Xerograph [illegible] sent to Dave [illegible] Shot Peener

THE USE OF "3M" BRAND ROTO PEEN PRODUCTS IN CONDITIONING METAL SURFACES

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I. INTRODUCTION

The residual stress condition of a metal part plays an important role in determining its useful life. Residual stresses normally exist in a heterogeneous condition caused by mechanical, thermal, or chemical treatments. The sense of the surface residual stresses is of primary importance. The highest stresses from the applied load usually occur at the surface, and the surface also has stress concentrating regions due to design geometry or metal processing. A net tensile (applied plus residual) surface stress tends to produce cracks, while a net compressive surface stress tends to prevent them. The two primary mechanisms of surface crack development, leading to ultimate failure, are fatigue and stress corrosion.

Mechanical prestressing, such as cold rolling, hammer peening, and shot peening, has commonly been used to produce favorable compressive residual stresses. These methods produce residual stresses by permanently deforming only the surface layers of a metal part. Surface layers are expanded radially so that when the deforming force is removed, the elastic spring-back from the underlying material leaves the surface layers in compression.

Conventional shot peening is an effective method of prestressing metal parts. However, the containment of free shot particles is a serious problem when a portable shot peening system is required. In addition, the requirement of relatively large special equipment prevents applications in certain desirable areas. To fill these needs, 3M has developed a new, portable, self-contained (bonded shot) shot peening product concept. Some typical applications for the 3M Brand Roto Peen Products are: reworking, repair, and reconditioning of critical

INTRODUCTION (continued)

parts; stress relieving weld joints; peening fuel tank assemblies and wing sections where contamination is intolerable; peen forming and contouring; stress relieving inside surfaces of pipes and holes; in-place peening with minimum disassembly; and repair of damaged parts in production.

II. DISCUSSION

A. Description of 3M Brand Roto Peen Products

Figures 1A, 2A, and 3A (pp. 4-6) show Roto Peen Products 9012, 9017B-9018, and 9037-9028, respectively. These products consist essentially of a ring of radially extending, peripherally separated flaps attached to a rigid core or mandrel. Each flap is a flexible, tough, fibrous support to which peening particles are bonded by a strong, resilient organic adhesive. In use, the Roto Peen Product is mounted on a shaft and rotated rapidly while the periphery is forced against the substrate to be peened. A portion of the flat face of each flap strikes the substrate, thereby causing the peening particles to perform their normal peening function while bonded in a wheel construction.

Figure 4A (p. 7) shows the 3M Brand Magnetic Almen Strip Holder which is used for Almen intensity measurements with the Roto Peen wheels. This holder consists essentially of an aluminum body with three permanent magnets recessed into the top side. The use of the 3M Brand Magnetic Almen Strip Holder allows reliable peening process control with Roto Peen Products by eliminating flap damage from screw heads in standard holder and allowing 100% coverage of Almen strip surface. Furthermore, this holder allows the Almen strip to assume its natural curvature during peening, and an Almen strip can be removed, measured, and replaced without affecting its curvature. Therefore, only one Almen strip is required to produce an entire saturation curve. As shown by the calibration curve (Fig. 4B, p. 7), the Almen A intensities greater than 5 are somewhat higher when the 3M Brand Magnetic Almen Strip Holder is used than when the standard holder is used.

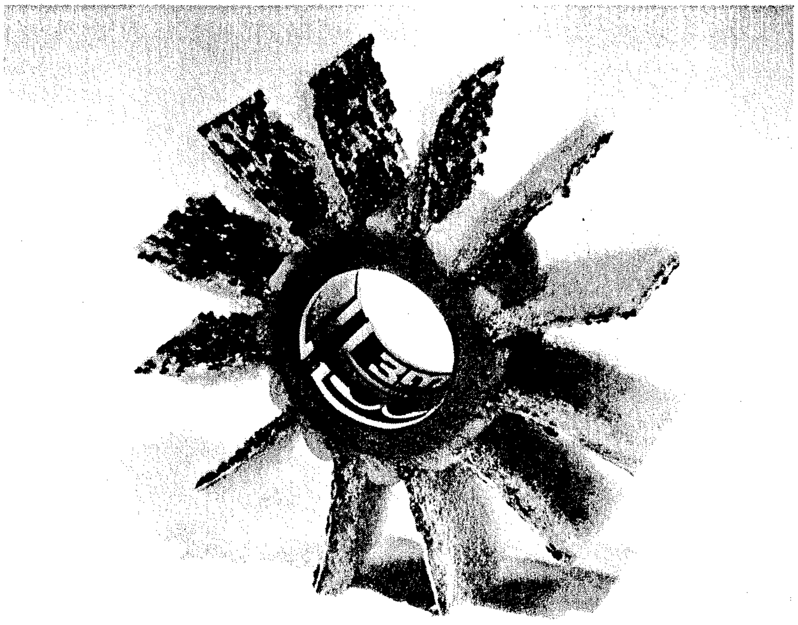


Figure 1A

ROTO PEEN Product No. 9012
(Size 330 Cast Steel Shot)

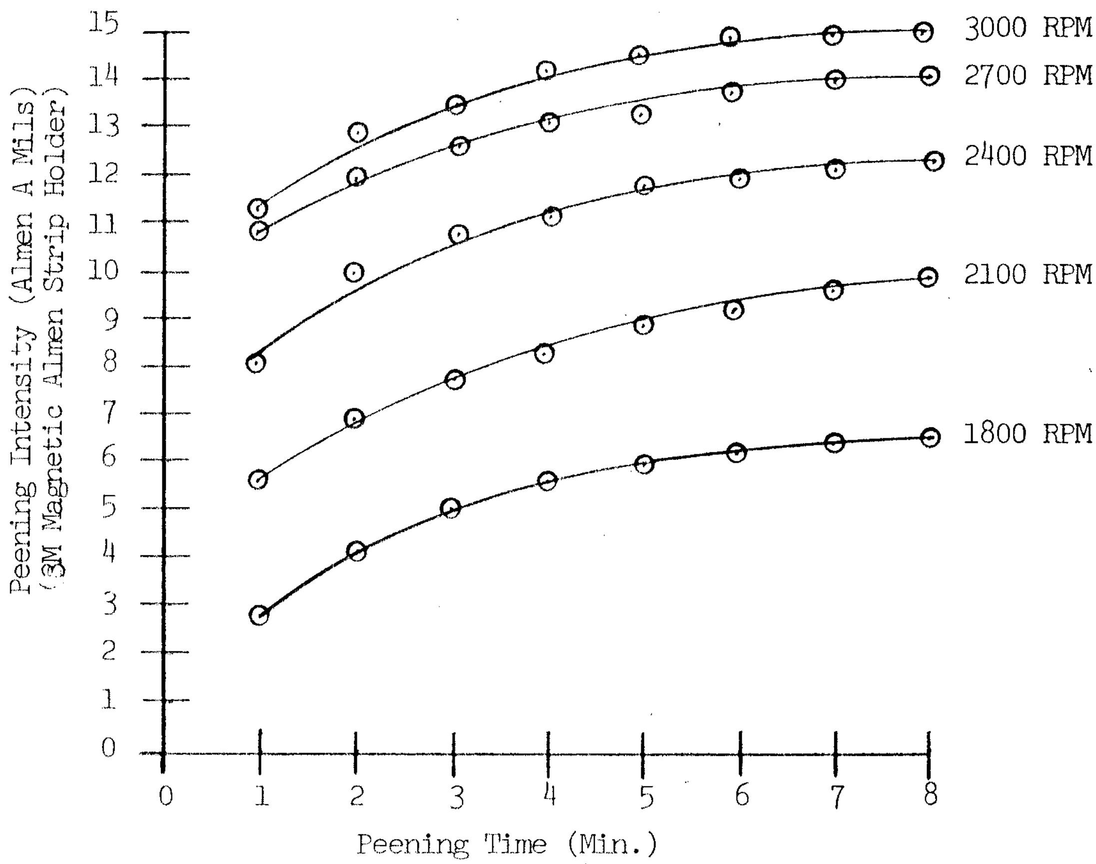


Figure 1B

Saturation Curves for ROTO PEEN
Product No. 9012

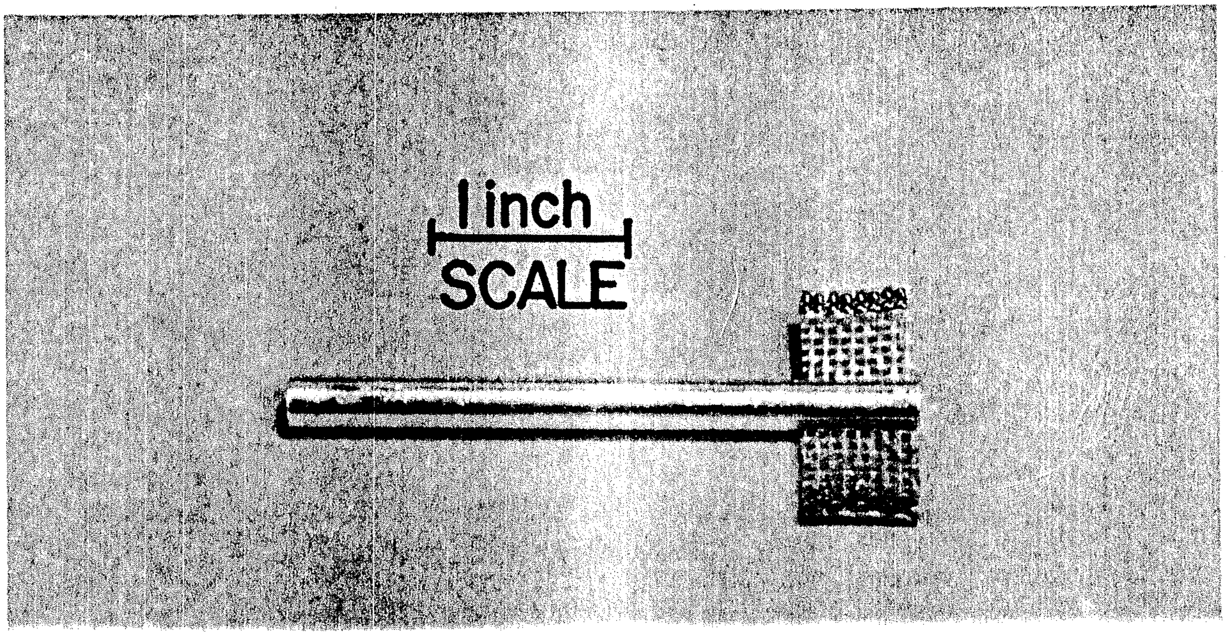


Figure 2A

ROTO PEEN Flap Assembly No. 9017B
(Size 330 Tungsten Carbide Shot)
In Mandrel No. 9018

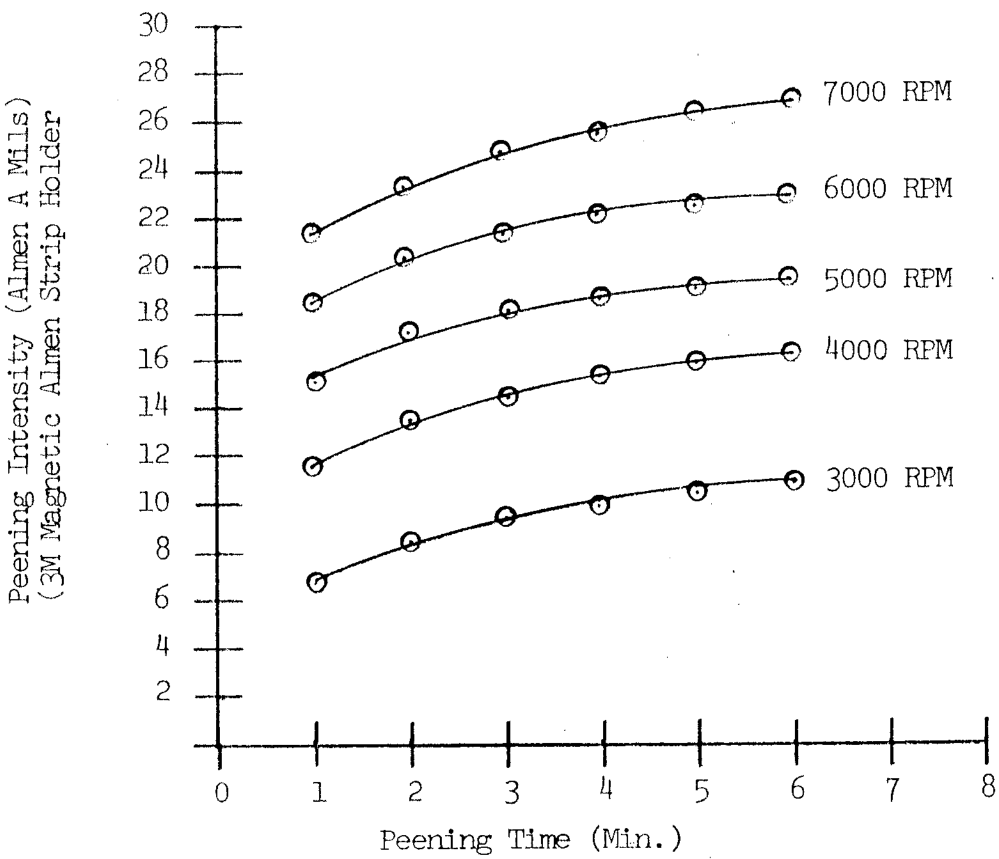


Figure 2B

Saturation Curves for ROTO PEEN
Product No. 9017B

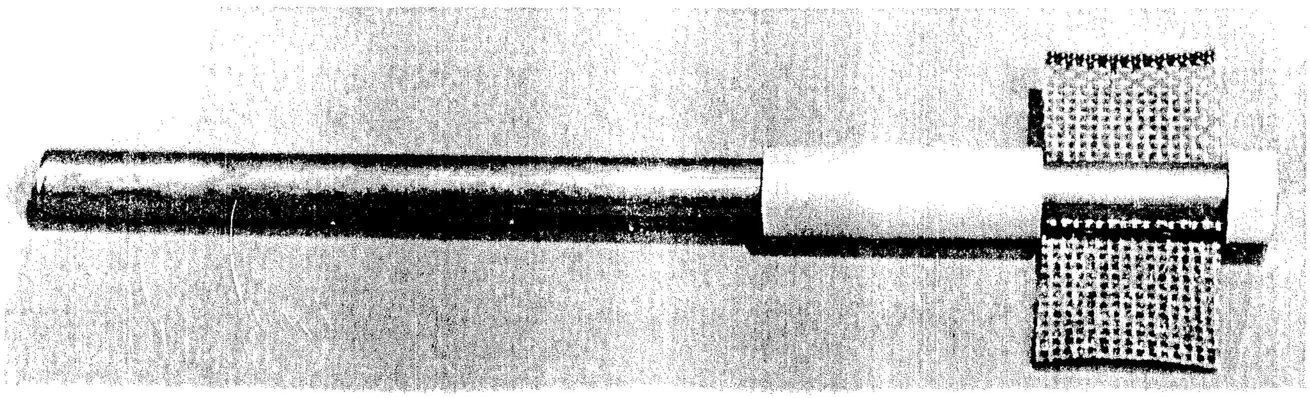


Figure 3A

ROTO PEEN Flap Assembly No. 9037
(Size 330 Tungsten Carbide Shot)
In Mandrel No. 9028

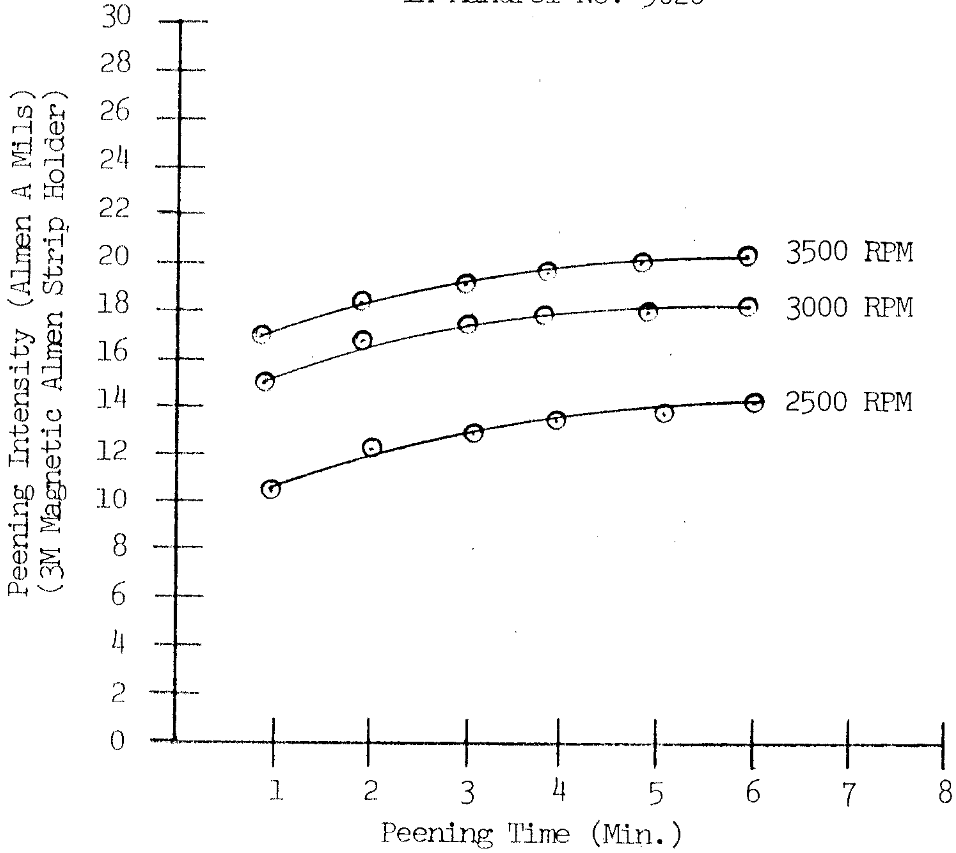


Figure 3B

Saturation curves for ROTO PEEN
Product No. 9037

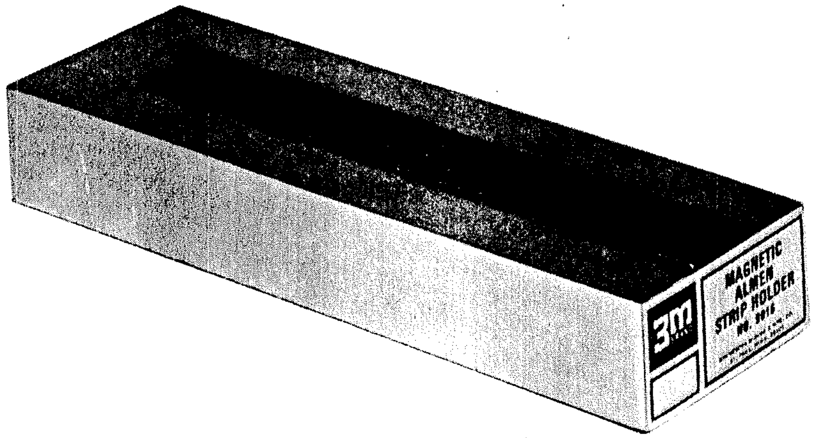
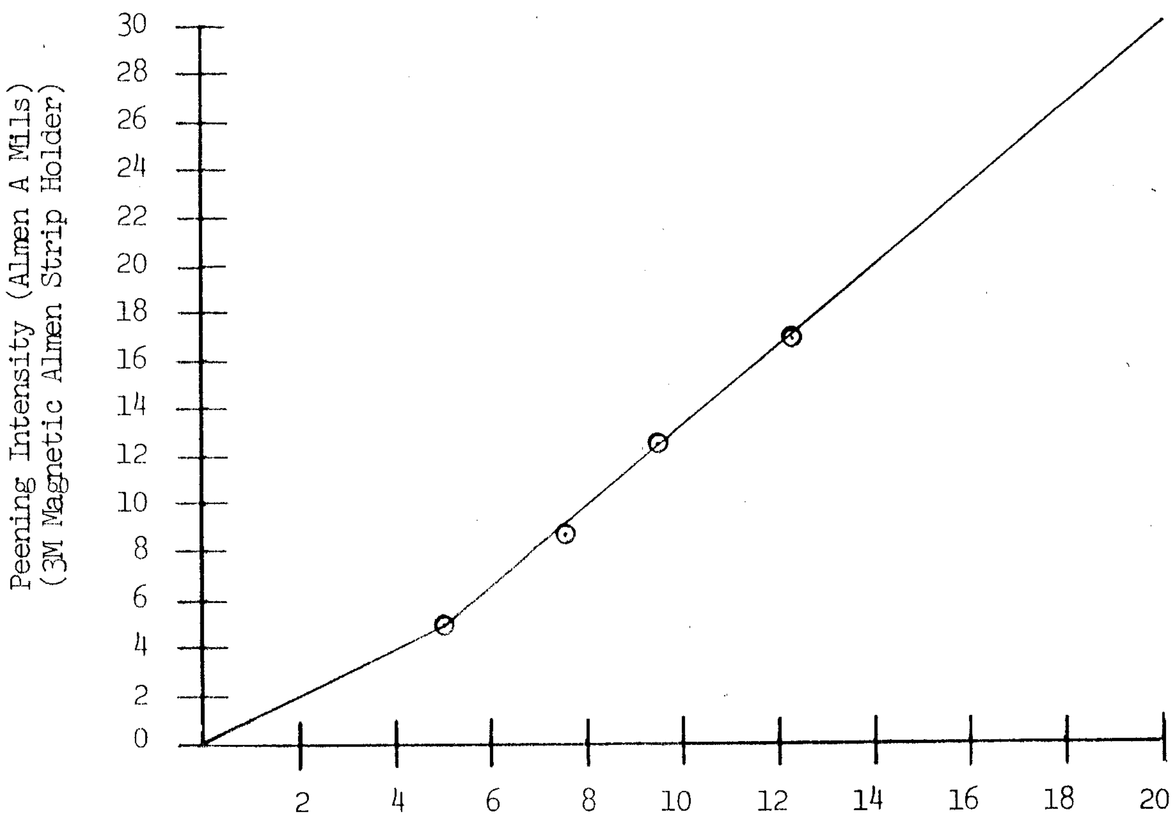


Figure 4A

3M Brand Magnetic Almen Strip
Holder No. 9016



Peening Intensity (Almen A Mils)
(Standard Almen Strip Holder)

Figure 4B

Peening Intensity Conversion Graph
Showing Correlation Between 3M
And Standard Holder Tests

II. DISCUSSION (continued)

B. Treatment Characterization

1. Surface Finish

The surface finish produced with Roto Peen Products consists predominantly of dimple impressions similar to those produced by conventional shot peening. The size of these impressions varies with shot density, shot size, shot hardness, tool speed, and substrate hardness. Figures 5 and 6 (p. 10) show photomicrographs of a prepolished Almen strip (1070 steel) peened with the No. 9012 product (330 cast steel shot - hardness 63 R_c) at 2700 RPM for 30 seconds and 60 seconds, respectively. Figures 7 and 8 (p. 11) show photomicrographs of a prepolished Almen strip (1070 steel) peened with a No. 9018-9017B assembly (330 tungsten carbide shot) at 5000 RPM for 10 seconds and 60 seconds, respectively. Surface roughness values produced on 1070 steel (hardness 45 R_c) and 2024-T4 aluminum alloy (hardness 80 R_b) are shown in Table I (p. 12). A comparison of the surface roughness values at 5-6 Almen A on 1070 steel produced by 3M Brand Roto Peen Products No. 9012 and No. 9044 (flap assembly like 9037 with size 280 tungsten carbide shot) with conventional shot peening reveals that the No. 9012 tool produces a smoother surface than conventional peening, while the No. 9044 product produces a surface of about the same roughness. This difference in surface roughness may be explained by the slight burnishing effect of the No. 9012 tool which does not exist with the 9044, 9037, or 9017B assemblies.

It has been found that a small portable surface profile measuring instrument can be used to determine the peening intensity range (6-10A or 12-16A) on a part peened with Roto Peen Products. This measurement, which does not work reliably for conventional peening where a relatively

II. DISCUSSION (continued)

B. Treatment Characterization (continued)

1. Surface Finish (continued)

wide range of shot diameters are employed, can conceivably provide a rapid, non-destructive measure of peening intensity.

The surface finishes produced by peening with Roto Peen Products have exceptional cleanliness. Aluminum alloy surfaces peened with the No. 9012 wheel (cast steel shot) have been tested for presence of iron residue by atomic absorption spectroscopy and potassium ferrocyanide solution methods. Less than 0.5 parts per million of residual iron was detected. In some cases, a very small amount of polymeric material from the flaps has been left on the peened surface. This material can be readily removed with a solvent or very light abrasion.

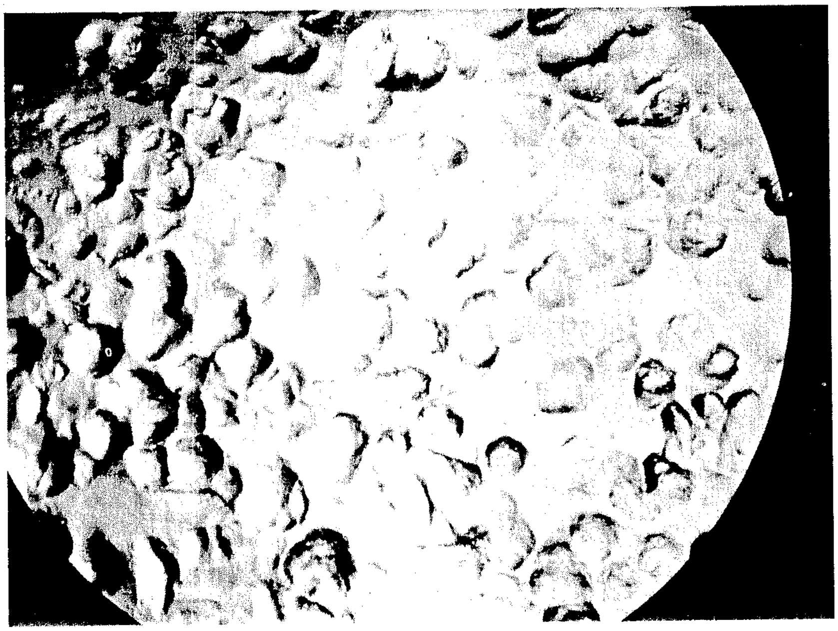


Figure 5

Prepolished Almen A Strip (1070 Steel, Hardness 45 R_c)
Peened With ROTO PEEN Product No. 9012 at 2700 RPM
for 30 seconds. Magnification 42x.

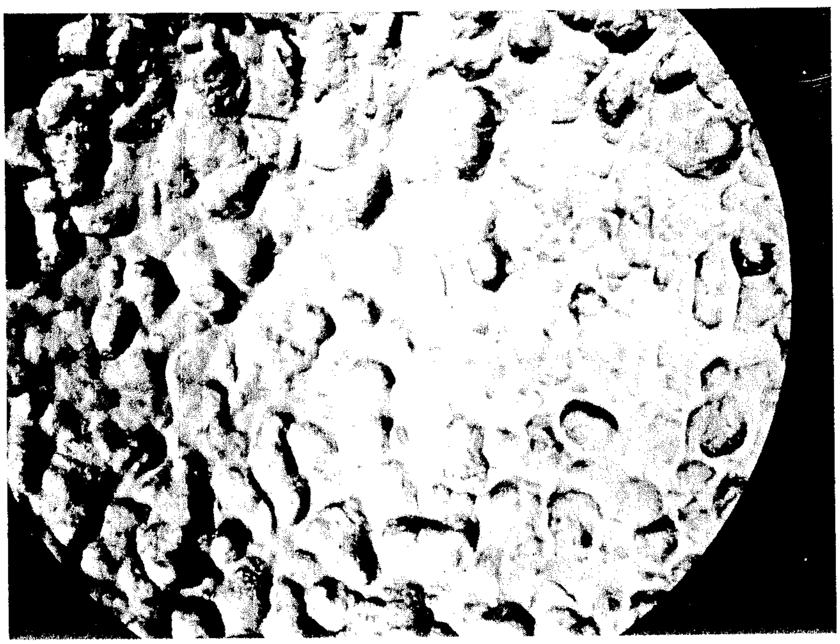


Figure 6

Prepolished Almen A Strip (1070 Steel, Hardness 45R_c)
Peened With ROTO PEEN Product No. 9012 at 2700 RPM
for 60 seconds. Magnification 42x.

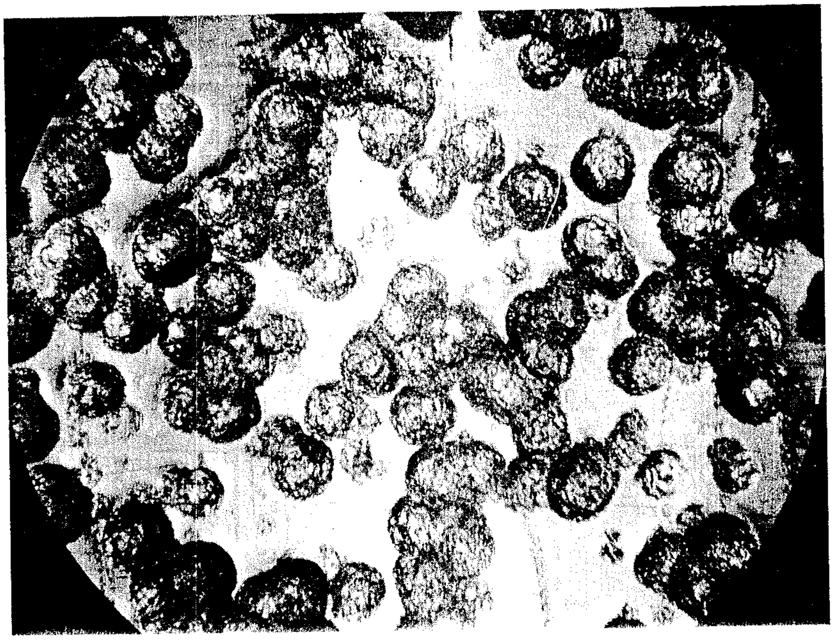


Figure 7

Prepolished Almen A Strip (1070 Steel, Hardness 45 R_c)
Peened with ROTO PEEN Product No. 9017B at 5000 RPM
for 10 seconds. Magnification 42x.

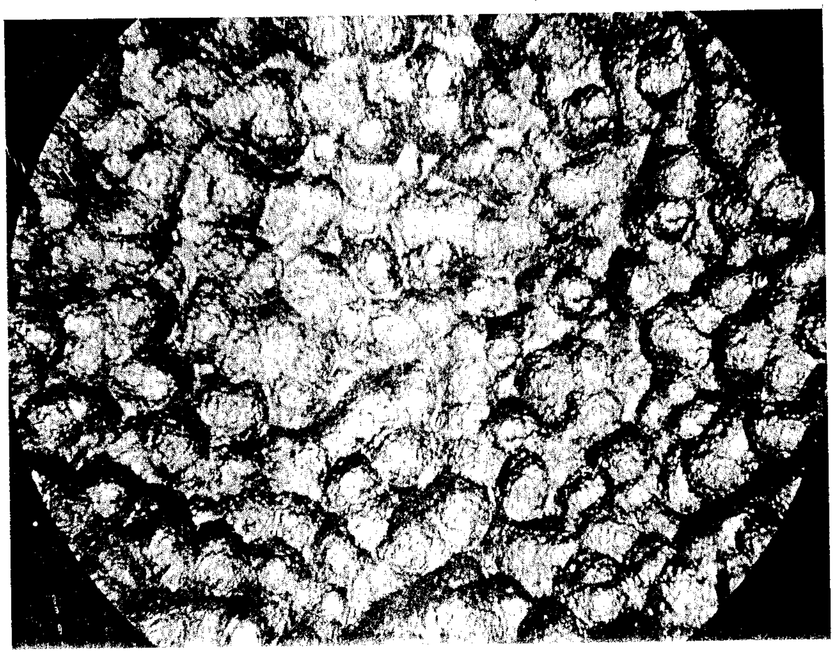


Figure 8

Prepolished Almen A Strip (1070 Steel, Hardness 45 R_c)
Peened With ROTO PEEN Product No. 9017B at 5000 RPM
for 60 seconds. Magnification 42x.

TABLE I

Surface Finish On 1070 Steel And 2024 Aluminum Produced By Peening With ROTO PEEN Products At Various Peening Intensities

ROTO PEEN Product	Metal Alloy Peened	Peening Intensity* (mils Almen A)	Surface Roughness (micro-in arithmetic average)	
			Longitudinal	Transverse
9012 (330 Cast Steel Shot)	1070 Steel	6	10	10
	1070 Steel	8	20	18
	1070 Steel	10	24	22
	2024 Al	6	48	90
	2024 Al	8	76	60
	2024 Al	10	110	120
9017B (330 Tungsten Carbide Shot)	1070 Steel	10	44	43
	1070 Steel	12	43	48
	1070 Steel	14	60	60
	2024 Al	10	120	110
	2024 Al	12	120	120
	2024 Al	14	120	130
9037 (330 Tungsten Carbide Shot)	1070 Steel	10	36	38
	1070 Steel	12	42	44
	1070 Steel	14	52	48
	2024 Al	10	105	110
	2024 Al	12	115	115
	2024 Al	14	125	130
9044 (280 Tungsten Carbide Shot)	1070 Steel	6	24	22
	1070 Steel	8	33	36
	1070 Steel	10	44	44
	2024 Al	6	75	70
	2024 Al	8	85	80
	2024 Al	10	105	105
Conventional Air Blast Shot Peening (330 Cast Steel Shot)	1070 Steel	5	22	25

* Converted from 3M Magnetic Holder data to standard intensity values.

II. DISCUSSION (continued)

B. Treatment Characterization (continued)

2. Peening Intensity

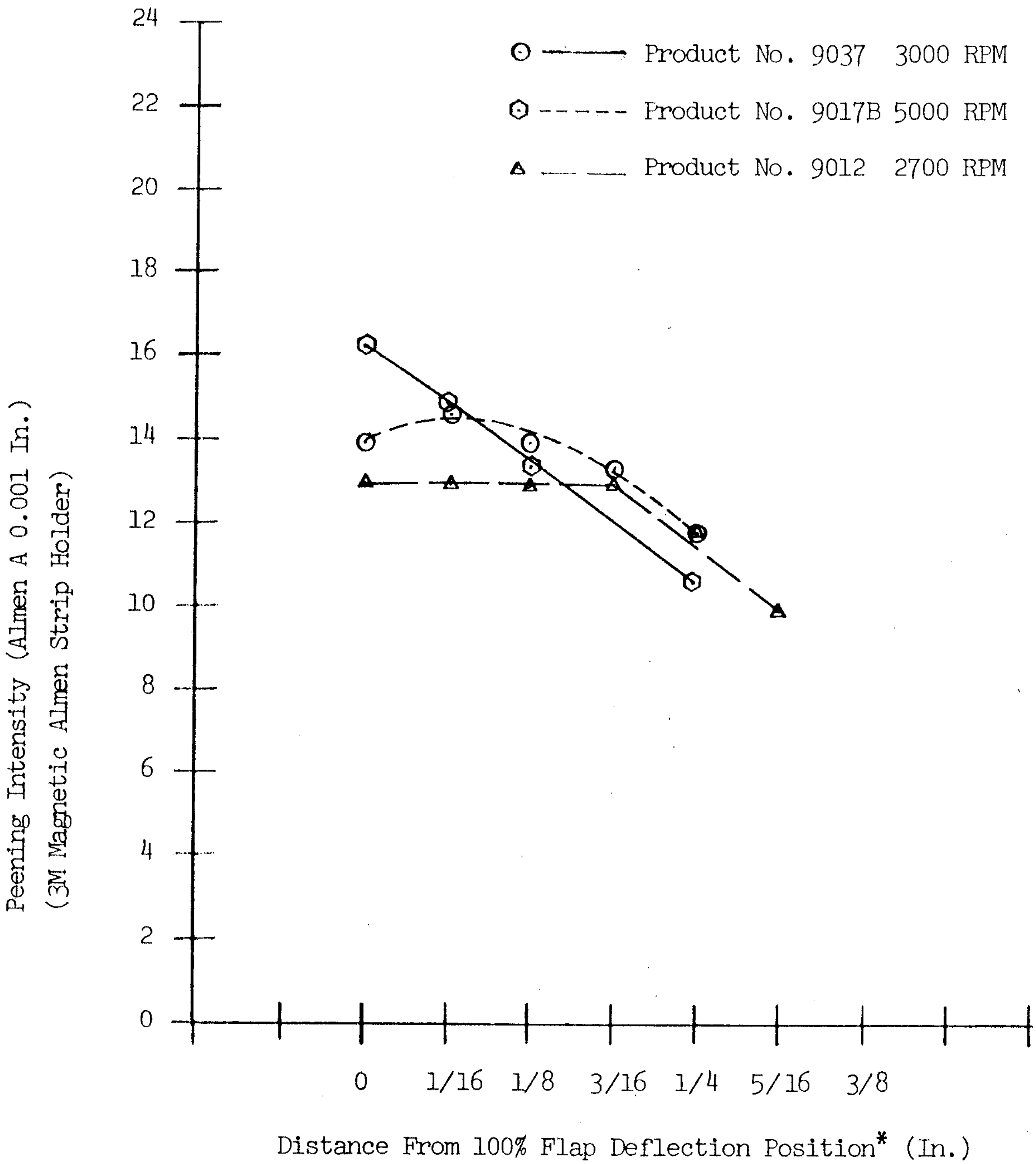
The 3M Brand Roto Peen Products will controllably produce peening intensities up to 20 mils Almen A. The two parameters which must be controlled are tool speed and flap deflection or mandrel to work surface distance. Figures 1B, 2B, and 3B (pp. 4-6) show the peening intensity versus time at various speeds for Roto Peen Products 9012, 9017B-9018, and 9037-9028; and Figure 9 (p. 14) shows the peening intensity versus distance from 100% flap deflection position for these wheels. (The 100% flap deflection position is the minimum operational distance between the mandrel or core and the surface being peened.) For offhand peening applications, it has been found that the 100% flap deflection position is the easiest position to maintain. With reasonable care as to flap deflection and uniformity of coverage, a hand controlled peening operation with a portable drive tool can yield a reproducibility of $\pm$ 10% of saturation peening intensity.

Figure 9

Effect of Flap Deflection On

Peening Intensity Produced by

ROTO PEEN Products



* The 100% flap deflection position is the minimum operational distance from the mandrel or core to the work surface.

II. DISCUSSION (continued)

B. Treatment Characterization (continued)

3. Residual Stress Distribution

Curves showing the residual stress versus depth below the peened surface obtained with 3M Brand Roto Peen Product treatments have been determined by a dissection technique developed by the author[1] and by X-ray diffraction techniques. Figure 10 (p. 16) shows the residual stress distribution in a 304 stainless steel sample treated with a Roto Peen wheel to an intensity of 3 mils Almen A. This distribution is typical of others obtained from similarly treated samples and shows the non-directionality which would be expected from a true shot peening operation. Figure 11 (p. 17) shows a comparison of residual stresses in 4340 steel (51 R_c) produced by shot peening with a Roto Peen tool (9018-9017B) and with conventional air blast peening to an intensity of 12 mils Almen A. All tests have shown that the residual stress distributions produced by Roto Peen Products are essentially equivalent to those produced by conventional shot peening.

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[1] "Biaxial Residual Surface Stresses From Grinding and Finish Machining 304 Stainless Steel Determined by A New Dissection Technique," by P. M. Winter and W. J. McDonald, JOURNAL OF BASIC ENGINEERING, Trans. ASME, Vol. 91, Series D, No. 1, 1969, pp. 15-22.

Figure 10

Residual Stress Distribution In
304 Stainless Steel Peened With
3M Brand ROTO PEEN Product

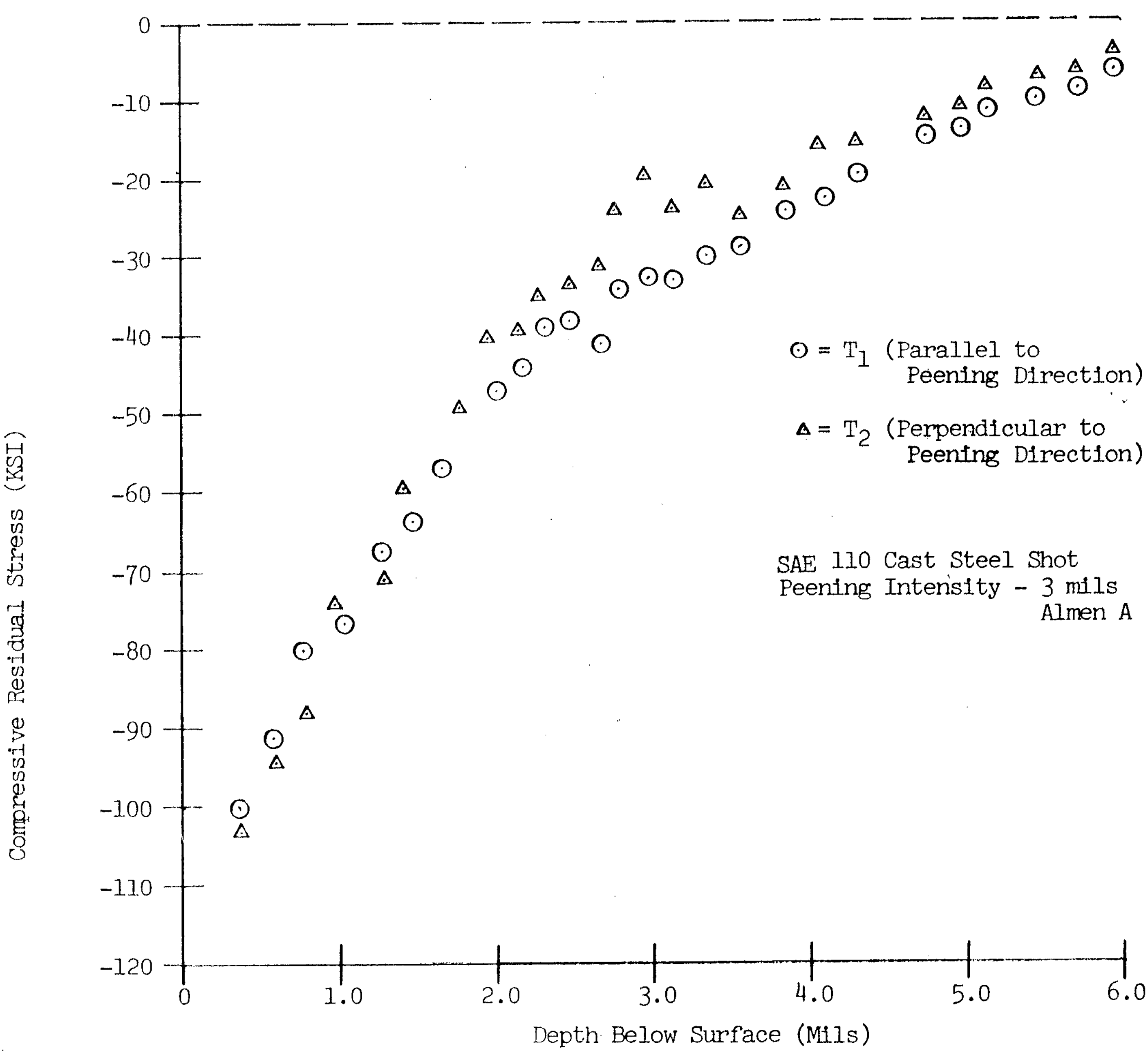
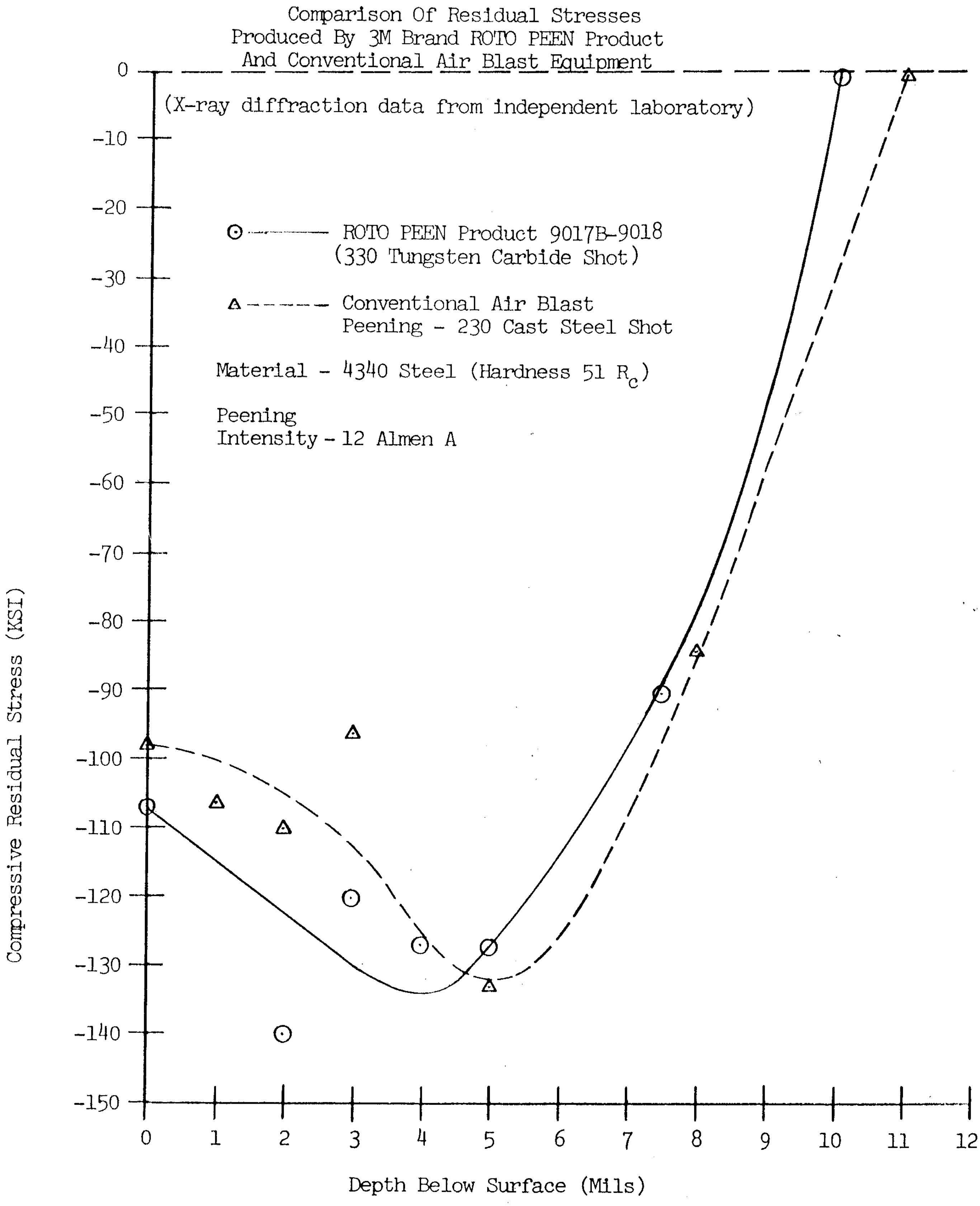


Figure 11


Comparison Of Residual Stresses
Produced By 3M Brand ROTO PEEN Product
And Conventional Air Blast Equipment
(X-ray diffraction data from independent laboratory)
ROTO PEEN Product 9017B-9018
(330 Tungsten Carbide Shot)
Conventional Air Blast
Peening - 230 Cast Steel Shot
Material - 4340 Steel (Hardness 51 Rc)
Peening
Intensity - 12 Almen A
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
Compressive Residual Stress (KSI)
0
1
2
3
4
5
6
7
8
9
10
11
12
Depth Below Surface (Mils)

II. <u>DISCUSSION</u> (continued)

B. Treatment Characterization (continued)

4. Fatigue Test Results

The effectiveness of 3M Brand Roto Peen Products in improving fatigue resistance of 7075-T6 aluminum alloy was determined by conducting R. R. Moore fatigue tests at the 3M Company Central Research Laboratories. Notched specimens containing grooves with a 0.125 radius were employed. These grooves were shot peened with 3M Brand Roto Peen Product No. 9012 (330 cast steel shot) and air blast equipment (330 cast steel shot) to a peening intensity of 8 mils Almen A. The fatigue test results are shown in Figure 12 (p. 19). It is shown that the 3M Brand Roto Peen treatment resulted in an improvement in fatigue life of from 8 to 30 times, with the largest improvement appearing at lower stress levels. Furthermore, it is shown that the 3M Brand Roto Peen tool treatment produces at least the same fatigue life improvement as conventional (air blast) shot peening.

Fatigue tests at an independent laboratory have shown similar fatigue performance improvements in 7075-T6 aluminum and 4340 steel (270-280 KSI).

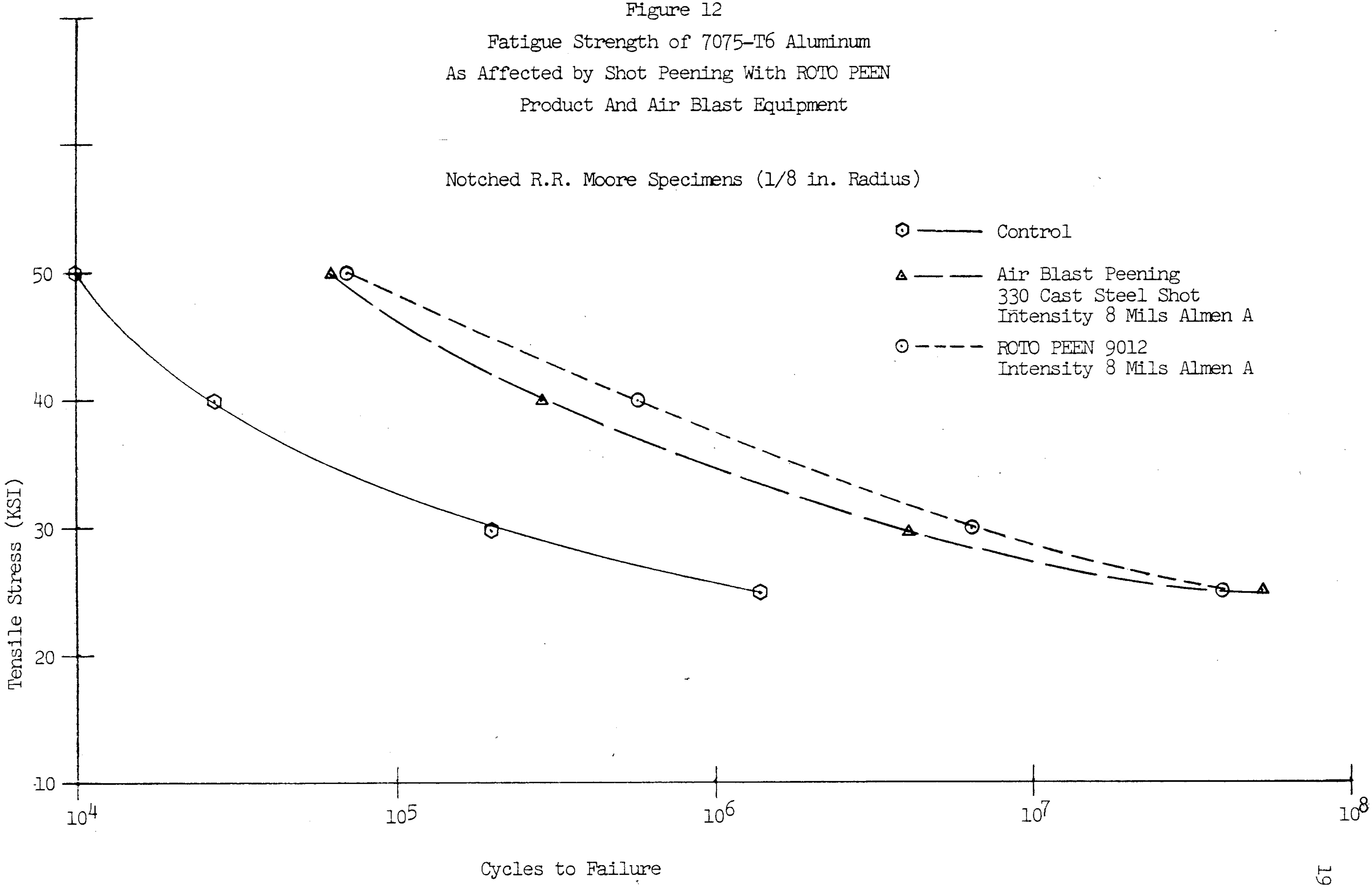
Figure 12

Fatigue Strength of 7075–T6 Aluminum

As Affected by Shot Peening With ROTO PEEN

Product And Air Blast Equipment

Notched R.R. Moore Specimens (1/8 in. Radius)



III. OPERATING PROCEDURES

A. Convert specified peening intensity to 3M peening intensity by referring to peening intensity conversion graph (Fig. 4B, p. 7).

B. Determine tool speed to achieve desired peening intensity by referring to the saturation curves (Fig. 1B, 2B, or 3B).

C. Mount 3M Brand Roto Peen Product on a rotary tool which will produce the required speed under load.

D. Set speed under load at approximately 100% flap deflection by using a strobe light tachometer or equivalent.

E. Conduct peening intensity test to determine whether a minor speed adjustment is needed to obtain desired intensity. A 3M Brand Magnetic Almen Strip Holder must be used to prevent product damage.

F. Conduct shot peening treatment.

1. The peening time (T) may be determined by multiplying the saturation peening time (T_S) from the saturation curves by the area to be peened (A) and dividing the result by the saturated area (A_S): ($T = T_S A/A_S$). The saturated area is equal to the Almen strip area of 2.25 sq. in. with a flap width $\leq$ 3/4 in. If the effective wheel width is > 3/4 in., multiply the effective flap width by 3 in. to obtain the saturation area.
2. The shot peening tool should be moved over the surface being peened in a manner which provides uniform coverage. Complete surface coverage should be determined by visual observation.
3. For optimum results, the flap deflection should be maintained between 80% and 100%.

IV. INSTRUCTIONS FOR INTENSITY MEASUREMENT WITH "3M" BRAND MAGNETIC ALMEN STRIP HOLDER

A. Set zero curvature position for new Almen strip with Almen No. 2 gauge.

B. Place Almen strip over magnets with the surface which contacted the gauge down. (One end of test strip should be contacting bonded strip.)

C. Orient holder so that Roto Peen tool rotation will tend to push test strip against bonded strip.

D. Peen for one minute at chosen tool speed with a technique which gives uniform coverage.

E. Determine strip arc height by placing unpeened side against gauge.

F. Convert arc height to standard intensity by referring to the peening intensity conversion graph (Fig. 4B, p. 7).

G. Repeat Steps B through F until saturation curve is developed.

H. Determine the peening intensity at saturation time from a graph of standard peening intensity versus peening time. (A definition of saturation time is that time which, when doubled, will result in an increase in peening intensity of 15% or less.)