SHOT PEENING COVERAGE

BY

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MEETING OF DIVISION XX
ON SHOT PEENING
IRON AND STEEL TECHNICAL COMMITTEE
SOCIETY OF AUTOMOTIVE ENGINEERS
HELD AT
HOT SPRINGS, VIRGINIA
SEPTEMBER 24, 25, AND 26, 1952

INTRODUCTION

THE DESIRED EFFECT OF A SHOT PEENING OPERATION IS PRIMARILY TO INCREASE THE FATIGUE LIFE OF A PART. THE PERCENTAGE INCREASE IN LIFE DUE TO PEENING IS DETERMINED BY COMPARING EITHER THE SERVICE LIFE OR TEST ENDURANCE LIFE OF A PEENED PART TO THAT OF AN UNPEENED PART.

AS A RULE, THE NEED FOR PEENING IS RECOGNIZED IN THE DESIGNING OR EARLY TESTING STAGES. FOR SOME PARTS SUCH AS SPRINGS, PEENING HAS LONG BEEN CONSIDERED A REQUIREMENT. OCCASIONALLY WHERE NEW DESIGNS ARE INVOLVED, THE NEED FOR PEENING BECOMES EVIDENT ONLY AFTER SERVICE FAILURES HAVE BEEN ENCOUNTERED.

EXPERIMENTAL SHOT PEENING IS GENERALLY CARRIED OUT IN LABORATORY EQUIPMENT OR IN SUITABLE PRODUCTION MACHINES UNDER CLOSELY CONTROLLED CONDITIONS.

WHEN THE PEENING OPERATION IS CARRIED OUT IN PRODUCTION, THE PROCESS IS CONTROLLED BY INSPECTING FOR INTENSITY AND COVERAGE. INTENSITY MEASUREMENT CAN BE ACCOMPLISHED SATISFACTORILY WITH THE ALMEN TEST STRIP. COVERAGE, ON THE OTHER HAND, IS LARGELY A MATTER OF JUDGMENT ON THE PART OF THE INSPECTOR. LABORATORY METHODS HAVE BEEN DEVELOPED FOR MEASURING COVERAGE, BUT UNTIL NOW THERE IS NO STANDARD METHOD FOR ITS EVALUATION IN THE SHOP.

THE PURPOSE OF THIS PAPER IS TO REVIEW THE SUBJECT OF COVERAGE AND TO EVALUATE SOME PROPOSED METHODS FOR ITS MEASUREMENT AND CONTROL.

WHAT IS COVERAGE?

COVERAGE MIGHT BE DEFINED AS THE PERCENT OF THE SURFACE STRUCK BY SHOT DURING THE PEENING OPERATION. 100% COVERAGE WOULD INDICATE THAT THE SURFACE, WHEN EXAMINED AFTER PEENING WOULD CONSIST OF OVERLAPPING SHOT IMPRESSIONS WITH NONE OF THE ORIGINAL SURFACE REMAINING. 90% COVERAGE WOULD INDICATE THAT 10% OF THE AREA HAD NOT BEEN STRUCK WITH SHOT.

THE DENTING OF THE SURFACE IS QUITE PRONOUNCED ON SOFT MATERIAL, LIKE MILD STEEL, BUT AS THE HARDNESS OF THE MATERIAL APPROACHES OR SURPASSES THE HARDNESS OF THE SHOT THE DENTING BECOMES LESS PRONOUNCED, AND THE AMOUNT OF COVERAGE BECOMES MORE DIFFICULT TO DETERMINE. IT SHOULD BE UNDERSTOOD THAT PEENING IS TO BE CARRIED OUT WITH SHOT OF UNIFORM SIZE. IT IS POSSIBLE, HOWEVER, TO COMPLETELY COVER A GIVEN SURFACE AND STILL PEEN INEFFECTIVELY IF THE SHOT BEING USED CONTAINS A SUBSTANTIAL AMOUNT OF BROKEN PARTICLES. THIS CONDITION MIGHT BE REFERRED TO AS FALSE COVERAGE. WHEN USING SHOT WHICH IS SUBJECT TO RAPID BREAKDOWN, THE BEST WAY TO INSURE AGAINST FALSE COVERAGE IS TO MAINTAIN GOOD SHOT SEPARATION FOR THE REMOVAL OF UNDERSIZE AND BROKEN SHOT PARTICLES. THESE COMMENTS SHOULD NOT BE CONFUSED WITH THE FACT THAT THERE IS A BENEFICIAL PEENING EFFECT FROM THE FINE PARTICLES IN THE BLAST AND MANY SUCCESSFUL PEENING OPERATIONS ARE CARRIED OUT WITH A LARGE PERCENTAGE OF BROKEN SHOT BEING USED. FALSE COVERAGE WOULD ONLY BE A FACTOR WHEN A JOB WAS DESIGNED TO OPERATE AT A FIXED SHOT SIZE AND THE SYSTEM BECOMES CONTAMINATED WITH EXCESSIVE FINES.

COVERAGE IN ITSELF, DOES NOT NECESSARILY INDICATE THE FATIGUE LIFE TO BE EXPECTED. THIS IS BECAUSE THE PRIMARY AIM IN SHOT PEENING IS NOT SIMPLY THE BATTERING OF THE SURFACE, BUT IS THE INDUCTION OF COMPRESSIVE STRESSES IN A SURFACE LAYER. THE COMPRESSIVE STRESS EXTENDS BEYOND THE SHOT IMPRESSION INTO THE UNPEENED AREAS SURROUNDING IT AND PENETRATES THE SURFACE TO SOME DEPTH. FOR SOME PARTS IT IS POSSIBLE TO PRODUCE A VERY SATISFACTORY FATIGUE LIFE AT CONSIDERABLY LESS THAN 100% COVERAGE.

COVERAGE OF THE SURFACE WITH SHOT IMPRESSIONS HAS A SECONDARY EFFECT WHICH PROBABLY AIDS IN THE RESISTANCE TO FATIGUE. SCRATCHES, GRINDING AND TOOL MARKS, AND OTHER STRESS RAISERS AT THE SURFACE ARE OBLITERATED. THE INCREASE IN FATIGUE LIFE FROM THE REMOVAL OF SURFACE STRESS RAISERS IS PROBABLY LOW WHEN COMPARED TO THE BENEFITS DERIVED FROM THE INTRODUCTION OF COMPRESSIVE STRESSES IN THE SURFACE METAL.

Factors Affecting Coverage

When the part is released for production it is frequently necessary to purchase equipment for the peening operation. In order to achieve the same results as were obtained on the test parts, it is necessary to secure equipment which will produce the same intensity and coverage as were present during the experimental peening. In order to do this, the following factors must be considered in the design of the new equipment.

1. Size of shot.
2. Flow rate of shot.
3. Conveyor, table speed or cycle time.
4. Accessibility of areas to be peened.
5. Shot spray pattern.
6. Shot velocity.

Shot size is generally specified with intensity in mind but is also of great importance to coverage. Once machine factors have been set, changes in shot size will cause a variation in coverage. Smaller shot will give better coverage and larger shot will produce less coverage. The intensity requirements will somewhat control the variation that can be tolerated in shot size but arc height, as measured by the Almen Strip, can be maintained with considerable variation in coverage.

Other factors such as the flow of shot, conveyor speed, shot spray pattern, and shot velocity are mechanical features of the peening operation which must be properly controlled at all times if adequate coverage is to be maintained.

Measuring Coverage

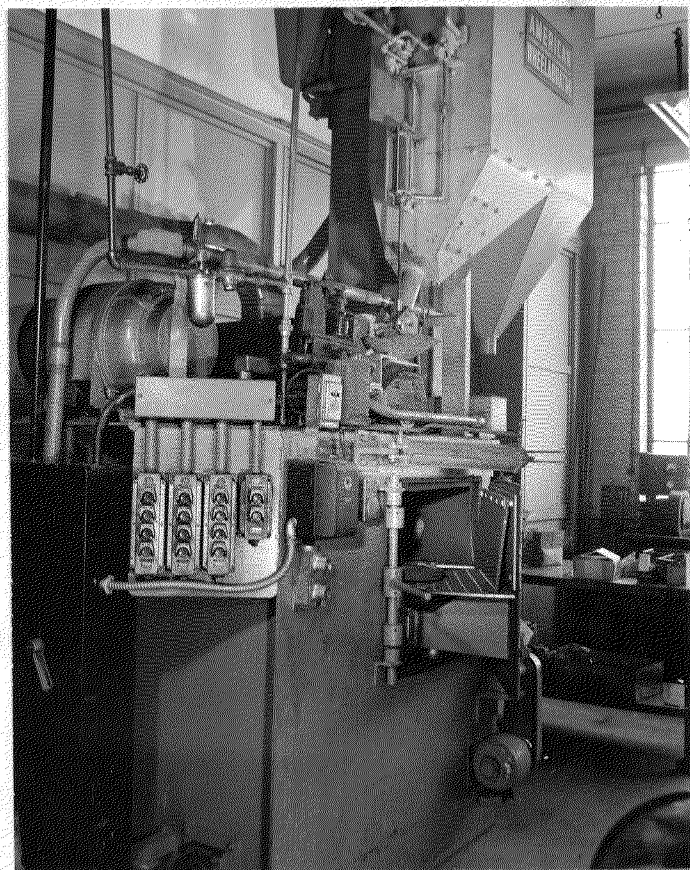
Generally the inspector will observe the part visually after the shot peening operation to determine if the coverage is satisfactory. He may use a low power glass to aid him, especially if the coverage is in the questionable category. As long as the coverage is near 100% this type of inspection is probably adequate. The part is either covered with shot impressions or it isn't. At coverages less than 100%, say 85%, it is not easy for an inspector to determine the quality of the operation. Other means must be employed. Following are some methods proposed for determining coverage:

1. The Straub Method
2. Valentine's Method
3. The Surface Replica Method

The detailed procedures are included in the Appendix of this paper.

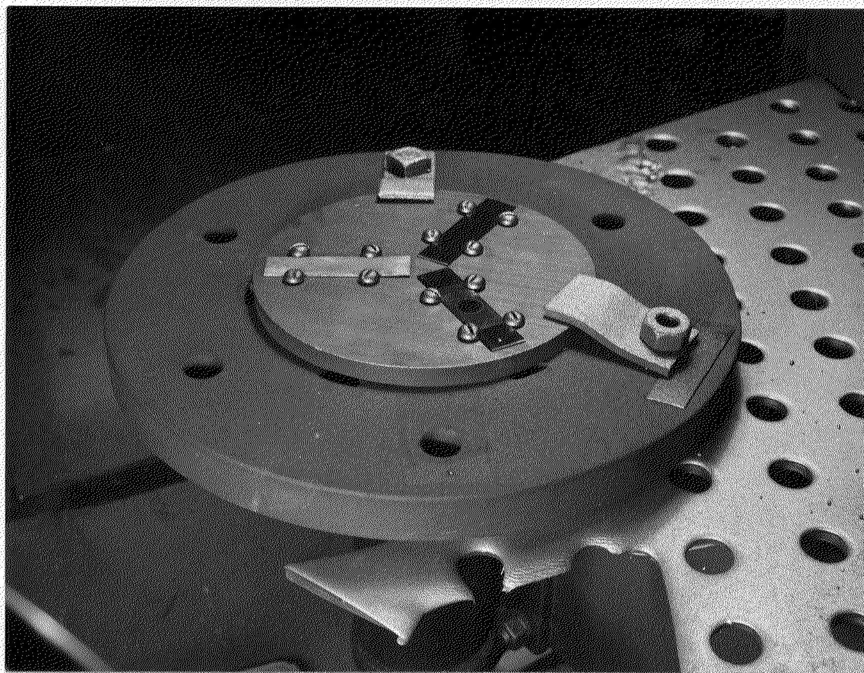
In an effort to determine the relationship between these proposed methods for determining coverage, a series of peening tests was conducted involving the application of various types and sizes of shot and grit. All work was carried out in a single station rotating table peening machine which is illustrated in the accompanying photograph, (figure 1). The machine data is as follows:

Wheel Speed	-	1750 R.P.M.
Wheel Diameter	-	17 1/2 inches
Wheel Width	-	2 1/2 inches
Table Speed	-	40 R.P.M.
Shot Control	-	Automatic timing with shot flowing through various orifices.



Peening Machine Used in Coverage Tests
Figure 1

Using a fixed wheel speed of 1750 R.P.M. and a peening time of 30 seconds, the various degrees of shot flow were controlled by orifices of 3/8", 1/2", 5/8", and 3/4" diameter. The various peening media used included cut wire shot CW 35 and CW 54, SAE-230 and SAE-330 chilled iron shot, SAE-170 cast steel shot, and G-50 grit. Peening was carried out on Standard Almen "A" strips, electropolished Standard Almen "A" strips, and normalized SAE 1008 "A" strips. The strips were mounted on a table fixture as illustrated. (Figure 2)



FIXTURE FOR HOLDING TEST STRIPS
FIGURE 2

THE PROCEDURE USED IN PEENING WITH EACH TYPE OF SHOT AND FOR EACH ORIFICE SIZE WAS AS FOLLOWS:

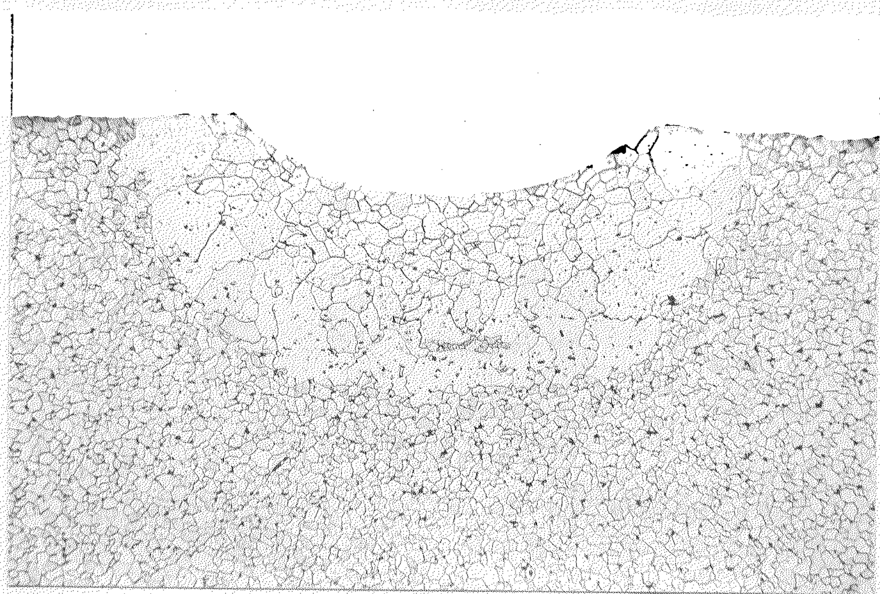
THE TEST STRIPS WERE FASTENED TO THE TABLE FIXTURE, THE CABINET CLOSED, AND THE MACHINE STARTED. WHEN THE WHEEL REACHED FULL SPEED, THE STRIPS WERE BLASTED FOR EXACTLY 30 SECONDS AFTER WHICH THEY WERE REMOVED AND IDENTIFIED. WITH EACH TYPE OF SHOT, COVERAGE WAS VARIED BY USING THE 3/8", 1/2", 5/8" AND 3/4" ORIFICES, WITH THE EXCEPTION OF THE CW 54 CUT WIRE TEST WHERE A 1" ORIFICE WAS ALSO USED. SHOT FLOW WAS MEASURED BY WEIGHING THE AMOUNT WHICH FLOWED THROUGH THE SPOUT FOR ONE MINUTE. A SAMPLE FOR SCREEN ANALYSIS WAS ALSO OBTAINED FROM THE SPOUT AT THE SAME TIME. WITH A TABLE SPEED OF 40 R.P.M. IT CAN BE ASSUMED THAT ALL THREE TEST STRIPS WERE PEENED EQUALLY. THE STANDARD ALMEN "A" STRIP WAS USED

FOR ARC HEIGHT MEASUREMENT, THE ELECTROPOLISHED "A" STRIP FOR COVERAGE BY THE STRAUB AND SURFACE REPLICA METHODS, AND THE SAE 1008 STRIP FOR DEPTH OF COLD WORK DUE TO PEENING ACCORDING TO THE VALENTINE METHOD.

AFTER PEENING, THE SAE 1008 STRIPS WERE ANNEALED AT 1300 F FOR 1/2 HOUR FOR GRAIN COARSENING, CROSS SECTIONED, MOUNTED IN BAKELITE, AND EXAMINED. PHOTOMACROGRAPHS AT 50 MAGNIFICATIONS WERE MADE OF EACH PEENED ELECTRO-POLISHED "A" STRIP FROM WHICH THE PERCENT COVERAGE WAS MEASURED WITH A PLANIMETER AS PRESCRIBED BY THE STRAUB COVERAGE METHOD. SURFACE REPLICA IMPRESSIONS WERE ALSO MADE OF EACH OF THE POLISHED STRAUB STRIPS.

AS SEEN IN THE PHOTOMICROGRAPHS OF THE LOW CARBON STRIPS IN THE APPENDIX, THE DEPTH OF COLD WORK AS EVIDENCED BY GRAIN GROWTH BECOMES PROGRESSIVELY GREATER WITH INCREASING COVERAGE. HOWEVER, NO APPRECIABLE DEPTH INCREASE WAS NOTED BEYOND 75% OR 80% COVERAGE. IT MUST BE REMEMBERED THAT THE DEPTH OF GRAIN GROWTH DOES NOT NECESSARILY INDICATE THE TRUE DEPTH OF COLD WORK. RATHER, IT OUTLINES THAT AREA WHICH HAS BEEN CRITICALLY STRESSED TO WITHIN A RANGE WHICH, UPON HEATING, WILL PRODUCE GRAIN GROWTH. THEREFORE, IT IS REASONABLE TO ASSUME THAT WHEN PEENING LOW CARBON STEEL, THE COLD WORK EFFECT ACTUALLY EXTENDS TO A DEPTH GREATER THAN THAT INDICATED BY GRAIN COARSENING. SIMILARLY, EXCESSIVLY COLD WORKED OR OVERPEENED METAL, AS SEEN IN FIGURE 13 OF THE APPENDIX, SHOWS THE PRESENCE OF FINE GRAINS AT THE SURFACE WITH UNDERLYING LARGE GRAINS. IN THIS CASE THE DEGREE OF COLD WORK AT THE SURFACE HAS EXCEEDED THE CRITICAL AMOUNT NECESSARY TO PRODUCE GRAIN COARSENING.

When arbitrarily used as a means of determining peening coverage, the Valentine low carbon duplicate method could be misleading. With a few exceptions, the photomicrographs of the Valentine strips indicate continuous cold working of the surface metal, and that complete coverage was present. The corresponding Straub photomacrographs in many cases, however, show only partial coverage. The natural assumption, based on Valentine's Method, is that the cold worked areas surrounding the shot indentations overlap, giving the impression of complete coverage when it does not actually exist. To illustrate the cold work effect of one shot particle, a Rockwell "B" hardness impression was made on a low carbon Almen strip. The strip was annealed at 1300 F for 1/2 hour and sectioned through the indentation. From the accompanying photomicrograph, (Figure 3) it is seen that the stressed area surrounding the impression is very widespread and would overlap with that of another impression 1/32" or more away.



X50 NITAL

Photomicrograph of Cold Work Effect of Rockwell "B" Impression

Figure 3

As previously mentioned, visual inspection for coverage is by necessity the most generally used method for the inspection of peened production parts. However, for the establishment of limits as well as for quality control of a peening job, more accurate means for determining coverage are necessary. The two direct methods available for this purpose are the Straub Method and the Surface Replica Method.*

Essentially the Straub Method involves the accurate measurement of percent coverage on a polished Almen "A" strip from its magnified image on the screen of a metallurgical microscope. The image of the peened strip at 50 magnification is traced and measured with a planimeter. For accurate determination of coverage this method is the only one yet developed. It has its limitation, however, because of the fact that its application is confined to a test strip rather than to the actual peened part itself. Quite frequently the design of a part to be peened may be such that a peened strip, however carefully positioned, will not represent the peening conditions on the part itself. It provides an excellent means of determining the exact peening conditions existent in a machine.

The third method for determining coverage is the Surface Replica Method. After a part has been shot peened, a transparent replica of the surface can be readily made as outlined in the following procedure.

A. Select the area where coverage is to be measured.

B. Apply the solvent.

C. Apply the transparent film to the area where the solvent has

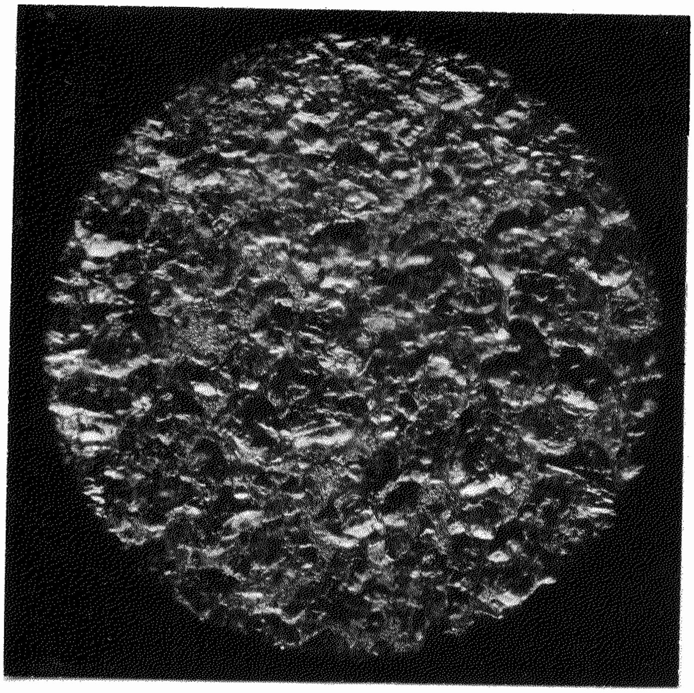
BEEN PLACED. PRESS THE FILM TO THIS AREA WITH THUMB PRESSURE FOR APPROXIMATELY ONE MINUTE.

D. QUICKLY PEEL THE FILM FROM THE SURFACE.

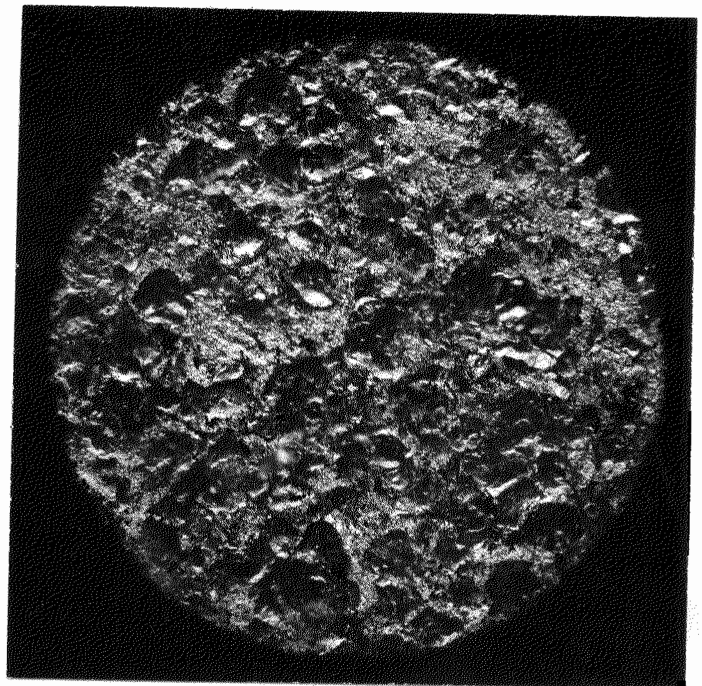
E. MOUNT THE FILM IN A HOLDER AND PROJECT IT ONTO SCREEN FOR VIEWING.

IT HAS AN ADVANTAGE OF REPRODUCING THE CONDITION OF THE PEENED SURFACE ON A FILM WHICH MAY BE PROJECTED ON A SCREEN FOR INSPECTION. THIS REPLICA NEED NOT BE CONFINED TO THAT OF A FLAT SURFACE BUT IS ADAPTABLE ALSO TO IRREGULAR CONTOURS. IN VIEWING ITS PROJECTION ON A SCREEN, AN EXPERIENCED EYE CAN ESTIMATE WITH GOOD ACCURACY NOT ONLY THE PERCENT COVERAGE, BUT THE MAGNIFIED CONDITION OF THE PEENED SURFACE AS WELL. THE METHOD HAS THE ADDED ADVANTAGES OF BEING FAST, FLEXIBLE, AND PORTABLE THEREBY LENDING ITSELF TO EASY APPLICATION AT THE SITE OF ANY PEENING OPERATION.

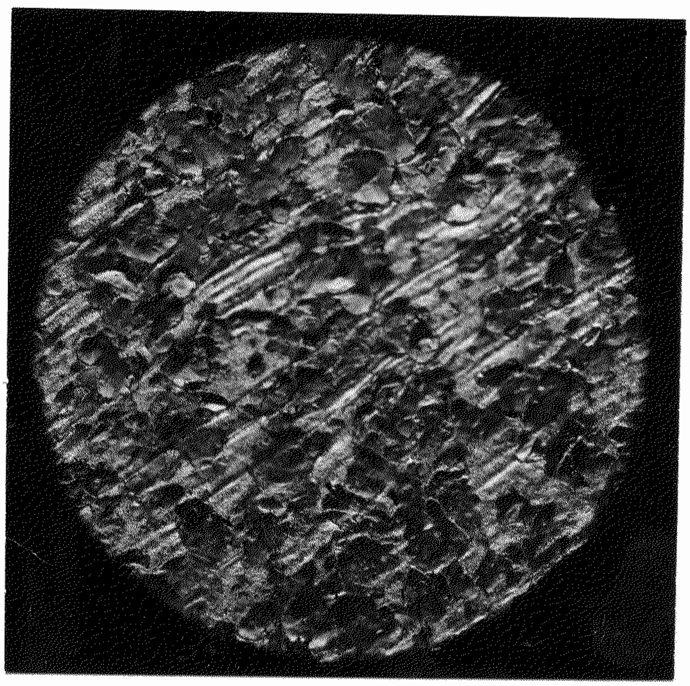
TO AID IN THE INSPECTION FOR PEENING QUALITY OF BUICK CHASSIS COIL SPRINGS, PHOTOGRAPHS OF SURFACE REPLICA FILMS OF VARIOUS DEGREES OF COVERAGE ARE USED AS STANDARDS. (FIGURE 4)



X 30 EXCELLENT



X 30 ACCEPTABLE



X 30 NOT ACCEPTABLE

SURFACE REPLICA STANDARDS FOR BUICK COIL SPRING COVERAGE

FIGURE 4

SUMMARY

Although the Straub and Surface Replica Methods differ somewhat in their application, together they provide a means by which coverage can be accurately measured and easily controlled. The Straub Method, although highly accurate, is time consuming and requires the use of special metallographic equipment. The Surface Replica Method, while one of comparison, is an excellent means of control, especially when used in conjunction with coverage standards. Setting up standards of reference such as Figure 4 has proved to be a successful and practical method of controlling coverage.

The ideal condition would be to have 100% coverage. In all cases, however, this is not easily accomplished and for some parts may not be necessary to gain the desired improvement in fatigue life. From Figure 22 of the SAE Shot Peening Manual, which is a theoretical curve of exposure time versus percent coverage, it can be seen that 100% coverage is approached only with considerable expense of time.

When shot peening on a production basis it is often difficult to consistently maintain true 100% coverage. Therefore, when referring to 100% coverage in a peening specification it will probably be advisable to permit a slight variation from 100%. It is suggested that in speaking of 100% coverage, it be interpreted that some percentage of the area can remain unpeened. Where coverage tolerances are permitted the unpeened areas should not be concentrated.

OCCASIONALLY THE FATIGUE LIFE AND SERVICE REQUIREMENTS OF A PART ARE SUCH THAT IT IS POSSIBLE TO SET A MINIMUM VALUE FOR THE PERCENT COVERAGE NEEDED.

IN GENERAL, HOWEVER, TO INSURE THE BEST PEENING RESULTS AND TO MINIMIZE INSPECTION PROBLEMS, NEW PEENING EQUIPMENT, WHENEVER POSSIBLE, SHOULD BE DESIGNED TO INSURE 100% COVERAGE.

APPENDIX

Shot Peening Data

		3/8"	1/2"	5/8"	3/4"	Screen Analysis
.035" Cut Wire	Arc Height (Almen Gage)	.011 0-.012	.017 .008-.012	.020 .010-.014	.024 .010-.012	.039" - 1.2% .0331" - 93.0% .0280" - 5.4% Pan - 0.4%
	Shot Flow #/min.	6.6	15.0	30.1	51.1	
	% Coverage	38.8	81.0	94.3	99.0+	
.054" Cut Wire	Arc Height	.008 .004-.012	.013 .006-.014	.021 .014-.016	.023 .032 .012-.016	.0787"- 0.0% .0555"- 9.6% .0469"- 63.5% Pan - 26.9%
	Shot Flow #/min.	5.2	13.4	26.6	45.8 .014-.016 104	
	% Coverage	27.6	72.7	91.5	99.0 — 100.0	
SAE 230 Chilled Iron	Arc Height	.011 0-.012	.015 .004-.010	.019 .008-.012	.020 .011-.016	.028" - 16.9% .0232" - 68.2% .0197"- 12.8% Pan - 2.1%
	Shot Flow #/min.	7.1	16.3	32.5	55.5	
	% Coverage	45.5	50.5 ?	95.8	100.0	
SAE 330-Chilled Iron	Arc Height	.016 0-.014	.020 .004-.010	.025 .008-.012	.0285 .009-.014	.0394"-0.8% .0331"- 73.9% .0280"- 20.5% Pan - 4.8%
	Shot Flow #/min.	6.7	15.1	29.9	51.4	
	% Coverage	47.5	81.0	94.3	100.0	
SAE 170 Cast Steel	Arc Height	.011 .004-.010	.017 .007-.010	.0185 .006-.010	.020 .010-.012	.0232"- 10.0% .0165" -88.9% Pan - 1.1%
	Shot Flow #/min.	7.6	17.3	34.4	59.1	
	% Coverage	31.6	84.5	97.5	100.0	
G-50 Grit	Arc Height	.008 .005-.008	.013 .004-.008	.014	.016 .007-.012	.0280"- 25.5% .0117"- 73.7% .0070"- 0.7% Pan -.1%
	Shot Flow #/min.	7.4	16.8	33.2	57.0	
	% Coverage	55.4	96.5 ?		100.0	

Exposure Time - 30 seconds
Wheel Speed - 1750 R.P.M.
Table Speed - 40 R.P.M.

Straub Method for Determining Coverage*

A. Polish the strips "A" (or "C") to obtain a reflecting surface by means of metallurgical polishing cloths or equivalent. (For this investigation a 1/2 inch circle was electropolished on metallographic electropolishing equipment.)

B. Fasten to test strip holder.

C. Expose the polished surface to the blast under conditions identical to that used in determining the arc height of Almen Gage reading.

D. Remove the strip from the holder and place it in the field of a metallurgical camera.

E. Using a piece of transparent paper as ground glass, and with a magnification of approximately 50 diameters, trace the indented areas with a sharp pencil. The indented areas can be indentified by the contrast of the polished surface and the inclined surfaces of the indentations.

F. Measure with a planimeter the area of all of the indentations enclosed by a circle of known diameter. The ratio of the indented area to the total area is the percentage coverage.

* Taken from S.A.E. Shot Peening Manual

VALENTINE'S METHOD FOR DETERMINING THE EFFECT OF PEENING*

WHEN PARTS TO BE PEENED ARE OF VARYING CROSS-SECTION OR CONTOUR, AS FOR EXAMPLE A ROCKER ARM, IT IS DIFFICULT TO STUDY THE PEENING INTENSITY DISTRIBUTED OVER THE COMPLEX SURFACE.

AN INGENIOUS METHOD OF DETERMINING THE EFFECT OF PEENING IN SUCH CASES IS DESCRIBED IN DETAIL BY VALENTINE IN TRANS. A.S.M., VOL. 40, 1948, PAGE 420-434.

IN BRIEF, A DUPLICATE OF THE PIECE BEING STUDIED CAN BE MADE FROM LOW CARBON STEEL OF A SPECIFIED CARBON RANGE, SUBJECTED WHILE IN THE SOFT CONDITION TO THE PROPOSED PEENING CYCLE AND THEN ANNEALED IN A DESCRIBED MANNER TO PRODUCE A RECRYSTALLIZATION AND GRAIN GROWTH. THE PIECE MAY THEN BE CROSS-SECTIONED IN ANY PLANE AND STUDIED UNDER THE MICROSCOPE. THE EXTENT OF PEENING WILL BE SHOWN BY THE DEGREE OF GRAIN GROWTH IN THE VARIOUS PARTS OF THE PIECE AND WILL BE IN PROPORTION TO THE INTENSITY OF THE PEENING BLAST TO WHICH THE AREA WAS SUBJECTED.

* TAKEN FROM THE S.A.E. SHOT PEENING MANUAL

Surface Replica Method

After a part has been shot peened, a transparent replica of the surface can be readily made.

Method

A. Select area where coverage is to be measured.

B. Apply solvent.

C. Apply the transparent film to the area where the solvent has been placed. Press the film to this area with thumb pressure for approximately one minute.

D. Peel film quickly from the surface.

E. Mount film in holder and project onto screen for viewing.

CONTENTS OF THE FOLLOWING PAGES

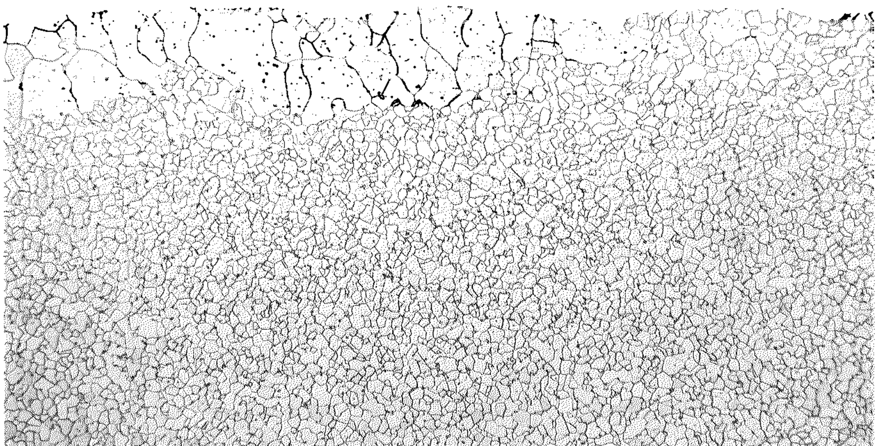
1. CROSS SECTIONAL PHOTOMICROGRAPH OF SAE 1008 TEST STRIP SHOWING THE DEPTH OF COLD WORK ACCORDING TO THE VALENTINE METHOD.

2. PHOTOMACROGRAPH OF THE CORRESPONDING ELECTROPOLISHED AND PEENED ALMEN "A" TEST STRIP FOR COVERAGE DETERMINATION ACCORDING TO THE STRAUB METHOD.

.035 CUT WIRE SHOT

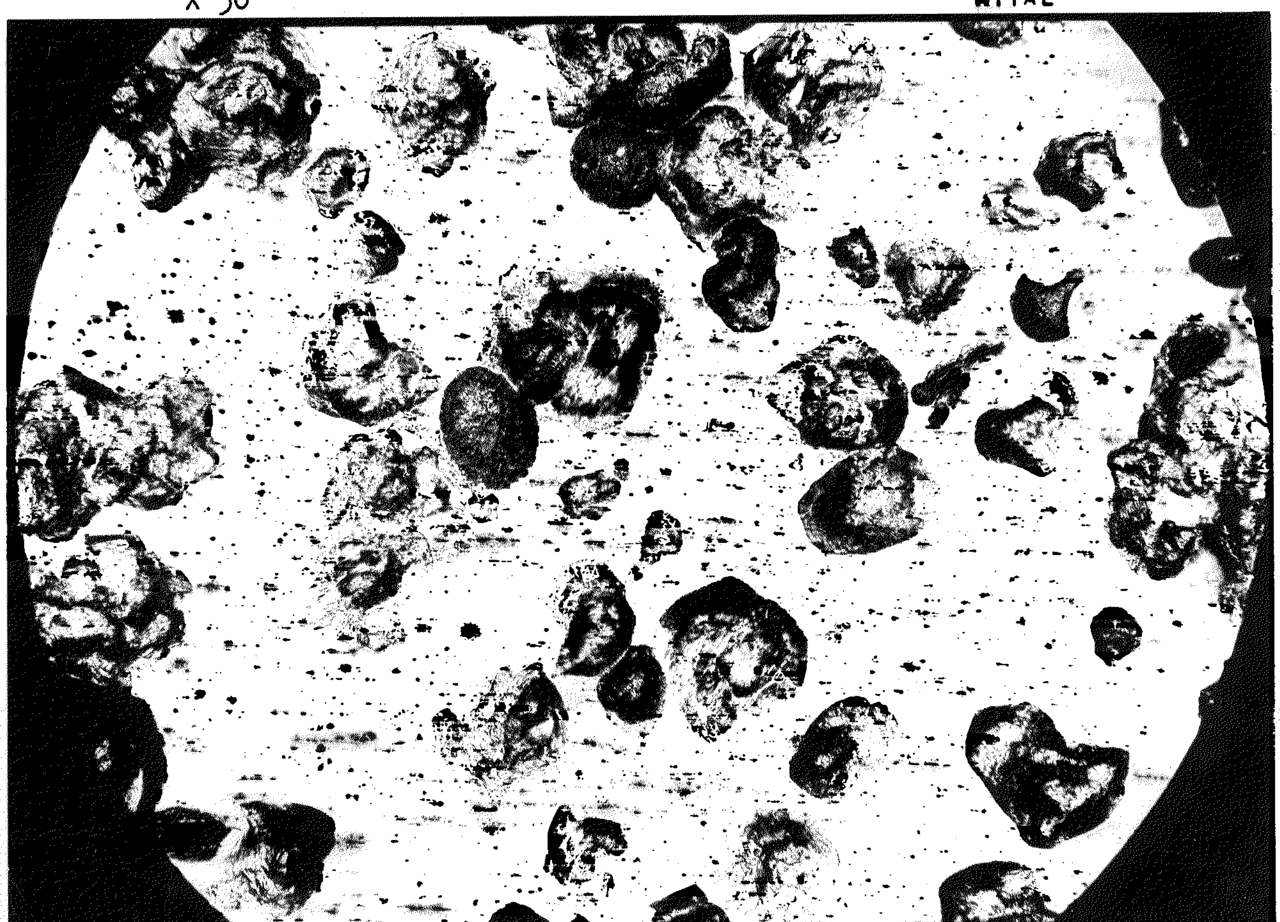
38.8% COVERAGE

ORIFICE SIZE --- 3/8 INCHES
EXPOSURE TIME -- 30 SECONDS
SHOT FLOW ------ 6.6 LBS./MIN.
ARC HEIGHT ----- 11.0 A-2



0 - .6 =
0" - .012"

X 50 NITAL



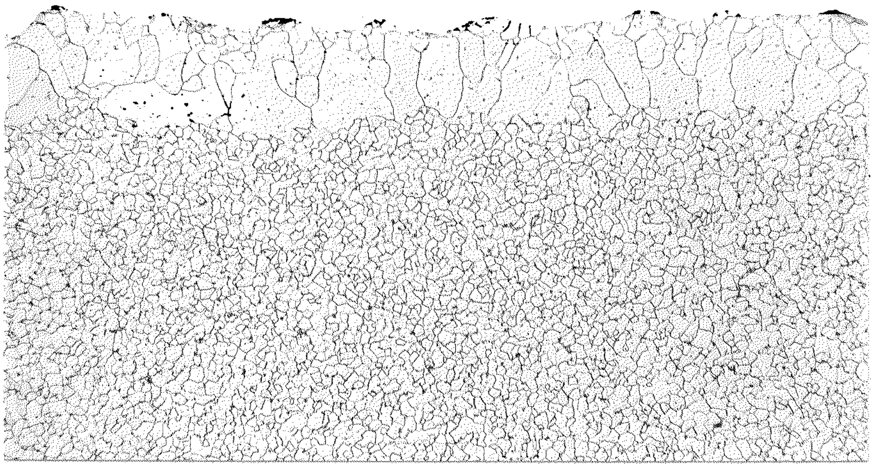
X 50 AS PEENED

FIGURE 5

.035 Cut Wire Shot

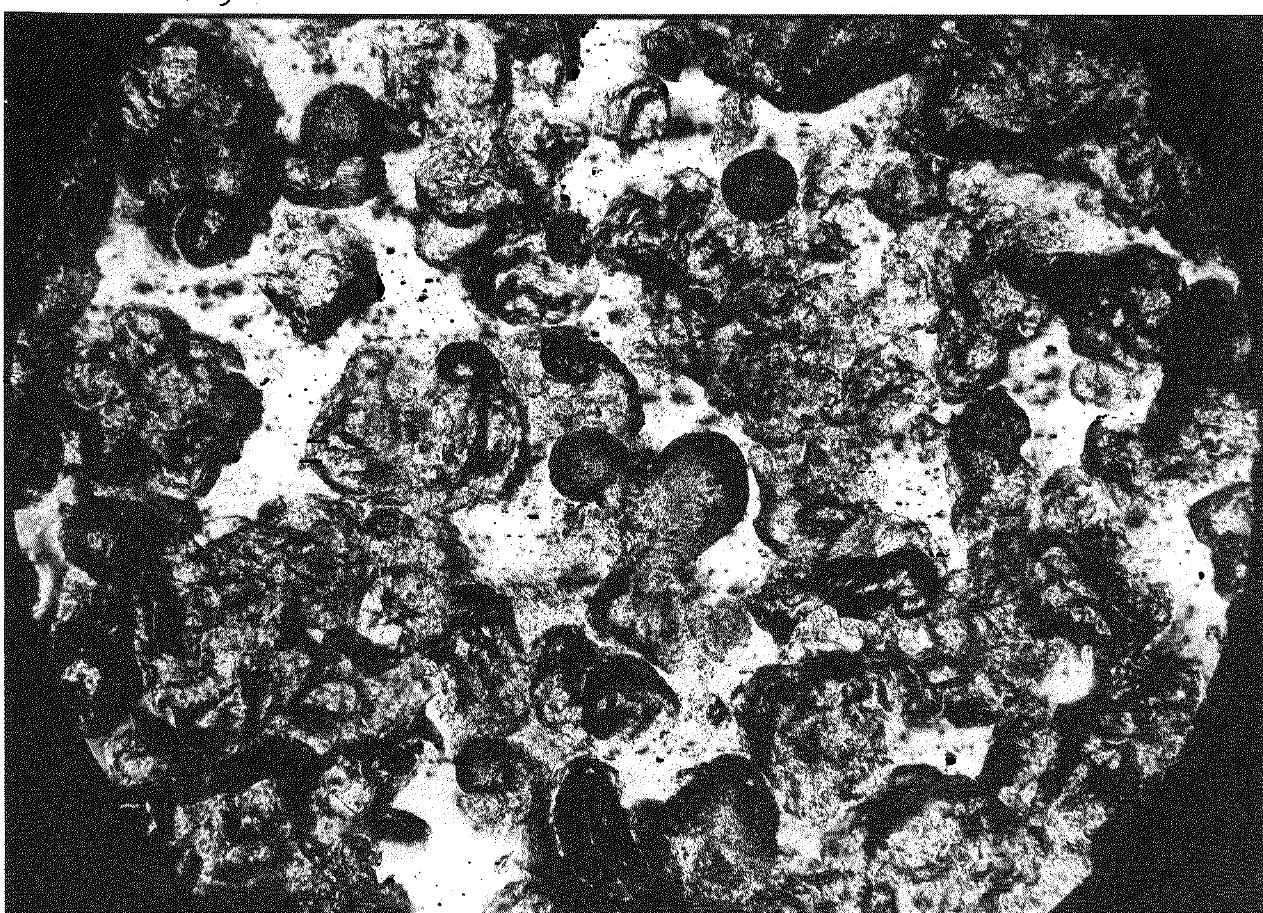
81.0% Coverage

Orifice Size --- 1/2 inches
Exposure Time -- 30 seconds
Shot Flow ----- 15.0 lbs./min.
Arc Height ----- 17.0 A-2



.4 - .6 =
.008" - .012"

X 50 Nital



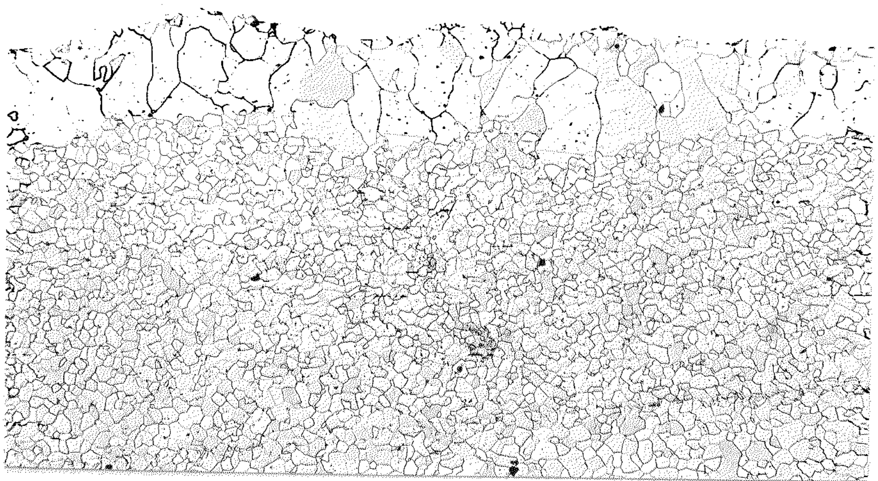
X 50 As Peened

Figure 6

.035 CUT WIRE SHOT

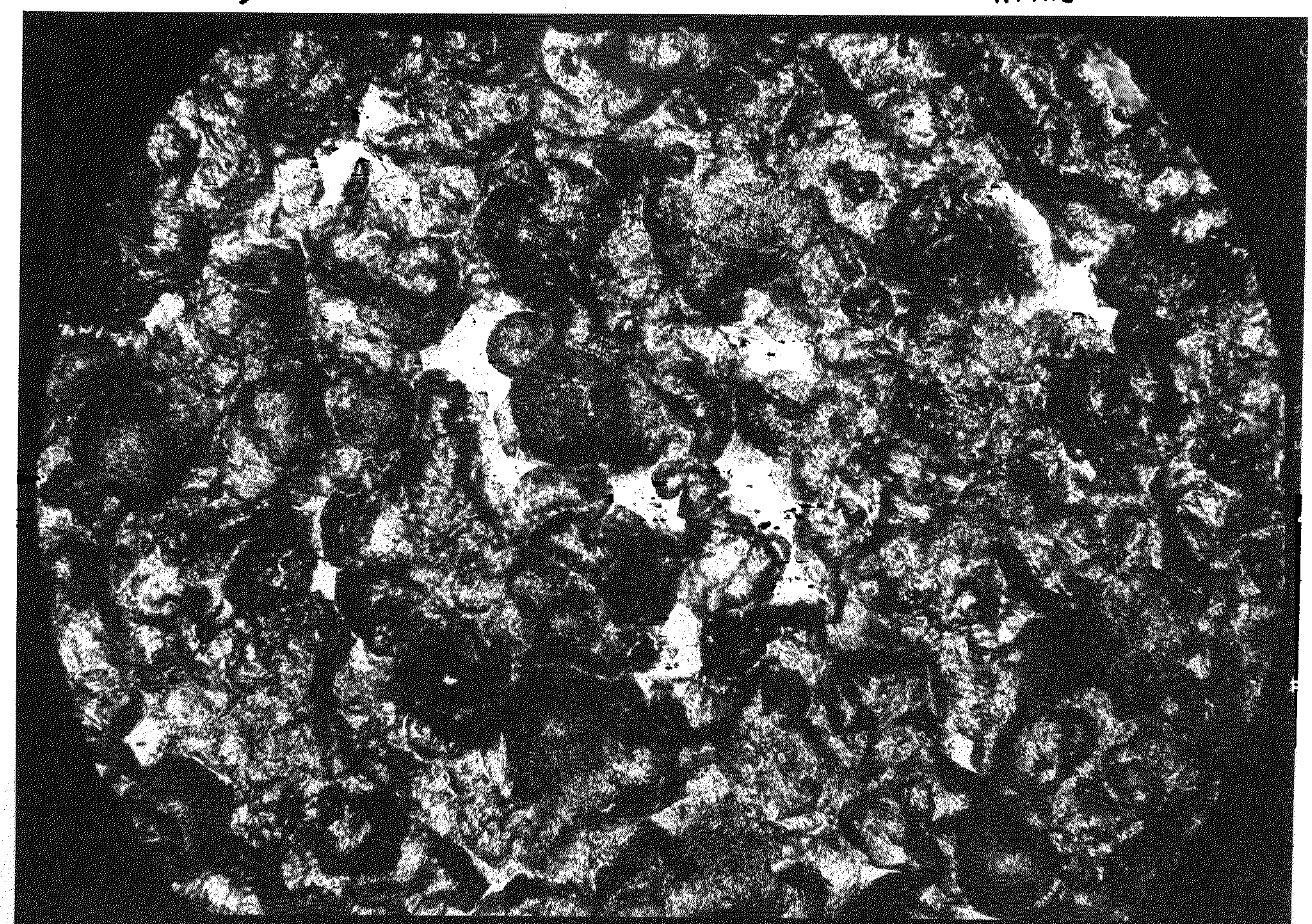
94.3% COVERAGE

ORIFICE SIZE --- 5/8 INCHES
EXPOSURE TIME -- 30 SECONDS
SHOT FLOW ------ 30.1 LBS./MIN.
ARC HEIGHT ----- 20.0 A-2



.5 - .7 =
.010" - .014"

X 50 NITAL



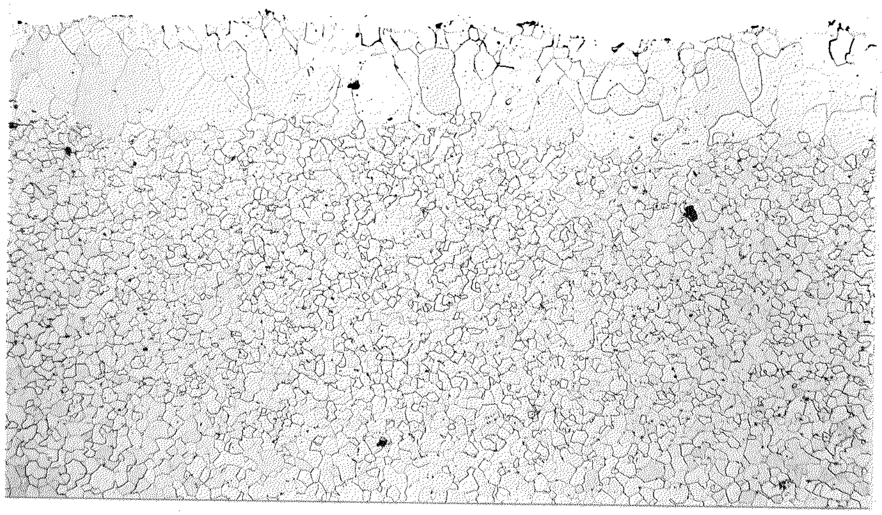
X 50 AS PEENED

FIGURE 7

.035 CUT WIRE SHOT

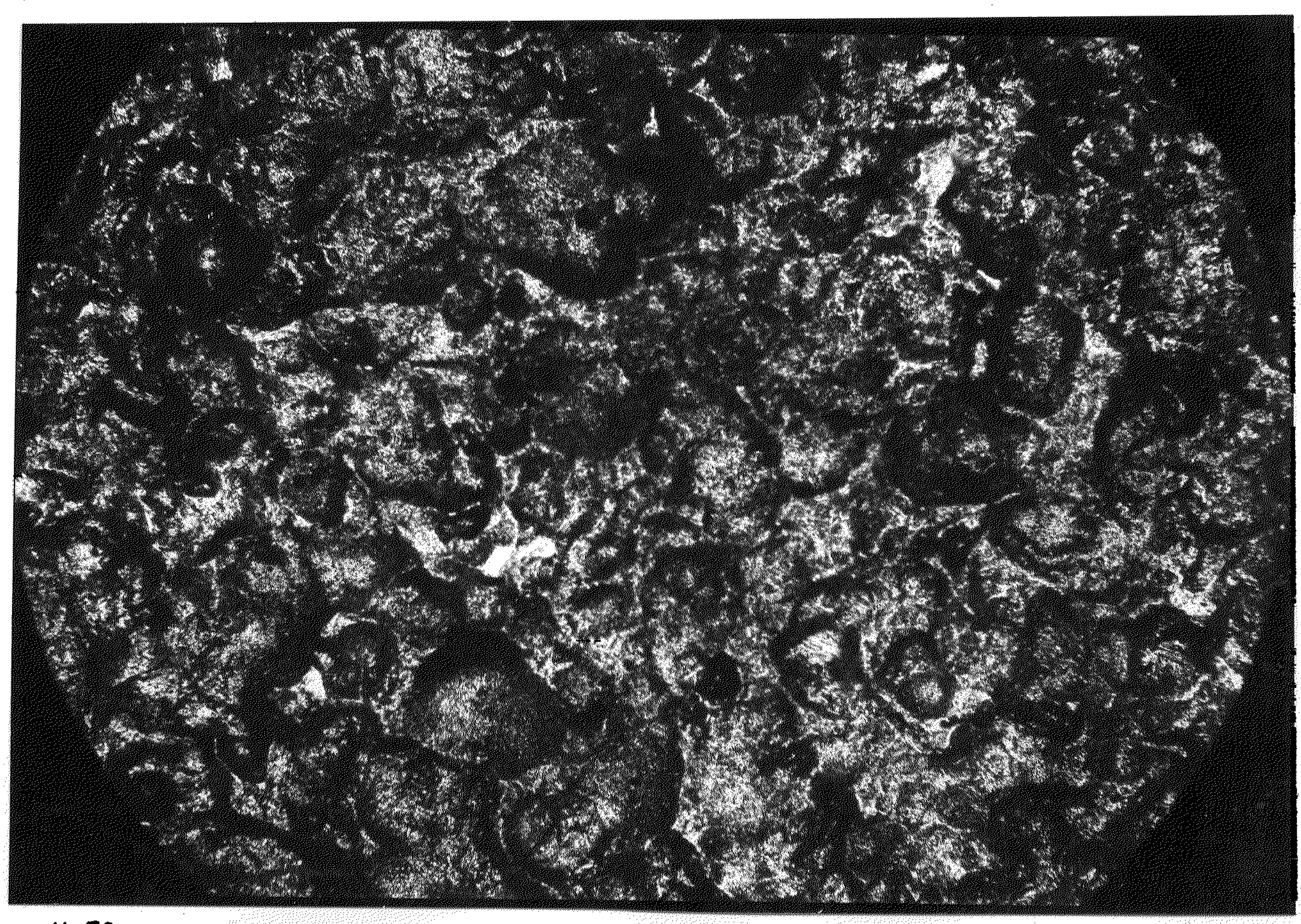
99+% COVERAGE

ORIFICE SIZE --- 3/4 INCHES
EXPOSURE TIME -- 30 SECONDS
SHOT FLOW ------ 51.1 LBS./MIN.
ARC HEIGHT ----- 24.0 A-2



.5-.6 =
.010"-.012"

X 50 NITAL



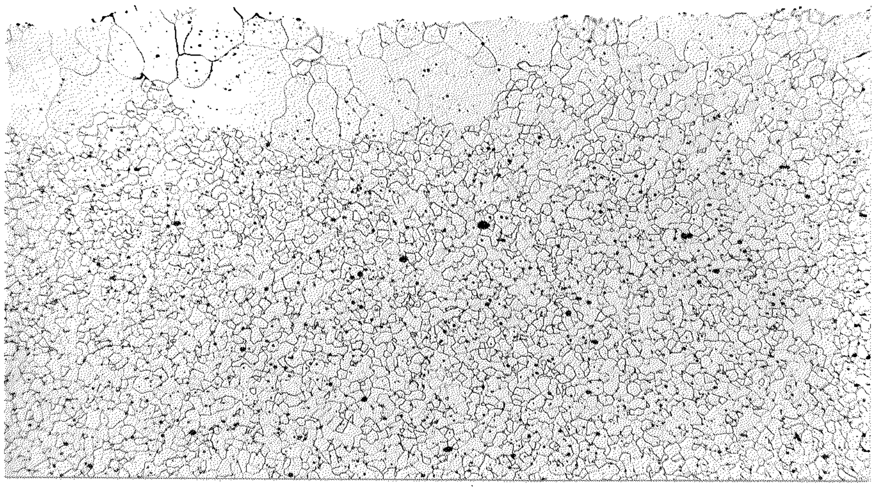
X 50 AS PEENED

FIGURE 8

.054 Cut Wire Shot

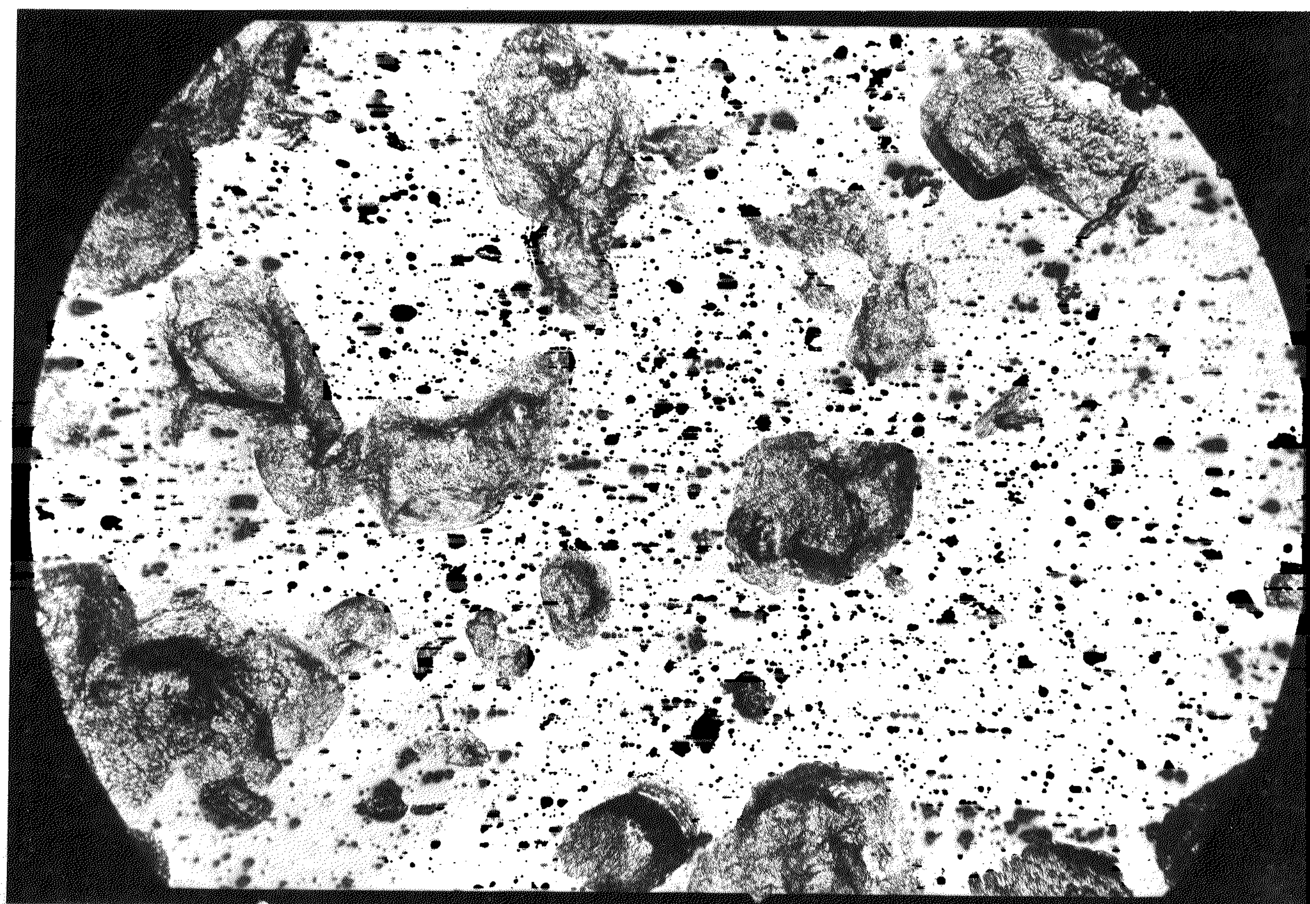
27.6% Coverage

Orifice Size ----	3/8 inches
Exposure Time ---	30 seconds
Shot Flow -------	5.2 lbs./min.
Arc Height ------	8.0 A-2



.2 - .6 =
.004" - .012"

X 50 Nital



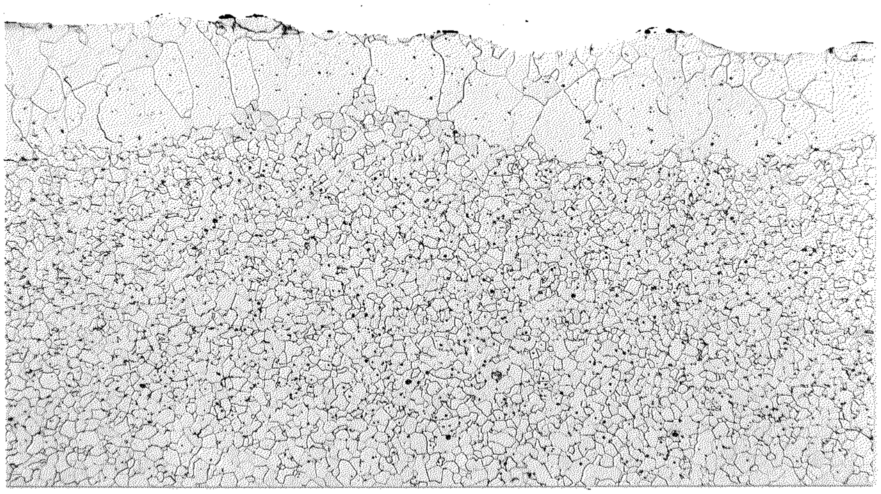
X 50 As Peened

Figure 9

.054 Cut Wire Shot

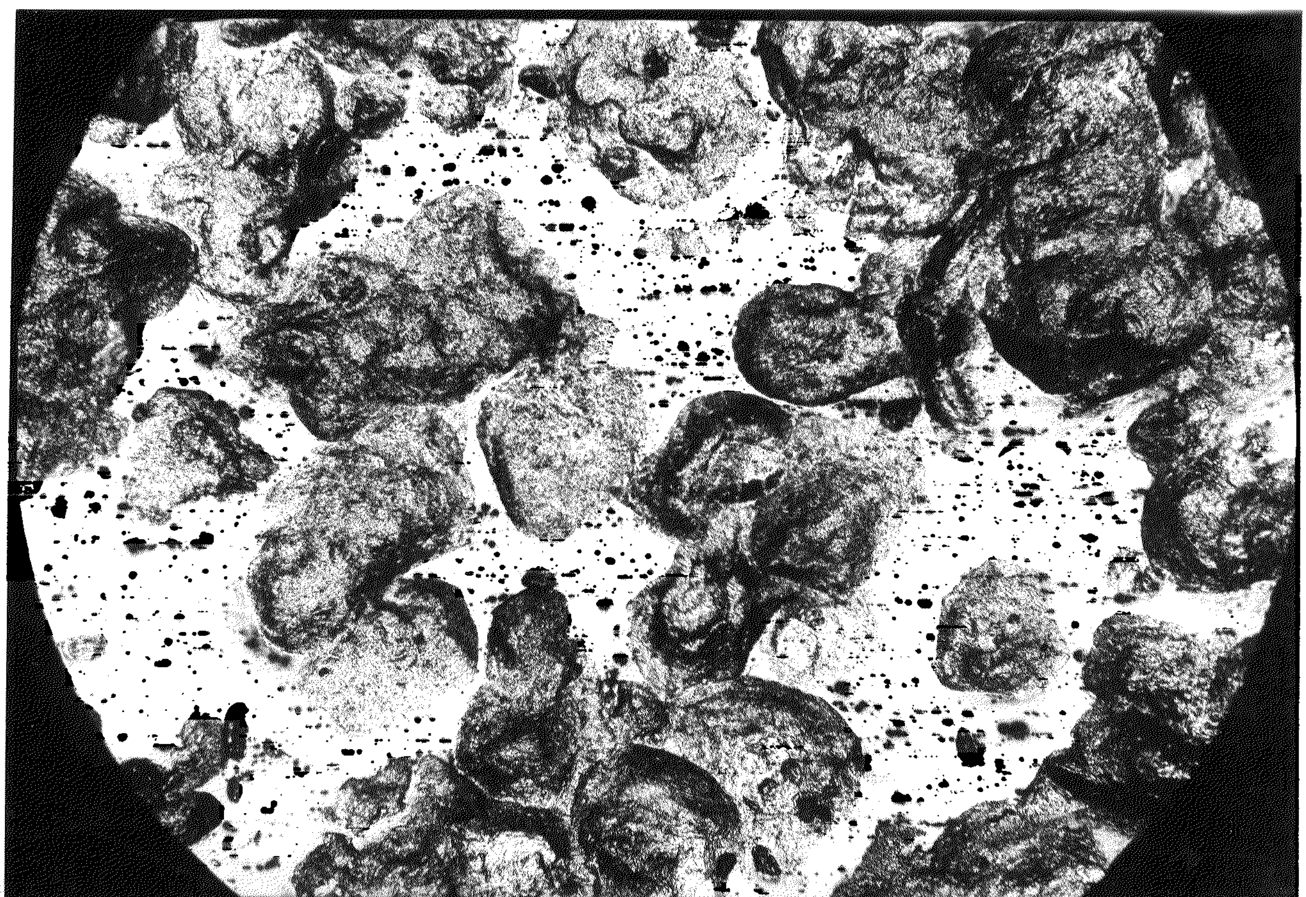
72.7% Coverage

Orifice Size --- 1/2 inches
Exposure Time -- 30 seconds
Shot Flow ------ 13.4 lbs./min.
Arc Height ----- 13.0 A-2



.3 - .7 =
.006" - .014"

X 50 NITAL



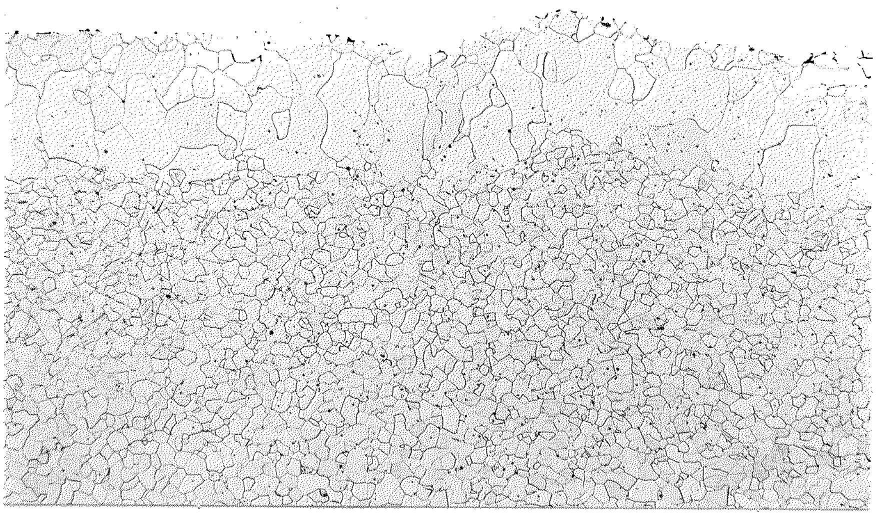
X 50 As Peened

Figure 10

.054 Cut Wire Shot

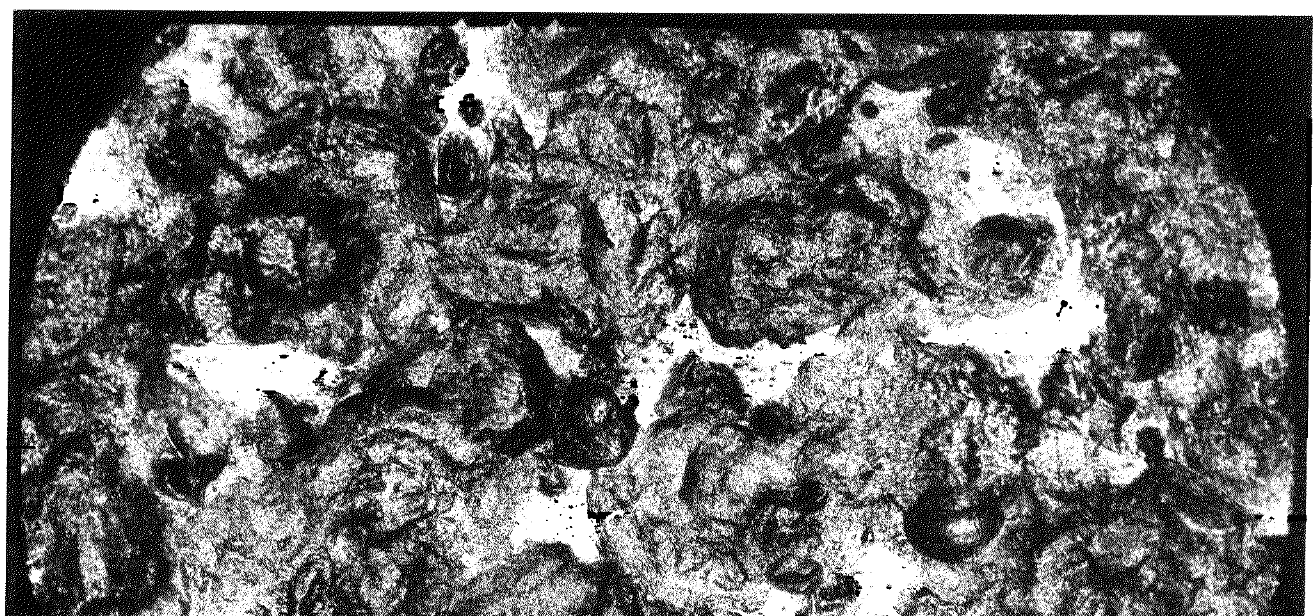
91.5% Coverage

Orifice Size ---	5/8 inches
Exposure Time --	30 seconds
Shot Flow ------	26.6 lbs./min.
Arc Height -----	21.0 A-2



.7 - .8 = .014" - .016"

X 50 NITAL



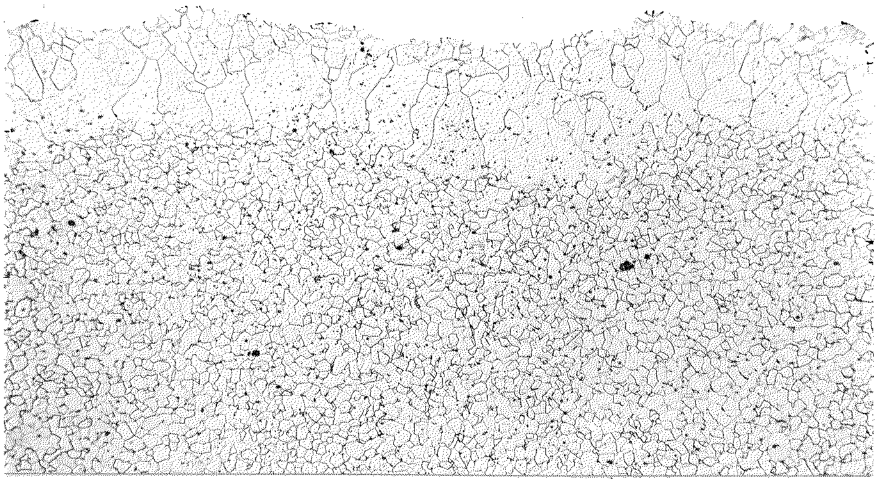
X 50 As Peened

Figure 11

.054 CUT WIRE SHOT

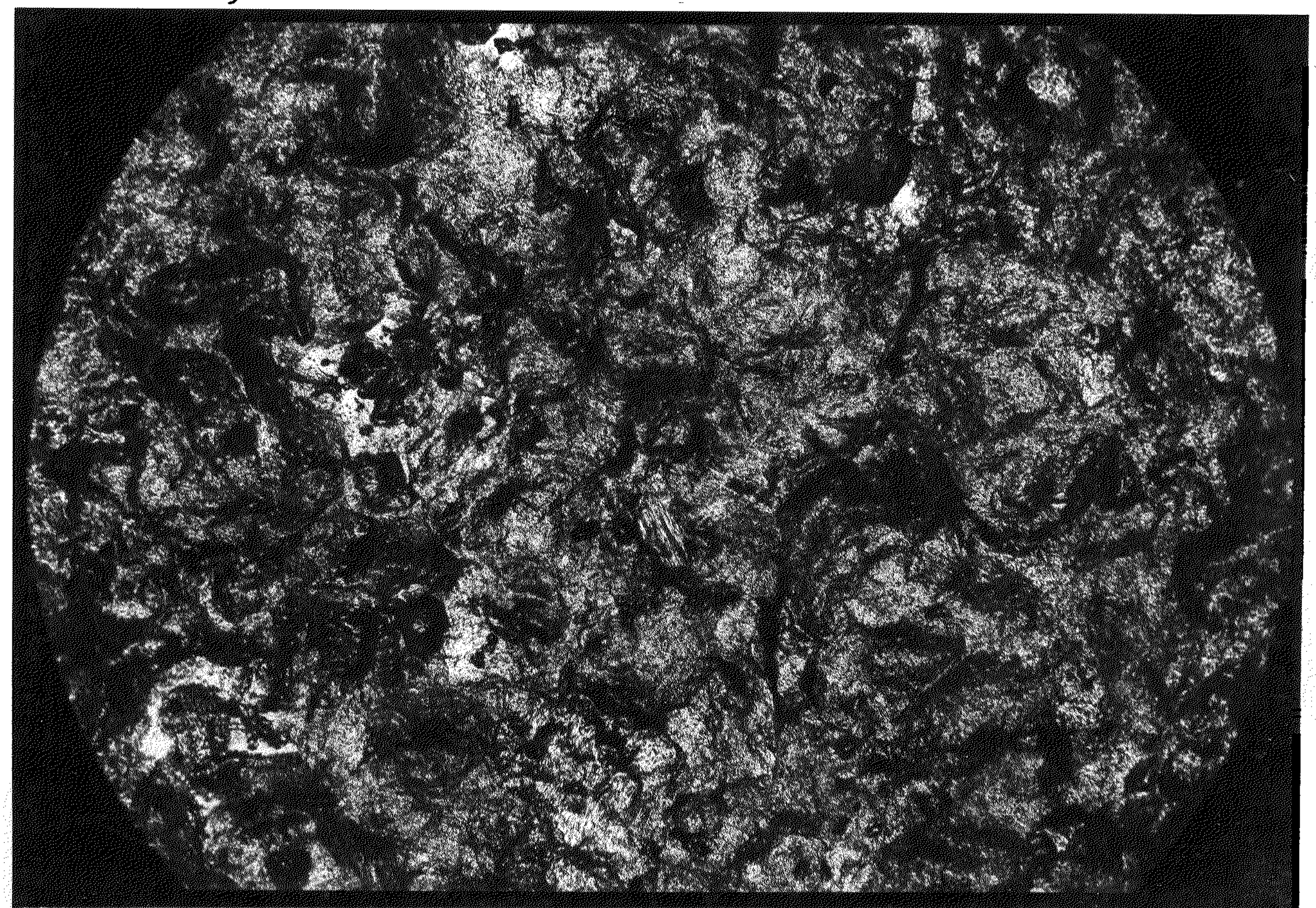
99+% COVERAGE

ORIFICE SIZE ---	3/4 INCHES
EXPOSURE TIME --	30 SECONDS
SHOT FLOW ------	45.8 LBS./MIN.
ARC HEIGHT -----	23.0 A-2



.6 - .8
.012 - .016

X 50 NITAL



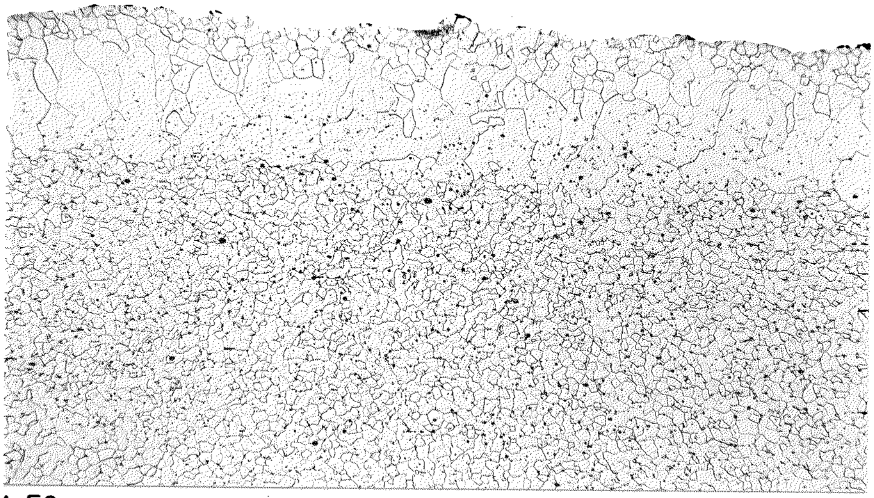
X 50 AS PEENED

FIGURE 12

.054 CUT WIRE SHOT

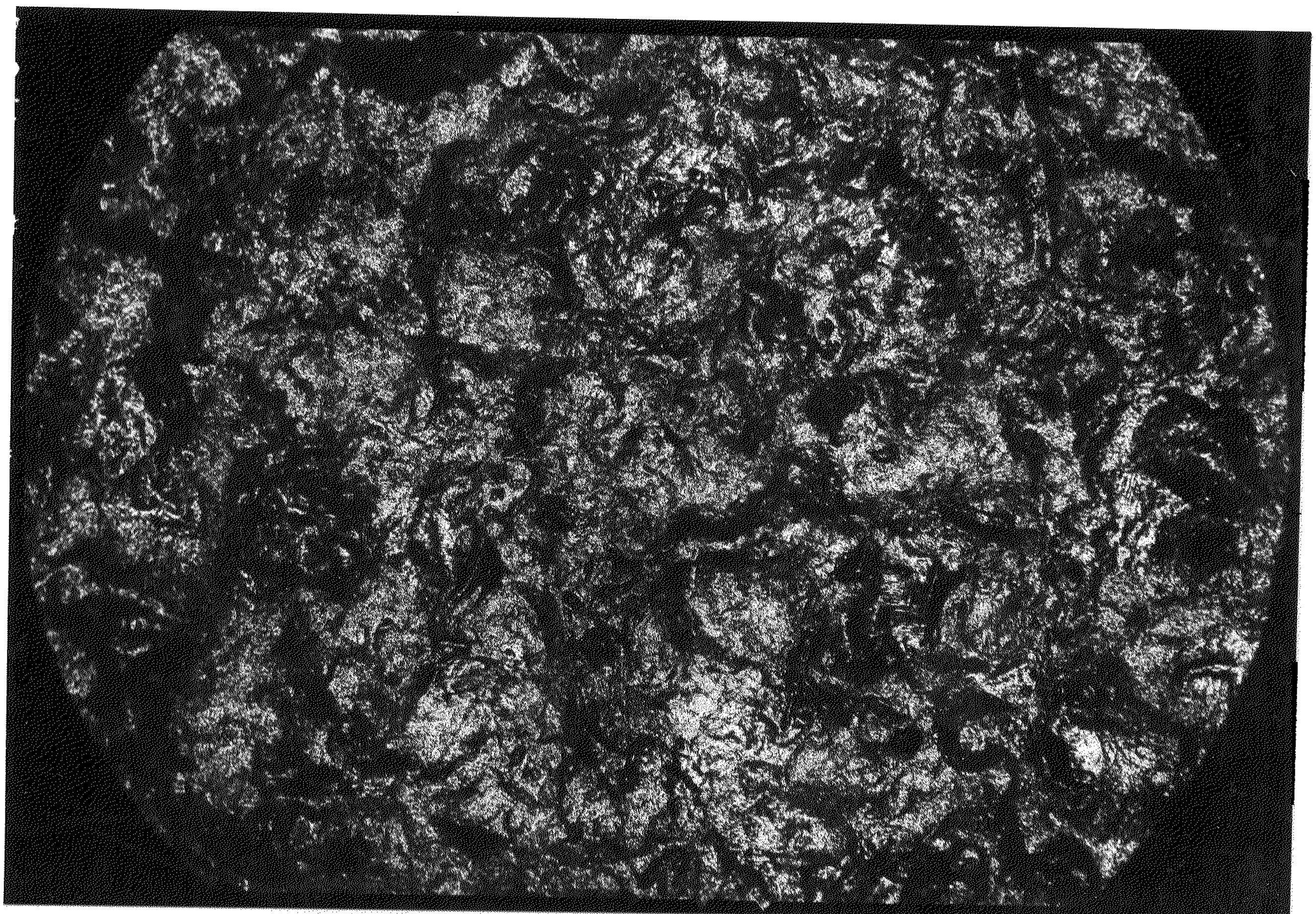
100% COVERAGE

ORIFICE SIZE ---	1 INCH
EXPOSURE TIME --	30 SECONDS
SHOT FLOW ------	104 LBS./MIN.
ARC HEIGHT -----	32.0 A-2



.7 -.8 =
.014" .016"

X 50 NITAL



X 50 AS PEENED

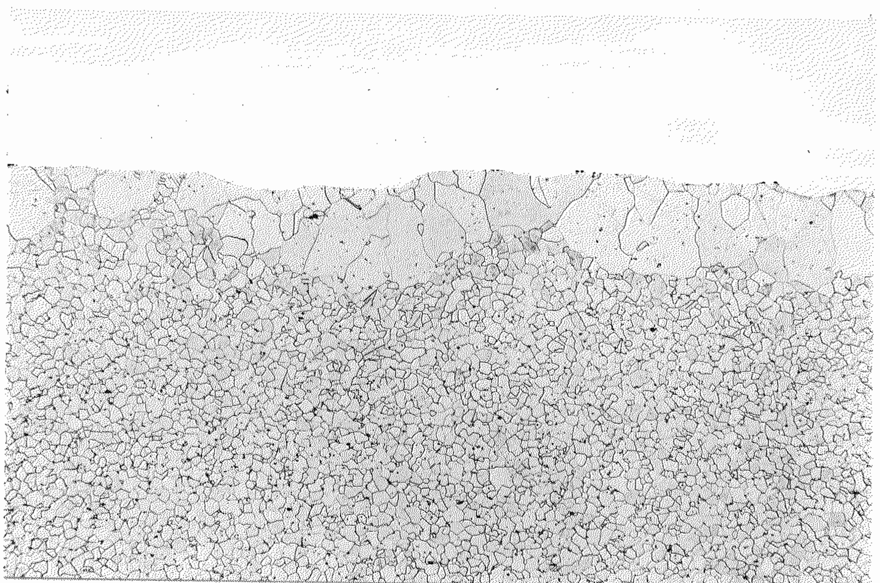
FIGURE 13

SAE-230 Chilled Iron Shot

45.5% Coverage

Orifice Size ---	3/8 inches
Exposure Time --	30 seconds 7.1 ?
Shot Flow ------	16.3 lbs./min.
Arc Height -----	15.0 A-2

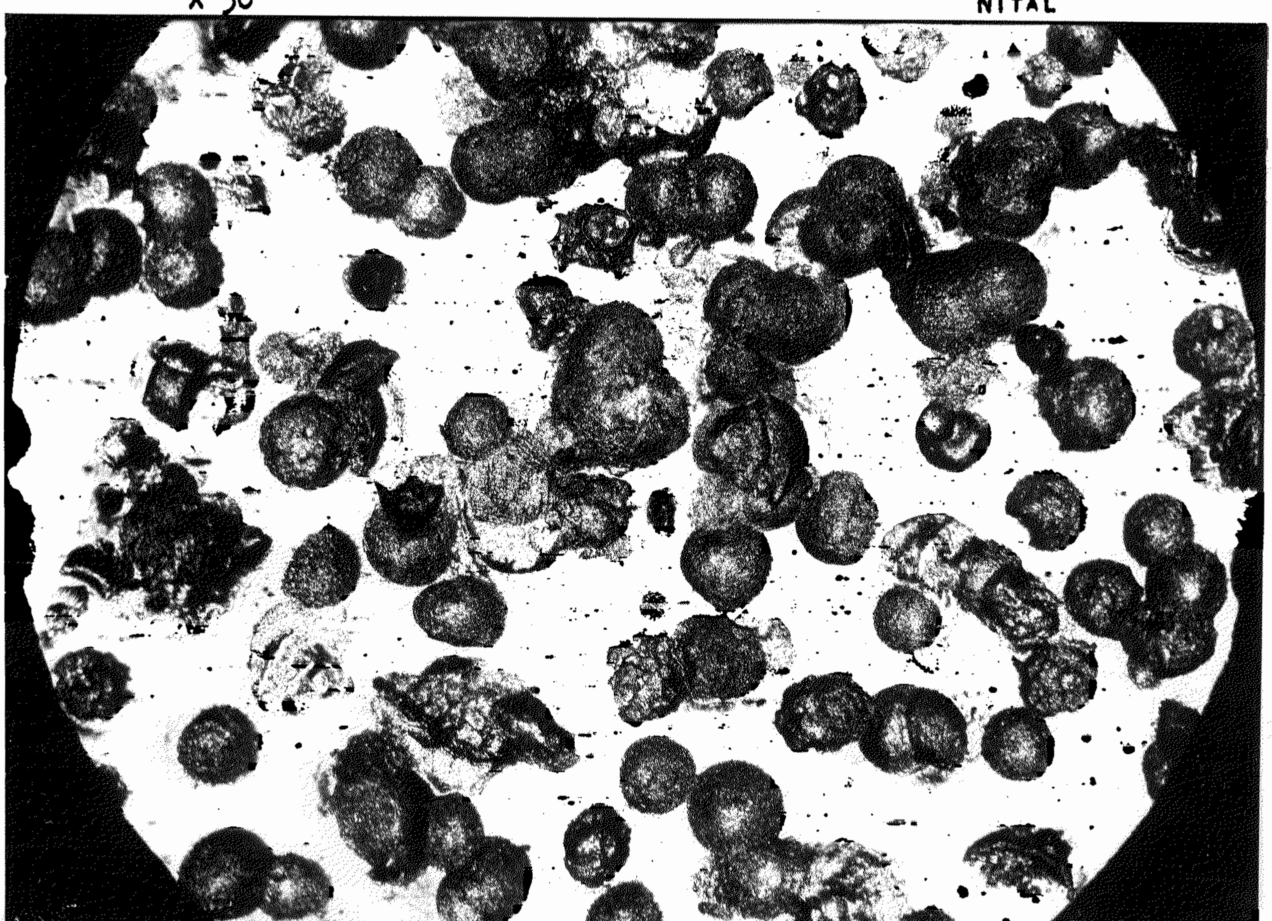
11A2 ?



0 - .6 =

0 - .012"

X 50 Nital



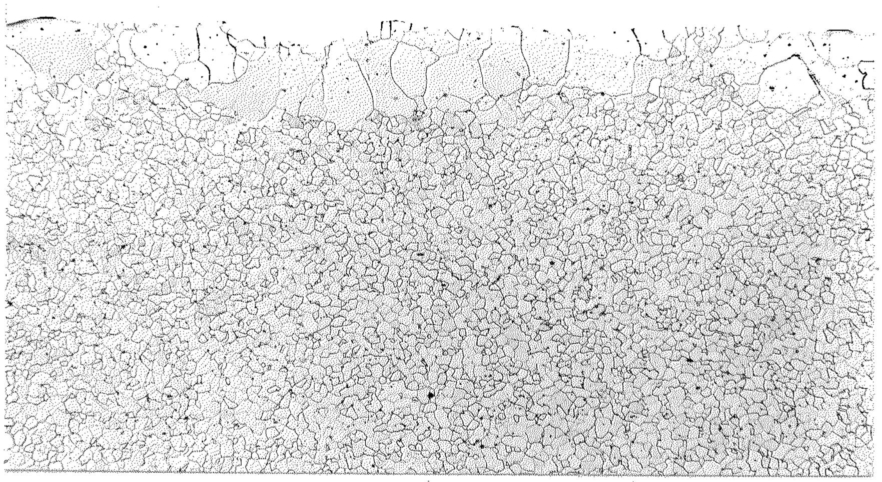
X 50 As Peened

Figure 14

SAE-230 Chilled Iron Shot

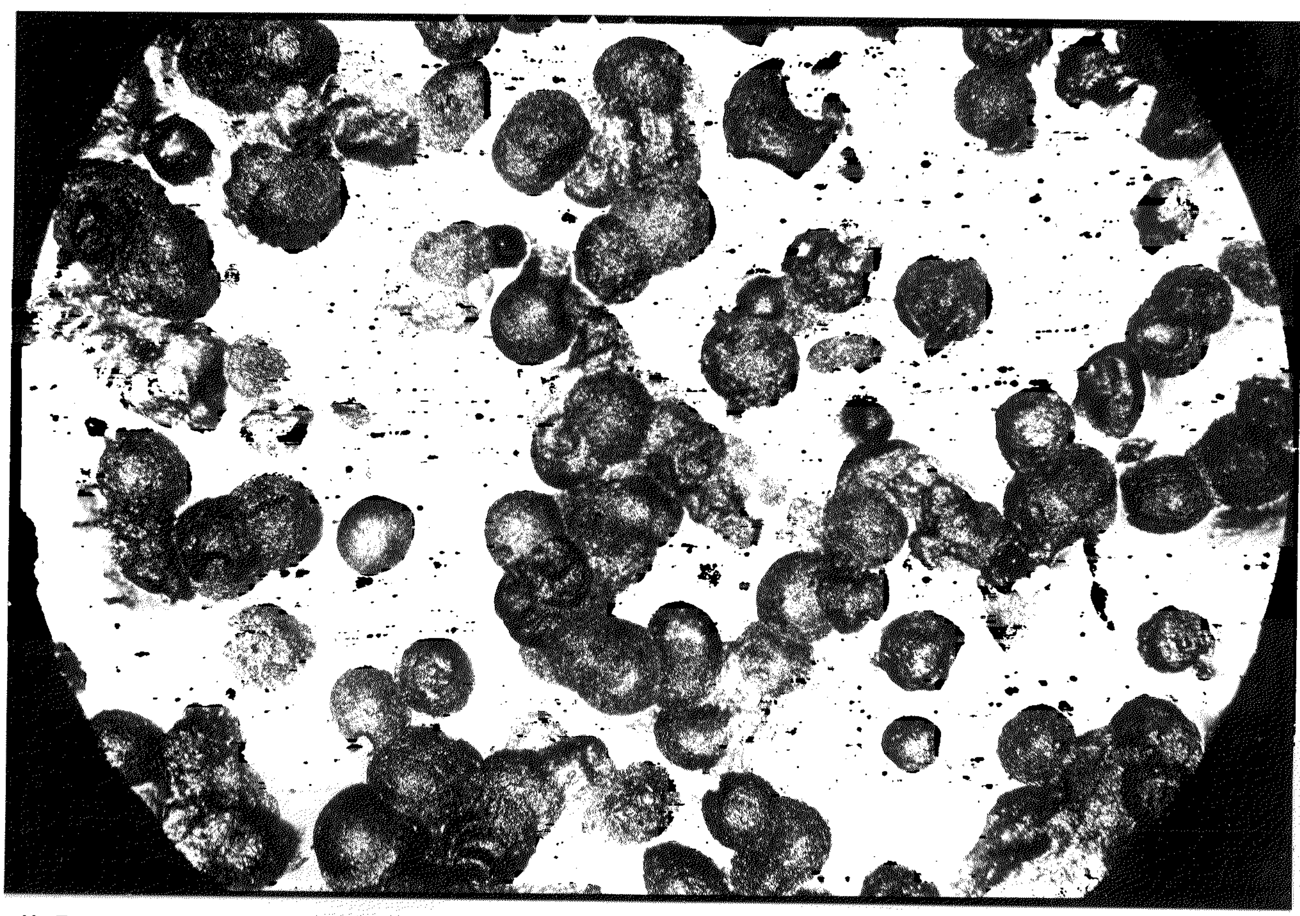
50.5% Coverage

Orifice Size ---	1/2 inches
Exposure Time --	30 seconds
Shot Flow ------	16.3 lbs./min.
Arc Height------	15.0 A-2



.2 - .5 =
.004" - .010"

X 50 NITAL



X 50 As Peened

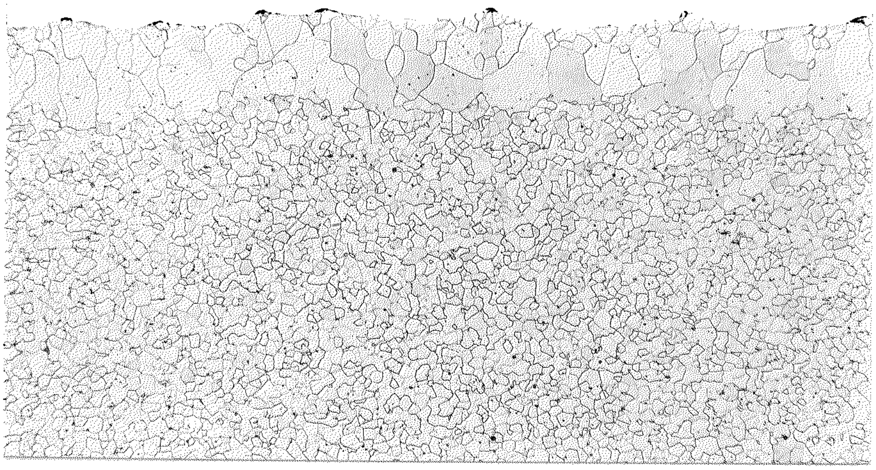
Figure 15

x 5

SAE-230 Chilled Iron Shot

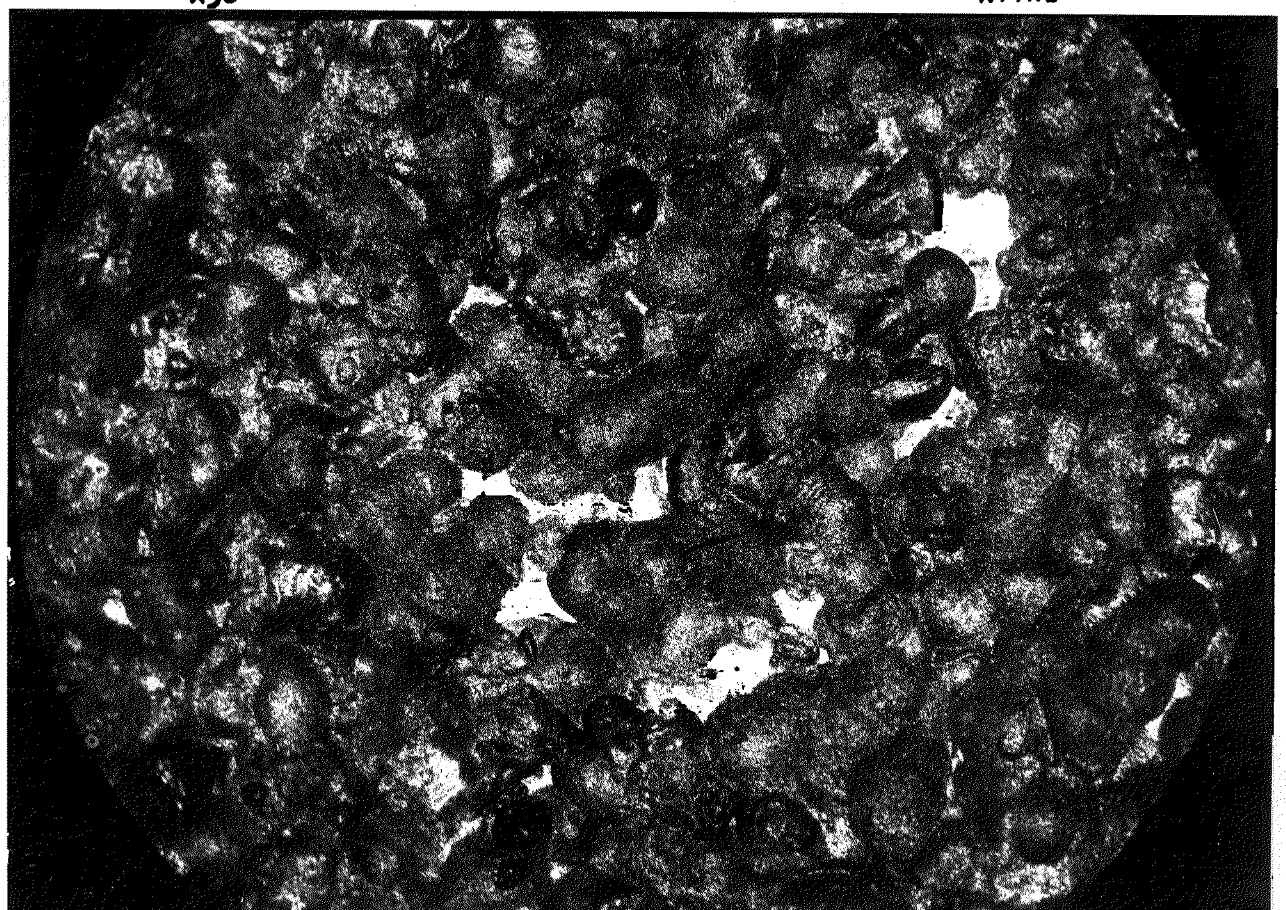
95.8% Coverage

Orifice Size-----	5/8 inches
Exposure Time----	30 seconds
Shot Flow--------	32.5 lbs./min.
Arc Height-------	19.0 A-2



.4 - .6 =
.008"-.012"

X50 NITAL



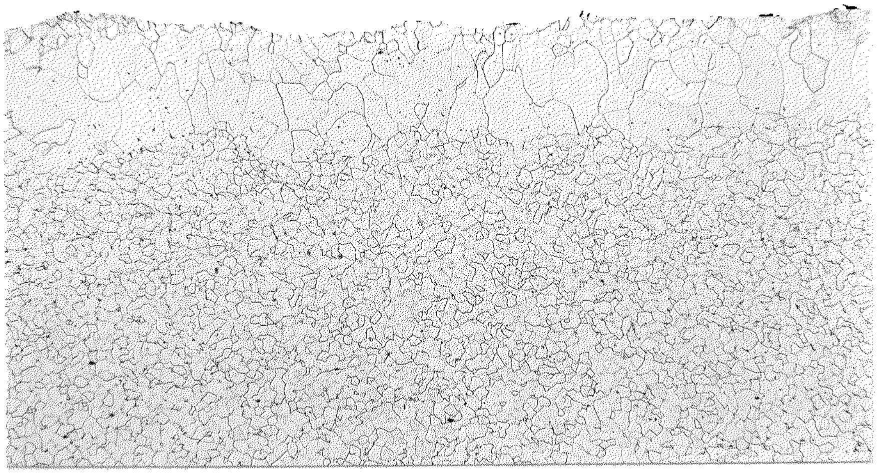
X 50 As Peened

Figure 16

SAE-230 Chilled Iron Shot

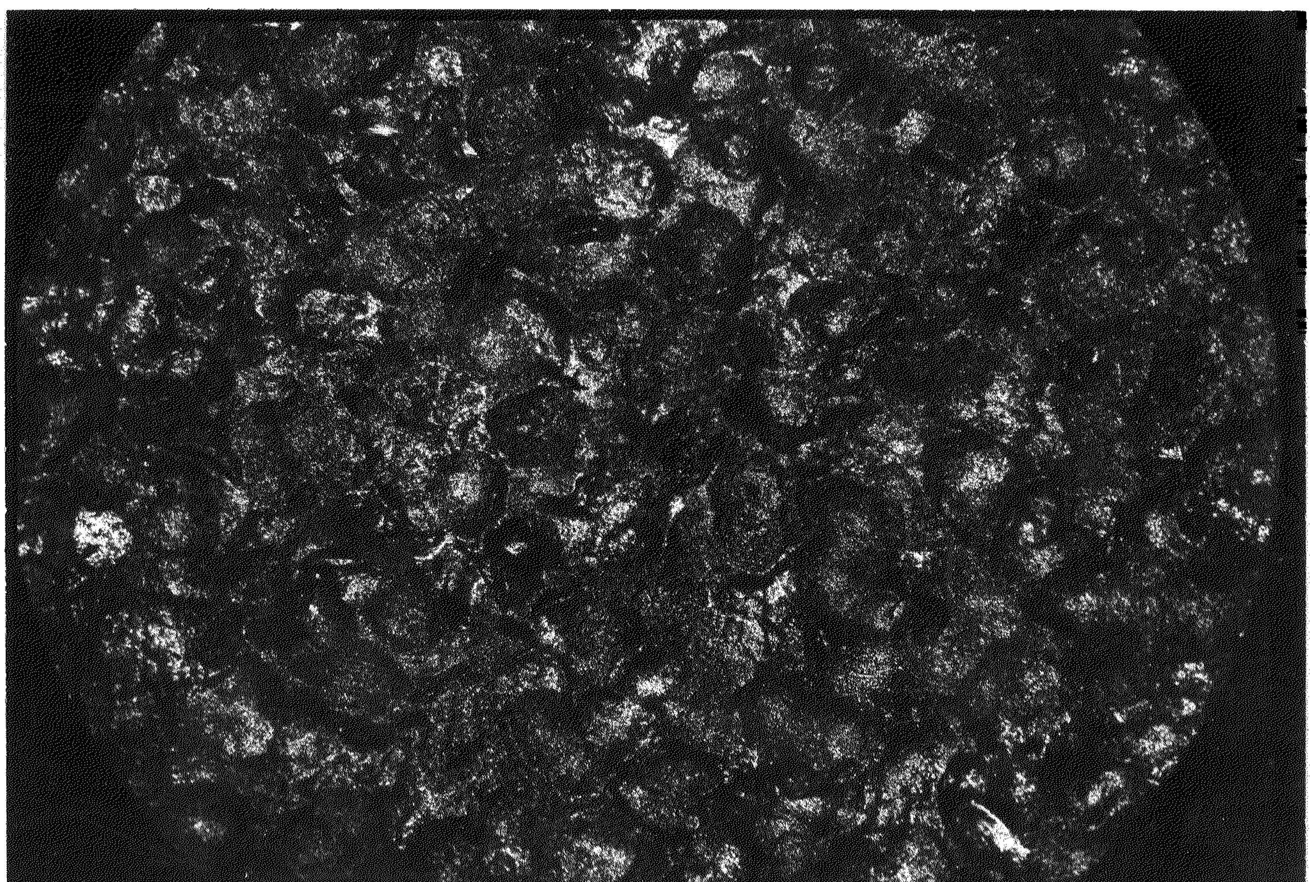
100% Coverage

Orifice Size ---	3/4 inches
Exposure Time --	30 seconds
Shot Flow ------	55.5 lbs./min.
Arc Height -----	20.0 A-2



.55 - .8 =
.011" - .016"

X 50 NITAL



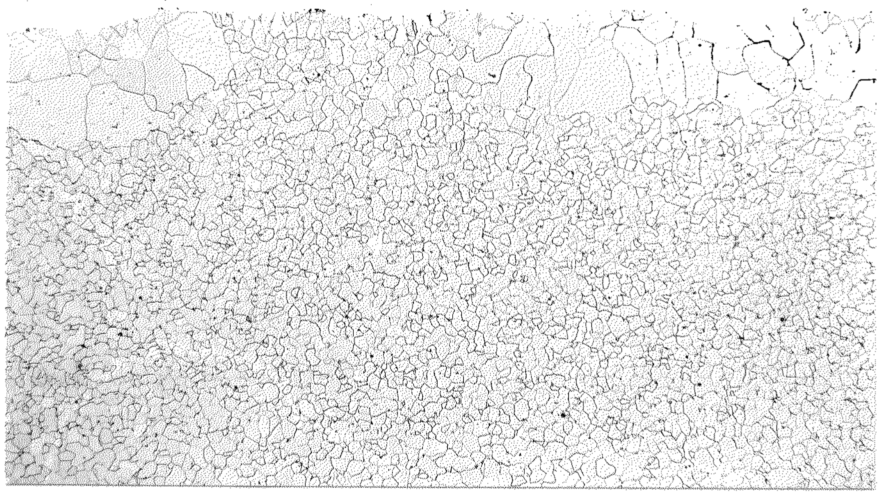
X 50 As Peened

Figure 17

SAE-330 CHILLED IRON SHOT

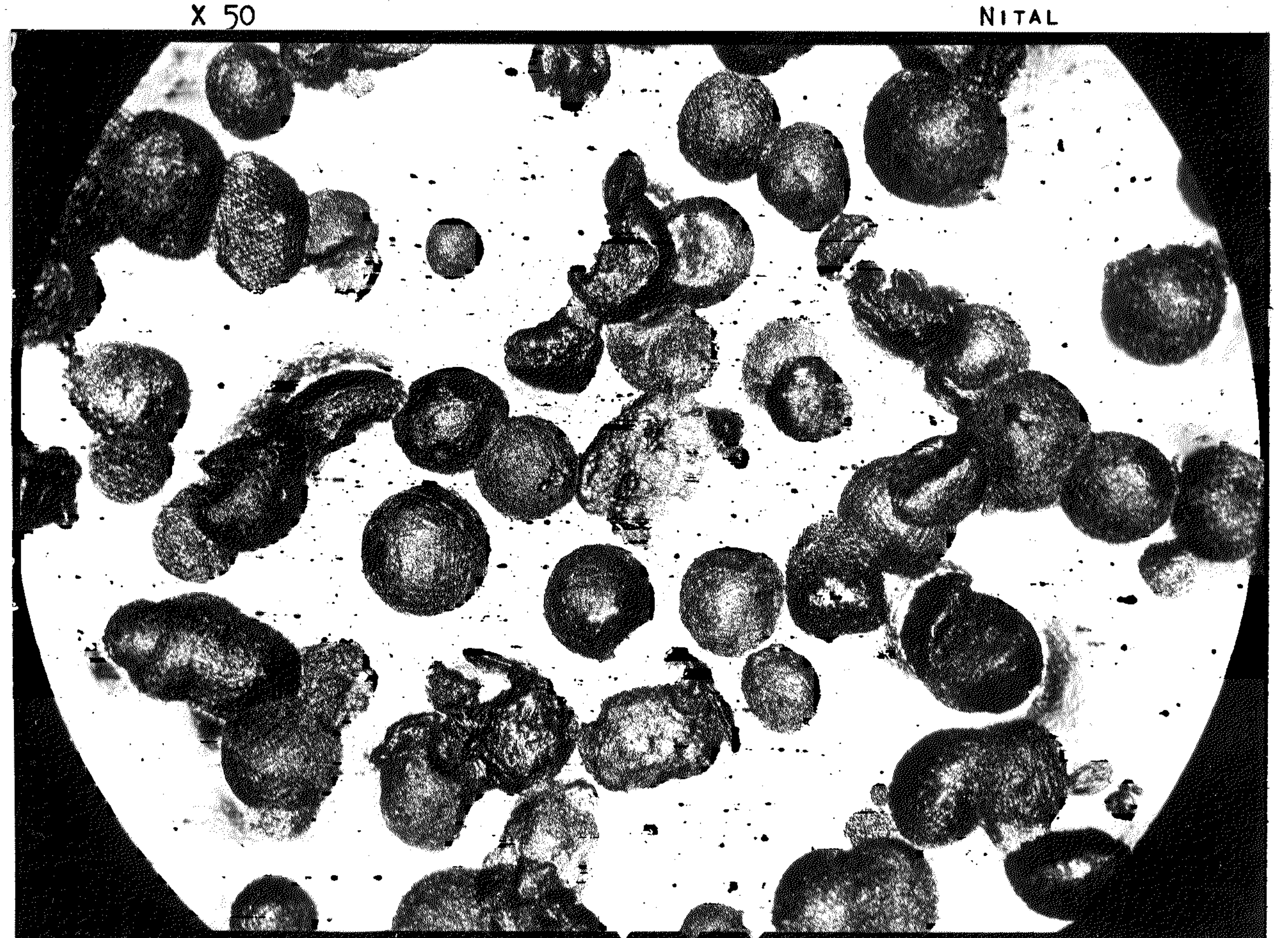
47.5% COVERAGE

ORIFICE SIZE ----	3/8 INCHES
EXPOSURE TIME ---	30 SECONDS
SHOT FLOW -------	6.7 LBS./MIN.
ARC HEIGHT ------	16.0 A-2



0 - .7 =
0 - .014"

X 50 NITAL



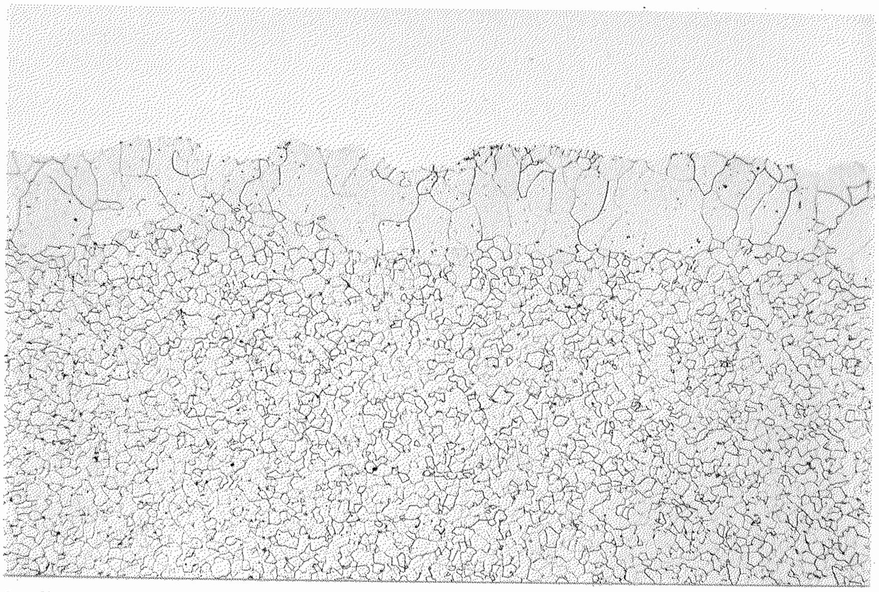
X 50 AS PEENED

FIGURE 18

SAE-330 CHILLED IRON SHOT

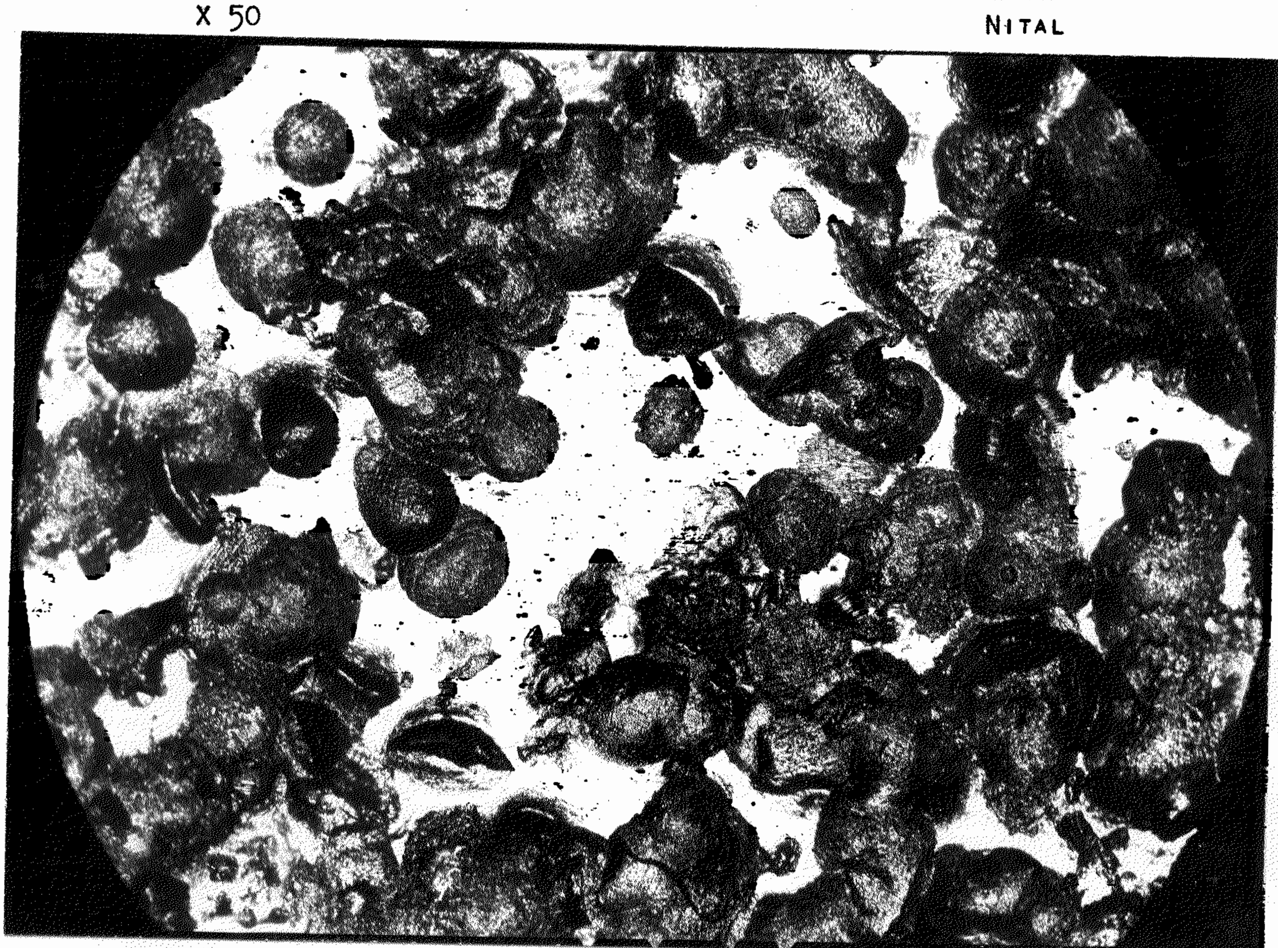
81.0% COVERAGE

ORIFICE SIZE ---	1/2 INCHES
EXPOSURE TIME --	30 SECONDS
SHOT FLOW ------	15.1 LBS./MIN.
ARC HEIGHT -----	20.0 A-2



.2 - .5 =
.004" - .010"

X 50 NITAL



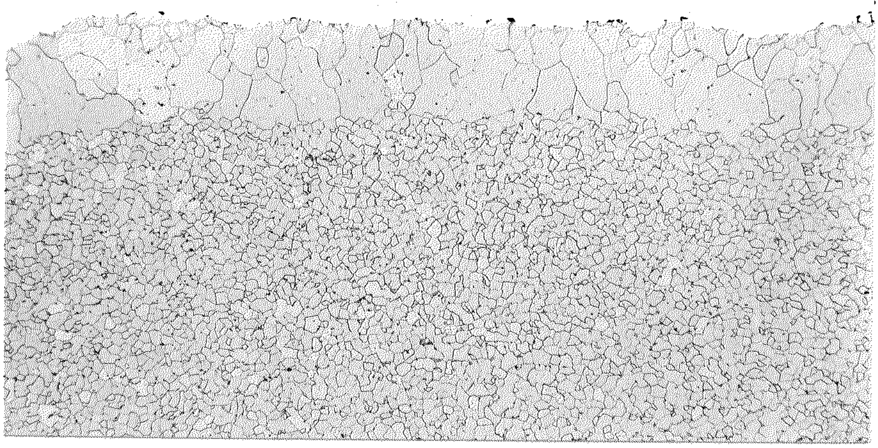
X 50 AS PEENED

FIGURE 19

SAE-330 CHILLED IRON SHOT

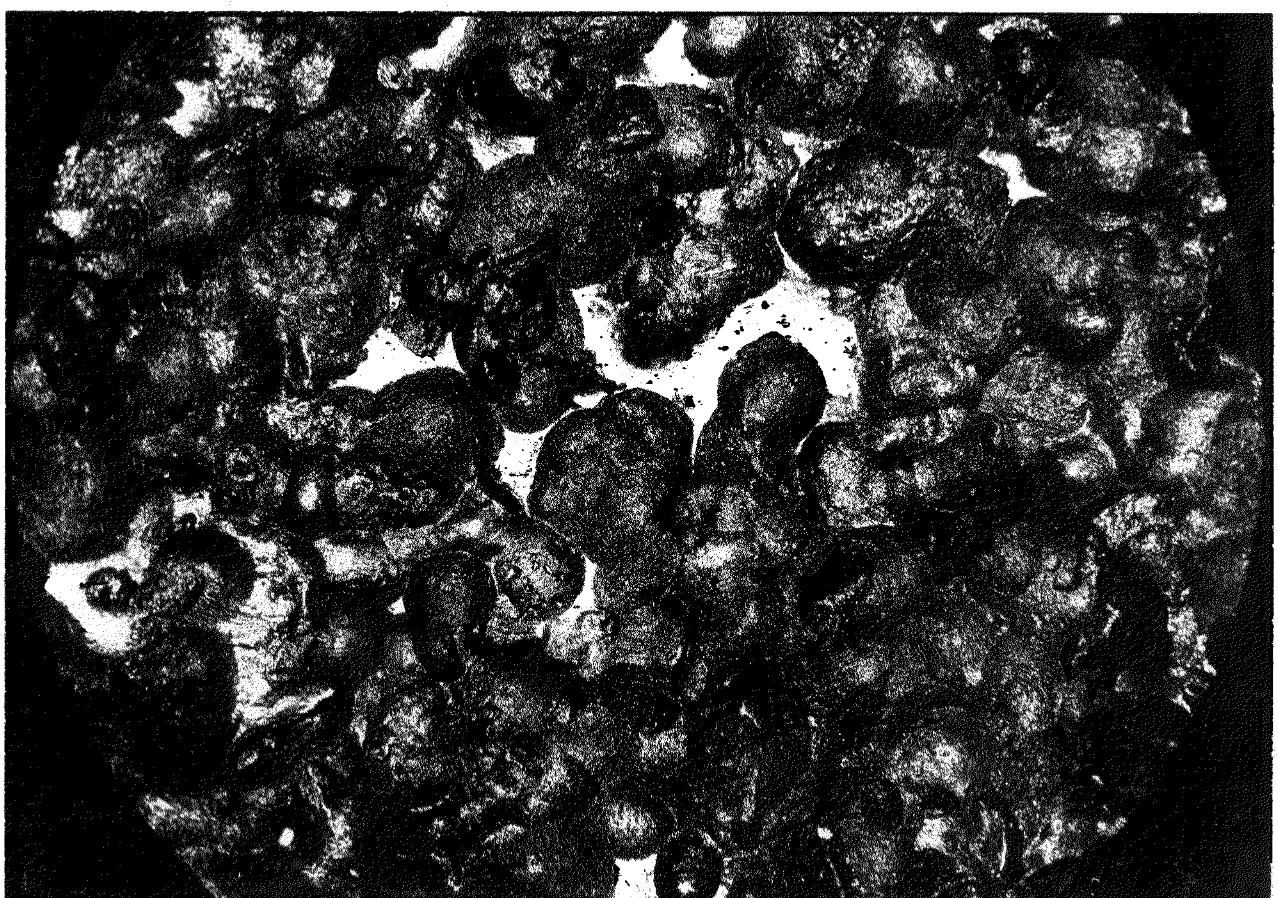
94.3% COVERAGE

ORIFICE SIZE ---- 5/8 INCHES
EXPOSURE TIME --- 30 SECONDS
SHOT FLOW ------- 29.9 LBS./MIN.
ARC HEIGHT ------ 25.0 A-2



.4 - .6 =
.008" - .012"

X 50 NITAL



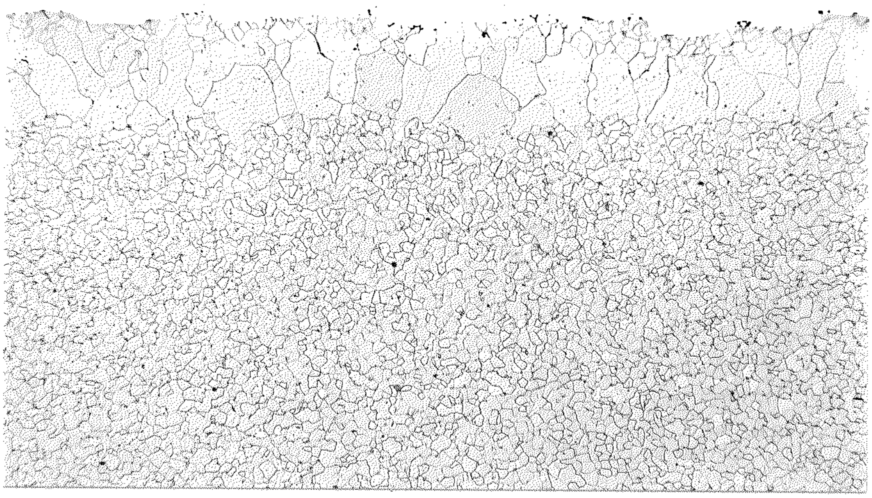
X 50 AS PEENED

FIGURE 20

SAE-330 Chilled Iron Shot

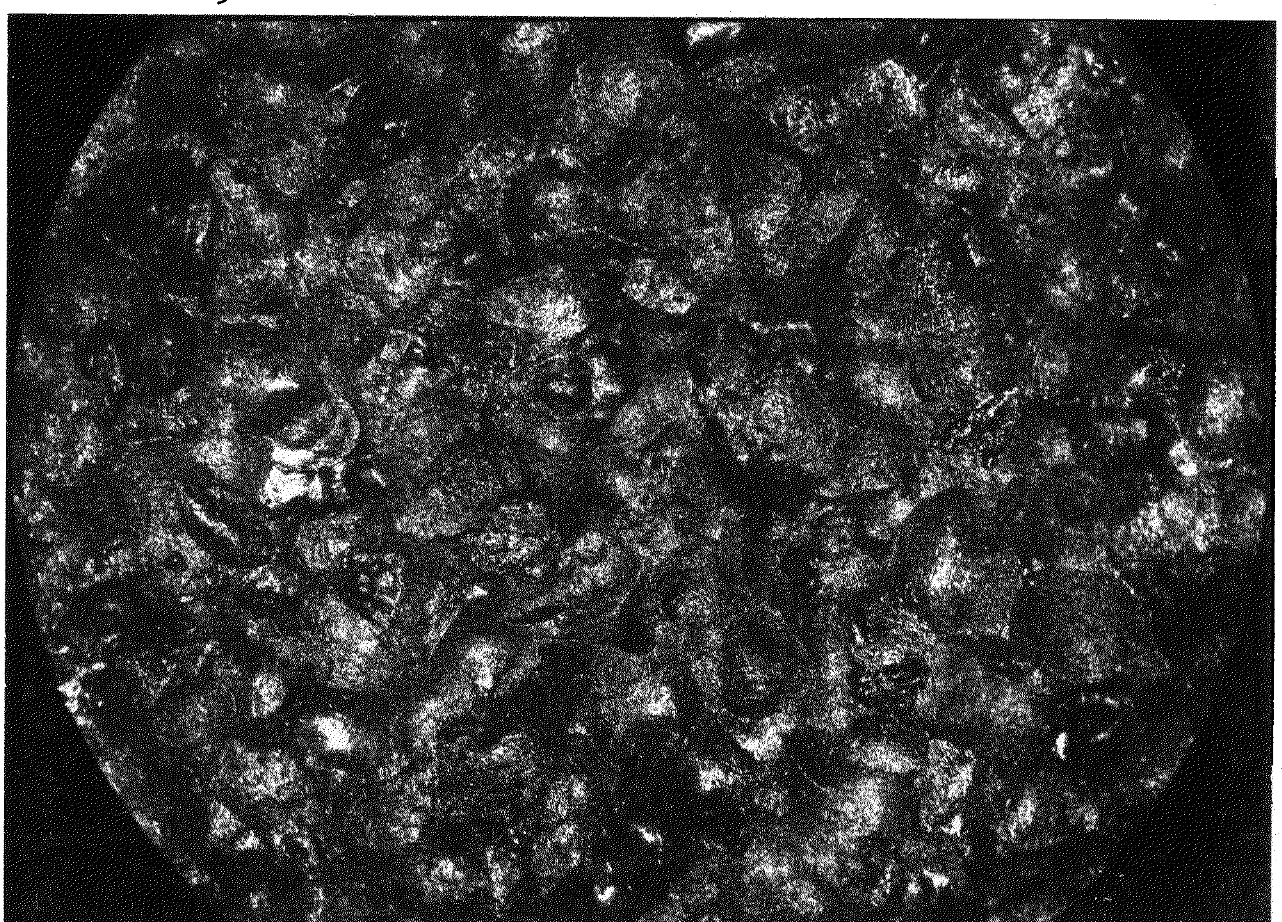
100% Coverage

Orifice Size ---	3/4 inches
Exposure Time --	30 seconds
Shot Flow ------	51.4 lbs./min.
Arc Height -----	28.5 A-2



.45 - .7
.009" - .014"

X 50 Nital



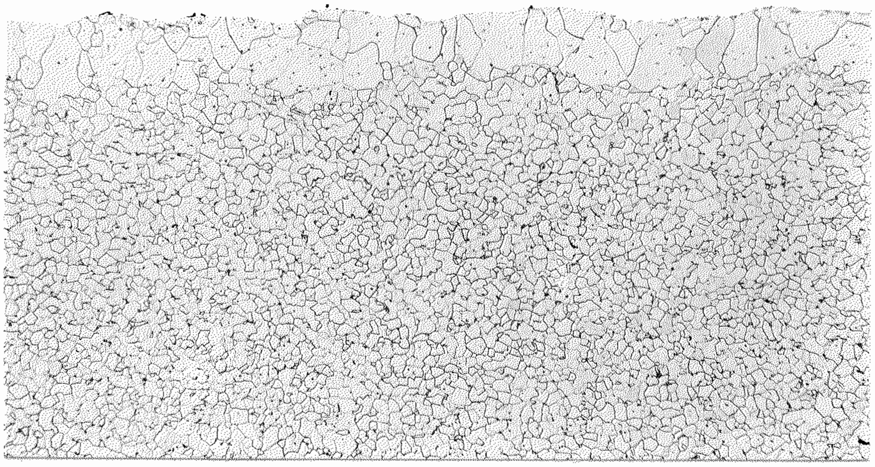
X 50 As Peened

Figure 21

SAE-170 CAST STEEL SHOT

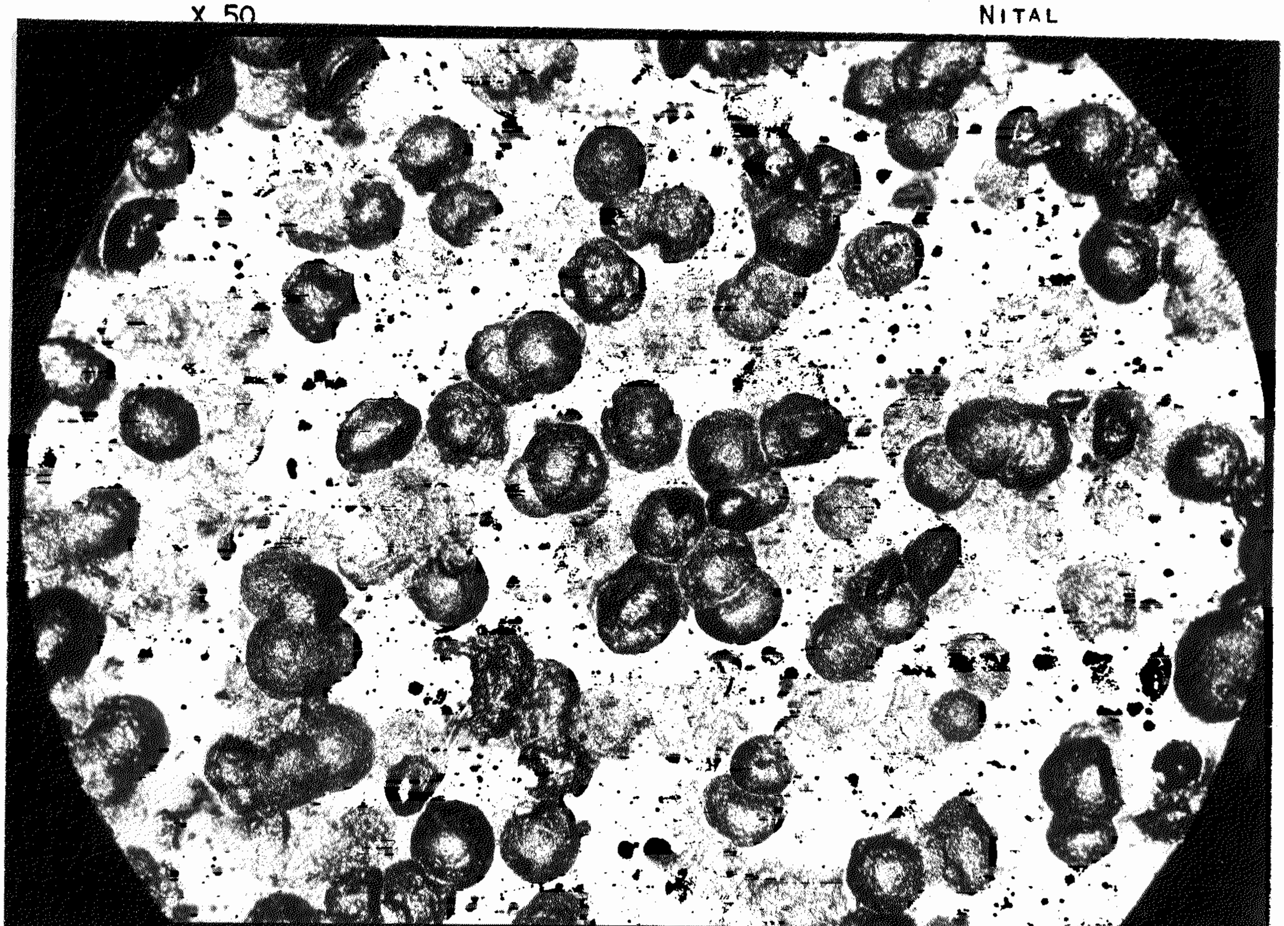
31.6% COVERAGE

ORIFICE SIZE ---	3/8 INCH
EXPOSURE TIME --	30 SECONDS
SHOT FLOW ------	7.6 LBS./MIN.
ARC HEIGHT -----	11.0 A-2



.2-.5 =
.004"-.010"

X 50 NITAL



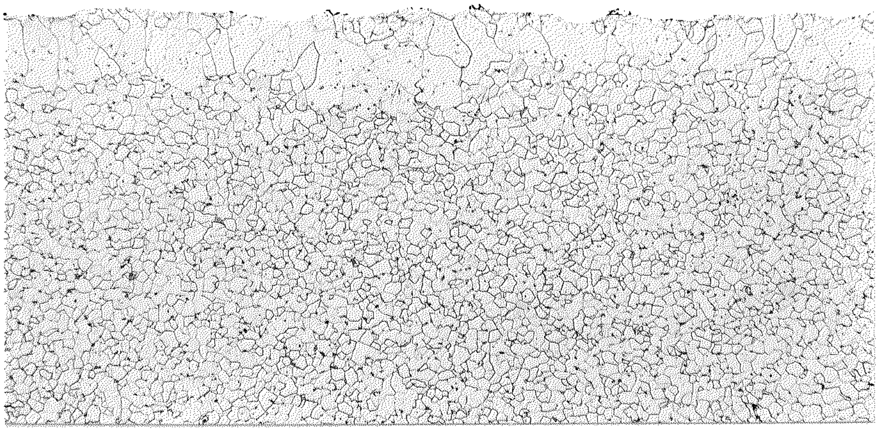
X 50 AS PEENED

FIGURE 22

SAE-170 CAST STEEL SHOT

84.5% COVERAGE

ORIFICE SIZE---- 1/2 INCH
EXPOSURE TIME -- 30 SECONDS
SHOT FLOW ------ 17.3 LBS./MIN.
ARC HEIGHT ----- 17.0 A-2



.35-.5 =
.007" - .010"

X 50 NITAL

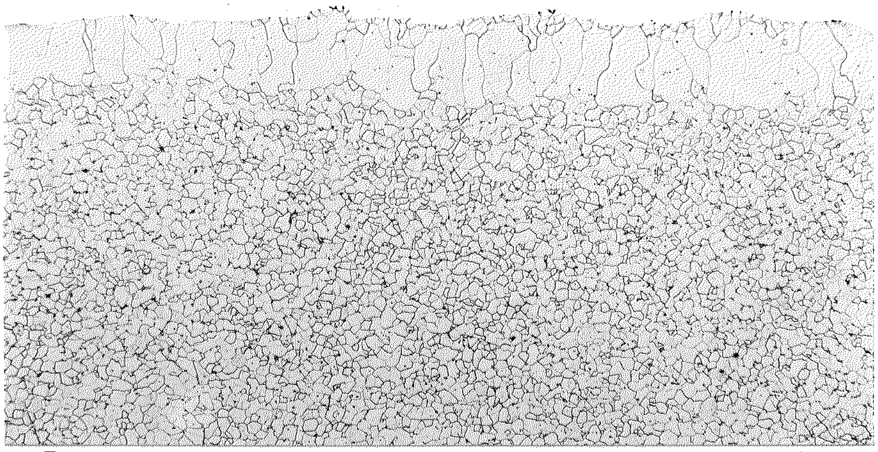
X 50 AS PEENED

FIGURE 23

SAE-170 Cast Steel Shot

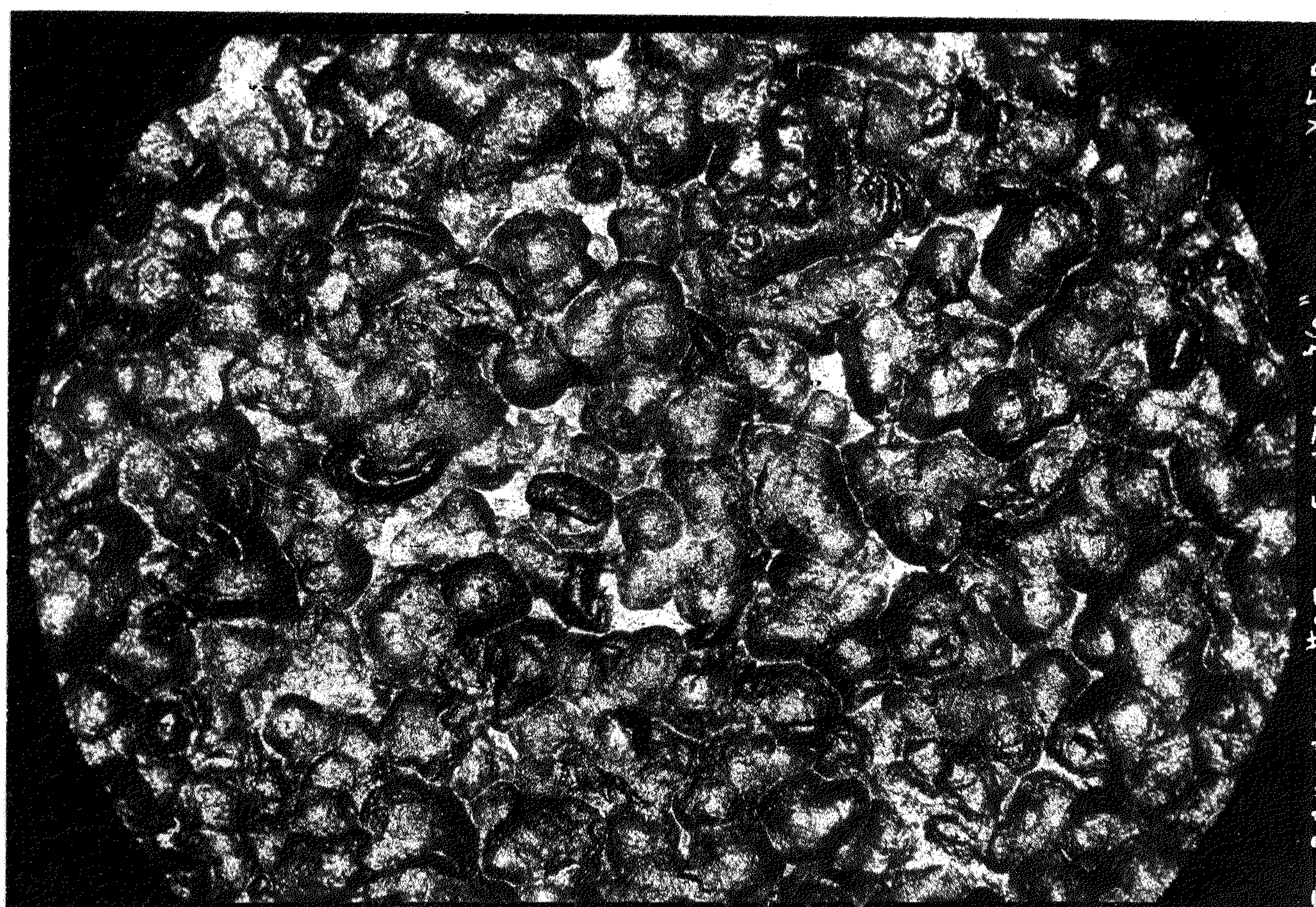
97.5% Coverage

Orifice Size ---	5/8 inches
Exposure Time --	30 seconds
Shot Flow ------	34.4 lbs./min.
Arc Height -----	18.5 A-2



.3-.5=
.006-.010"

X 50 NITAL



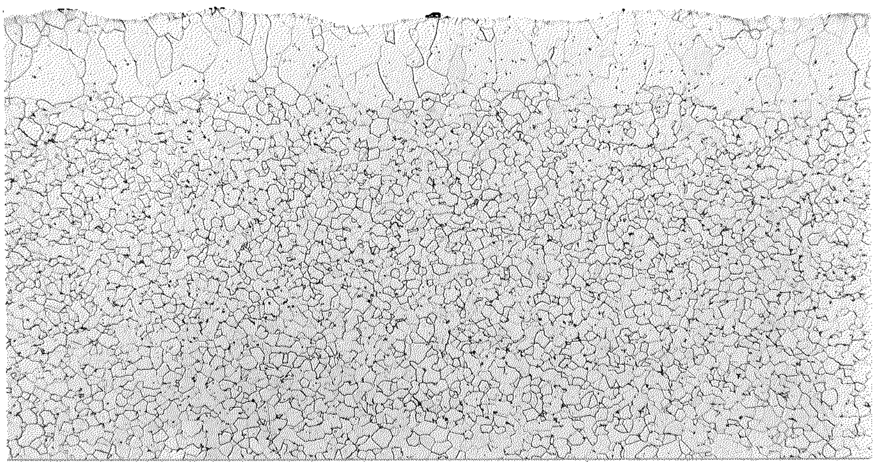
X 50 AS PEENED

FIGURE 24

SAE-170 Cast Steel Shot

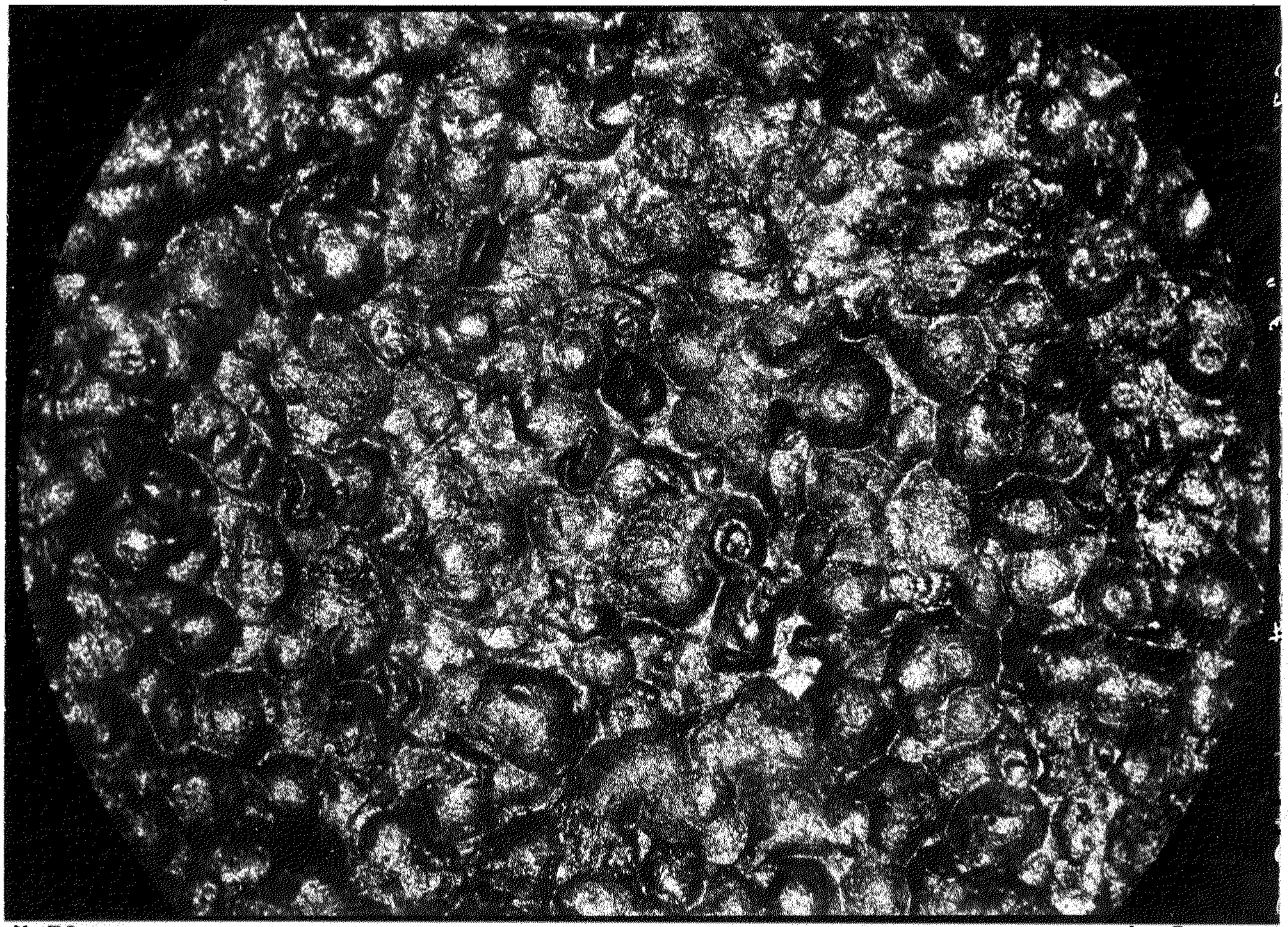
100% Coverage

Orifice Size ---	3/4 inches
Exposure Time --	30 seconds
Shot Flow ------	59.1 lbs./min.
Arc Height -----	20.0 A-2



.5-.6 = .010"-.012"

X 50 NITAL



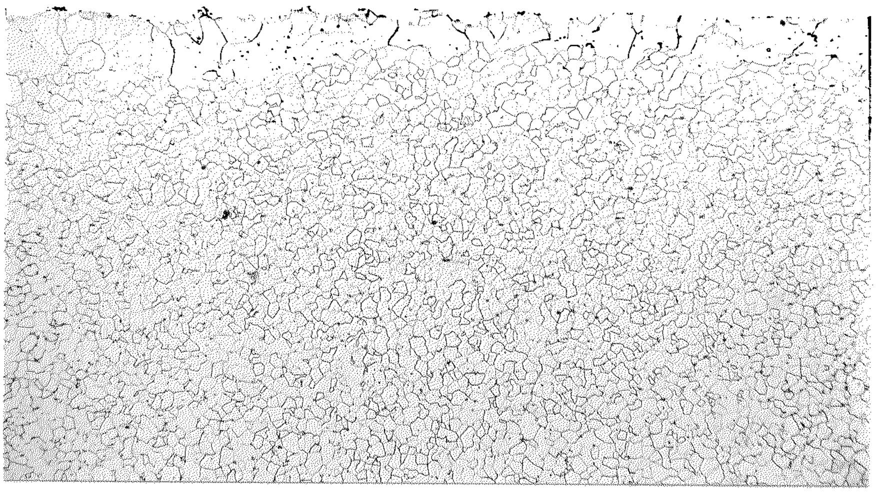
X 50 As Peened

Figure 25

G-50 GRIT

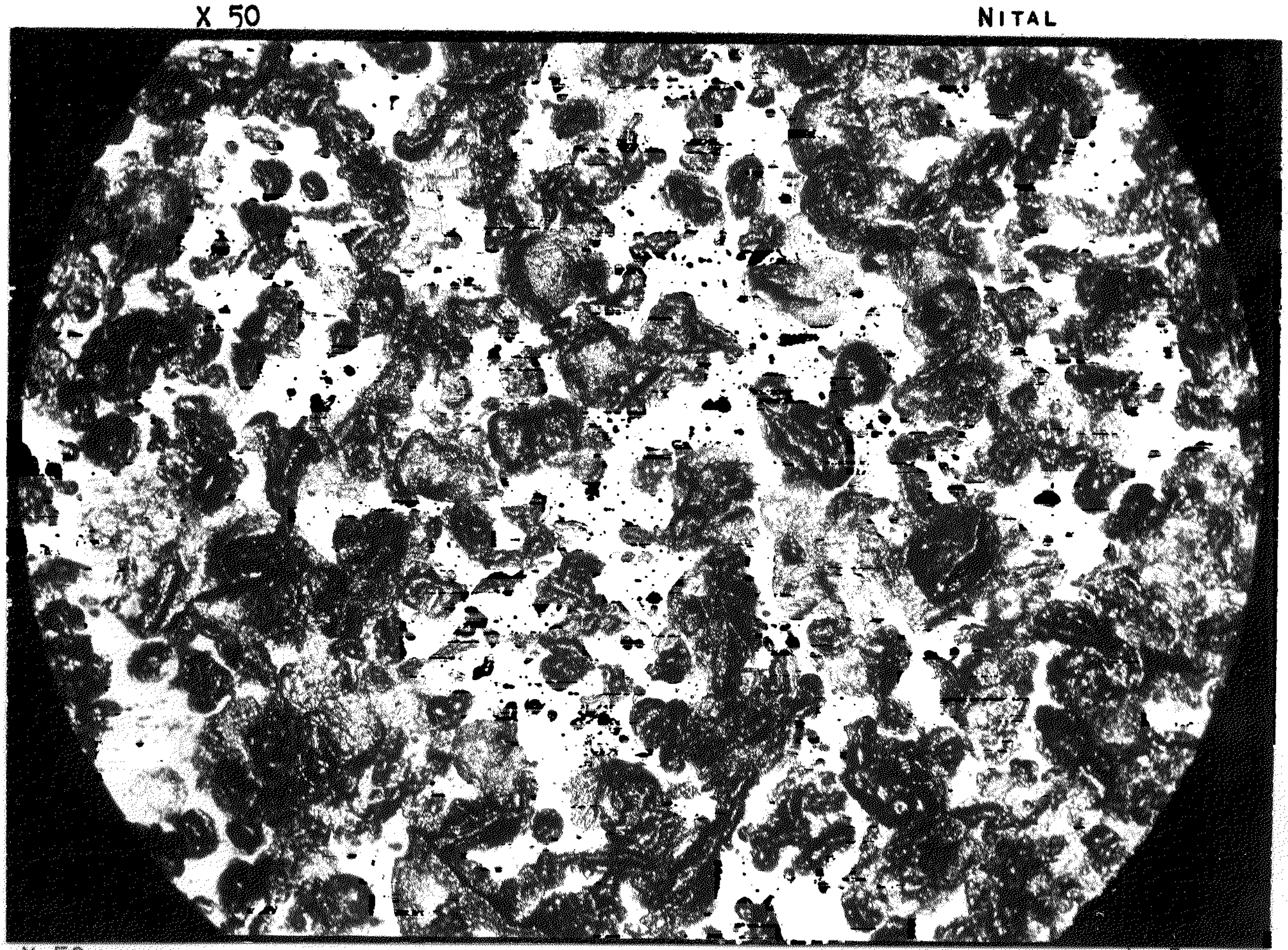
55.4% COVERAGE

ORIFICE SIZE ---- 3/8 INCHES
EXPOSURE TIME --- 30 SECONDS
SHOT FLOW ------- 7.4 LBS./MIN.
ARC HEIGHT ------ 8.0 A-2



.25-.4 =
.005-.008"

X 50 NITAL



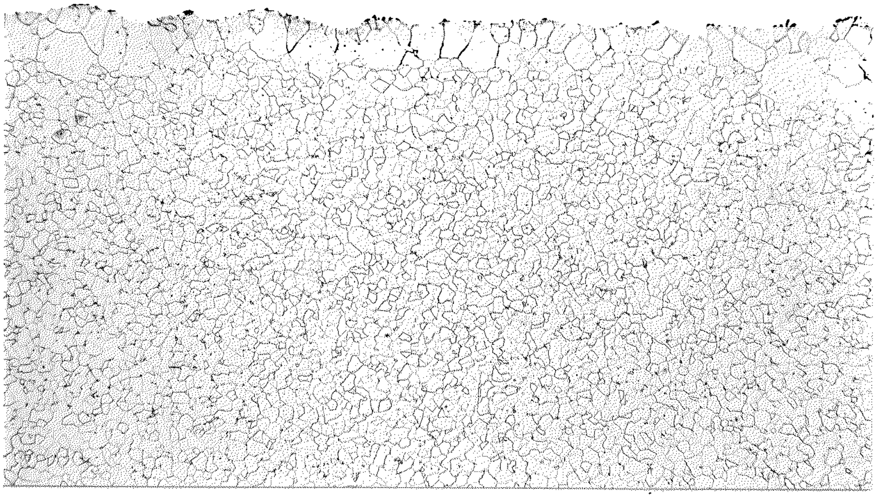
X 50 AS PEENED

FIGURE 26

G-50 GRIT

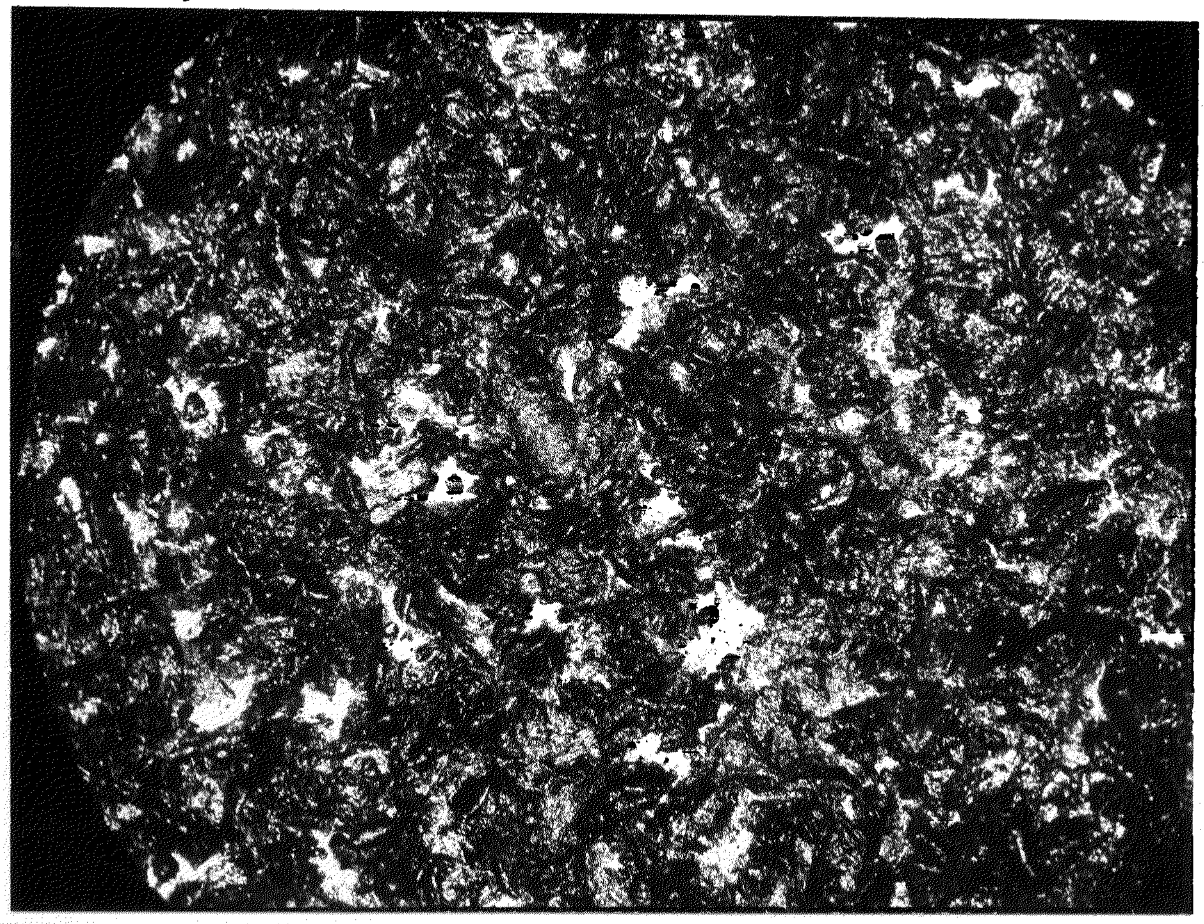
96.5% COVERAGE

ORIFICE SIZE ---	1/2 INCHES
EXPOSURE TIME --	30 SECONDS
SHOT FLOW ------	16.8 LBS./MIN.
ARC HEIGHT -----	13.0 A-2



.2 - .4 =
.004" .008"

X 50 NITAL



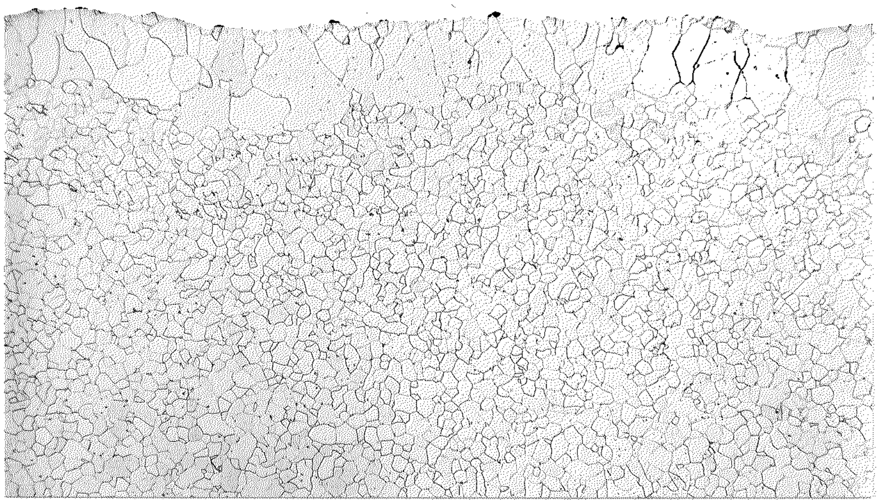
X 50 AS PEENED

FIGURE 27

G-50 GRIT

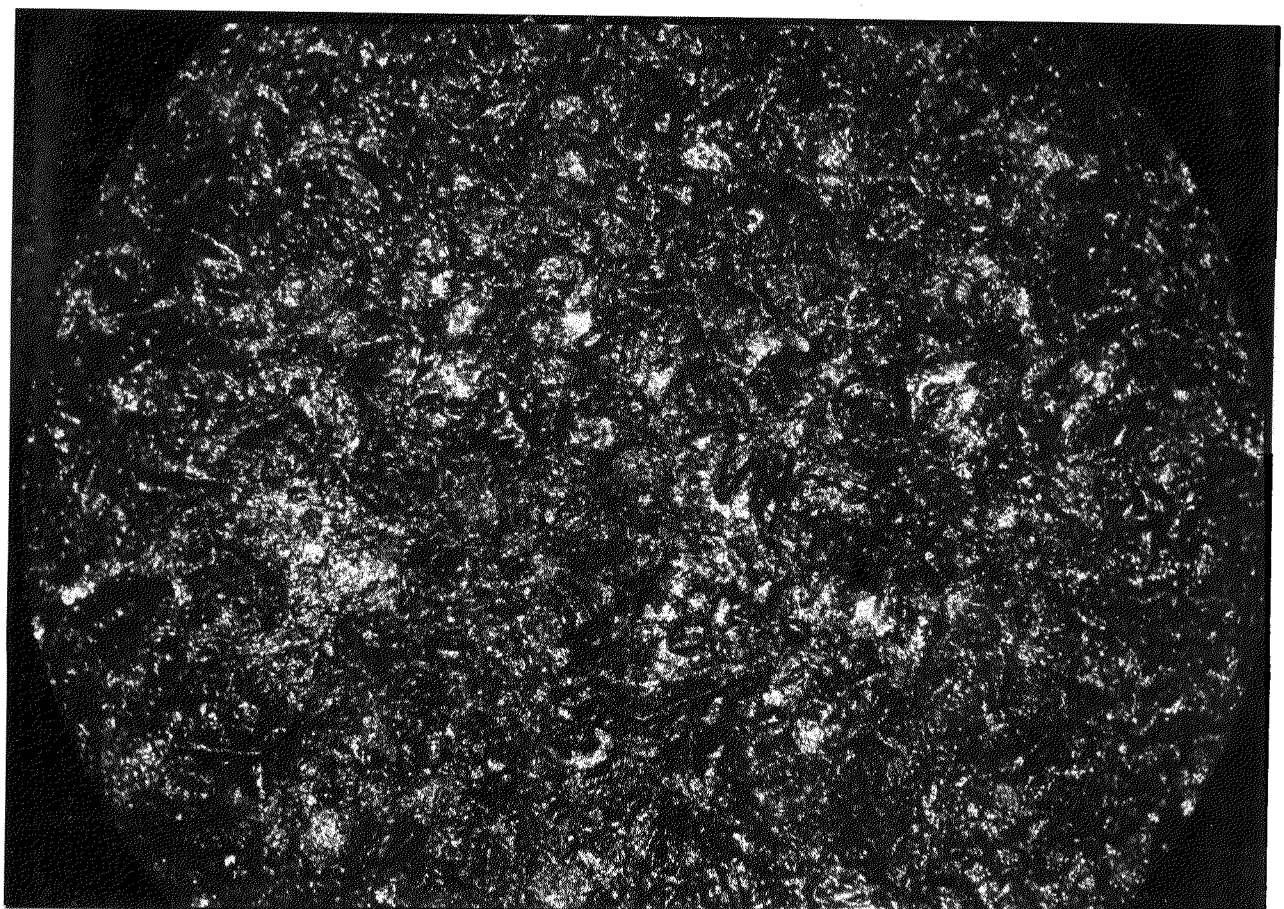
100% COVERAGE

ORIFICE SIZE ---	3/4 INCHES
EXPOSURE TIME --	30 SECONDS
SHOT FLOW ------	57.0 LBS./MIN.
ARC HEIGHT------	16.0 A-2



.35 - .6 =
.007" - .012"

X 50 NITAL



X 50 AS PEENED

FIGURE 28