

SHOT PEENING APPLICATIONS AND TECHNIQUES IN THE AIRCRAFT INDUSTRY

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Aeronautical Materials Specification 2430 covering shot peening was first issued in September 1943. The general requirements of this specification can be summarized briefly.

When this specification appears on a drawing, the part is peened all over except in small holes or cavities which are inaccessible to the shot, unless specific areas are indicated. The phrase "peening optional" means that in the area where it applies, that area if peened must have the same peened appearance as the specified peened areas but the intensity requirements are waived. Specified unpeened areas may be stopped off by a mask or peened and subsequently machined to remove the effects of peening.

Normally, parts are finished to dimensional tolerances and surface finish requirements before peening, including all burring and blending operations. Magnetic and Fluorescent Penetrant inspection is performed also before peening.

The procedure requires that parts to be peened are suitably mounted and masked. Test strips shall be included with every batch or at intervals of every four hours if there is a continuous run. Honing is permitted after peening. Heating to a temperature which would reduce the imposed stresses is prohibited. Tolerance on arc height intensity is a .005" range between maximum and minimum, dimensional tolerance on areas peened is -0 to $+1/8$ " where specific areas are indicated. Once a part has gone into production, no changes in the peening procedure may be made without Engineering approval.

Rocker arms were the first part to be shot peened on a production basis. After preliminary work was done on a converted sand blast hand cabinet, a rotary track automatic piece of equipment was ordered. A so-called "creeper" or deslugger gear of a thru-hardening steel was the second part. From then on peening began to grow until at the present time there are slightly over four hundred part numbers or assemblies that are peened according to AMS 2430, plus eighty-five additional parts released for experimental testing. These parts can be broken down into approximately sixteen types of parts as follows:

1. Rocker arms ✓
2. Linkrods ✓
3. Master rods and caps ✓
4. Crankshafts ✓
5. Propeller shafts ✓
6. Crankcases ✓
7. Cylinder barrels (head attachment threads) ✓
8. Pistons (aluminum) ✓
9. Piston pins ✓
10. Tappet rollers (inside diameter only) ✓
11. Torquemeter pistons (steel) ✓
12. Gears ✓
13. Miscellaneous shafts with and without gears ✓

- 14. Gear cages and supports
- 15. Compressor blades (roots only)
- 16. Turbine shafts

The equipment to handle this load has grown to twenty-eight different machines roughly classified as follows:

- 10 Hand cabinet - single nozzle
- 10 Automatic - air blast
 - 5 Multi-station wheel
 - 3 Miscellaneous including 1 combination wheel and air
 - 1 endless belt
 - 1 rotary track

Practically all of the gears that are shot peened are of a carburizing grade of steel, and are peened to improve the fatigue strength of the teeth at the root fillets. It is generally agreed that peening contributes nothing to the pitting or scuffing resistance of gear teeth, though it may give a better break-in appearance. Most of the other parts are of AMS 6415 (SAE 4340) in the hardness range of Rockwell C 35-40. Of course there are exceptions, a few of which will be discussed.

The peening of aluminum crankcases and pistons usually evokes the most comment. The advantages, especially if operating temperatures are considered, are not too apparent. Laboratory data show that the peening effect at the intensity used in production is about .030-.035" deep as determined by hardness gradient and by the removal of successive layers of the peened surface of a beam until no further change in curvature was noted. The maximum compressive stress at the surface is approximately 30,000 psi. Heating to 300F (which may be considered the nominal operating temperature) for one to two hours reduces this stress by nearly one-half. After six thousand hours at 300F, there is very little stress left, but it is still on the compression side. Mean average values of fatigue tests on test specimens with the "as-peened" surface show a definite improvement over "as-machined" surfaces. However, the scatter on "as-peened" surfaces is quite large so that if the comparison is based on minimum values, the percent improvement is not so great. If, however, the peened surfaces are machined to remove a minimum amount of stock to just clean up the roughened surface, the scatter in results is again reduced and a significant improvement is attained.

One source of trouble on the aluminum crankcase was galling and small fatigue cracks on the pad on which the cylinder barrels are mounted. This surface is machined after peening with .005" maximum stock being removed which is sufficient to remove all peening impressions, but still leaving the surface compressively stressed and thus more fatigue-resistant.

Stress analyses by Alcoa on aluminum alloys in the solution treated and aged condition indicate residual stress of high magnitude which may be either tensile or compressive. Quenching speed and geometry are the most important factors which influence residual stress; but unfortunately they can not be controlled to give uniform results. Peening offers the advantage of putting all surfaces in a uniform compressively stressed condition. Service records show that there is a definite benefit in peening aluminum.

Peening of magnesium has never been done on a production part. When this was investigated, laboratory fatigue tests showed that unless the peened surfaces were machined smooth again, the possibility of doing damage was almost as great as

producing improvement. Cast iron shot also contaminated the surface to such an extent that satisfactory corrosion resistance presented a very difficult problem. Non-metallic shot (plastic) and lead caused no corrosion problems, but the peening effect was too small to be attractive. Dow Chemical Company, Magnesium Department, has made considerable progress in peening magnesium; and very substantial benefits are reported on such parts as landing wheels. It is reported that it is very sensitive to temperature such that the effects are practically eliminated at 200F to 250F.

Peening of titanium is a comparatively new application, and so far as we have had only limited production experience with it, though considerable laboratory and experimental work is going on. All of our work has shown that an improvement in fatigue properties can be expected, which is contrary to the results obtained by Hannink of Wright Aeronautical. We have shown improvements from 10% to over 40% in endurance limit on compressor blade root attachments. This wide range appears to be associated with the initial processing or means by which the root was generated, grinding, milling or broaching, though this has not been proved yet. It does appear that fairly high and consistent results are obtained on shot peened compressor blade roots where the results on unpeened blades are apt to show a wide variation, especially between lots involving different manufacturing techniques. We do know that damage by grinding is a serious hazard in processing titanium. Minor burns are difficult to detect even by metallographic means but severe grinding will produce burns which are detectable by metallographic etching and may also produce cracks. It seems logical to assume at this point that undesirable residual stresses due to machining or poor grinding practice can be neutralized by shot peening. Laboratory tests on Westinghouse High Temperature Fatigue equipment show that on one alloy tested, where peening showed an improvement of 30% over smooth specimens at room temperature, there was still an improvement of 22% when tested at 400F and 17% at 600F.

As previously stated, rocker arms were the first parts to be peened. These parts now are both nitrided and peened, which may sound like a complicated processing procedure and a duplication of effort in that nitriding may be considered the ultimate in prestressing the surface in compression. Actually the bore for the rocker shaft is the only area that is nitrided. Service experience shows that in this case a nitrided surface oscillating on a silver plated shaft gives much greater life than roller bearings, ball bearings or bronze bushing inserts. Ball and roller bearings tend to "brinell" and bronze bushings tend to pound out or loosen. The surface of the forging is not machined and as such is not suitable for nitriding because of the partial decarburization. Consequently, the bore must be stopped off as well as the valve adjusting screw thread and the socket end, during the peening operation. Inadequate cleaning prior to plating or imbedded scale resulting from the blast cleaning operation at the forging source may cause occasional poor bond of the tin plate used for nitriding stop off and allow small pin points of nitriding to take place which are readily disclosed in the peening operation. These spots are objectionable from an appearance standpoint only since the residual stress from both operations are in the same direction and probably are of the same order of magnitude.

The valve tappet roller of AMS 6440 (SAE 52100) is one of two parts where peening is employed on a finished part for reasons other than strengthening it by prestressing it. It has been found that peening the bore of the tappet roller is a very effective method of producing a multidirectional surface finish which is adequate for holding in place a press-fitted bronze bushing.

Another use of shot peening which is not associated with producing compressive stress is in bond testing of silver plate. Peening is used quite extensively on silver plated parts where bond is considered extremely important, and where heating is prohibited, as on carburized parts. The difference between the coefficient of expansion of silver and steel causes the silver, upon heating, to raise up or blister where the bond is poor; this is more pronounced with increase in temperature. The temperature frequently used for this test is 950F. Similar blisters are produced by peening the silver where poor bond is present. A chart has been worked out at Pratt & Whitney Aircraft from which the necessary intensity or arc height can be determined in relation to the thickness of the plate. A companion chart has also been worked out to show the amount of silver which must be removed for clean-up after peening.

What may be the greatest difference in peening procedures between the aircraft industry and automotive or other industries is the amount of masking that is done on the individual parts. Peening is usually done on finish machined parts where design and weight considerations dictate close dimensional tolerances. Journal surfaces, tapped holes and other critical areas must be stopped off. Some typical parts before and after masking for peening are shown in the illustrations:

- No. 1 Rocker arm with and without mask
- No. 2 Master rod and cap
- No. 3 Master rod and cap and mask
- No. 4 Cylinder barrel
- No. 5 Cylinder barrel and mask
- No. 6 Propeller shaft
- No. 7 Propeller shaft and mask
- No. 8 Propeller shaft
- No. 9 Propeller shaft and mask
- No. 10 Crankshaft
- No. 11 Crankshaft
- No. 12 Crankcase
- No. 13 Crankcase and mask
- No. 14 Compressor blade without and with mask

About two years ago a rather serious problem arose in production when a new batch of Almen test strips were put into use. It was reported that the new strips showed .002-.003" less arc height than the old ones under identical machine settings. Investigation showed that this was true in those machines which were using malleable cast iron shot; but where chilled iron shot was used, the difference was negligible. Laboratory examination showed that on the old strips there was almost .015" partial decarburization while the new strips had practically none. Rockwell C hardness readings showed both lots to be running in the 46-50 range with the decarburized ones averaging about one point lower. However, light load Vickers hardness readings showed a Rockwell C conversion hardness of eight or nine points lower. It became apparent that the softer malleable shot could not work the harder surface to the same extent as the softer decarburized surface, thus resulting in a lower arc height. It was found that by retempering test strips of the new lot to the low side of the specified hardness to Rockwell C44-46, the difference in arc height between the old strips and the new retempered strips was insignificant when subjected to the same peening condition. This led to the practice of retempering all Almen strips before they were released for production use and later to purchasing strips to this special range. The reason for this procedure is this. Engineering wished to maintain the same shot peening intensity that had been in effect on experimental and service tests. It appeared that since the so-called standard test strip allowed that much variation, an engineering change or correction factor could

be only a temporary expedient, and they were loath to take any action until the situation had been stabilized. It is hoped that the new specification for Almen strips now under consideration will soon be available and can be considered a standard.

Cast steel shot has been in production use for peening steel parts for some time and has proved to be equally effective and more economical due to its longer life in spite of its higher initial cost. When peening of aluminum was first considered, it was recommended that malleable shot be used; and it became a drawing requirement. Greater durability of cast steel shot indicated it would be desirable to use it on aluminum also. In order to evaluate the relative effects of peening aluminum with malleable iron and cast steel, test strips were made of the aluminum crankcase alloy to the Almen C strip dimensions. A hand cabinet was used in this test, first filling the cabinet with the malleable iron shot and adjusting it to give .015" arc height on an Almen test strip, then with the conditions maintained the aluminum strip was peened. The machine was cleaned out and filled with cast steel and the procedure repeated with both types of strips. The results were rather startling. The aluminum specimens peened with malleable shot showed an arc height of about .030" and appeared to be severely overpeened compared to those done with cast steel which had an arc height of only .010". The answer is simple in that the soft iron shot is softer than the steel test strip so that part of the energy is absorbed in deforming the shot itself and part in acting on the test strip. Approximately forty psi pressure was required to produce the .015" A2 reading with malleable iron shot. The cast steel is harder than the test strip and a greater proportion of its energy is acting on the steel test strip. About twenty psi pressure was required to produce the same A2 reading with C.S. shot. The aluminum is so much softer than either type of shot that it accepts practically the full energy from each.

During this investigation, some of the arc heights produced in aluminum strips were so great that the use of thicker specimens was indicated. Consequently, the experiment was repeated using one-inch thick specimens which could be used for determining stress gradient and hardness gradient for a better evaluation. For a quick check the drilled-hole method was used where three SR-4 strain gages are placed 120° apart in a circle. Stress is calculated from the difference in strain gage readings taken before and after drilling a small hole at the center of the circle. In this case .005" was milled off the surface to get a smooth enough surface to apply the strain gages for the first determination. This procedure was repeated in .005" increments until no stress was indicated. Although these data were not considered very conclusive, it did give a consistent trend and indicated stress gradients extending to depths of approximately .020" and .025". It also indicated that the difference between the two types of shot was not as great as indicated by the first test.

About this time the laboratory was experimenting with a new method of determining stress and/or stress gradients. "New" is used here in the sense of new application of existing tools and methods. It is an adaptation of Letner's work on stresses due to grinding, "Application of Optical Interference to the Study of Residual Surface Stresses"⁽¹⁾, and R. L. Mattson's "Method of Calculating Residual Stress in a Simple Beam of Rectangular Cross Section From Measurements of Its Longitudinal Curvature as Layers of the Material Are Removed."⁽²⁾

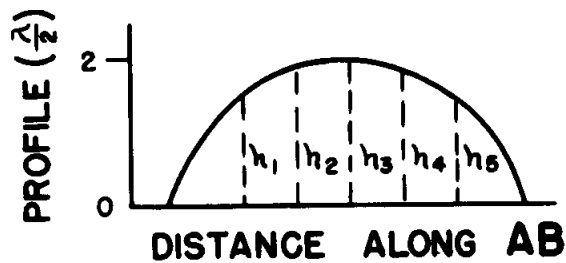
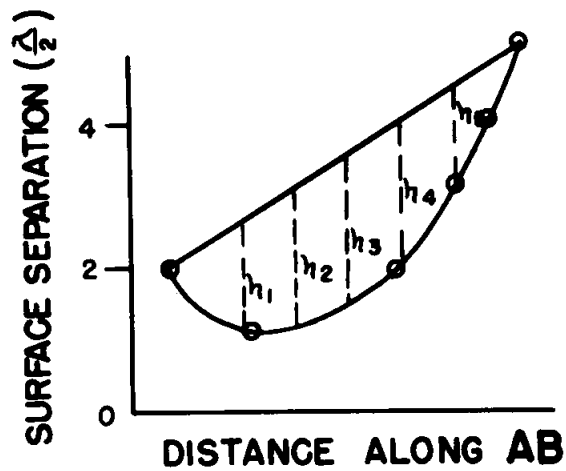
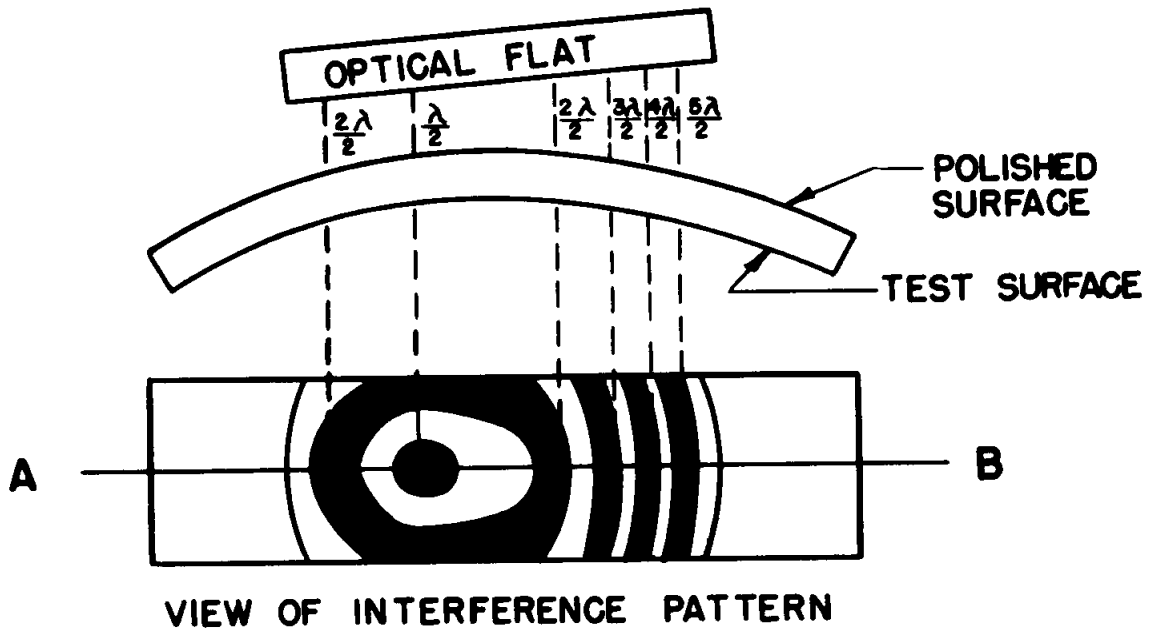
The method involves the use of an optical flat in measuring extremely small changes in curvature of a beam when small increments of stock have been removed from the stressed surface which is opposite to the optically flat side. In this case, blocks three-fourths inch square by four inches long were machined, and

one side of each was polished to a high degree of specular reflectivity. By use of mercury monochromatic light, the polished surface was photographed through the optical flat, and the deviation from true flatness was determined by plotting the interference fringes (height or distance between the surface and the optical flat) against the distance between the fringes. These points are then transposed against a new base line which represents the actual surface contour of the part. After the initial reading has been taken, the side opposite the specially prepared flat was shot peened, all other sides having been stopped-off.

For this determination blocks were prepared in duplicate for peening with both types of shot according to the schedule mentioned previously. After peening, the prepared flat surface was again photographed, following which .002" stock was removed from the peened side by milling. Photographing and stock removed in increments of .002" was repeated until a total of .010" had been removed, and then continued in increments of .005". Plots from this series of photographs showed the arc height of the beam caused by peening, and the change in arc height as successive layers of stressed material was removed.

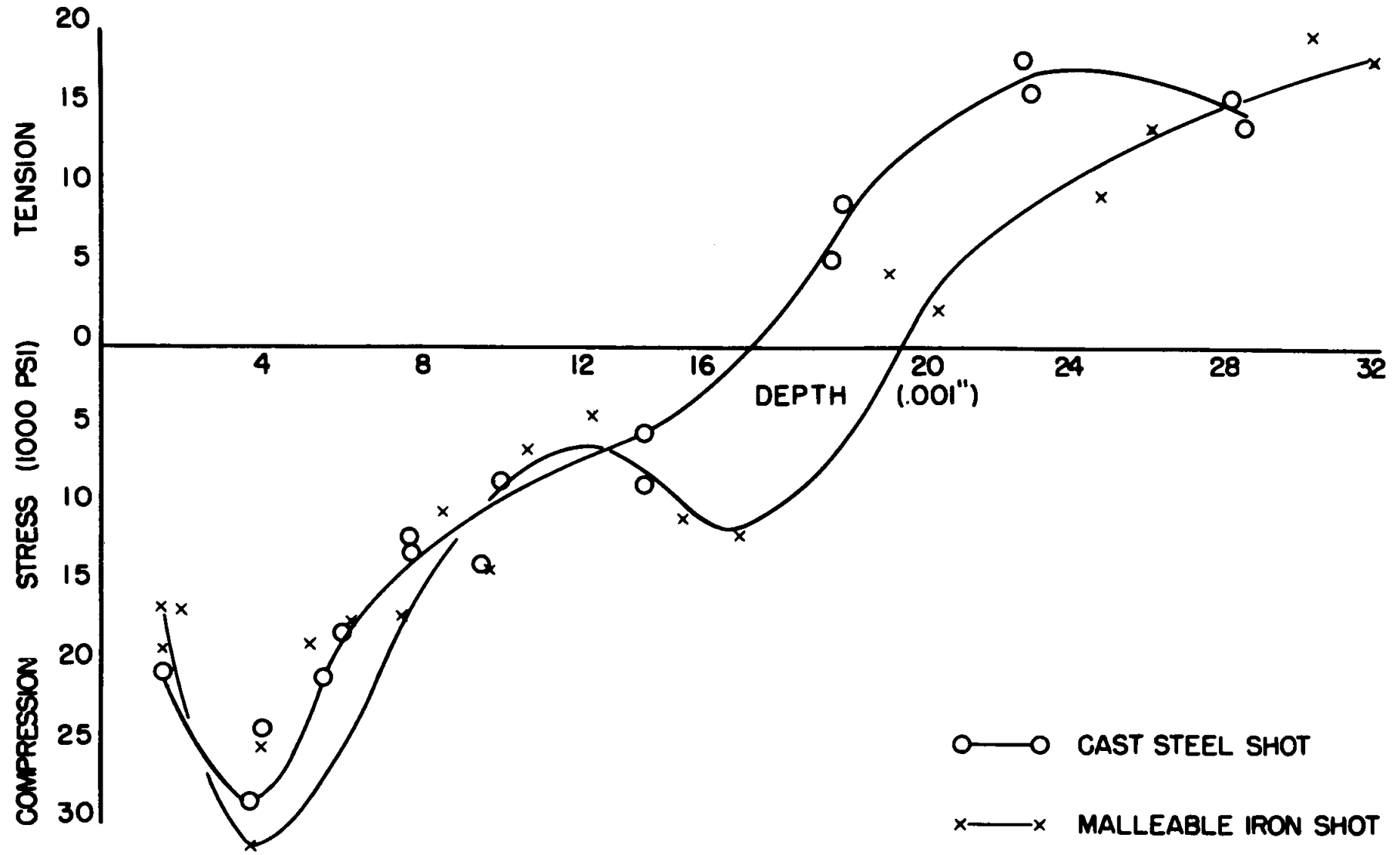
Another set of specimens was prepared at the same time for stock removal by electrolytic etching instead of machining; but because of the large amount of stock to be removed, it became increasingly difficult to remove a uniform amount, plus the difficulty of maintaining a highly reflective surface during the numerous maskings and immersions in the etching solution.

- (1) Proceedings of the Society for Experimental Stress Analysis, Vol. 10, No. 2
- (2) General Motors Research Laboratory, Division of General Motors Corporation



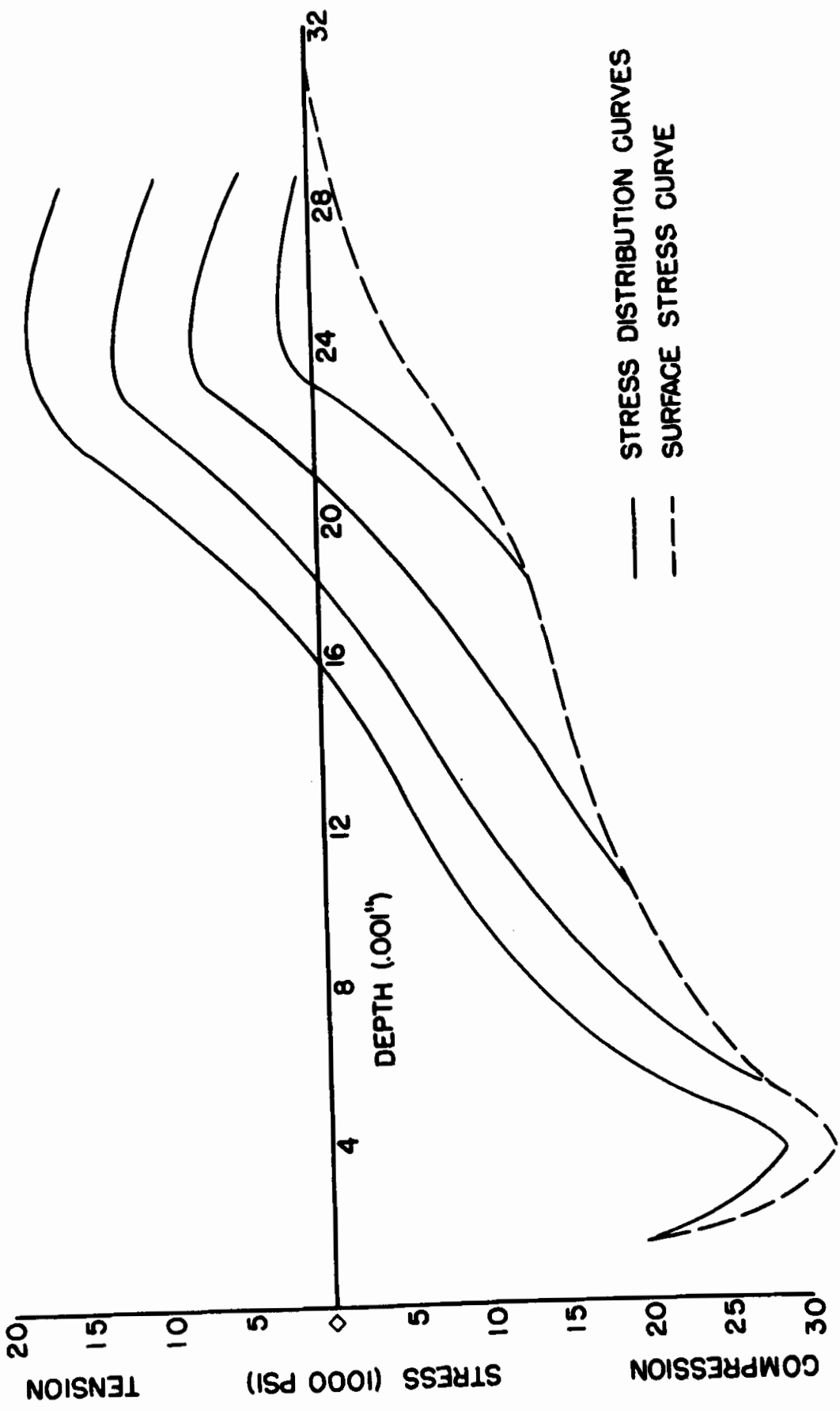
METHOD OF OBTAINING SPECIMEN CURVATURE
FROM INTERFERENCE PATTERN

81 ON



RESIDUAL STRESS DISTRIBUTION IN AMS 4125 ALUMINUM PEENED WITH ARC HEIGHT INTENSITY OF .015" A-2

J-24



— STRESS DISTRIBUTION CURVES
- - - SURFACE STRESS CURVE

RESIDUAL STRESS DISTRIBUTIONS IN AMS 4125 ALUMINUM PEENED
TO PRODUCE ARC HEIGHT INTENSITY OF .015" A-2 USING CAST STEEL SHOT
AS PEENED FACE WAS MILLED OFF

SUMMARY OF SHOT PEENING PRACTICE

SHEET #1.

The following is a list of shot peening practices that have been successfully used or are currently being used. It must not be construed that any of these represent the optimum treatment for the particular part. Except in a few instances, such a conclusion is not justified.

Part	Material	Heat Treatment	Hardness	Surface Before Peening	Shot Hardness	Shot Type	Shot Size New	Shot Size in Machine	Intensity	Coverage	Wheel or Air	Wheel Dia.	Wheel Speed	Treatment After Peening
Crankshaft, Aircraft	AMS6415Steel	H & T	331-375	Polished	625-850 VPN	C.I.	170	- - - - -	.010 .020 A2	Visual	Both ¹	19½	Var.	
Crankcase, Aircraft	AMS4125Alum.	- - - - -	- - - - -	Forged and machined	250-350 VPN	M	390	- - - - -	.012 .017 A2	Visual	Wheel	19½		
Cylinder Barrels, Aircraft	PWA956 Steel	H & T	285-381BHN	Machined	- - -	C.S.	170	- - - - -	.009 .014 A2	Visual	Air	- -		
Compressor Blades, Aircraft	AMS 5615 Stainless	H & T	Rc 32-40	Machined	625-850 VPN	C.I.	170	- - - - -	.012 .017 A2	Visual	Air ³	- -		
Shaft Gears, Aircraft	AMS6260Steel	C	Rc 81-84	Machined	625-850 VPN	C.I.	170	- - - - -	.012 .017 A2	Visual	Air	- -		
Pistons, Aircraft	AMS4145Alum.	- - - - -	- - - - -	Forged	250-350 VPN	M	230	- - - - -	.007 .012 A2	Visual	Air	- -		
Piston Pins, Aircraft	AMS6312Steel	H & T	Rc 47-50	Machined	625-850 VPN	C.I.	170	- - - - -	.006 .011 A2 ⁶	Visual	Air ²	- -		
Propeller Shaft, Aircraft	AMS6415Steel	H & T	- - - -	Machined	625-850 VPN	C.I.	170	- - - - -	.010 .015 A2	Visual	Air	- -		
Rocker Arms, Aircraft	AMS6322Steel	H & T	Rc 35-40	Forged & Machined	- - -	C.S.	170	- - - - -	.014 .019 A2	Visual	Air	- -		
Master Rods, Aircraft	AMS6415Steel	H & T	331-375	Ground	625-850 VPN	C.I.	170	- - - - -	.010 .015 A2	Visual	Wheel	19½	Var.	
Link Rods, Aircraft	AMS6415Steel	H & T	331-375	Ground	625-850 VPN	C.I.	170	- - - - -	.008 .013 A2	Visual	Wheel	19½	Var.	
Silver Bond Testing, Aircraft	- - - -	- - -	- - - -	Silver Plate	250-350 VPN	M	390; 230; 170.	- - - - -	According To Plate	Visual	Wheel or Air	- -		
Turbine Shafts, Aircraft	AMS6415Steel	H & T	Rc 30-35	Machined	625-850 VPN	C.I.	170	- - - - -	.010 .015 A2	Visual	Air	- -		
Valve Rollers, Aircraft	AMS6440Steel	H & T	- - - -	Machined	625-850 VPN	C.I.	170	- - - - -	.010 .015 A2	Visual	Wheel	19½		
Axle Shaft	1330	H & T	Rc 36-41	Forged	- - - -	C.W.	CW-41	- - - - -	.014 .018 A2	Visual	Wheel	19½	2250	
Axle Shaft	- - - - -	- - -	3.2-3.4 3000 kg ld	As Forged	- - - -	C.W.	CW-41	- - - - -	- - - - -	- - - - -	Wheel	19½		
Axle Shaft	1046	H & T	Surf. 514-601 Core 250-300	Ground	- - - -	C.I.	390	70% @ 390; 30% - 460	.007 .011 A2	Visual	Wheel	15	2300	
Axle Shaft, Pass., Truck and Commercial	8653	C & H	3.2-3.4 BHN	Rolled & Forged	- - - -	C.I. C.S.	390	Air stream removes shot (½ app. size of new material)	78-80 lb. of line air pressure, Nozzle 7" from work	Visual	Air	- -		
Front Axle Shaft & Un. Jt. outer and inner ends	6125	Carb.	Rc 60 min.	- - - -	- - - -	M	550 or 330 fin.	550 rough forging 330 finish	For cleaning only		Wheel	19½	2250	Grinding
Brake Band Anchor for Automatic Transmission	5140	H & T	41C	Machined	- - - -	C.I.	230	- - - - -	.012 .016 A2	Exfilm	Air			
Brake Band for Automatic Transmission	1020	As rolled	B90	As rolled	- - - -	C.W.	CW-35	- - - - -	.008 .012 A2	Exfilm	Wheel	19½	1400	
Overrun Cam, Stator Reverse Brake Band Line & Lever	RCA5120, C1045 5140	Carb. & coarse Grained	Rc 60 min.	- - - -	- - - -	M	330	350 Approx.	For cleaning only		Wheel	19½	2250	Grinding
Connecting Rod	1141	N.O.Q.D.	212-251 BHN	Forging	- - - -	C.W.	CW-41	- - - - -	- - - - -	- - - - -	2 wheels	19½	2000	
Connecting Rod	1035 modified	H & D	Brinall 3.8-4.2	Forged	Rc20-22	C.W.	CW-41	- - - - -	- - - - -	Visual	wheel	20	2320	Grinding
Connecting Rod	GMX 1335	Normalize	180-228 BHN	Forging	- - - -	C.W.	CW-41	- - - - -	- - - - -	- - - - -	2 wheels	19½	2000	

SUMMARY OF SHOT PEENING PRACTICE

Sheet # 2

The following is a list of shot peening practices that have been successfully used or are currently being used. It must not be construed that any of these represent the optimum treatment for the particular part. Except in a few instances, such a conclusion is not justified.

Part	Material	Heat Treatment	Hardness	Surface Before Peening	Shot Hardness	Shot Type	Shot Size New	Shot Size in Machine	Intensity	Coverage	Wheel or Air	Wheel Dia.	Wheel Speed	Treatment After Peening
Gear, Fan Drive GAF 6870-C	8620	C	Rc 58-63	Machined	---	--	230	-----	.010	---	---	19½	2250	350-400°F
Gear, Fan Drive GAF 6886-C	8620	C	Rc 58-63	Machined	---	--	230	-----	.014 A1	---	wheel	19½	2250	350-400°F
Gear, Drive (Tank Eng. Acc)	8620-8617 Steel forging	C	H	Machined	---	--	230	-----	.010	Visual	wheel	19½	2250	350-400°F
Gear, Oil Pump	1141	N	---	Machined	Rc 35-40	C.S.	330	-----	.010			19½	2250	400°F
Gear, Timing	1141		Rc 26-33	Machined	Rc 35-40	C.S.	330	-----	.014 A1		wheel	19½	1970	
Gear, Timing	8620	Annealed		Machined	Rc 35-40	C.S.	330	-----			wheel	19½	1970	
Gear, Balance	1141	N		As Forged	Rc 35-40	C.S.	330	-----			wheel	19½	1970	
Gear, Timing	8620	Annealed		As Forged	Rc 35-40	C.S.	330	-----			wheel	19½	2250	
Gears	5145 & 1035	Cycle Annealed	Rc 4.2-4.5	Forged	Rc 45	C.W.	CW-41	-----			wheel	19½	2250	
Gears and Shafts	8620, 8640, 4340, 9310	N, C & H	Rc 20-60	Machined	Unknown	C.S.	170	.033-.044	Unknown	visual	wheel	19½	1900	none
Pinions, Diff. Drive & Knuckles, Steering				Machined		C.I.	330	.016-.030	Unknown	visual	wheel	19½	2200	none
Center Guide and Cap	TS4140	Anneal							.016					
Transmission Torus Hub	WD4140		179-210 BHN	Forging		C.W.	CW-41		.019 A2 ⁴		wheel		1525	
Knuckles, Steering	5140	H & T	335-355 BHN	Forging							2 wheels	19½	2100	
Knuckles, Steering	3130	H & T	285-341			Shot & Erit	390 40 230	390			wheel	15½	2300	
Knuckles, Steering	3130	H & T	285-341					.023	.015 .018 A2					
Knuckles, Steering	1340	N, O, Q, D	255-293 BHN	Forging		C.I.	230	80% F-23 20% F-28	.015 .018 A2		Air	19½	2250	
Knuckles, Steering	1340	None	255-293 BHN	Forging		C.W.	CW-54 CW-41				2 wheels	19½	2100	
Knuckle, Support						C.W.	CW-54 CW-41				2 wheels	19½	2100	
Knuckle, Arm	1340	N, O, Q, D	241-285 BHN	Forging		C.W.	CW-54 CW-41				2 wheels	19½	2100	
Knuckle, Support Shaft	1024	N, O, Q, D	217-255 BHN	Forging		C.W.	CW-54 CW-41				2 wheels	19½	2100	
Motor Frame, Center and End	1015, 1020, GM 2428 BR	1200°F - 1 hr. stress relief												
Miscellaneous					Rc 42	C.W.	CW-41	70% broken			wheel	19½	1800	
Spring Clip Plate	1020	None				C.I.	230		.008 .010 A2		wheel	15	2250	
Shaft	4140	N, O, Q, D.	269-321 BHN	Forging		C.W.	CW-54 CW-41				2 wheels	19½	2100	
Shaft	1141	N, W, Q, D.	217-255 BHN	Forging		C.W.	CW-54 CW-41				2 wheels	19½	2100	
Shaft, Final Drive Gear	Stl. Forg. 4150H, 4340H	H & T	Rc 42-45	Ground	Rc 46-52	C.W.	CW-54 CW-41				2 wheels	19½	2100	
Shaft, Inner Generator	4150	H & T	Rc 38-41			C.W.	.030-.056		.012	90% min				

SUMMARY OF SHOT PEENING PRACTICE

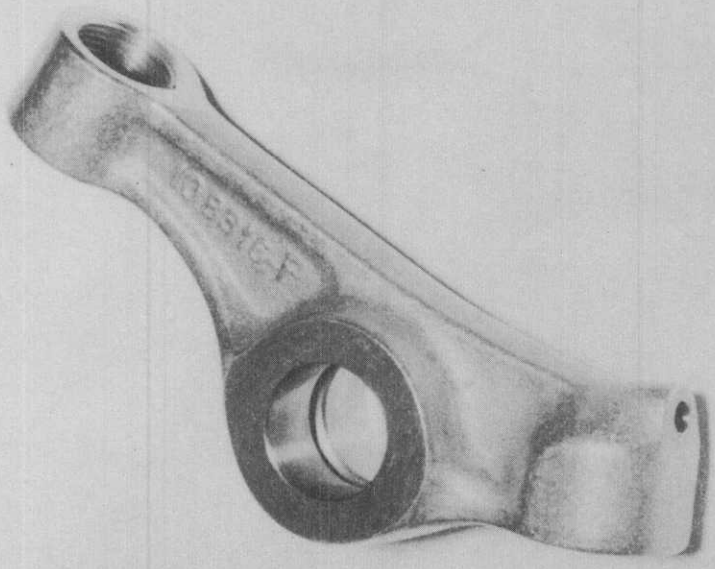
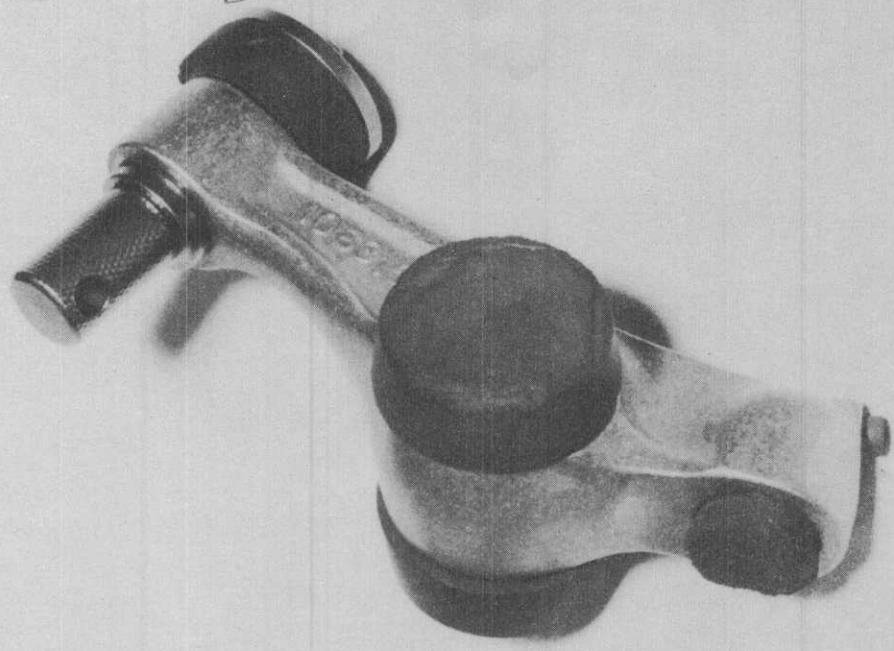
Sheet # 3

The following is a list of shot peening practices that have been successfully used or are currently being used. It must not be construed that any of these represent the optimum treatment for the particular part. Except in a few instances, such a conclusion is not justified.

Part	Material	Heat Treatment	Hardness	Surface Before Peening	Shot Hardness	Shot Type	Shot Size New	Shot Size in Machine	Intensity	Coverage	Wheel or Abr	Wheel Dia.	Wheel Speed	Treat-ment After Peening
Spring, Mount Coll	5160	H & D	2.8 - 3.10 3000 Rc Id before Heat.	Ground	Rc 45-50	C.W.	CR-35	80% above .028	.017 .021 A2	Visual & Barfilm	Wheel	19 1/2	1800	None
Spring, Coll	9260	H & T	Rc 51	As Rolled		C.W.	CR-35		.012 .016 A2 .008 A2 Inside .011 A2 Outside	Barfilm	Wheel	19 1/2	1800	
Spring, Coll, 8 1/2" x 1-5/16" wire			415-461			C.I.	460				Wheel	19 1/2	1500	
Spring, Gun	BS 4140	Anneal		Forging		C.W.	CR-54 CR-41 CR-41				2 Wheels	19 1/2	2100	
Spring, Leaf	Alloy	H & T	418-461	As Rolled & Rd 48 Conv.							Wheel	19 1/2	2000	
Spring, Leaf	5150	H & T	418-444	As Rolled			230		.012 .016 A2	Visual	Wheel	19 1/2	2250	
Spring, Disc, Clutch	1085	H & T	Rc 40-45	Ground	15N. 87-89	C.S.	230		.010 .014 A1 .012 A1		Wheel	19 1/2	2250	
Spring, Disc, Clutch	1080	X	Rc 40-45	H.T.		C.I.	110		Arc Hgt 13-17 .012/.017 A2	Visual	Wheel	19 1/2	1865	Pre-stroke
Spring, Disc, Clutch	1080	X	Rc 40-45	H.T.		C.I.	330			Barfilm	Wheel	15	1800	None
Spring, Disc, Clutch	9262	X	Rc 38-43	H.T.		C.I.	110			Barfilm	Wheel	15	1800	None
Spring, Disc, Clutch	SAE 950	C-H & T	45C	As Rolled		C.I.	230		.010	Barfilm	Wheel	15	1800	None
Torque Bar On Generator	6150	H & T	Rc 48-52	Machined		C.S.	330	30% broken	.014 A2	Visual	Wheel	19 1/2	1750	
Torque Rod End	4145	Anneal		Forging		C.W.	CR-54 CR-41			Visual	Air			
Torsion Bar, Suspension	8653H, 4150H, 9262H	H & T	Rc 47-51	90 RMS Max. Rc 46-52		C.W.	.035- .043 CR-41		.012		2 Wheels	19 1/2	2100	
Torsion Bar, Door	8750, 6150, 8650, 8653	H & T	Rc 45-50	Ground		C.W.	.018- .024 230		.015 A2 .012 .016 A2	90% min. 90% min.				
Quill 006350	4140	N H & T	Rc 41-44	Machined			230		.010 .014	Visual				
Universal Joint Yoke	1151	H & T	229-255 HB	Forging			390	390			Wheel	15	2250	
Universal Joint Yoke	8615, 1016, 1115	Carb.	Rc 60 min.				390				Wheel	15	2300	
Trunion Bolt, Yoke Trunion Bearing.						M	330	330 approx.	For Cleaning Only		Wheel	19 1/2	2250	Grinding
Washers, Thrust	Hot Rolled	N H & T	Rc 45-50	Ground			230		.010 .014 A1	Inspected For	Wheel	19 1/2	2250	450°F

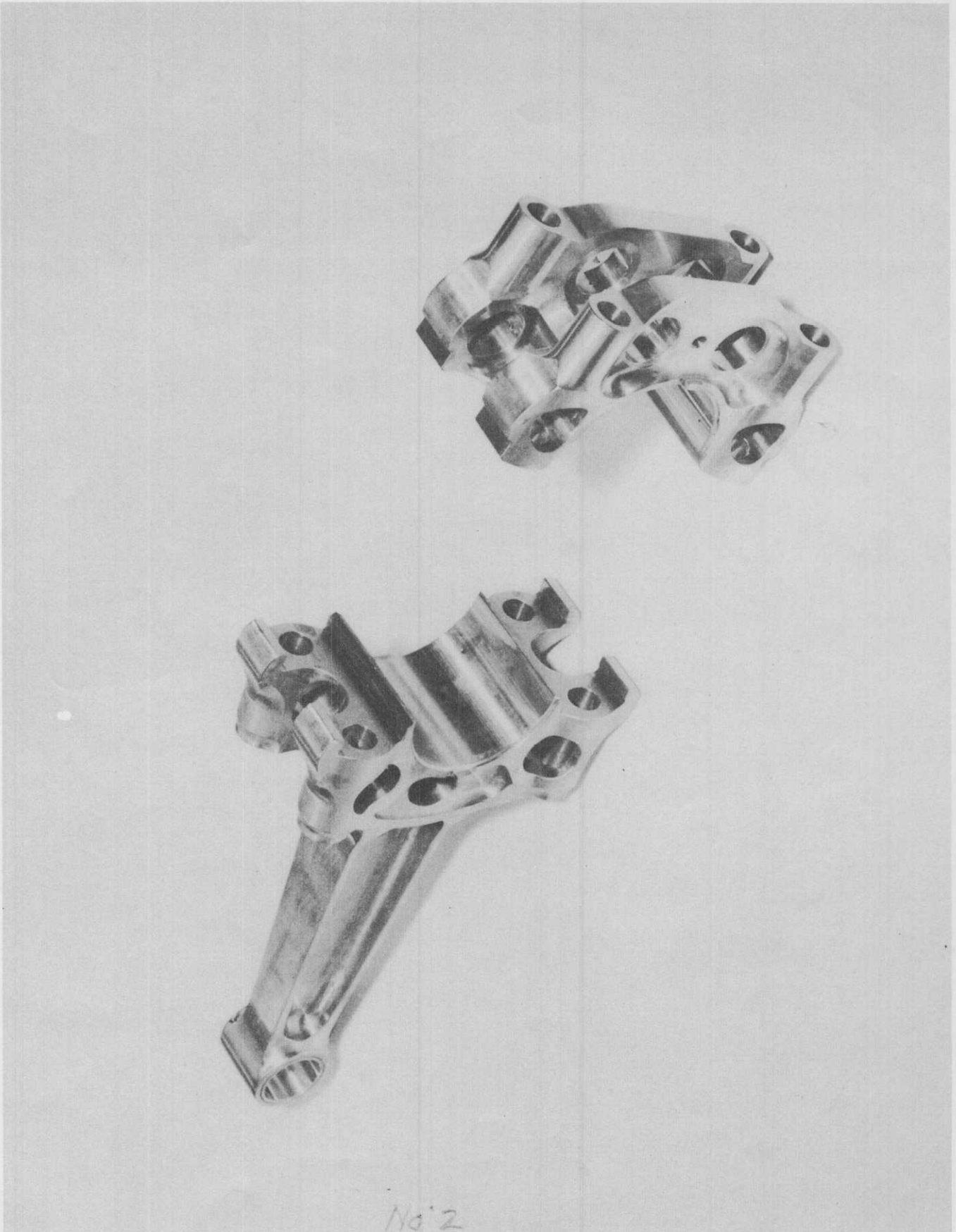
Heat Treatment:
H & T - Hardened and Tempered

Universal Joint Yoke	1151	H & T	229-255 BHM	Forging	Shot & 390 Grit 40	390								
Universal Joint Yoke Trunnion Univ. Jt. Yoke Trunnion Bearing.	8615,1016, 1115	Carb.	Rc 60 min.		M 330	330 approx.	For Cleaning Only			Wheel	15	2300		
Washers, Thrust	Hot Rolled	N H & T	Rc 45-50	Ground		230	.010 .014 Al	Inspected For		Wheel	19 $\frac{1}{2}$	2250	450°F	
Heat Treatment:														
H & T - Hardened and Tempered														
N H & T - Normalized, Hardened and Tempered														
C H - Carburized and Hardened														
H & D - Hardened and Drawn														
A or N - Annealed or Normalized														
H T & C - Hardened, Tempered and Carburized														
N C & H - Normalized, Carburized and Hardened														
Shot Types:														
CW - Cut Wire														
CS - Cast Steel														
CI - Chilled Cast Iron														
Cr.S - Crushed Steel														
RSS - Round Steel Shot														
M - Malleable														
Special Notes On Above:														
1. Wheel used on OD surfaces; air used in bore or male journal														
2. Feened ID only														
3. Root attachment area only														
4. Mounted on fixture simulating part														
5. Interval between measurement varies between 4 and 8 hours														
6. Inside diameter.														



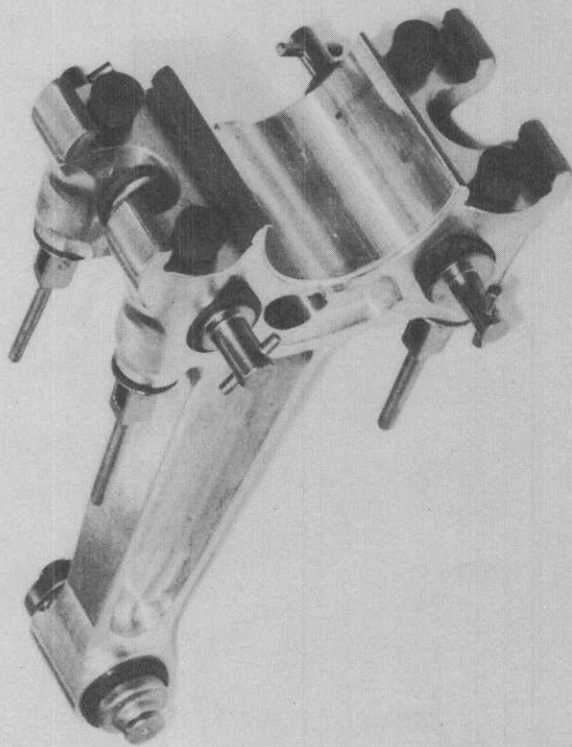
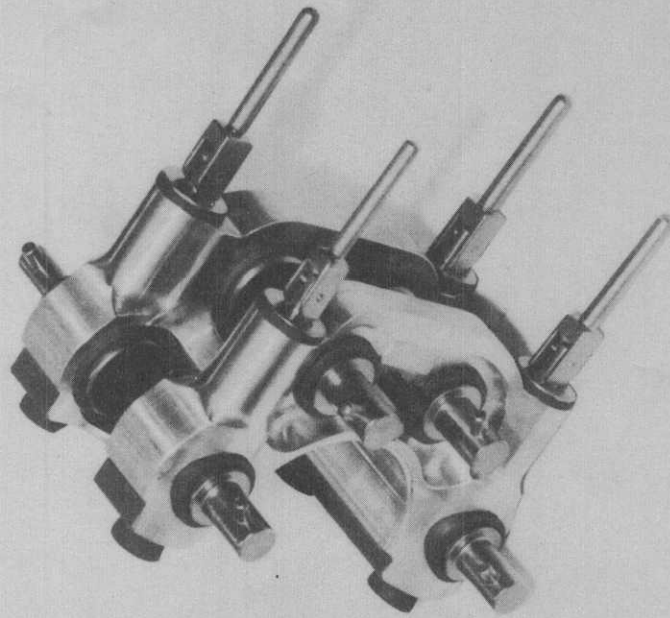
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J-8



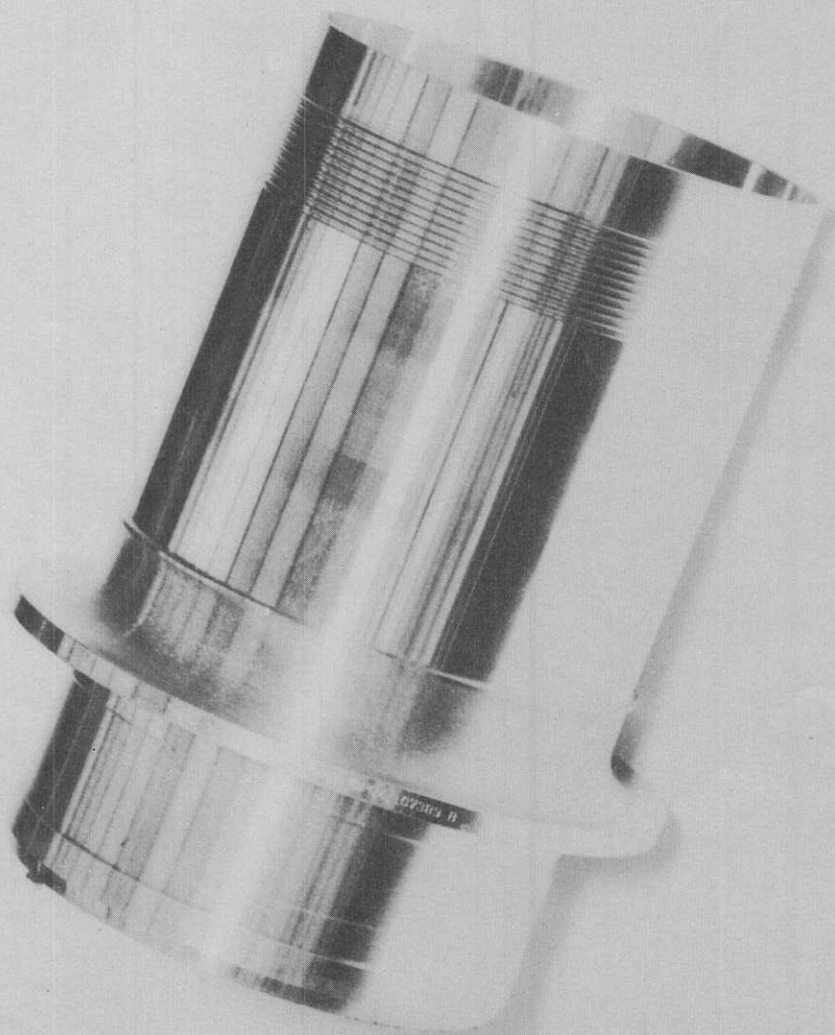
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J-9



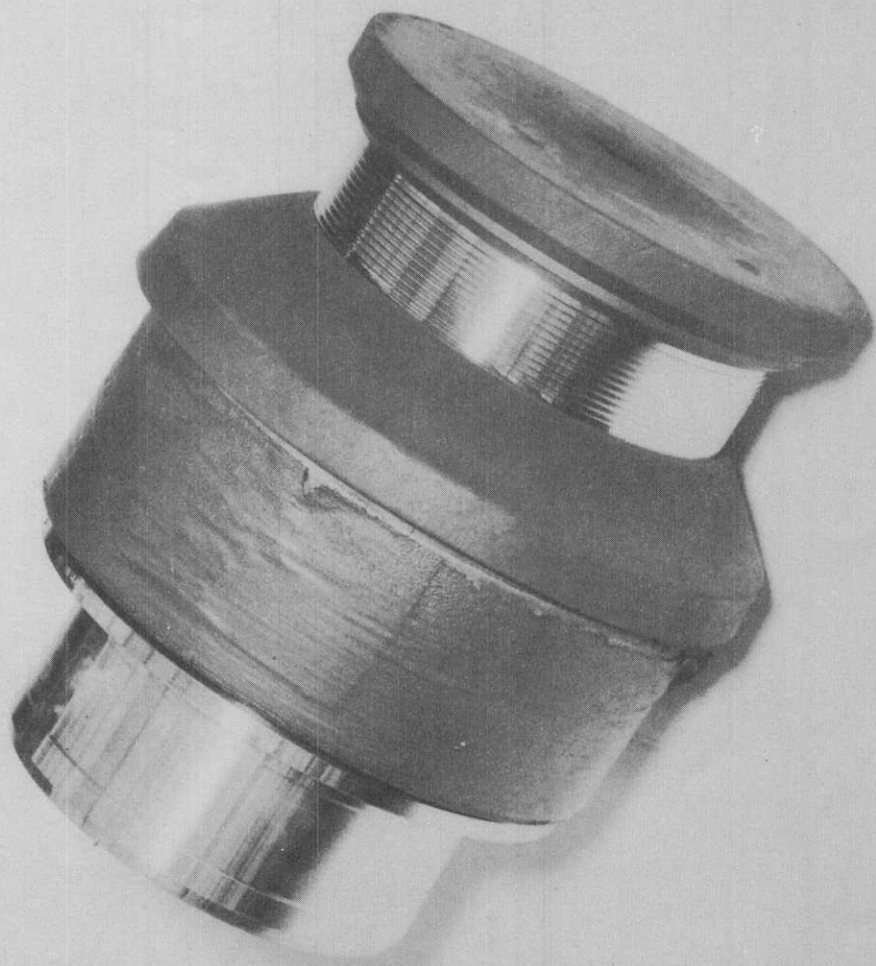
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J-10



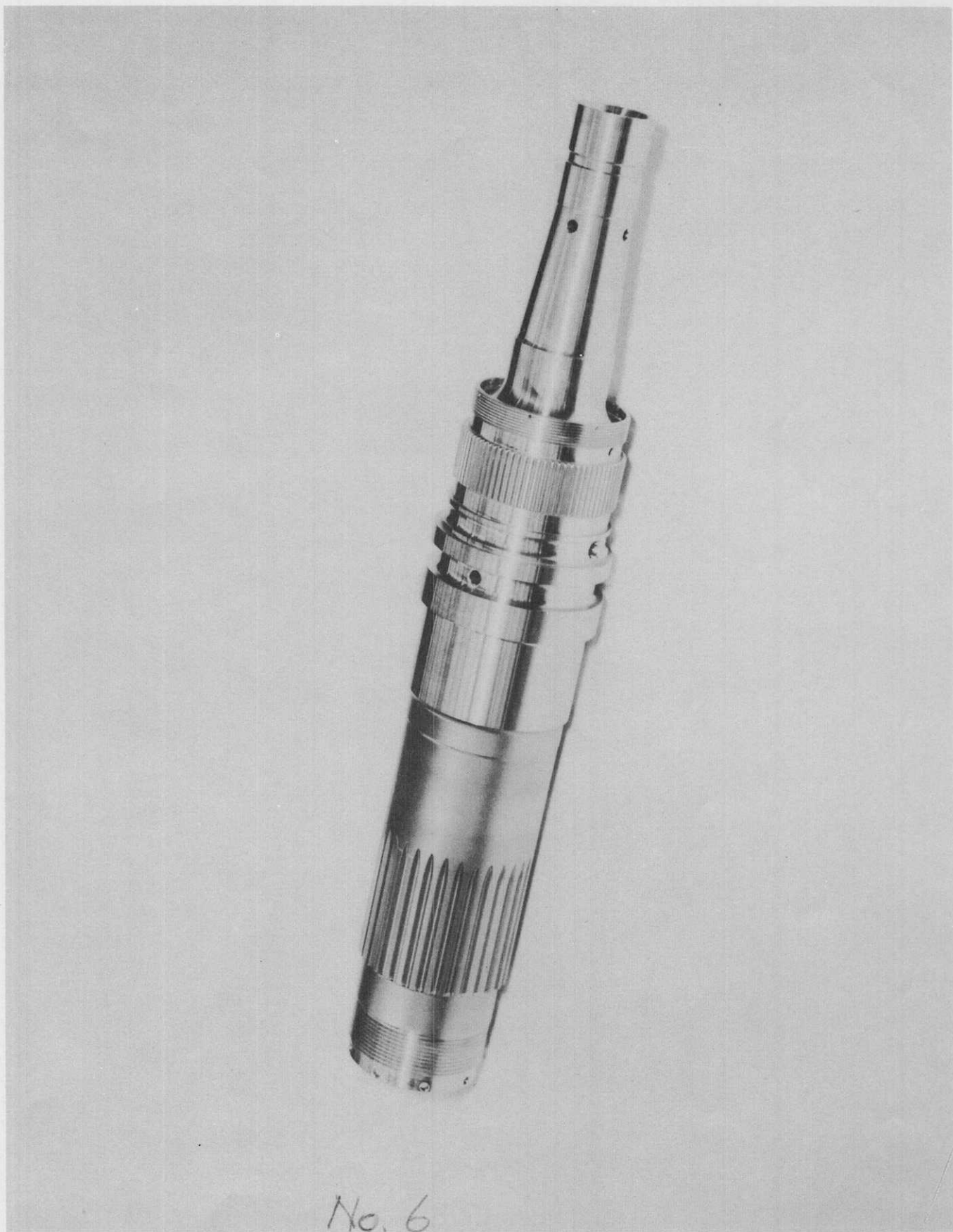
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J-11



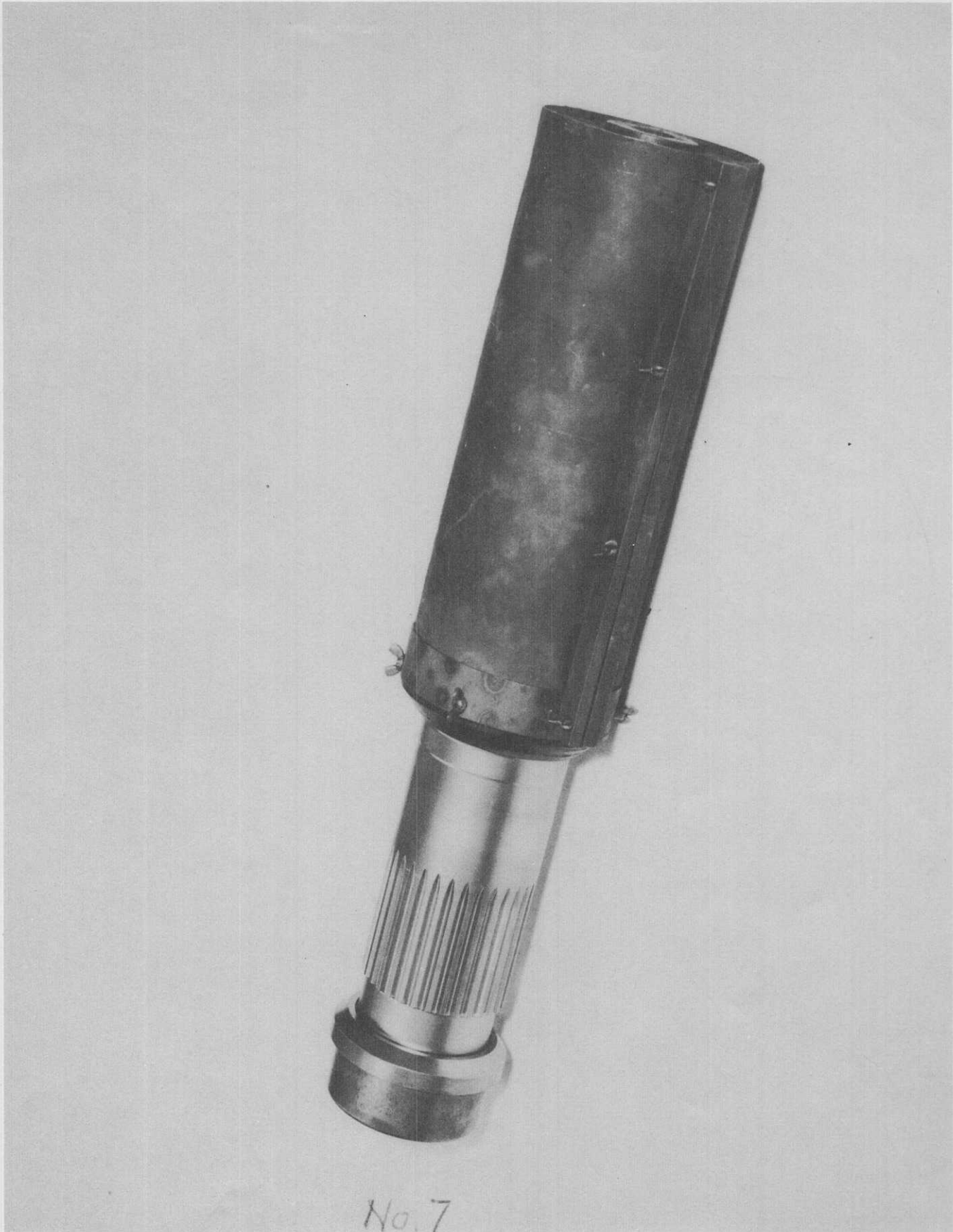
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J-12



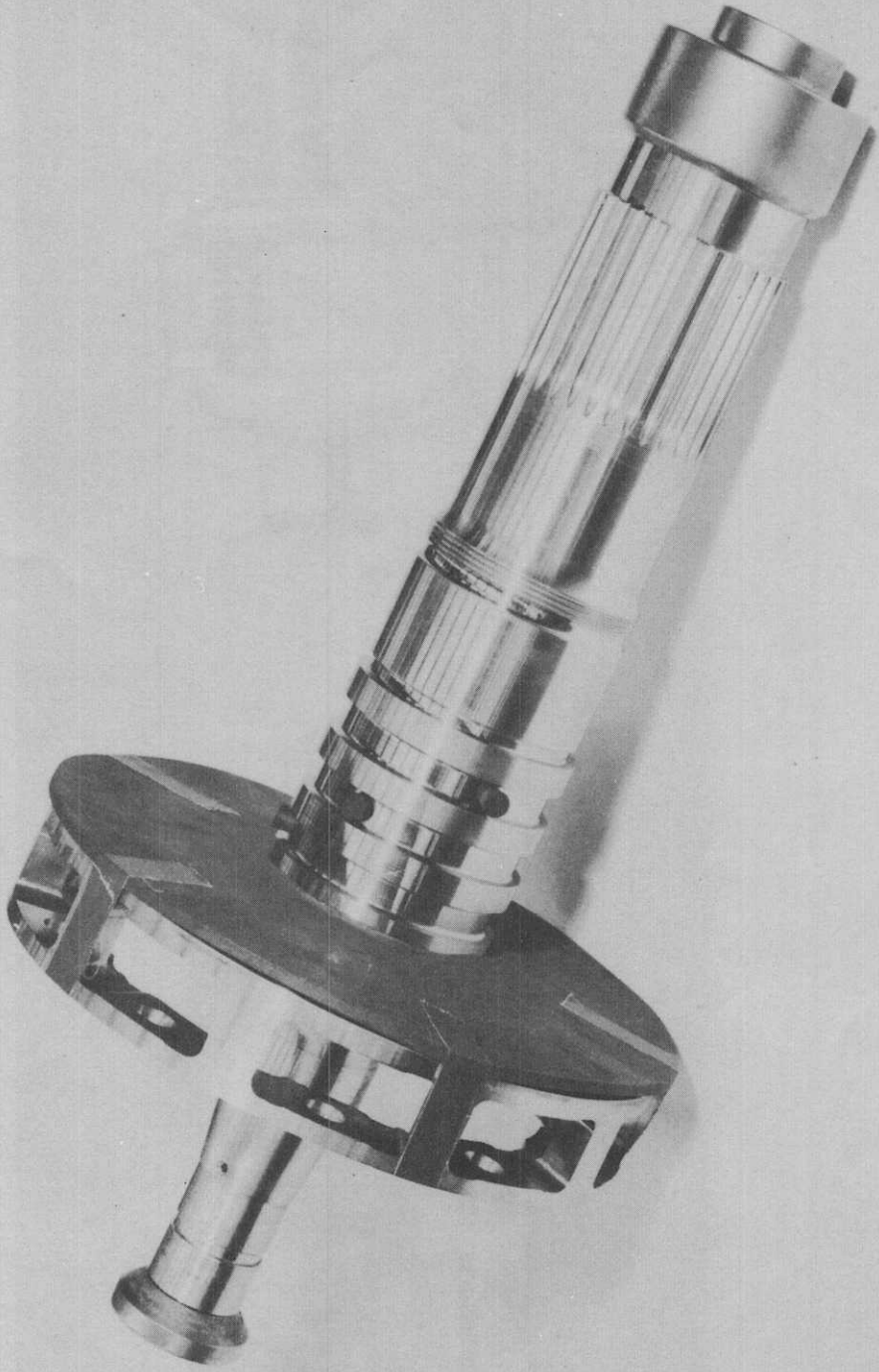
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J-13



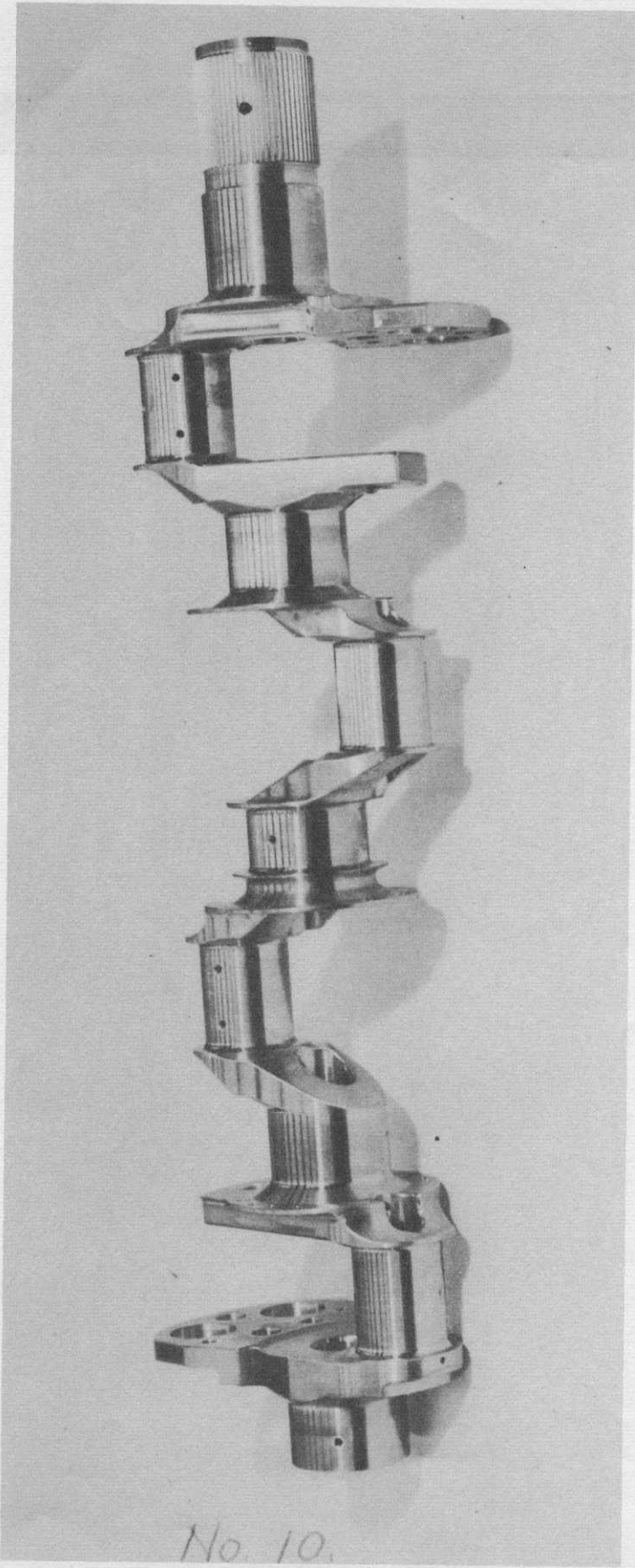
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J-15



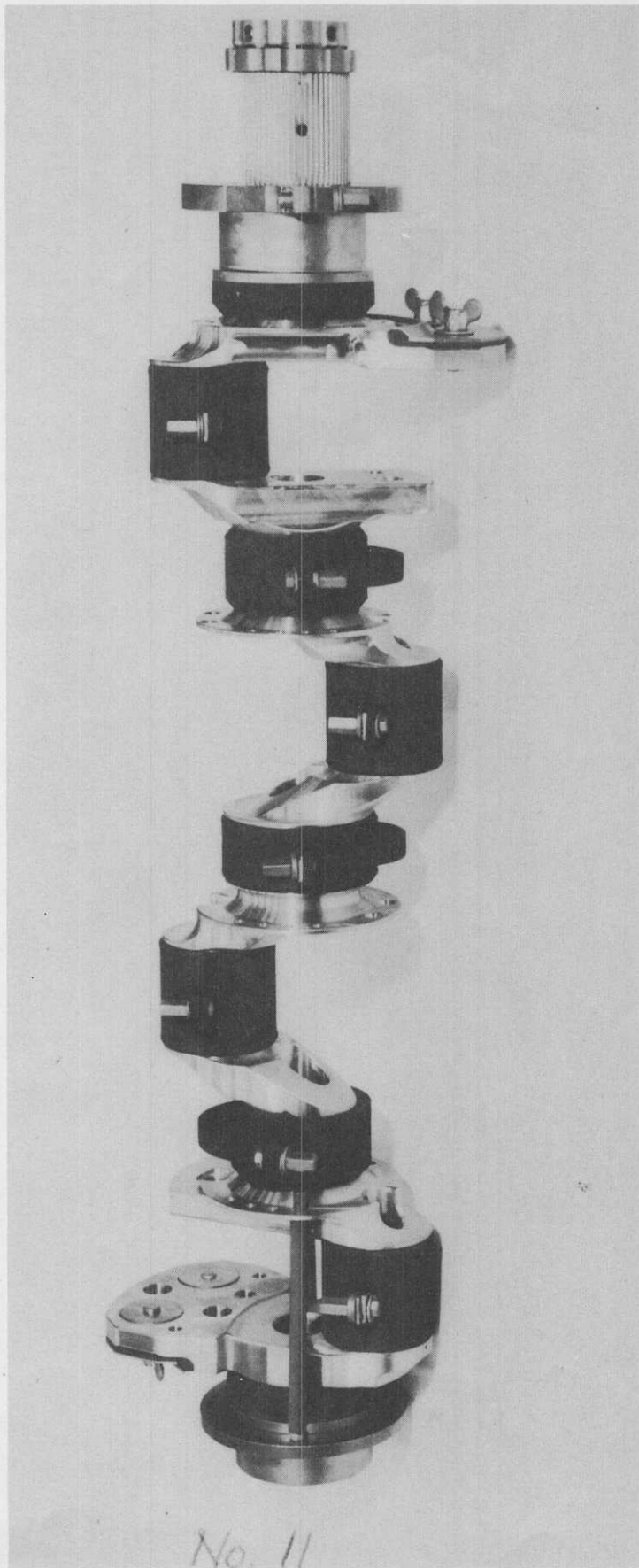
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J-16



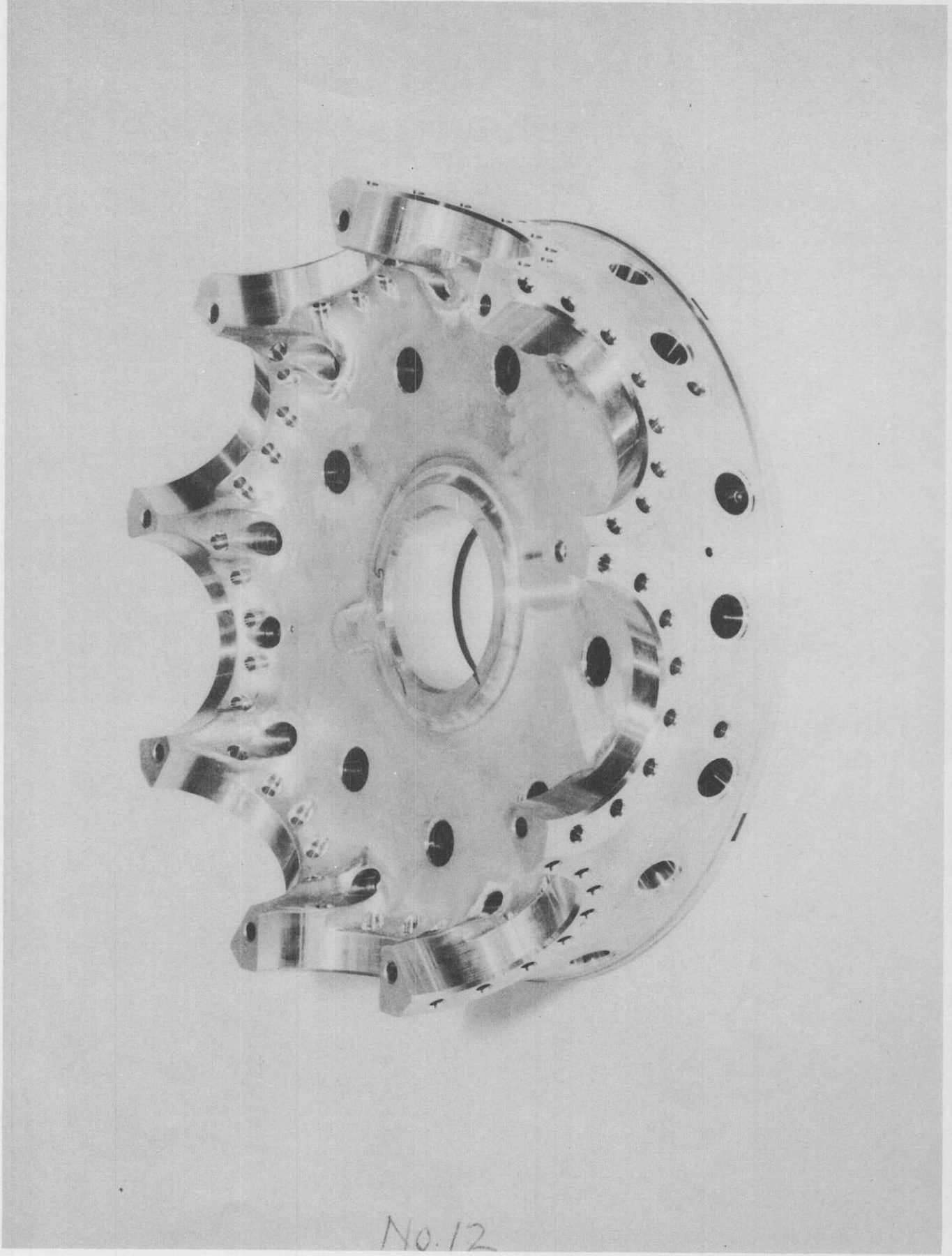
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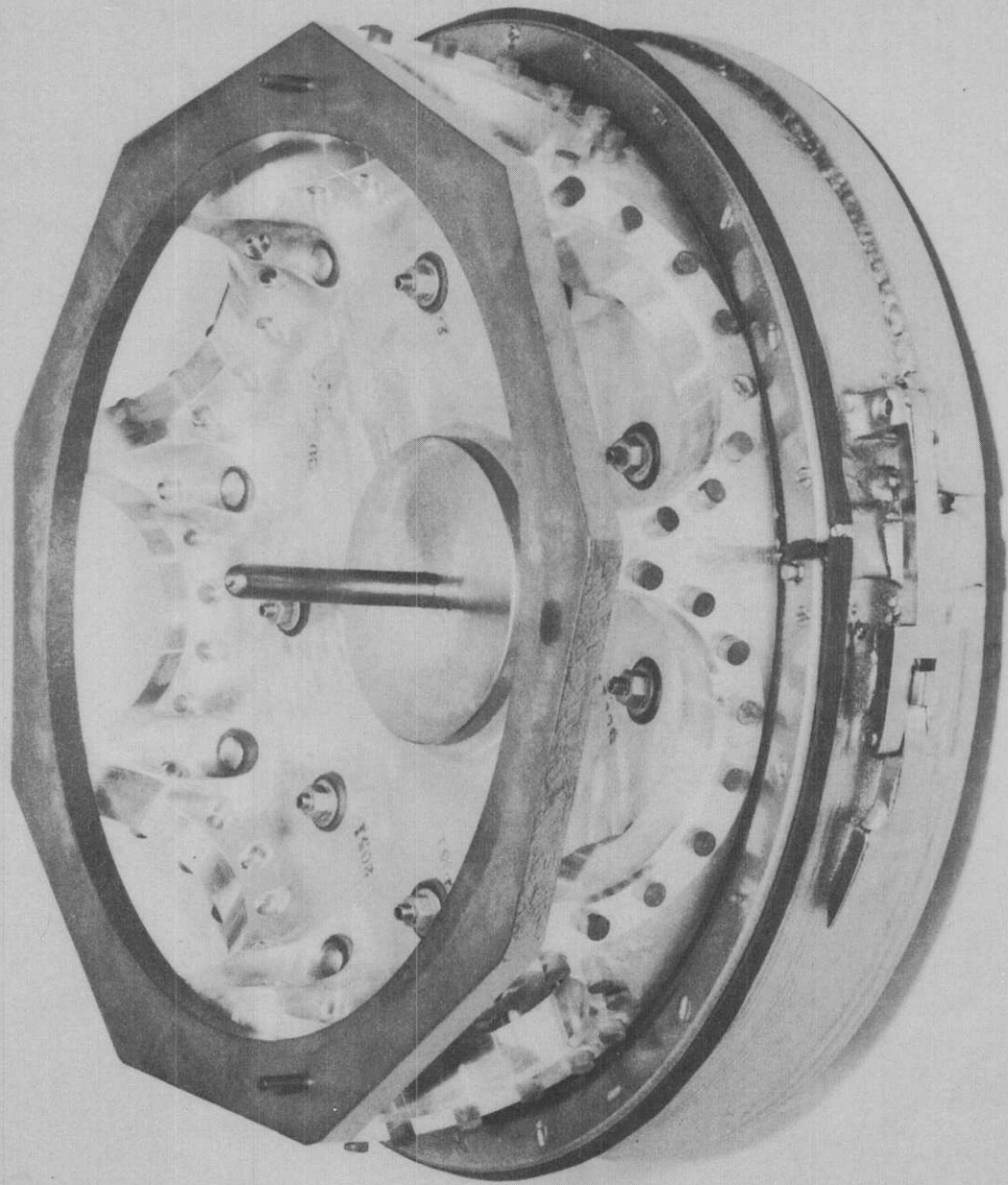
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J-18

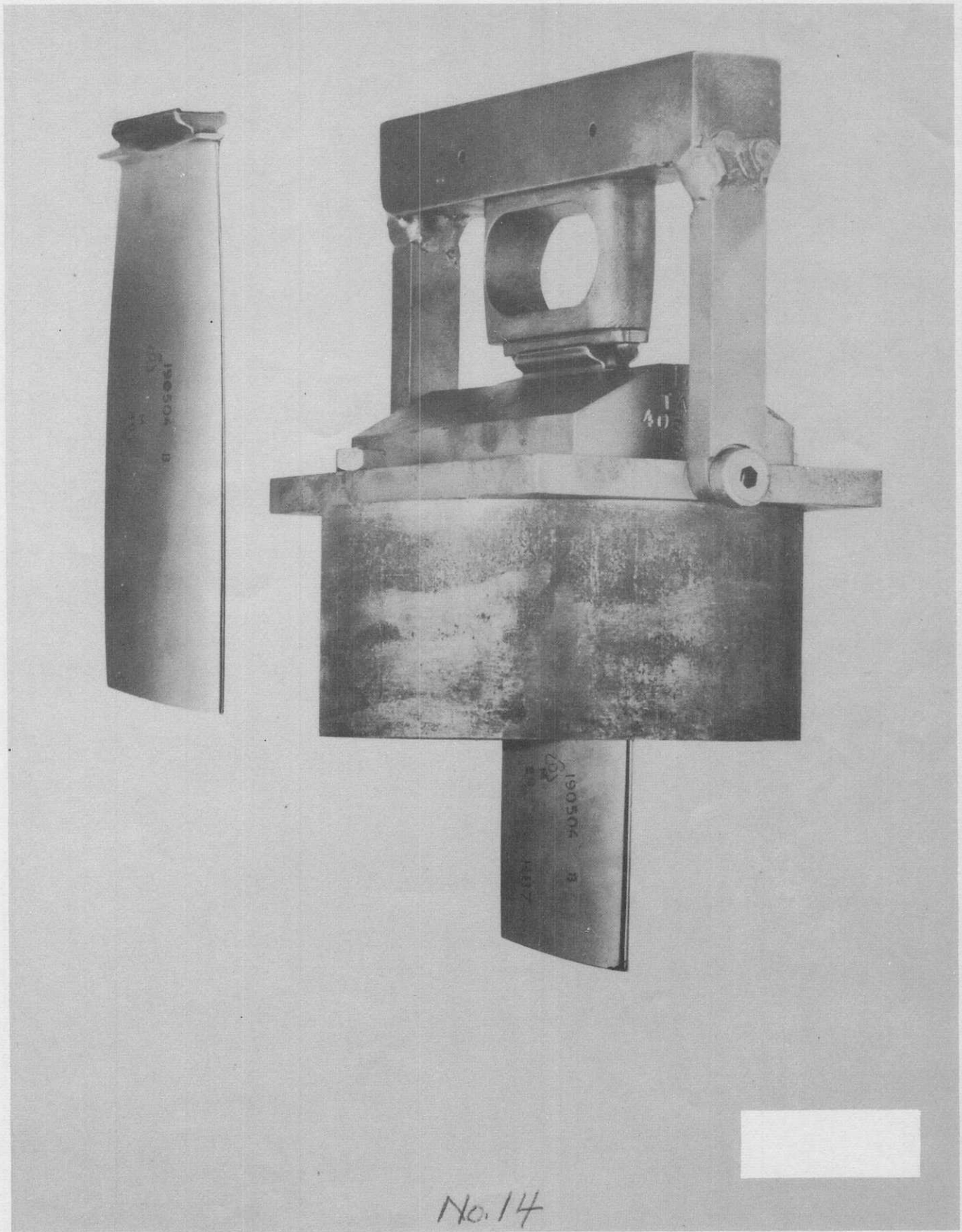


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J-19



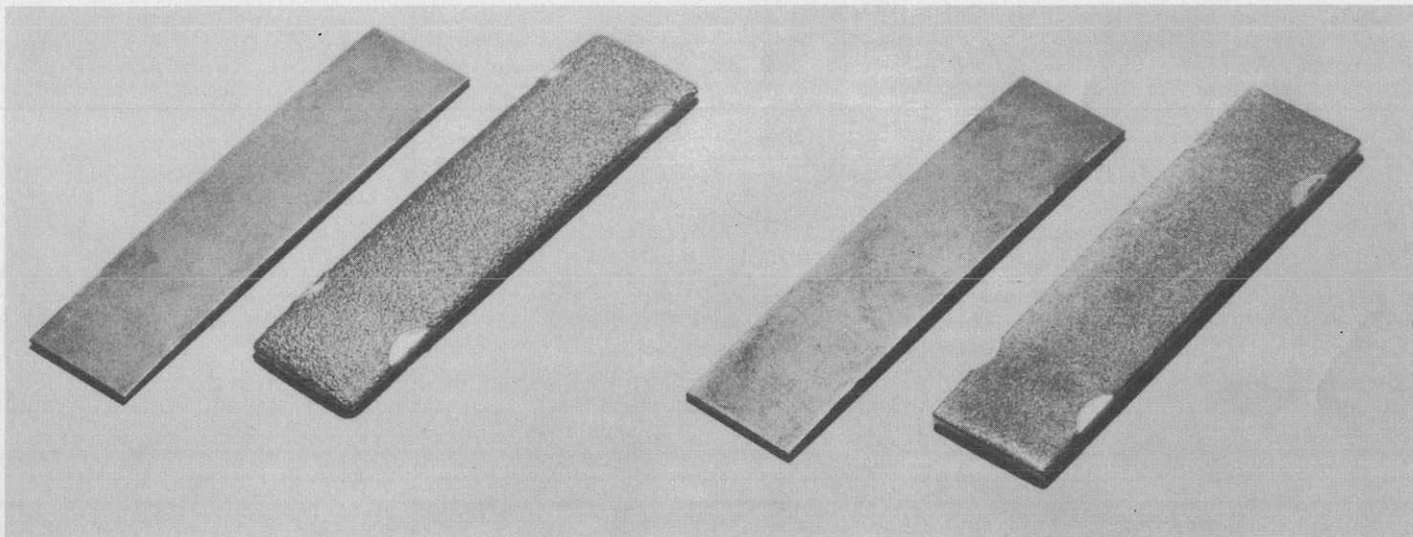
No. 13



No. 14

PEENED WITH MALLEABLE IRON SHOT
S-390 (APPROX. 40 PSI PRESSURE)

PEENED WITH CAST STEEL SHOT
S-390 (APPROX. 20 PSI AIR PRESSURE)



No. 15

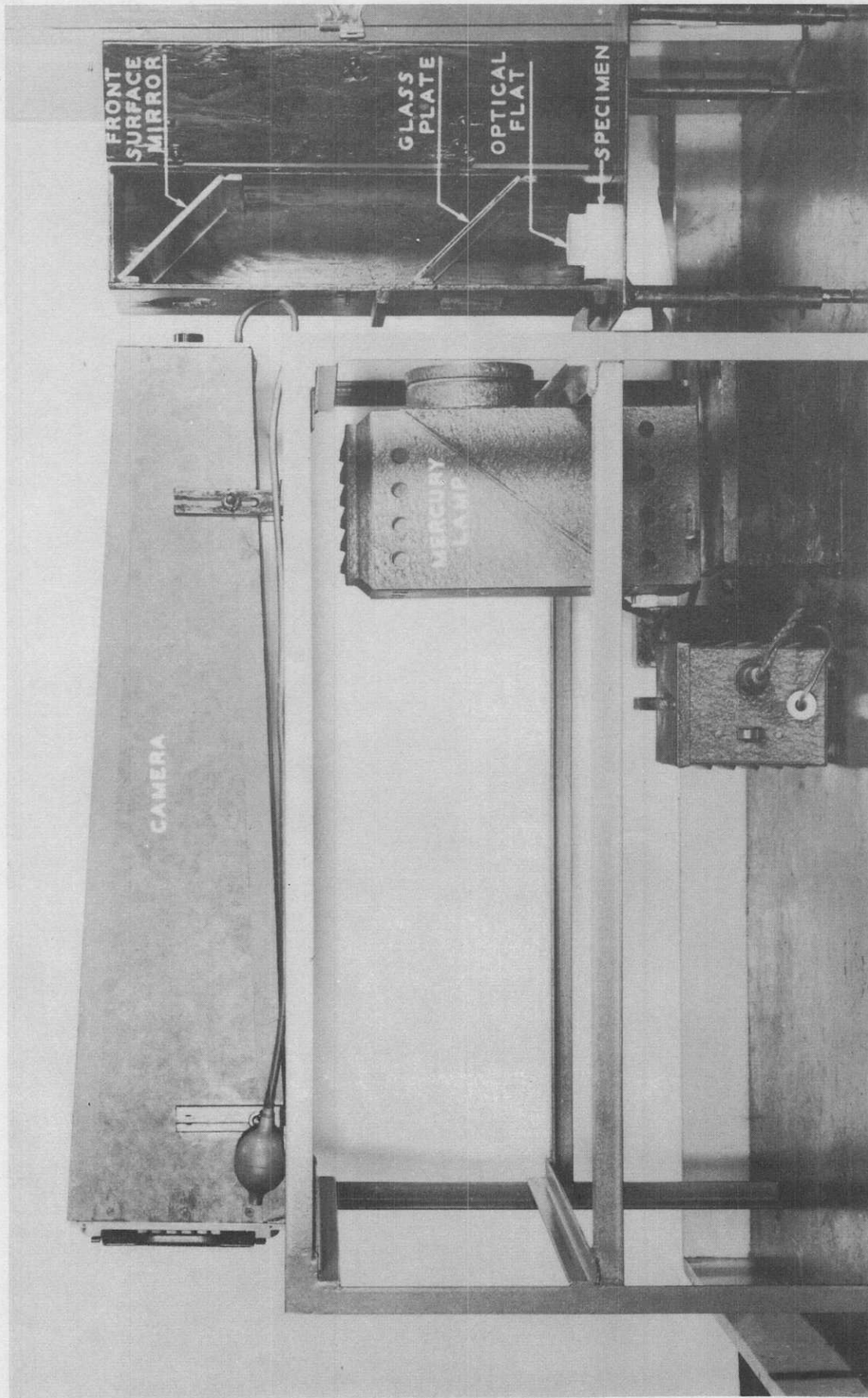
ALMEN
"A" STRIP
.015A₂

ALUMINUM
"C" STRIP
.030C₂

ALMEN
"A" STRIP
.015A₂

ALUMINUM
"C" STRIP
.010C₂

5-21



FRONT SURFACE MIRROR
 GLASS PLATE
 OPTICAL FLAT
 SPECIMEN

CAMERA

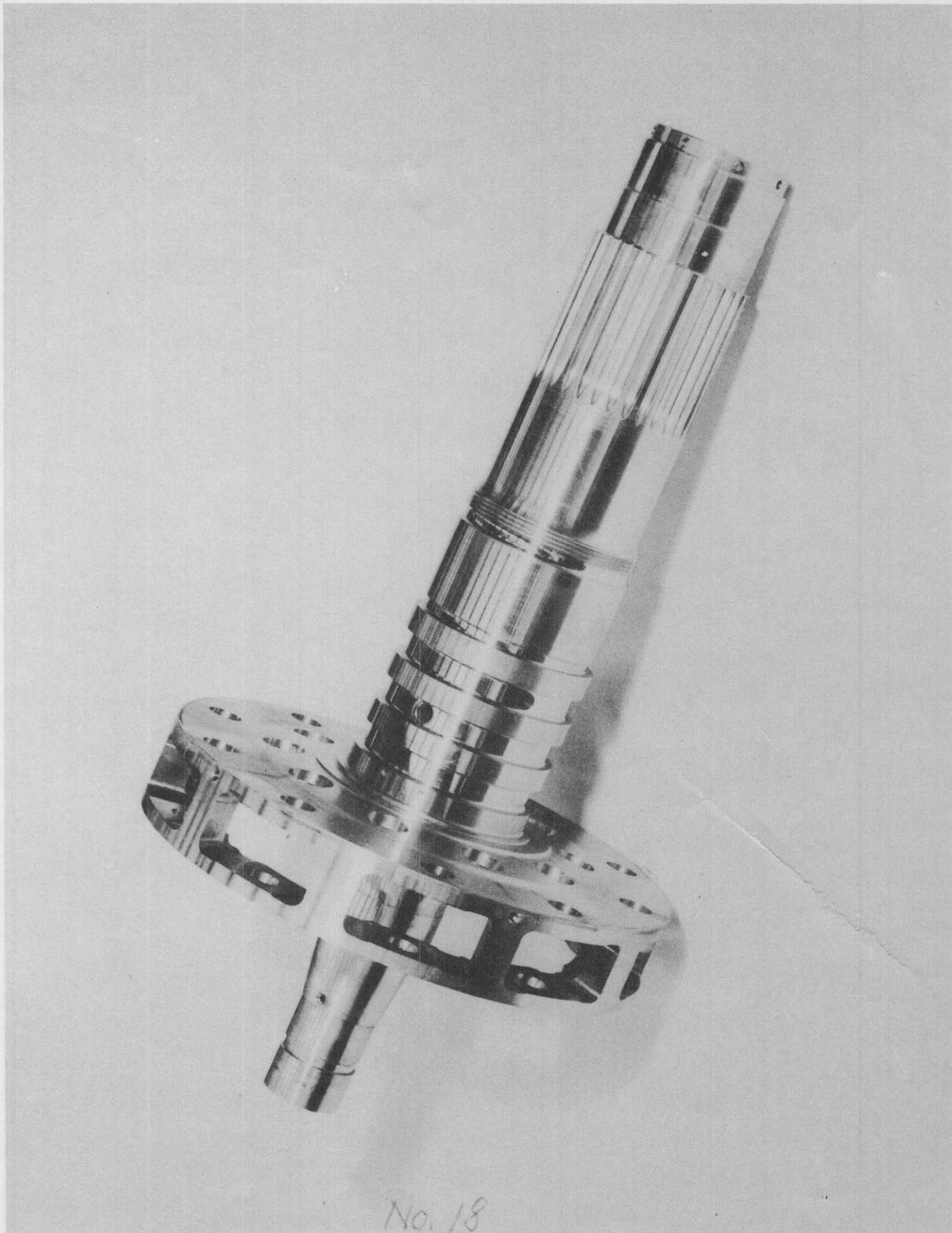
MERCURY LAMP

No. 16

INTERFEROMETER FOR PRODUCING AND PHOTOGRAPHING INTERFERENCE PATTERNS FOR RESIDUAL STRESS STUDIES.



J-14



No. 18