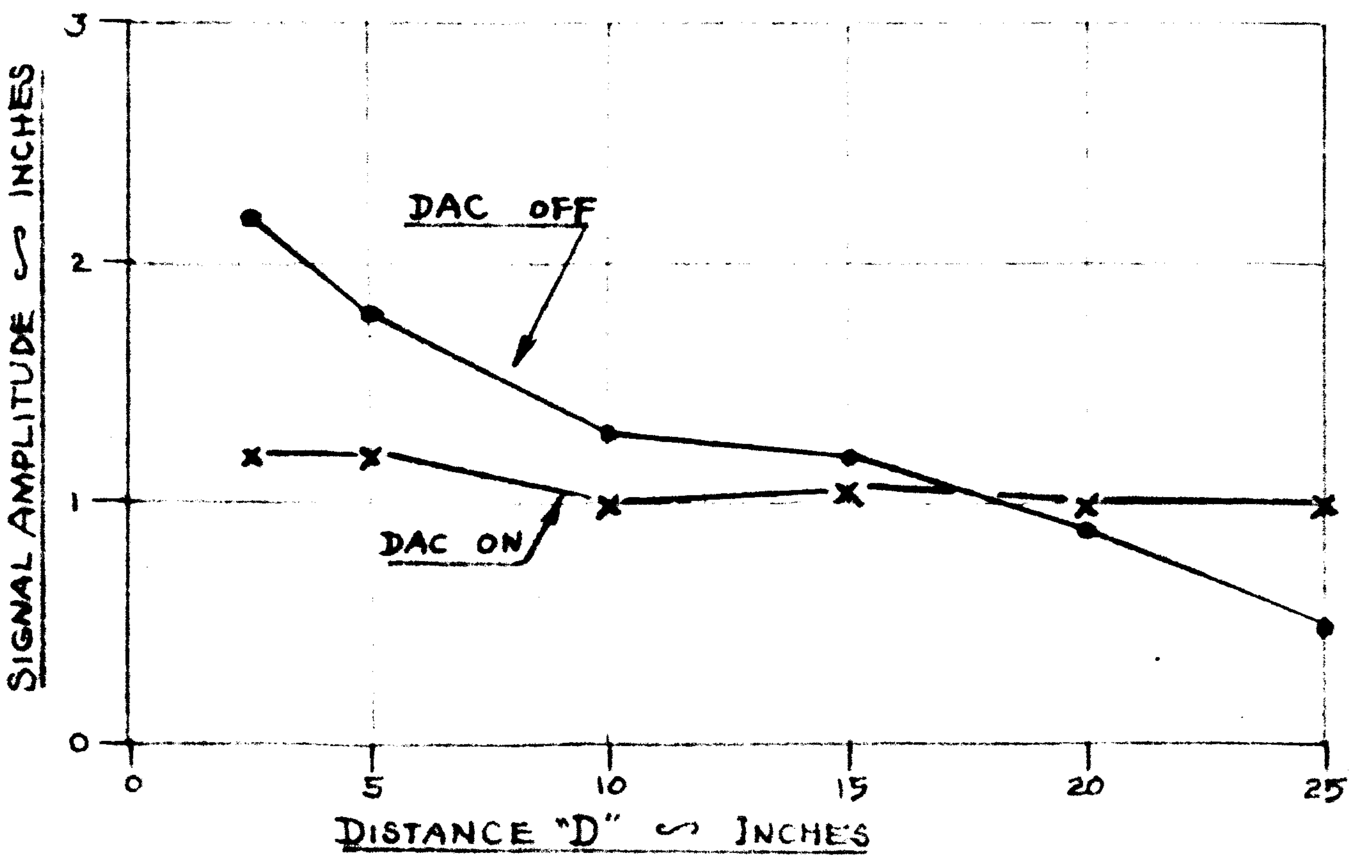
FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 27	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE GRAPH — DAC PERFORMANCE	
DRAWN BY A.M. MURDOCH	DATE 3-21-66

DISTANCE AMPLITUDE CORRECTION (DAC) MODULE PERFORMANCE



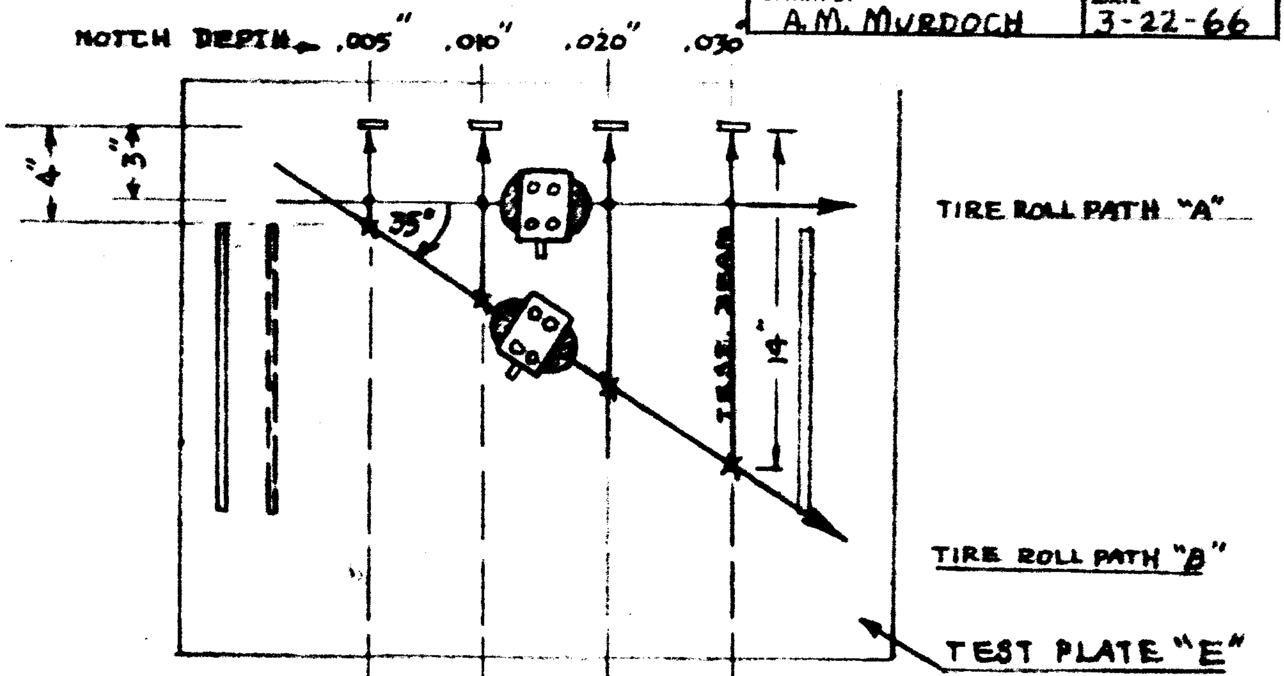


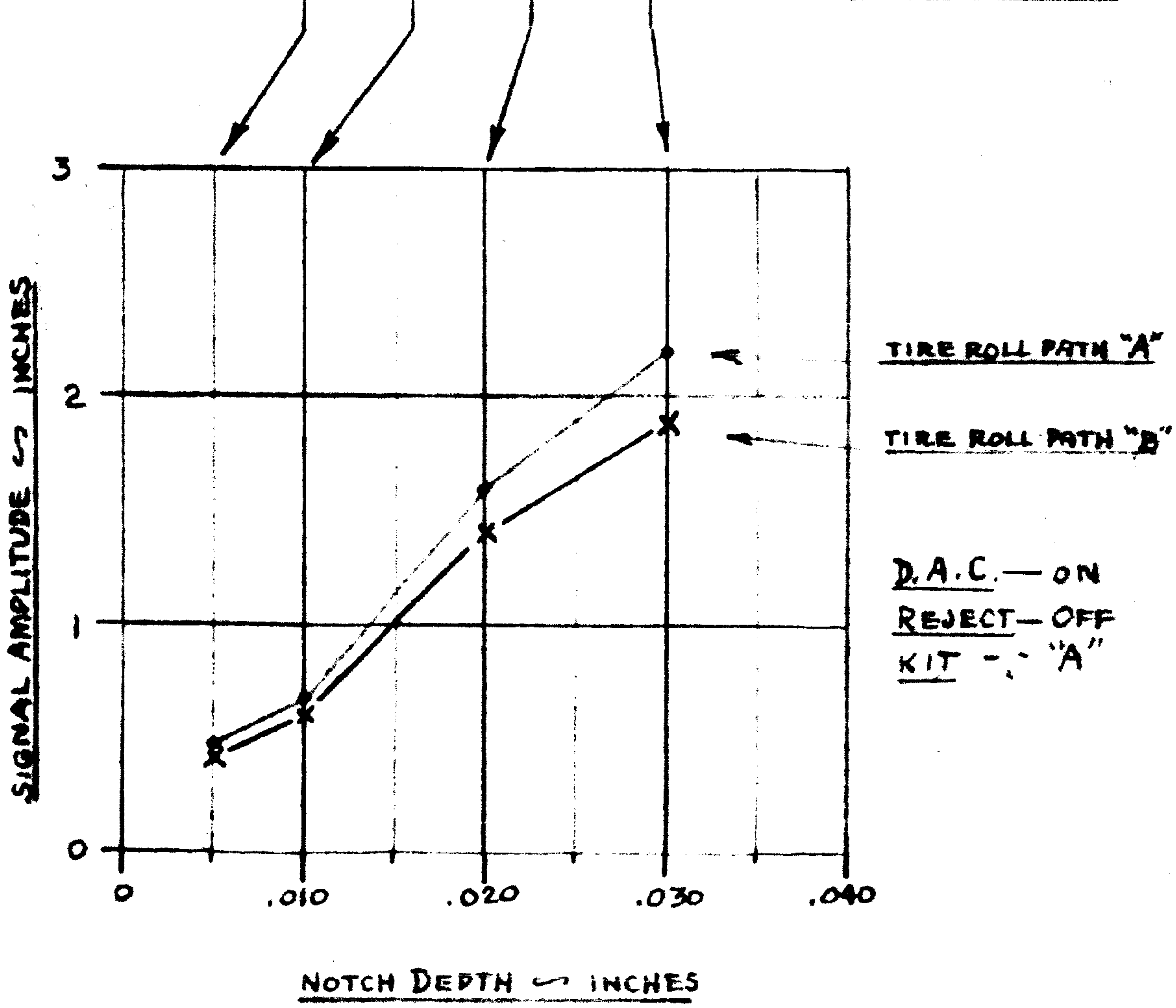
REJECT - OFF
KIT — "A"

FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 28	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE GRAPH ~ SIGNAL AMP/NOTCH DEPTH	
DRAWN BY A.M. MURDOCH	DATE 3-22-66

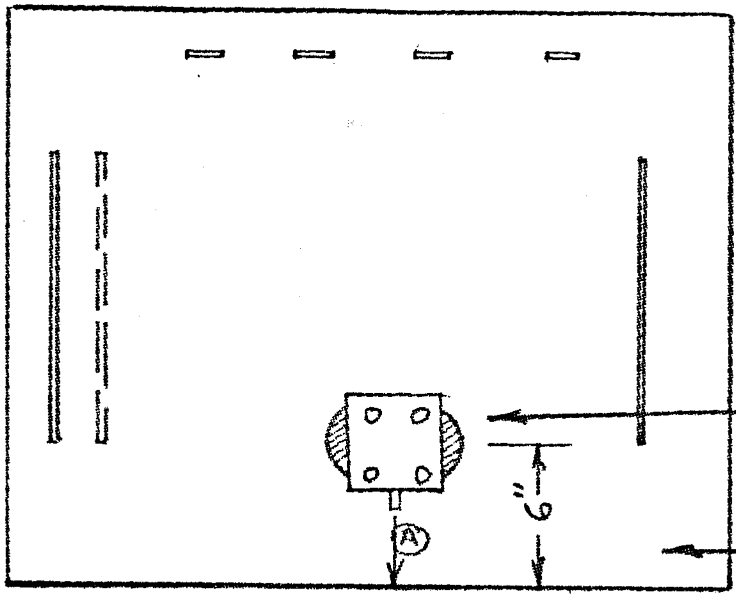




SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

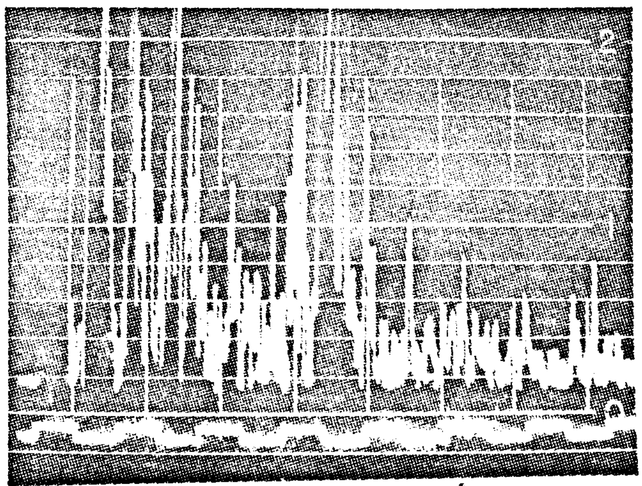
SKETCH NO. 29	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE REFLECTOR KIT "B"	
DRAWN BY A.M. MURDOCH	DATE 3-23-66

OPERATION OF REFLECTOR KIT "B"



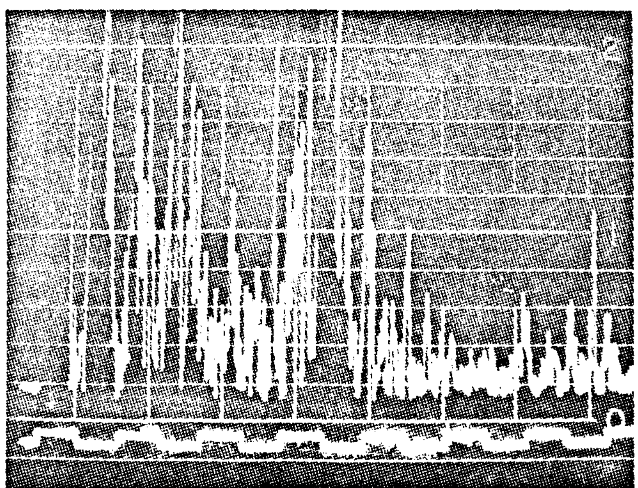
WHEEL UNIT WITH REFLECTOR KIT "B"

TEST PLATE "E"



MARKERS
1 CYCLE = 50 μSec.

REFLECTION FROM EGDE 6" AWAY



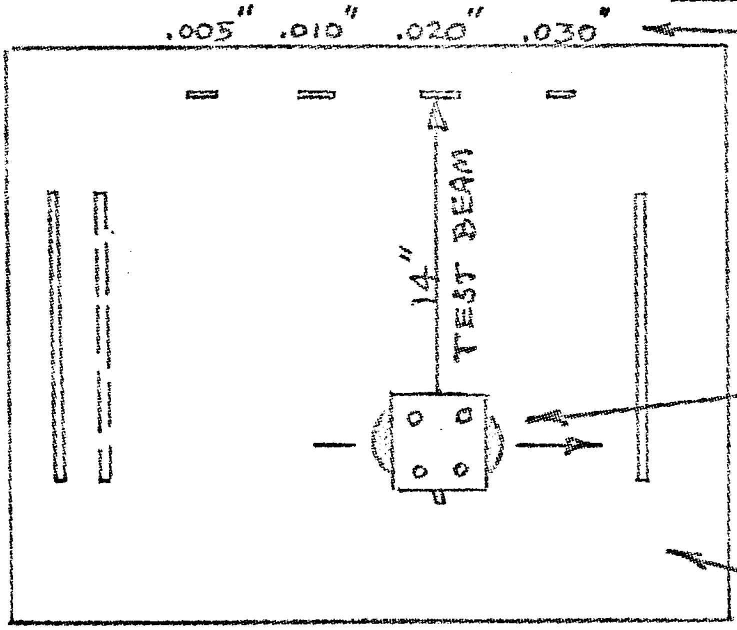
EDGE REFLECTION DAMPED BY FINGER PLACED AT A

FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 30	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE REFLECTOR KIT "B"	
DRAWN BY A. M. MURDOCH	DATE [illegible]

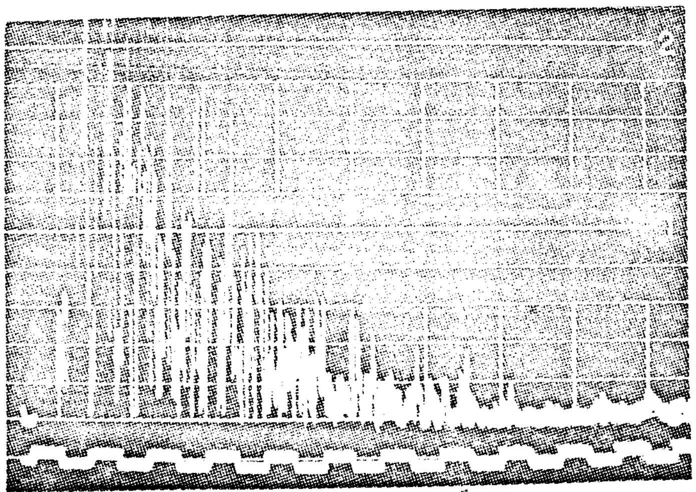
OPERATION OF REFLECTOR KIT "B"



NOTCH DEPTH

WHEEL UNIT WITH REFLECTOR KIT "B"

TEST PLATE "E"

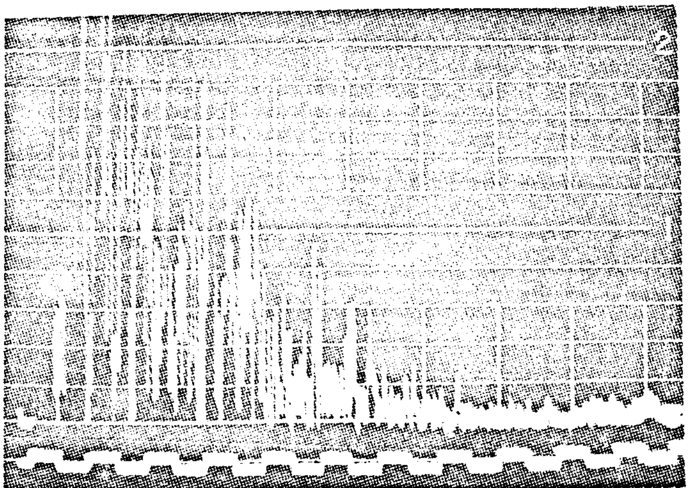


MARKERS
1 CYCLE = 50 μ Sec.

WHEEL UNIT POSITIONED AS IN SKETCH

INITIAL PULSE

SIGNAL FROM 0.020" NOTCH 14" AWAY



WHEEL UNIT ROLLED 2" TO THE RIGHT

NO NOTCH SIGNAL

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO.	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE SCANNING METHOD	
DRAWN BY G. M. Murdoch	DATE 9-28-65

DETECTION OF ROUND HOLES

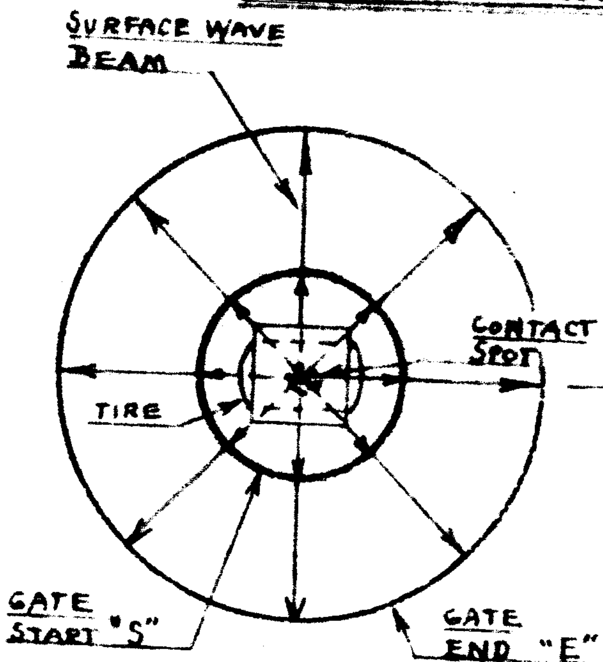


FIG. 31

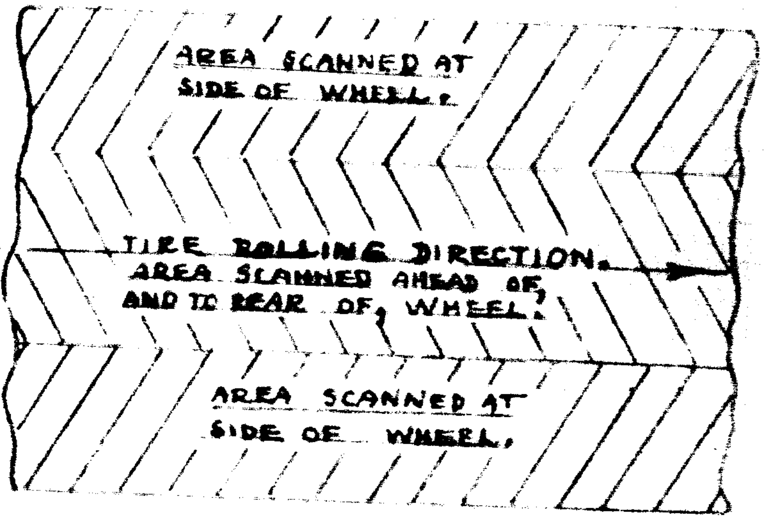


FIG. 32

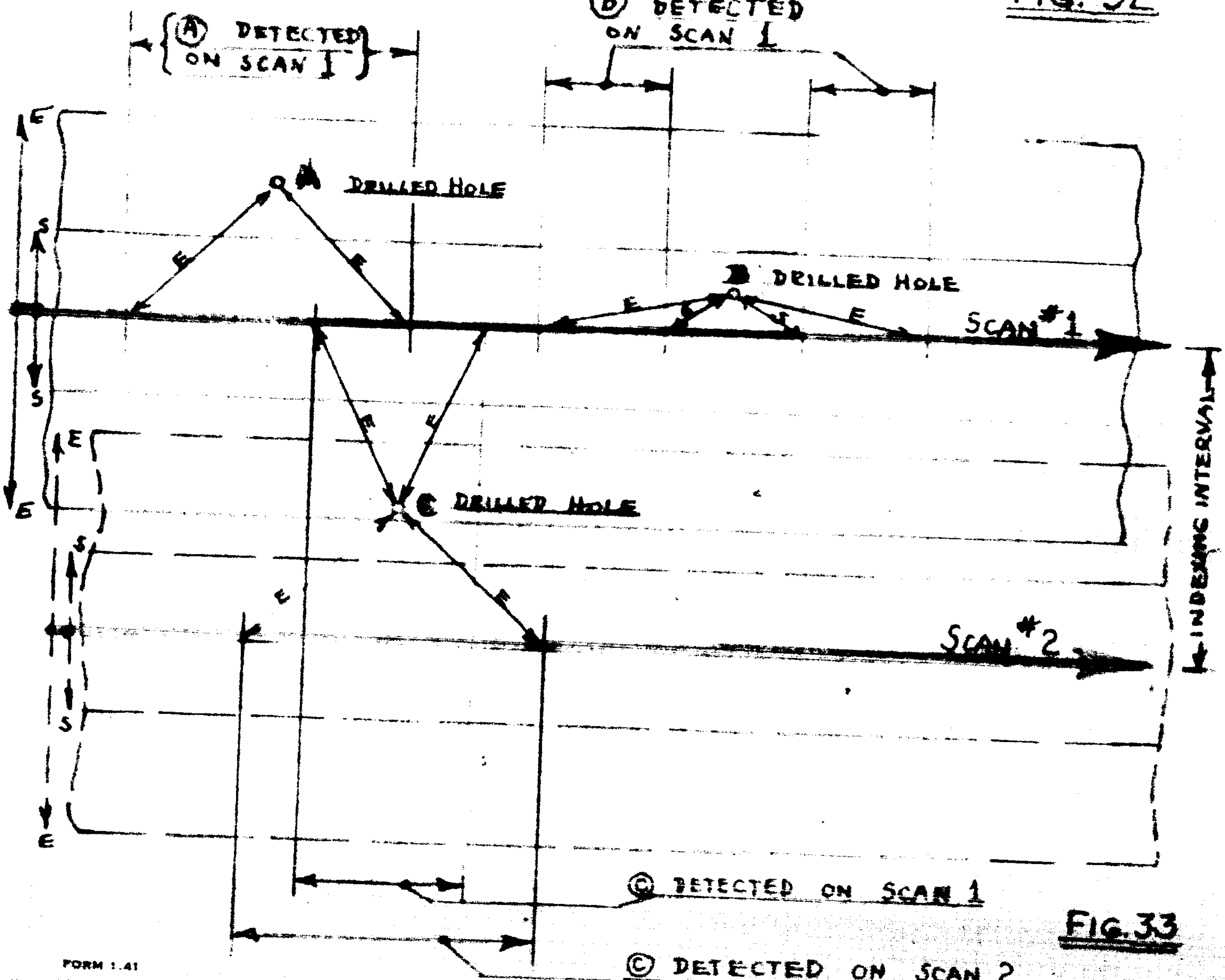


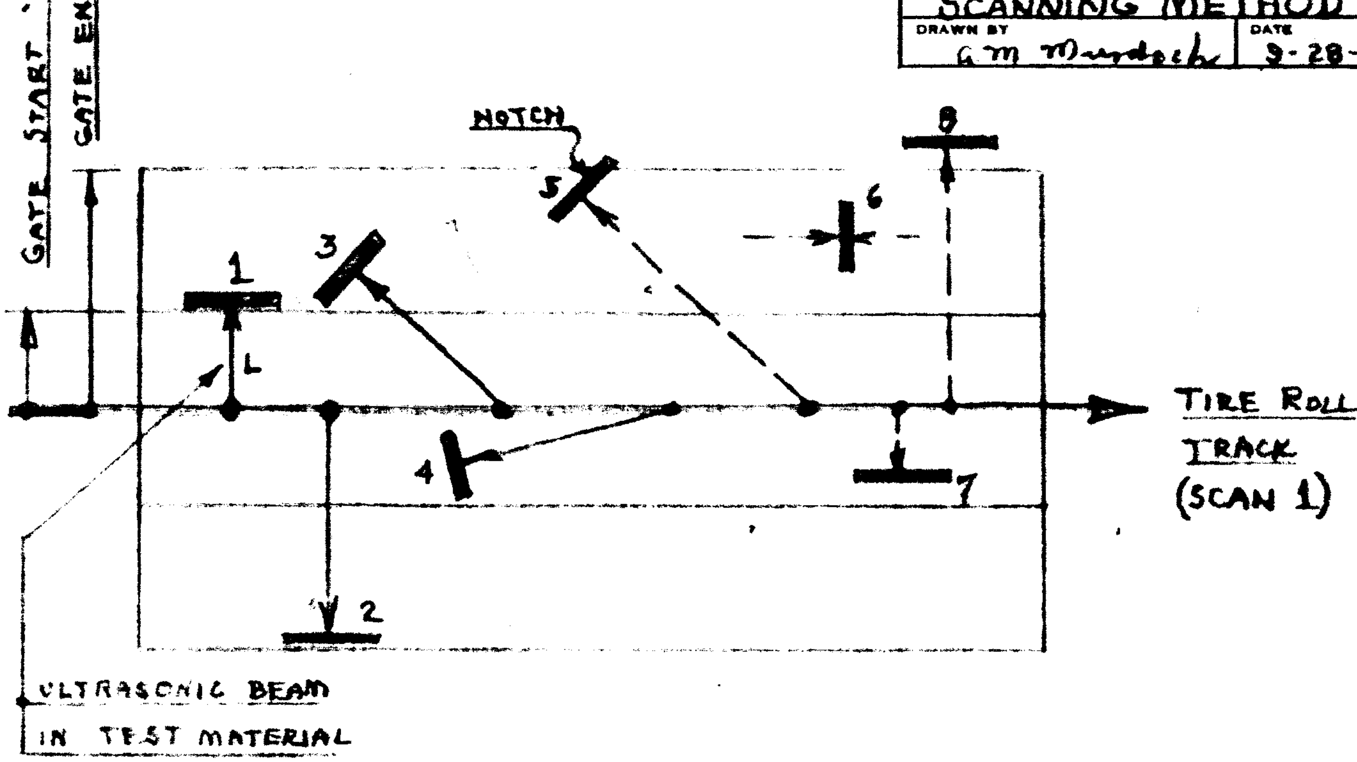
FIG. 33

FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 34	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE SCANNING METHOD	
DRAWN BY G M Murdoch	DATE 9-28-65

DETECTION OF NOTCHES



NOTCHES 1, 2, 3, AND 4 ARE DETECTED AT ASSOCIATED POINTS (—●—) ON TIRE ROLL TRACK BECAUSE:

(A) PERPENDICULAR TO EACH NOTCH INTERSECTS TIRE ROLL TRACK;

(B) ULTRASONIC BEAM LENGTH "L" MEASURED ON ITS PERPENDICULAR FALLS IN GATED INTERVAL, OR

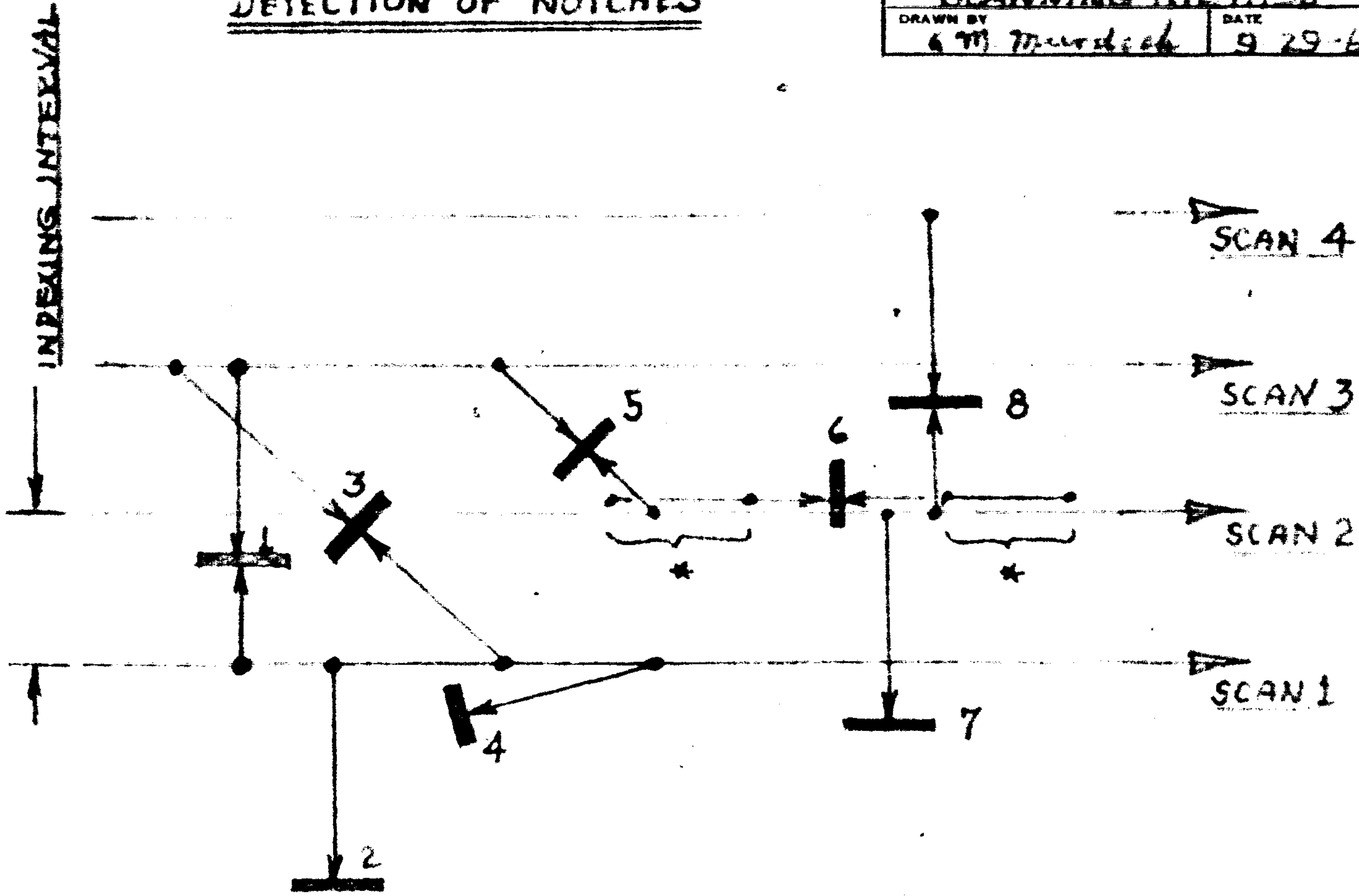
$$S < L < E$$

NOTCHES 5, 6, 7, AND 8 FAIL TO MEET THE ABOVE REQUIREMENTS (A) AND (B) AND THEREFORE ARE NOT DETECTED AND INDICATED BY A RECORDING SYTEM.

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 35	FILE REF. C-3037-11
CUSTOMER NASA	
ADDRESS	
TITLE SCANNING METHOD	
DRAWN BY G M Murdock	DATE 9-29-65

DETECTION OF NOTCHES



NOTCHES ① THROUGH ⑧ AS IN FIGURE 34 ARE REPRODUCED HERE, AGAIN SHOWING DETECTION OF ①, ②, ③, AND ④ ON SCAN #1

SCAN #2 DETECTS NOTCHES ⑤, ⑥, ⑦, AND ⑧
* (NOTCH ⑥ IS DETECTED IN BRACKETED POSITIONS)

SCAN #3 DETECTS NOTCHES ③ AND ⑤

SCAN #4 DETECTS NOTCH ⑧

GATE START (S) AND GATE END (E), ALTHOUGH NOT SHOWN HERE, ARE ASSUMED TO HAVE SAME VALUES FOR EACH OF THE FOUR SCANS AS USED IN SCAN 1, FIGURE 34

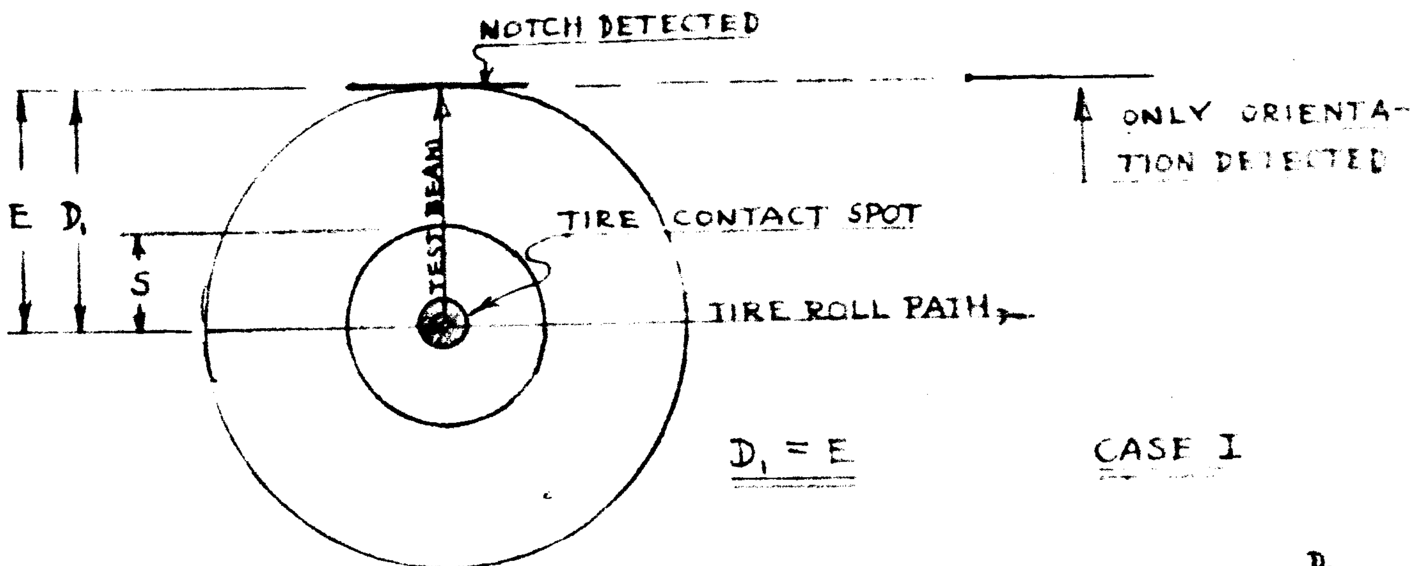
FORM 1.41

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

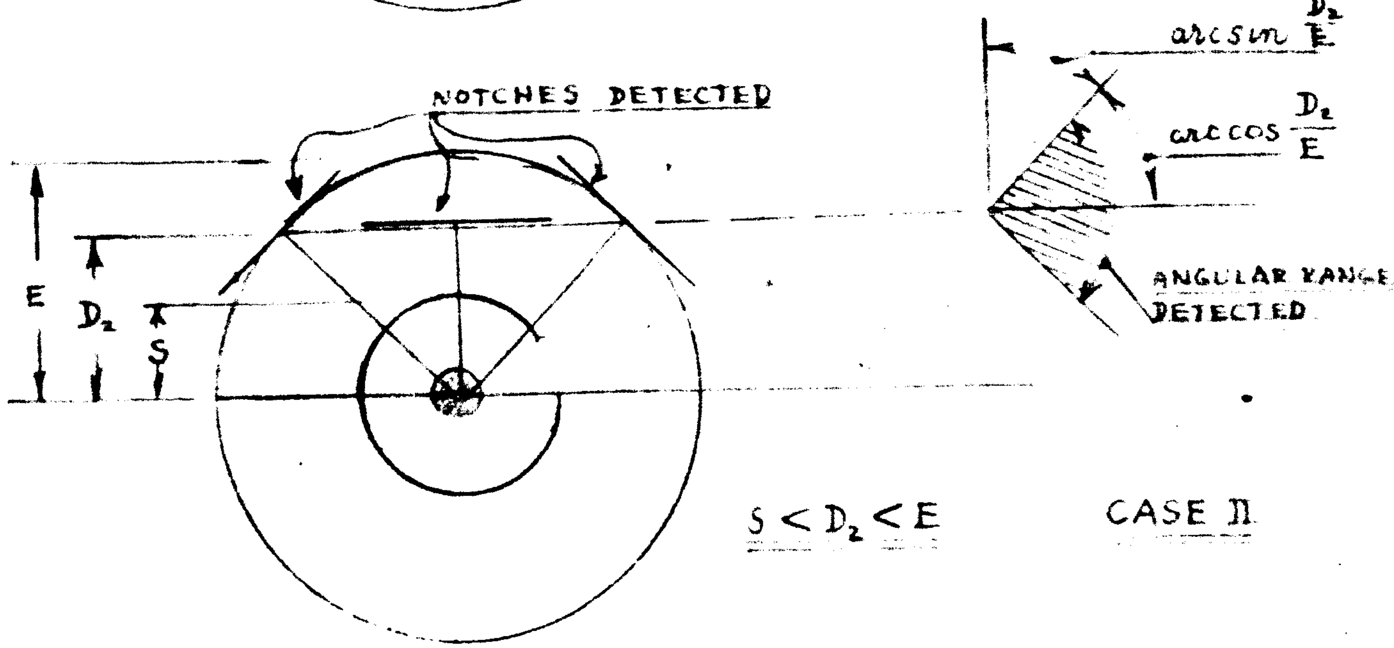
SKETCH NO. 36	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE SCANNING METHOD	
DRAWN BY A.M. MURDOCH	DATE 3-27-66

DETECTION OF NOTCHES

D = DISTANCE, NOTCH TO TIRE ROLL PATH, INCHES
S = GATE START, INCHES FROM SPOT CENTER
E = GATE END, INCHES FROM SPOT CENTER



$D_1 = E$ CASE I



$S < D_2 < E$ CASE II

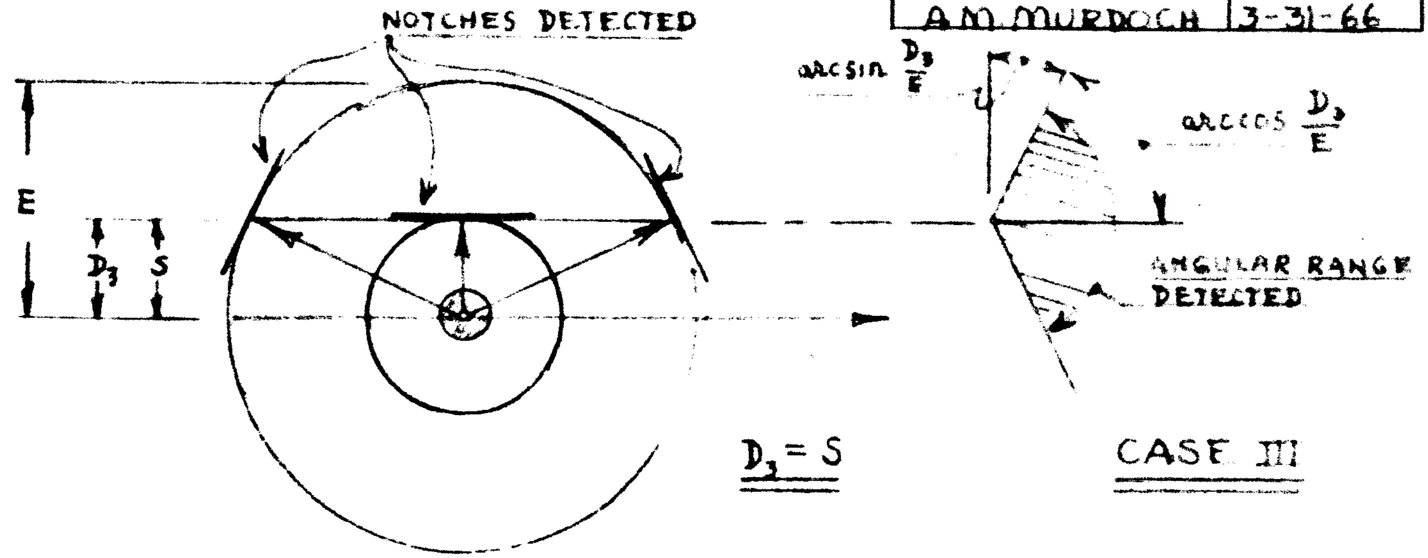
SPERRY PRODUCTS

DIVISION OF AUTOMATION INDUSTRIES, INC.

SKETCH SHEET

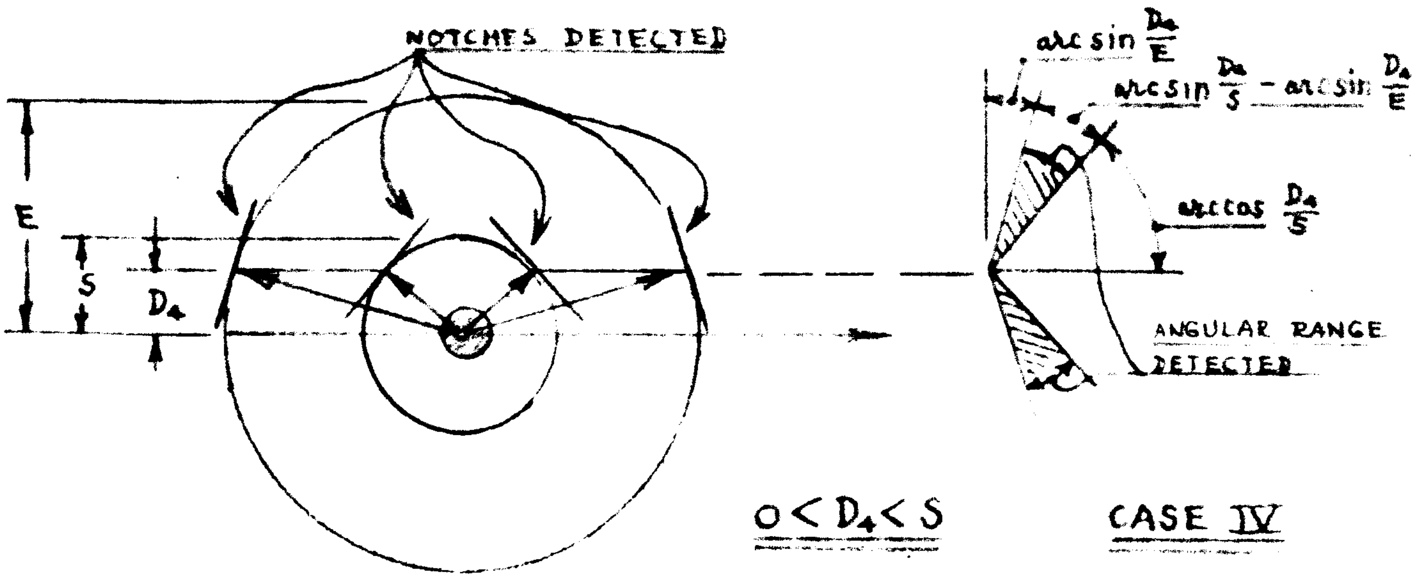
SKETCH NO. 36-A	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE	
DRAWN BY A.M. MURDOCH	DATE 3-31-66

DETECTION OF NOTCHES



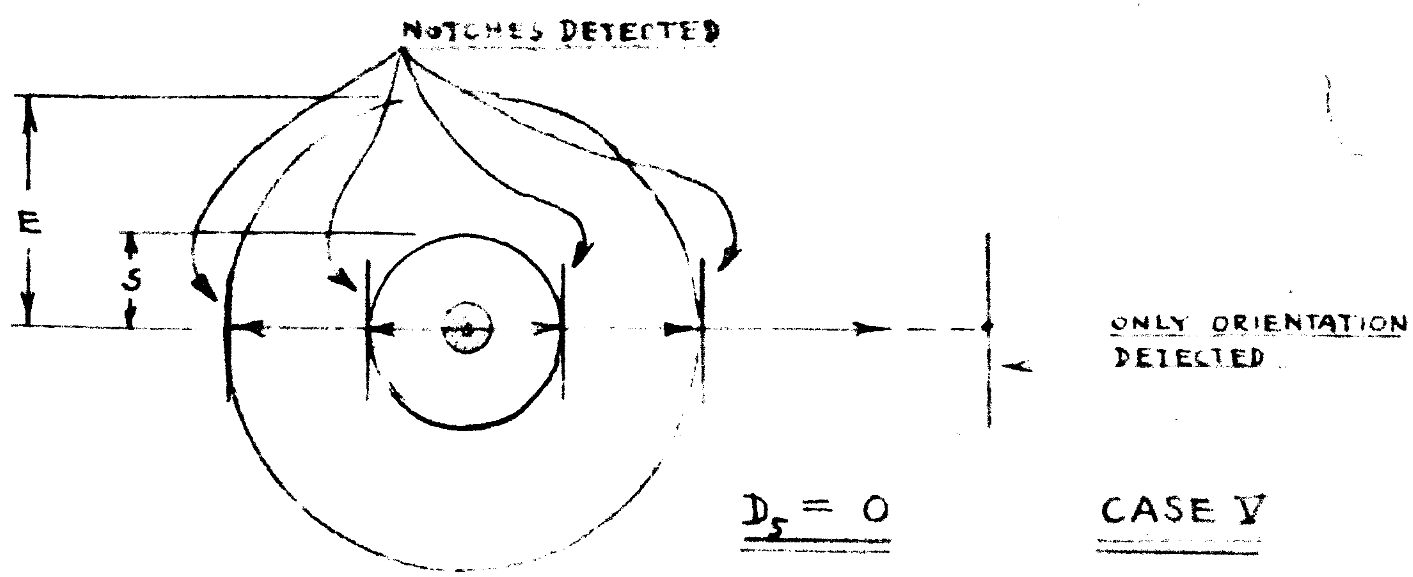
$D_3 = S$

CASE III



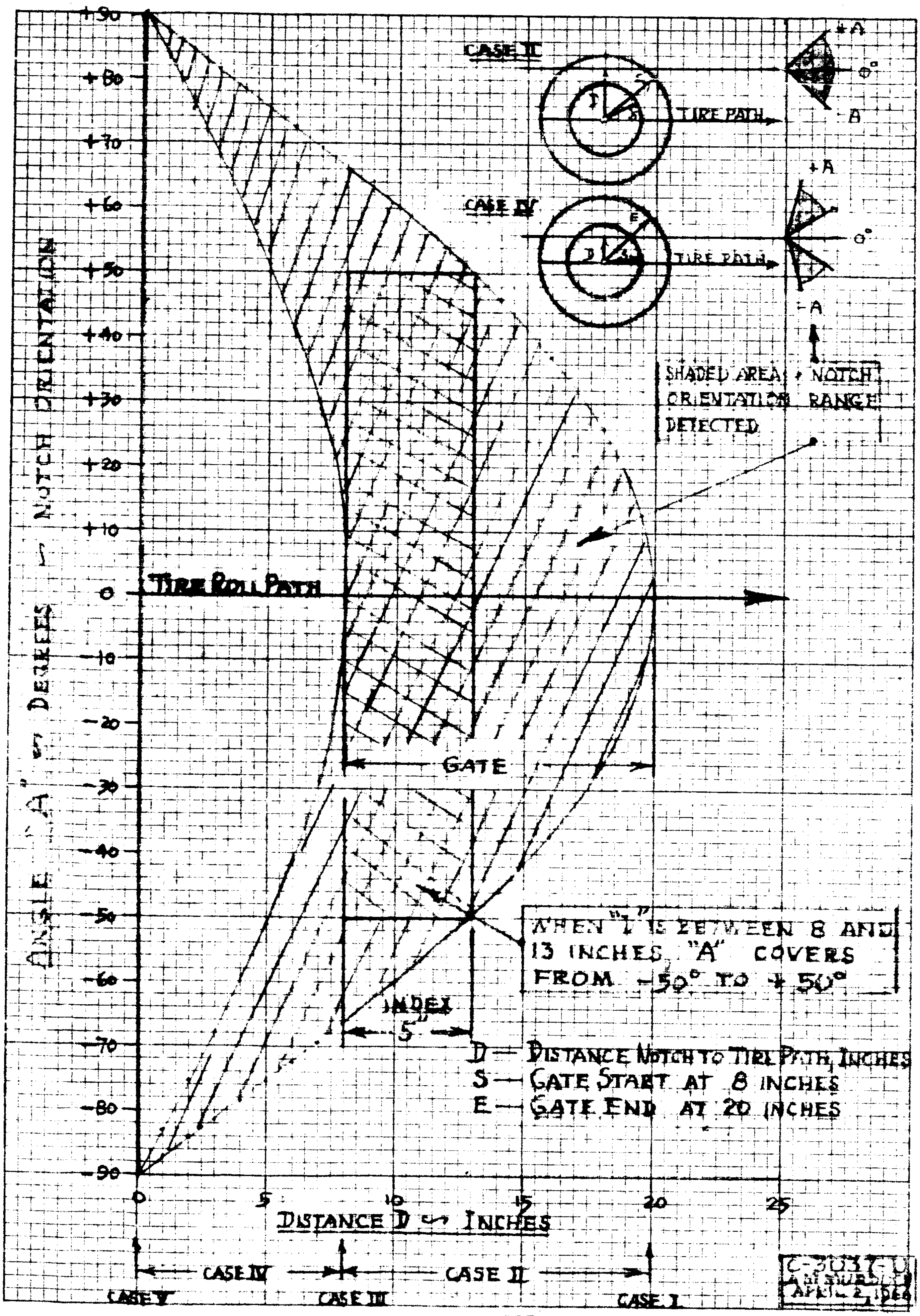
$0 < D_4 < S$

CASE IV



$D_5 = 0$

CASE V

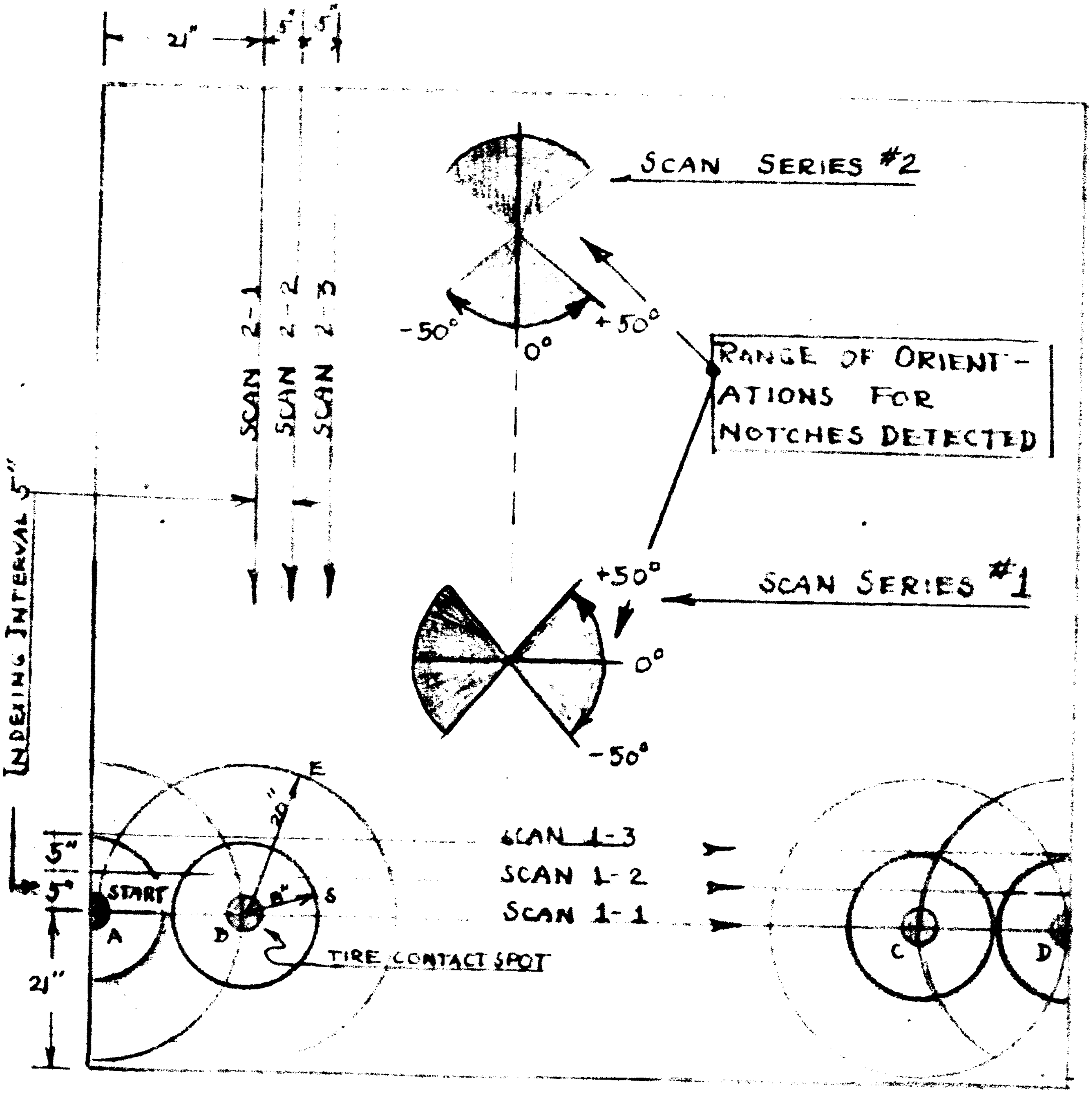


CASE II
TIRE PATH
CASE IV
TIRE PATH
SHADED AREA = NOTCH ORIENTATION RANGE DETECTED
TIRE ROLL PATH
GATE
WHEN "L" IS BETWEEN 8 AND 13 INCHES "A" COVERS FROM -50° TO +50°
INDEX
5"
D — DISTANCE NOTCH TO TIRE PATH, INCHES
S — GATE START AT 8 INCHES
E — GATE END AT 20 INCHES
ANGLE "A" ~ DEGREES — NOTCH ORIENTATION
DISTANCE D ~ INCHES
CASE IV
CASE II
CASE V
CASE III
CASE I

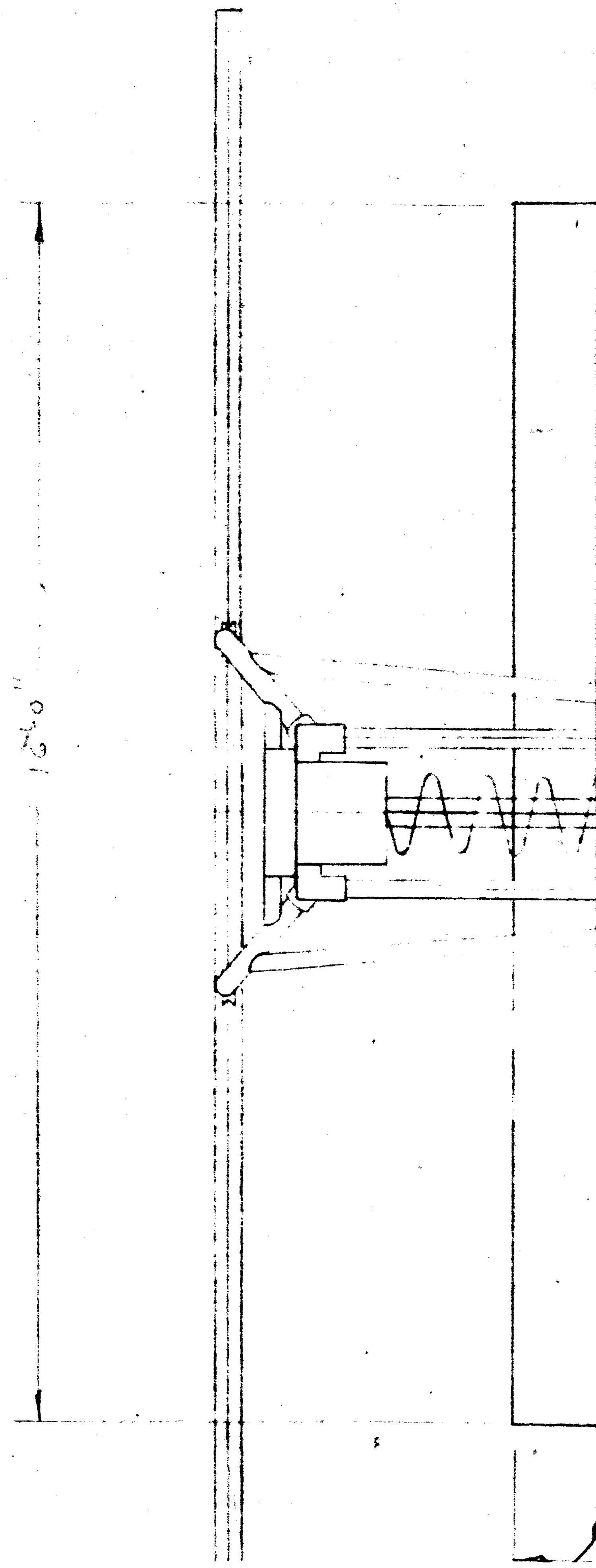
FIG. 37

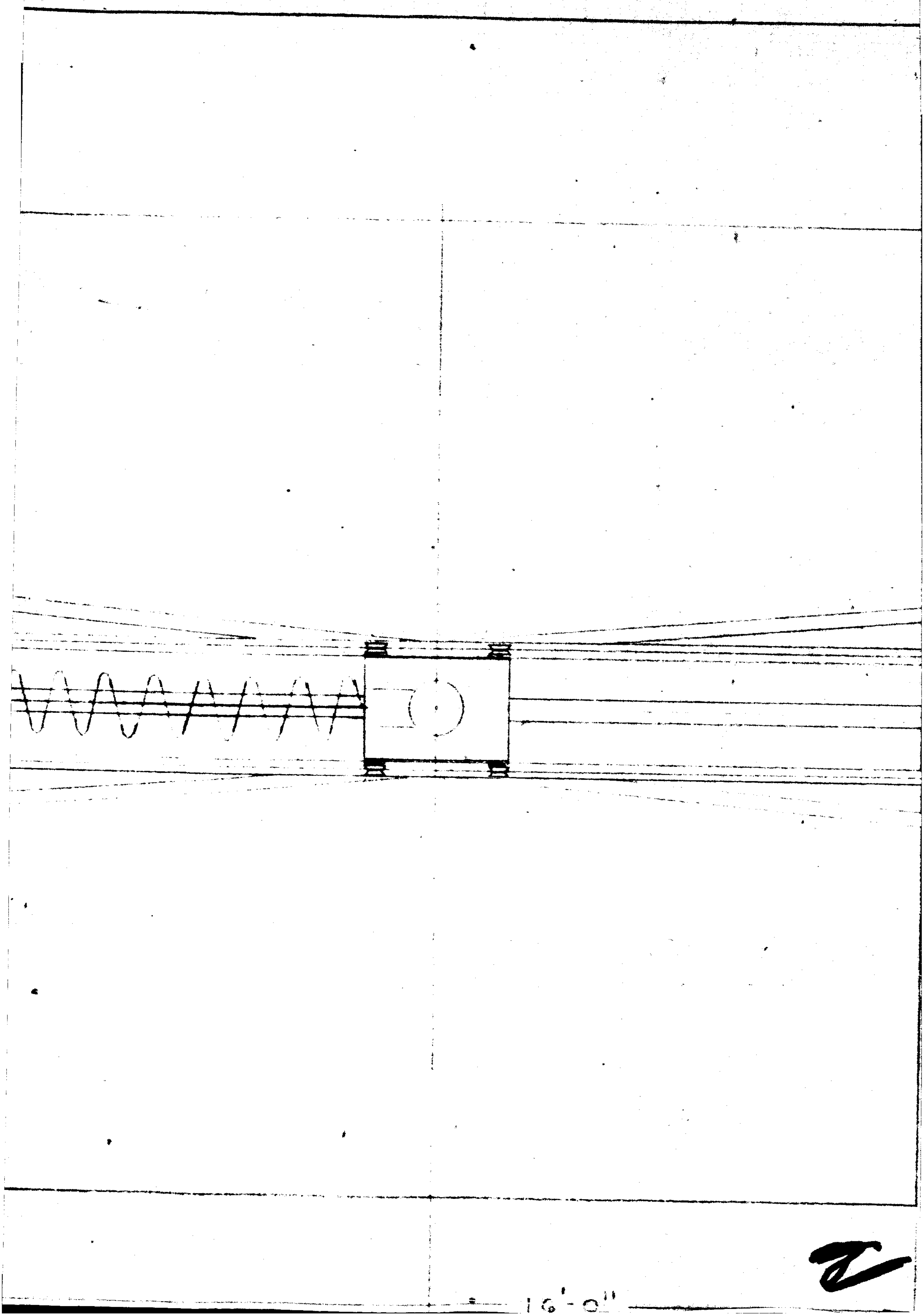
SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

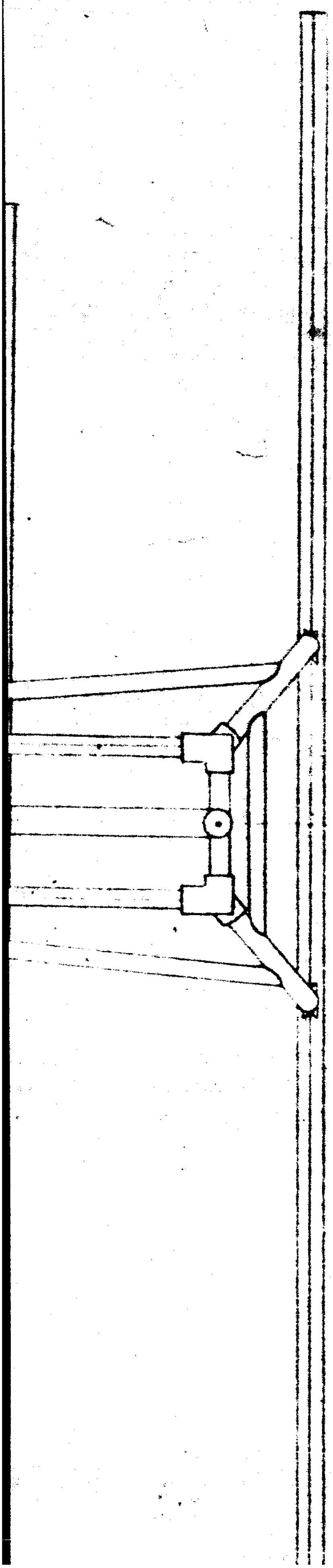
SKETCH NO. 38	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE PRACTICAL SCANNING METHOD	
DRAWN BY A.M. MURDOCH	DATE 4-2-66



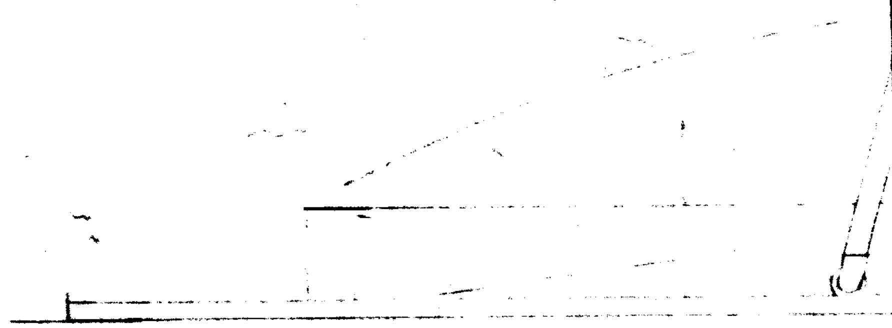
S = GATE START
E = GATE END

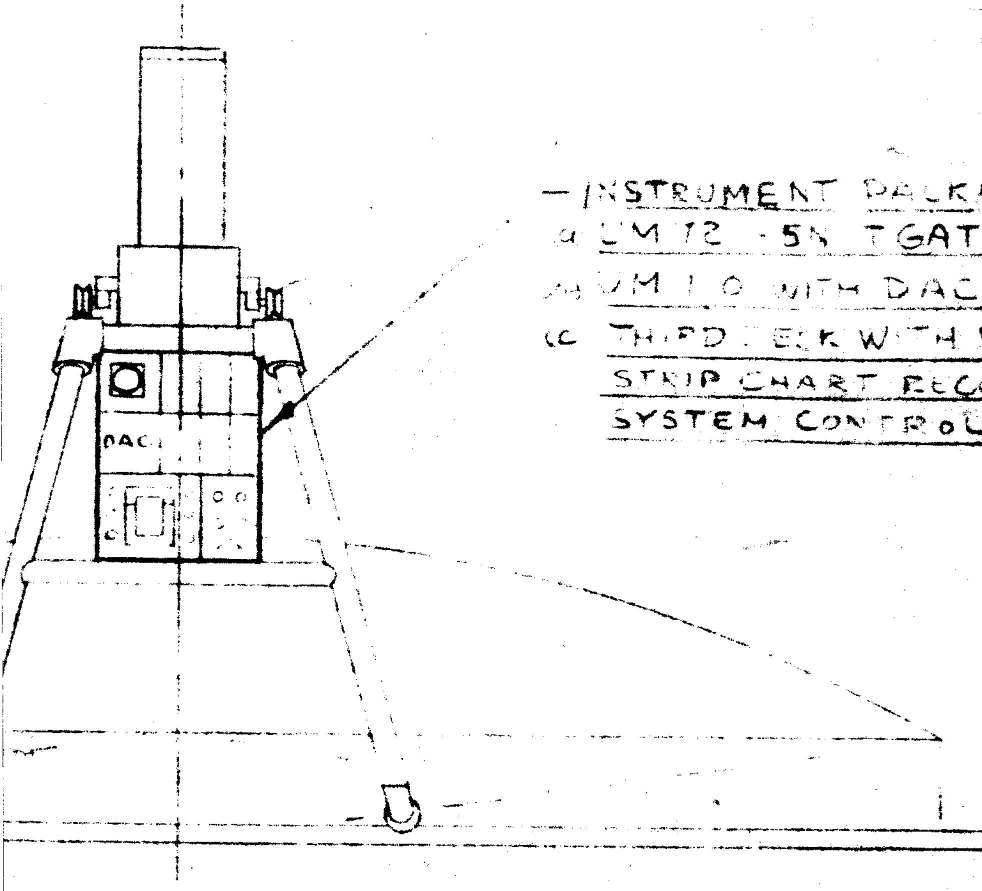



16'-0"



3

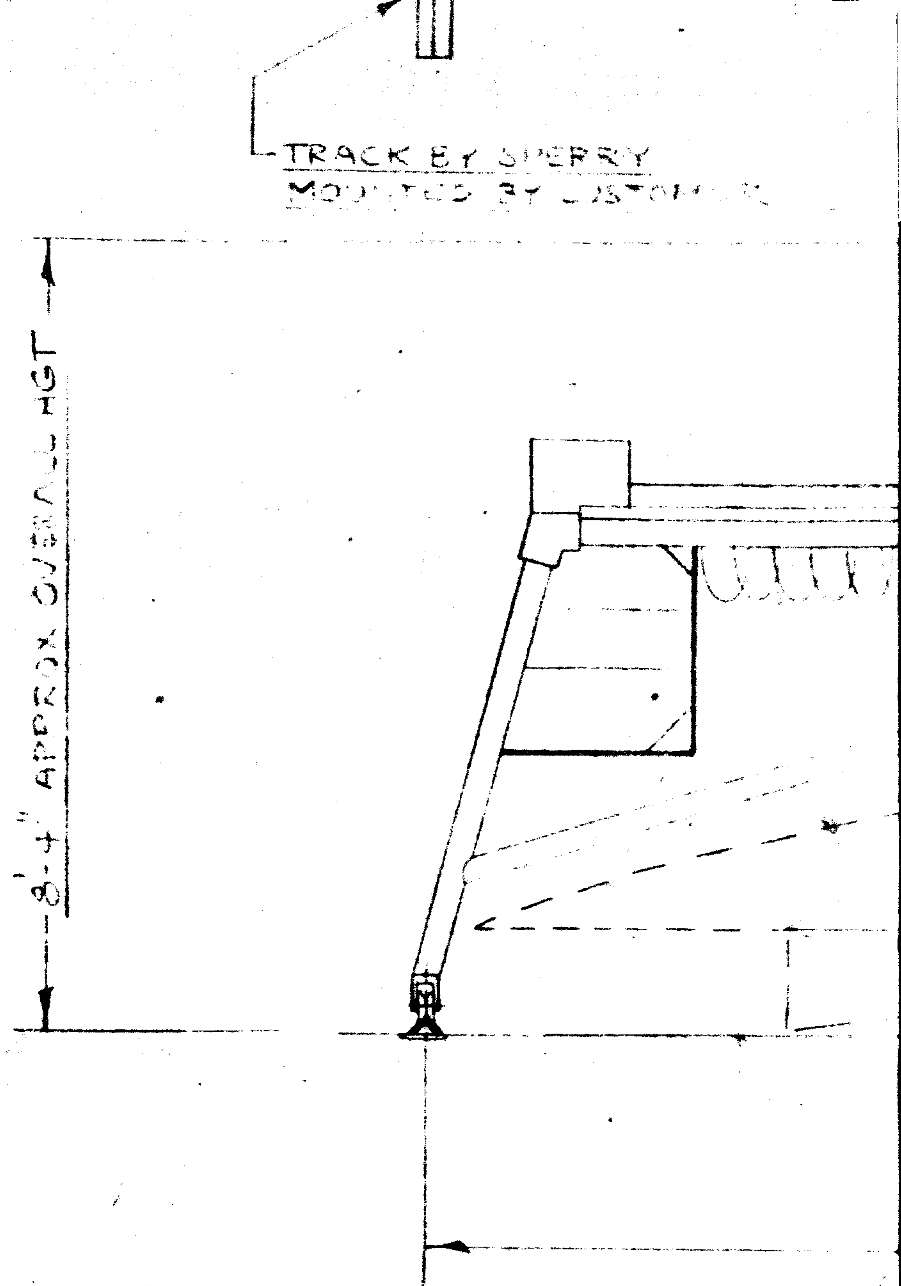




NOTE:

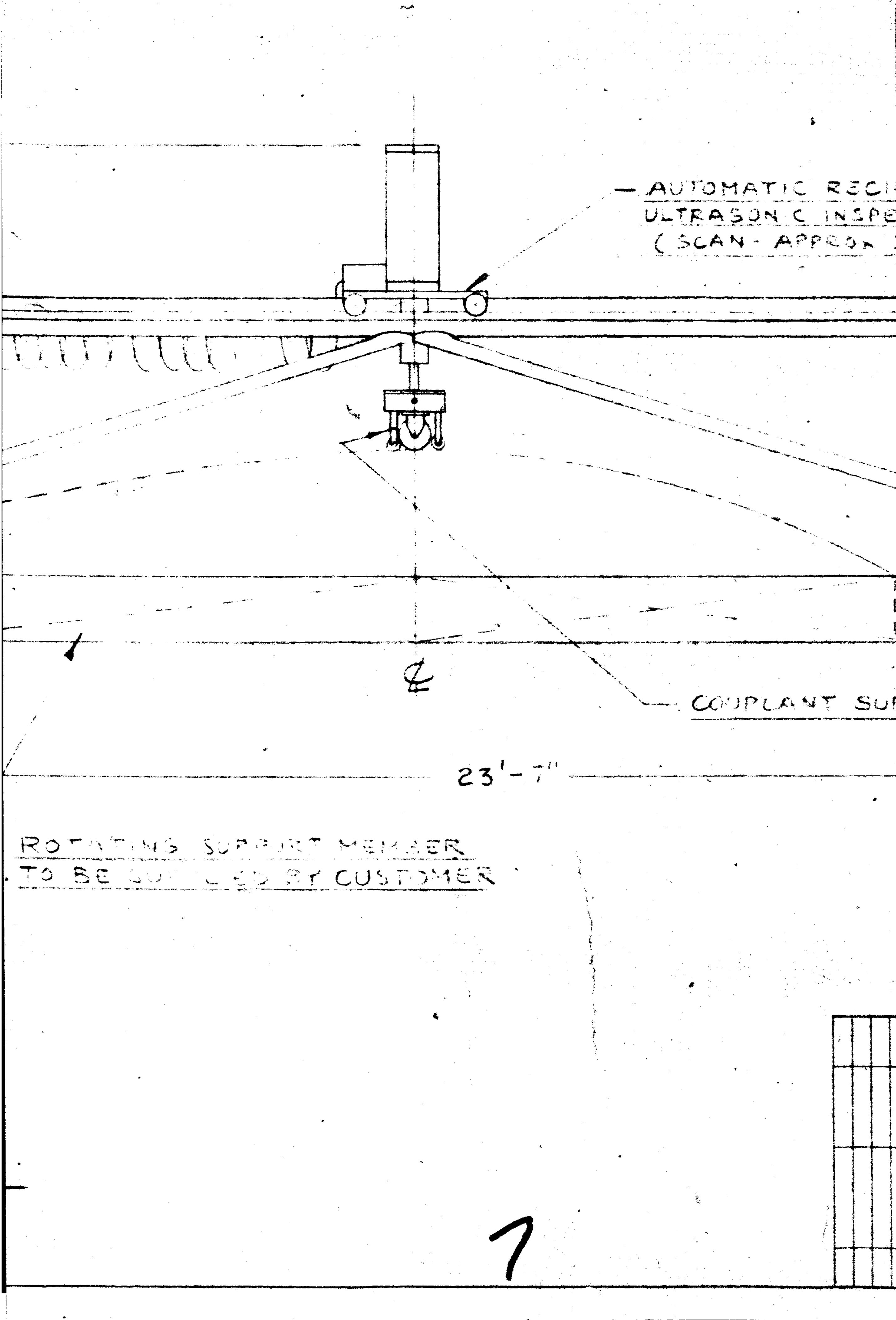
1

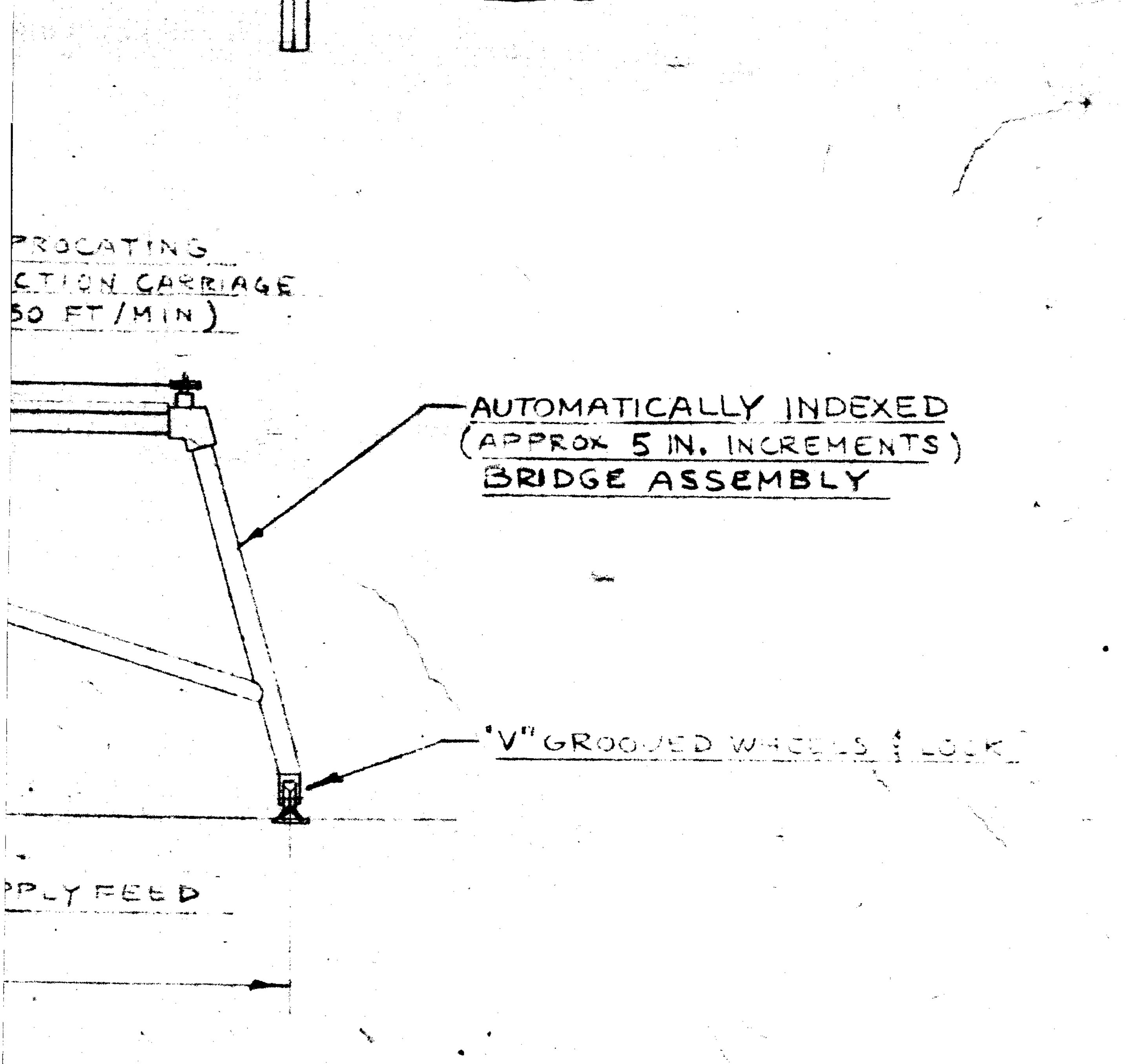
AGE
E
R'S CHASSIS
SINGLE CHANNEL
ORDER AND



STOMER TO SUPPLY
1) 90 P.S.I.-AIR
2) 115 VAC 60 CYCLE - ELECTRIC
3) COUPLANT MAKEUP

FIG 39


AUTOMATIC RECI
ULTRASON C INSPE
(SCAN - APPROX
COUPLANT SU
23'-7"
ROTATING SUPPORT MEMBER
TO BE SUPPLIED BY CUSTOMER
7



ITEM NO.	DWG. OR PART NO.	NAME	QUAN. REQ.

BILL OF MATERIAL

LTR.	E.C.N. NO.	DATE	CHK	ENG. REF.	TIMES USED

SCALE $\frac{1}{2}$" = 1'-0"
EXCEPT AS NOTED
DEC. ± —
FRAC. ±
ANGLES, ±
MACH. ✓
DEBURR & BREAK SHARP EDGES & CORNERS

REF. ASS'Y. NO. —
MAT. OR P. SPEC. —
FINISH 8

AUTOMATION INDUSTRIES, INC.
SPERRY PRODUCTS DIVISION
DANBURY, CONNECTICUT • U.S.A.

PROPOSED SYSTEM FOR SURFACE WAVE INSPECTION

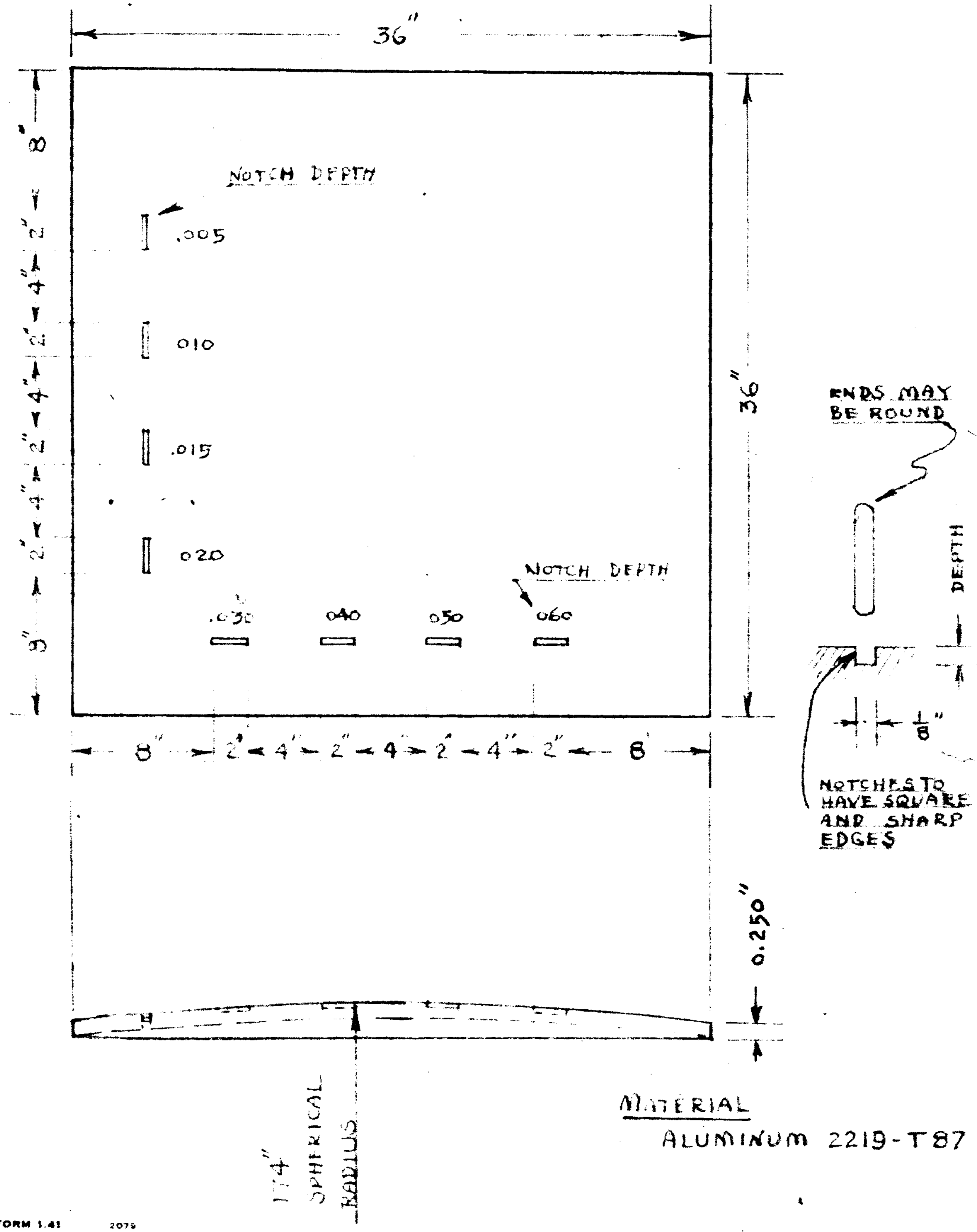
Sperry 52D443

H W SCOTT 4-5-66
DRAWN BY DATE
HWS 4-5-66
CHECKED BY DATE
R 4/5/66
APPROVED BY DATE
MFG. CHECK BY DATE

52D443

SPERRY PRODUCTS
DIVISION OF AUTOMATION INDUSTRIES, INC.
SKETCH SHEET

SKETCH NO. 40	FILE REF. C-3037-U
CUSTOMER NASA	
ADDRESS	
TITLE TEST PLATE	
DRAWN BY G M Murdock	DATE 3-17-65



MATERIAL
ALUMINUM 2219-T87

FORM 1.41 2079

10.0 APPENDIX

10.1 Work Performed During Final Period

The following studies were made as described and illustrated in this report:

Analysis of Tire Pattern	Figs. 18,19,20
Amplitude/Notch Depth	Figs. 21,22,23
Amplitude/Notch Angle	Figs. 24,25,26
D.A.C. Operation	Figs. 27,28
Scanning Methods	Figs. 36,37,38

The System Layout was completed as described in Paragraphs 6.4.2 and 6.4.3.

The Final Report was prepared and issued.

10.2 NASA Property

At the close of this project the following items, all property of NASA, are on hand at Sperry Products, Danbury, Conn.

Quantity	Description
1	Variable Angle Wheel Search Unit Type SOB, Freq. 1.0 Mc., Size 1/2 x 1 Style 50D403 Serial T-1719
1	Variable Angle Wheel Search Unit Type SOB, Freq. 2.25 Mc., Size 1/2 x 1 Style 50D340 Serial T-1723
1	Variable Angle Wheel Search Unit Type SOB, Freq. 5.0 Mc., Size 1/2 x 1 Style 50D404 Serial T-1720
7	Aluminum Specimen Plates designated A to G
1	Ring Beam Wheel Search Unit, Type SOZ, Freq. 2.25 Mc. Angle 90R, Style 50D440, Serial W-2096, with Reflector Kit "A" and Reflector Kit "B"
1	Assembly (spare) of: Transducer - 50A3618 Facing - 50A3617 Spacer - 50A3621 Backing - 50C1005
1	Tire (spare) - 50B1408