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AMC TECHNICAL REPORT 60-2
September 1960

FABRICATION ANALYSIS OF
RENE' 41 ALLOY PRODUCTION PARTS
FOR THE F-105 SPEED BRAKE
(Rene' 41 Fabrication)

F. Smith
W. Trepel

REPUBLIC AVIATION CORPORATION

Special Technical Engineering Report
July 1959 - June 1960

Heat resistant, high strength nickel base alloy (Rene' 41) parts for high performance aerospace vehicles are being fabricated using revisions of standard manufacturing and tooling techniques. Corrosion resistance is retained by avoiding contamination with lead, zinc, magnesium, aluminum, tin and their alloys.

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MANUFACTURING AND MATERIALS TECHNOLOGY DIVISION

AMC Aeronautical Systems Center
United States Air Force
Wright-Patterson Air Force Base, Ohio

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Heat resistant, high strength nickel base alloy (Rene' 41) parts for high performance aerospace vehicles are being fabricated using revisions of standard manufacturing and tooling techniques. Corrosion resistance is retained by avoiding contamination with lead, zinc, magnesium, aluminum, tin and their alloys.

Forming should be in the annealed condition using high pressure in lubricated steel dies with 2T minimum bend radius. Operations must be avoided wherein the high notch sensitivity of Rene' 41 would be involved.

Solution heat treating at 1975°F requires rapid cooling to retain ductility. Precipitation aging for 16 hours at 1400°F with non-critically controlled air cooling gives room temperature ultimate tensile strength of about 175000 psi and yield strength of 130000 psi. Cutting and forming lubricants, paints, oil, ink and low melting alloys must be completely removed from Rene' 41 before heating.

Optimum drilling operations use 8% cobalt hi-speed steel drill material with carefully controlled geometry turning at 13 sfm with a feed rate of 0.002" per revolution. Material cost reduction and increased hole production yield per drill are achieved by using "Jobbers Length" (minimum length) drills to replace special Kellermatic drills by using specially developed drill drivers and adapters.

FOREWORD

This Technical Engineering Report presents work performed in support of the F-105. The manuscript was released on 8 July 1960 by Republic Aviation Corporation and the F-105 Weapon System Project Office to the Manufacturing and Materials Technology Division for publication as an AMC Technical Report.

The work was performed under the F-105 Weapon System Contract AF 33(600)34752 by F. Smith and W. Trepel of the Manufacturing and Research Group of Republic Aviation Corporation, Farmingdale, New York. It was supervised and approved by R. W. Hussa, Senior Manufacturing Research Group Engineer and T. F. Imholz, Chief, Manufacturing Research Engineer.

The primary objective of the Air Force Manufacturing Methods Program is to increase producibility, and improve the quality and efficiency of fabrication of aircraft, missiles, and components thereof. This report is being disseminated in order that methods and/or equipment developed may be used throughout industry, thereby reducing costs and giving "MORE AIR FORCE PER DOLLAR".

Your comments are solicited on the potential utilization of the information contained herein as applied to your present or future production programs. Suggestions concerning additional Manufacturing Methods development required on this or other subjects will be appreciated.

PUBLICATION REVIEW

This report has been reviewed and is approved

FOR THE COMMANDER:



PRESTON L. HILL
Colonel, USAF
Chief, Manufacturing & Materials
Technology Division

INTRODUCTION

Rene' 41 was selected for use in the F-105 to provide mechanical and physical properties at elevated temperatures beyond those offered by previously used alloys. The advantages of Rene' 41, however, were partially offset by problems whose solutions required the revision of existing manufacturing and tooling policies. The recent development of the material with attendant deficiencies of information concerning tooling, material handling, fabrication, heat treatment, assembly and inspection precluded its use without investigation within these areas. Programs were initiated to provide a knowledgeable approach to each phase.

Information pertinent to the utilization of Rene' 41 has been mainly derived at Republic Aviation Corporation through the investigative efforts of Engineering Structures, Quality Control, Manufacturing Research and Processes, and Manufacturing Planning. While technical information was solicited from the various material suppliers and field trips were made to fabricators using the material, technical development at these sources was rudimentary and of relatively little value with regard to the specific problems existing within the F-105 program.

CONCLUSIONS:

The following general conclusions and manufacturing process recommendations are made as a result of these programs:

A. Room temperature mechanical properties required in Rene' 41 in the aged condition are shown below:

<u>Thickness</u>	<u>Tensile Strength</u> <u>PSI - Minimum</u>	<u>Yield Strength</u> <u>0.2% Offset</u> <u>PSI - Minimum</u>	<u>% Elongation</u> <u>in 2" Minimum</u>
Up to .025	175,000	130,000	8
.026 - .094	175,000	130,000	10
.095 - .187	170,000	130,000	10
.188 & Up	165,000	120,000	10

B. Manufacturing Requirements

1. Forming shall be accomplished on steel tooling at high pressures to prevent extensive refining and/or material contamination.

2. Mechanical properties shall be maintained by strict control of heat treatment cycles.

3. Optimum drill performance shall be attained through use of positive feed drill motors and development of specific drill geometry and the maintenance of minimum gap tolerances between parts and assembly tools to provide rigid support during drilling operations.

C. Forming

1. All major forming shall be accomplished with material in the annealed condition.

2. A minimum bend radius of 2T is recommended for design purposes. Lesser radii may result in excessive stress concentrations.

3. After blanking, shearing or similar shaping operations blanked edges shall be refined to remove burrs to prevent cracking and tearing during the forming operations. Deburring may be accomplished by barrel finishing or by belt sanding on mechanical equipment (Figure 1 through Figure 4).

4. Springback will vary with the yield strength and percentage of elongation of the material, and is dependent upon the nature of the bend and the type of tooling used. In the solution annealed condition the average springback of straight 90° brake bends is approximately 5 degrees.

5. Forming without lubrication should be avoided. Special forming lubricants are not required but where a choice of lubricant is possible, the preferable one is that with the lowest sulfur content.

6. Rene' 41 work hardens rapidly and secondary forming operations (i.e.: forming subsequent to bending, drawing or stretching) can usually be performed only after re-solution heat treatment. Re-solution treatment may be repeated whenever required without deleterious effect. Subsequent forming may be accomplished without scale removal, with the exception of dimpling operations.

7. Parts may be refined either by restriking in forming tools or by hand refining using steel refining tools. Shrinking or stretching using mechanical shrink presses is prohibited because of the notch sensitivity of Rene' 41, unless the operations are performed outside the finish trim.

8. Parts cold worked in excess of an angular deflection of 45°, or by stretch forming or deep drawing shall be re-solution treated prior to aging. Re-solution treatment is not required following roll forming, dimpling or forming flanged lightening holes.

D. Heat Treatment

1. Solution treatment (Condition ST) is carried out by heating material in air in a muffle type furnace to $1975^{\circ}\text{F} \pm 25^{\circ}\text{F}$ for 20 minutes at temperatures for thicknesses up to and including .025" nominal gage or for 30 minutes at temperature for thicknesses greater than .025".

a. Material shall be cooled from the solution treatment temperature (1975°F) to room temperature as rapidly as possible. The cooling rate becomes critical when additional forming is necessary after solution treatment since the percentage of elongation decreases as the cooling time increases. Springback and formability can be adversely affected by the injudicious cooling of solution treated material. Where part configuration permits, water quenching from 1975°F will yield the maximum ductility, providing immersion is made within 5 seconds after removal from the furnace. (Figure 5 and Figure 6).

b. Parts shall be individually suspended to permit free air circulation around all surfaces to assure that cooling to room temperature is completed in a minimum of time. Forced air cooling is desirable providing parts do not come in contact with one another or with other objects during cooling.

2. Precipitation aging treatment (Condition STA) is accomplished by heating material in air to $1400^{\circ}\text{F} \pm 25^{\circ}\text{F}$, holding at temperature for 16 hours followed by air cooling. The cooling rate is not critical.

3. It is extremely important that cutting and forming lubricants and compounds, paints, oil, ink, metals such as lead, tin, antimony, aluminum, Kirksite, etc., be completely removed from Rene' 41 before it is subjected to heat treatment. Any supporting wire or identifying tags shall be stainless steel.

4. Fixturing parts during heat treat cycles is not deemed feasible.

5. The full heat treat cycle (Conditions ST and STA) may be repeated when necessary.

6. Protective atmospheres (i.e.: argon, helium, dry hydrogen) can be used to minimize oxidation of Rene' 41 during thermal treatment. There is no common effective method of rapidly cooling from 1975°F to room temperature in a protective atmosphere, therefore, the value of a noble atmosphere within the furnace is lessened considerably.

E. Tooling

1. All tooling for Rene' 41 shall be wear resistant, non-contaminating steel or its equivalent. The use of low melting point metals should be avoided since waste metal deposited upon Rene' 41 parts during forming operations can seriously effect mechanical properties and material integrity after subjection to elevated temperatures. The use of lead, Kirksite, aluminum, etc., is permissible on condition that the tools are capped with steel, Inconel X or epoxy plastic to prevent intimate contact of the base metal with the Rene' 41.

2. High pressure is required to form parts with shrink or stretch flanges, beads or joggles. Male and female die sets are recommended for all forming excepting stretch wrapping, rolled contours or straight bends. (photographs 1, 2, and 3). Wherever possible tooling shall incorporate draw beads to stretch material tightly against the bend radii and contours of the tool. Concave curling will develop in the flanges, requiring hand refining, when there is insufficient pressure, tool height or restriction.

3. Hydropress tooling may be used for production of relatively simple shapes providing high pressures are induced locally by means of draw beads, wiping dams, hinges, restriction plates or intensifiers in order to reduce hand refining to a minimum.

4. Shearing and blanking of Rene' 41 can be performed with standard tooling and equipment. In the solution annealed condition the material is ductile and will roll or bend over if the clearances on shear or punch and dies are too liberal. Blanking and shearing tools shall be kept sharp to minimize burring and edge cracking.

5. Rene' 41 shrinks approximately .0005"/inch during the aging cycle. Expanding the tooling is not necessary except where large structural parts are to be processed.

6. Assembly fixtures and drill jigs employed in conjunction with positive feed drills shall be capable of support without deflection to permit maximum bushing and drill life. Back up blocks and contour plates shall be steel capped aluminum or magnesium to prevent contamination. Close tolerances between back-up components and parts shall be maintained to prevent part distortion during drilling operations.

F. Cleaning and Descaling

1. The following forms of surface contamination may be found on, or introduced to Rene' 41:

a. Solvent soluble impurities - code paints, some marking inks, grease, oils, etc..

b. Water soluble impurities - some marking inks, salts, penetrant developers, etc..

c. Forming contaminants - pick up from soft die and tool materials such as lead, Kirksite, etc., during forming.

d. Thermal treatment scale - oxides of chrome, nickel, cobalt, etc., formed during solution annealing and aging in an air atmosphere.

e. Mill scale - rolled in impurities on the "as received" material.

2. Cleaning and descaling of Rene' 41 for the various surface contaminations is accomplished as follows:

a. Code paints, grease, oils and some marking inks are removed by vapor degreasing in stabilized trichlorethylene or by alkaline cleaning (Turco bath, Okite, etc.).

b. Salts, penetrant developers and some marking inks are removed by hot water rinse or in some cases, by vapor degreasing.

c. Thermal treatment scale is removed by vapor blasting. The use of chemical means of descaling is currently under investigation.

Rene' 41 parts to be vapor blasted shall be segregated from non-nickel base alloys and processed with abrasives restricted to their use alone to reduce the incidence of contamination.

3. Oxide scale formed during solution treatment must be removed in order to permit Zyglo (penetrant) inspection of Rene' 41 parts. Descaling may take place:

a. After final solution treatment and prior to age hardening when dimpling is performed. Descaling is not required after age hardening.

b. After final solution treatment and aging cycle.

It is not necessary to descale after age hardening if solution treatment has not preceded it.

G. Dimpling

1. It is recommended that Rene' 41 be dimpled in the solution treated condition only. Dimpling in the aged condition requires that:

a. All material must have a minimum elongation of 15% in the fully aged condition.

b. All material must be fine grained and of homogenous structure and free of cold work.

While the material received and tested generally meets or exceeds 15% elongation the material suppliers have been unwilling to increase the minimum elongation specifications on "run of the mill" material (presently 8 to 10% minimum elongation). Republic Aviation Corporation certification of the acceptable minimum requirements for dimpling in the aged condition would exact severe Quality Control surveillance.

2. Standard T4 punches and rams shall be used in conjunction with standard T4 titanium type dies. In restricted areas where coin dimpling tooling is not feasible press dimpling tooling shall be used.

3. Power units in use for the dimpling of Inconel X shall be used for Rene' 41.

4. All dimpling shall be performed at room temperature.

5. All holes must be drilled round; elongated or irregular holes cause stress risers during the forming of the dimples and may cause radial cracks.

6. Care must be taken not to "burn" the material during the drilling operation. Overheating adversely affects subsequent forming of Rene' 41.

7. All holes shall be deburred prior to dimpling; the following deburring procedure shall be adhered to:

a. The "flush" or outer surface shall be deburred using a sharp countersink. This operation removes the burr or sharp edge of the hole. Care should be taken not to countersink the surface.

b. The "lower" or inner surface shall be countersunk approximately 30% of the gauge thickness in materials under .030" thickness. This operation is important in eliminating radial cracking tendencies in thin gauge materials. Material thicker than .030" shall be countersunk only sufficiently to remove the burrs or sharp edges.

A sharp countersink is recommended wherever possible, however spherical rotary files, burr away tools or drills of at least two times the diameter of the hole may be used providing the resulting chamfer is chatter-free.

8. The outside surface (flush side) shall be vapor blasted in the dimple area. The use of emery paper to remove scale is not acceptable.

9. Slow forming of dimples is desired. All equipment shall be maintained at minimum forming speeds.

H. Drilling

1. The recommended drill for optimum performance shall consist of 8% cobalt high speed steel material, 135° included angle, chisel point (conventional grind), 9° lip clearance, slow spiral and short flute length to accommodate the particular application. To reduce drilling forces, drills larger than No. 30 (.128") shall have the web thinned by notching similar to NAS 907 to a point having a chisel edge .010" to .015" in length.

2. The recommended drill spindle speed is approximately 13 S.F.M. with a feed rate of .002" per revolution. Kellermatic air drills (300 R.P.M., .002" F.P.R.) are adequate for drill sizes up to 1/4 inch in diameter. (Photograph 4)

3. Off-hand drilling is not recommended and should be used only when power feed drilling is not feasible.

4. Material to be drilled shall be rigidly backed and supported to accommodate the drilling forces and high thrust loads and shall be restrained to prevent upward movement after drill break thru.

5. All layers of metal shall be in close contact during stack drilling.

6. Drill life is slightly improved when lubrication is used. Hangstorfer's J-1 or equivalent oil may be brushed on drills.

7. Rene' 41 exhibits similar behavior when drilled in either the solution annealed or aged conditions.

8. "Jobbers length" drills (minimum length) can replace special Kellermatic drills when used in conjunction with drill drivers and adapters (Figure 7 and Photographs 5 and 6) with attendant material cost reduction and increased hole production yield per drill.

I. Corrosion Resistance

1. Rene' 41, although classified as a corrosion resistant nickel alloy is subject to severe attack and embrittlement when exposed to elevated temperature while in contact with certain low melting metals.

2. To prevent these types of attacks, it is necessary to insure that all Rene' 41 parts are free of low melting metallic materials prior to thermal exposure. Special care must be used during the manufacture of Rene' 41 parts to avoid contamination by lead, zinc, magnesium, aluminum, tin and alloys of these metals, including Kirksite, in all stages of manufacture.

DISCUSSION:

A. The effect of mechanical deburring, using various grit belts, upon the mechanical properties of .050 gage Rene' 41 aged at 1400°F for 16 hours and tested at 1400°F after 30 minutes at temperature.

Figure 1

<u>Grit Belt Used</u>	<u>Spec. No.</u>	<u>Yield PSI</u>	<u>Ultimate PSI</u>	<u>Elongation % in 2"</u>	<u>Hardness, Rc</u>
Control	A1	118,500	147,100	6.0	41
	A2	115,600	146,000	7.0	42
	A3	116,500	141,900	6.5	42
	A4	114,600	143,900	7.0	41
	A6	115,300	143,400	6.5	42
#240	B1	118,700	142,600	6.0	41
	B2	125,700	159,900	7.0	41
	B3	119,600	142,600	6.0	42
#280	C1	115,700	146,400	6.5	41
	C2	110,900	142,500	5.0	41
	C3	119,100	138,700	5.0	41
#320	D1	114,000	140,400	6.0	42
	D2	128,100	142,300	6.5	41
	D3	113,100	142,900	6.5	41
#400	E1	126,200	141,900	6.5	41
	E2	133,100	148,900	6.5	42
	E3	134,200	149,500	8.0	41
RE-MS-17-10 Requirements			140,000	3.0	

The effect of mechanical deburring, using various grit belts upon the mechanical properties of .020 gage Rene' 41 aged at 1400°F for 16 hours and tested at 1400°F after 30 minutes at temperature.

Figure 2

<u>Grit Belt Used</u>	<u>Spec. No.</u>	<u>Yield PSI</u>	<u>Ultimate PSI</u>	<u>Elongation % in 2"</u>	<u>Hardness, Rc</u>
Control	A7	111,700	124,500	3.5	43
	A8	**	146,100	10.0	43
	A9	118,700	145,100	7.5	43
	A10	114,400	152,700	10.0	43
	A12	121,800	153,700	10.5	45
#240	B4	118,300	147,300	8.0	46
	B5	110,800	136,600	6.0	44
	B6	119,300	141,100	6.0	43
#280	C4	114,700	140,000	6.0	43
	C5	118,900	144,200	10.0	44
	C6	120,500	152,100	10.0	44
#320	D4	107,000	125,000	3.5	43
	D5	114,900	142,800	6.5	43
	D6	115,500	140,200	6.5	44
#400	E4	115,700	145,100	8.0	43
	E5	110,900	140,600	6.0	44
	E6	116,100	141,100	6.0	44
RE-MS-17-10 Requirements			135,000	3.0	

The effect of mechanical deburring, using various grit belts, upon the mechanical properties of .050 gage Rene' 41 aged at 1400°F for 16 hours and tested at room temperature.

Figure 3

<u>Grit Belt Used</u>	<u>Spec. No.</u>	<u>Yield PSI</u>	<u>Ultimate PSI</u>	<u>Elongation % in 2"</u>	<u>Hardness R15N</u>
Control	A1	136,400	190,300	17.5	82
	A2	133,900	189,900	20.0	83
	A3	135,100	188,000	19.0	82
	A4	133,100	191,100	20.0	83
	A5	137,000	189,800	18.0	83
	A6	131,400	189,000	18.0	81
#240	B1	137,000	190,200	18.5	83
	B2	136,100	191,200	20.0	83
	B3	135,400	189,900	20.0	82
#280	C1	133,700	189,600	18.5	81
	C2	137,100	191,200	18.5	82
	C3	135,500	190,800	17.5	82
#320	D1	132,300	187,400	16.5	81
	D2	138,300	190,000	21.0	82
	D3	133,800	189,600	18.5	82
#400	E1	134,400	188,000	18.0	83
	E2	130,700	189,600	18.0	83
	E3	131,500	189,100	17.0	82
RE-MS-17-10 Requirements		130,000 Min 175,000 Min		10.0	

The effect of mechanical deburring, using various grit belts, upon the mechanical properties of .020 gage Rene' 41 aged at 1400°F for 16 hours and tested at room temperature.

Figure 4

<u>Grit Belt Used</u>	<u>Spec. No.</u>	<u>Yield PSI</u>	<u>Ultimate PSI</u>	<u>Elongation % in 2"</u>	<u>Hardness R15N</u>
Control	A7	135,100	189,600	19.0	81
	A8	136,900	191,300	20.5	83
	A9	136,900	192,200	21.5	83
	A10	135,800	191,700	22.0	82
	A11	136,400	191,300	22.0	82
	A12	139,000	193,000	23.5	83
#240	B4	137,600	191,900	22.0	82
	B5	139,200	190,600	19.5	82
	B6	130,400	189,200	21.0	82
#280	C4	132,600	187,800	17.0	81
	C5	136,300	191,500	21.5	82
	C6	139,200	190,600	19.0	82
#320	D4	138,700	194,700	21.5	82
	D5	136,800	189,600	21.5	83
	D6	133,300	190,500	21.5	82
#400	E4	136,300	191,200	19.0	83
	E5	132,400	192,200	23.5	82
	E6	129,400	193,100	21.5	84
RE-MS-17-10 Requirements		130,000 Min	175,000 Min	8.0	

The Effect of Cooling Rate Upon the Room Temperature Properties of Solution

Annealed Rene' 41 - .025 Gage

Figure 5

Spec No.	Time At 1975° Minutes	Time In Seconds 1975° to 1200°	Time In Seconds 1800° to 1200°	Yield Strength 0.2% Offset PSI	Tensile Strength Ultimate PSI	% Elongation In 2" Min
1	Mill Annealed @ 1975° For			75,000	141,000	43.5
2	30 Minutes and Water			71,000	143,000	44.5
3	Quenched			78,000	142,000	45.5
4	20	13	10	108,000	164,000	35.5
5	60	12	9	96,000	154,000	32.5
6	20	12	9	102,000	145,000	35.0
7	20	30	21	115,000	173,000	26.0
8	60	26	17	110,000	163,000	30.0
9	20	27	22	110,000	176,000	27.5
10	20	60	50	119,000	172,000	25.5
11	20	70	55	116,000	169,000	26.0
12	20	75	60	125,000	178,000	22.5
13	20	240	180	138,000	189,000	22.0
14	20	240	180	138,000	184,000	18.0
15	20	240	180	132,000	188,000	22.5

The Effect of Cooling Rate Upon the Room Temperature Properties of Solution

Annealed Rene' 41 - .051 Gage

Figure 6

<u>Spec No.</u>	<u>Time At 1975° Minutes</u>	<u>Time In Seconds 1975° To 1200°</u>	<u>Time In Seconds 1800° To 1200°</u>	<u>Yield Strength 0.2% Offset PSI</u>	<u>Tensile Strength Ultimate PSI</u>	<u>% Elongation In 2" Min</u>
1	Mill Annealed @ 1975° For			72,000	141,000	37.0
2	30 Minutes and Water			79,000	151,000	41.5
3	Quenched			76,000	148,000	35.0
4	35	18	15	121,000	195,000	33.5
5	40	15	11	128,000	199,000	33.0
6	30	12	10	131,000	193,000	34.0
7	30	63	48	125,000	182,000	31.0
8	30	67	48	123,000	176,000	29.0
9	30	63	48	141,000	188,000	25.0
10	30	71	62	130,000	187,000	29.5
11	40	75	60	131,000	189,000	24.0
12	30	80	60	140,000	187,000	27.5
13	30	240	180	129,000	189,000	25.0
14	30	240	180	146,000	202,000	24.0
15	30	240	180	144,000	190,000	24.5

B. Corrosion of Parts During Processing

Rene' 41, although classified as a corrosion resistant nickel alloy, is subject to severe attack and embrittlement when exposed to elevated temperature while in contact with certain low melting metals. This type of attack is not limited to Rene' 41, but exists in other nickel alloys and is similarly found in other non-ferrous and ferrous alloys. The severity of the attack varies in intensity, depending on the specific alloy involved, the type of molten metal available for attack and the time and temperature of exposure.

Prior to its proposed use in the speed brake assembly of the F-105, there had been no application for Rene' 41 at Republic Aviation Corporation. When its intended use was announced, a program was initiated at Manufacturing Research & Processes in order to determine the behavior of this material during fabrication and to set the basic formability parameters to be used for the manufacture of parts. Among the recommendations made at the close of the preliminary program was one to provide steel tooling for part production.

Steel tooling is being currently employed for Rene' 41 fabrication. Prior to receiving these tools, however, an attempt was made to manufacture two of the more difficult parts on the drop hammer using temporary tools of lead and Kirksite (a zinc base alloy). Due to the wiping action of the dies, the large pressures involved and the rather soft tooling materials employed, small particles of lead and Kirksite were deposited on the surfaces of the parts. In addition, it was found that the deposit remained undetected on some parts after the normal cleaning operation which precede thermal processing.

One such part is shown in Photographs 8 and 9 after process annealing at 1975°F for thirty minutes. The attack was catastrophic, penetrating the material throughout its thickness.

The effects to be encountered on Rene' 41 after attack by some typical aircraft tooling materials are shown in Photographs 10 and 11. As evident from the photographs, the attack by lead was by far the most serious, with aluminum next in severity and Kirksite the least damaging. In all cases, the results were completely undesirable.

The attack at 1975°F was particularly harmful when the usual Rene' 41 protective mechanisms against elevated temperature oxidation were inoperative, as for example at the molten lead - Rene' 41 interbase. The slagging action of lead oxide destroyed the protective Rene' 41 surface film as rapidly as it could be produced and formed a spongy, oxygen-rich lead-nickel conglomeration which was extremely voluminous and completely lacking in mechanical integrity. The attack apparently was initiated at the grain boundaries of the material and thence proceeded rapidly, destroying the entire matrix. Photograph 12 is micrograph at 100 diameters showing the attack by lead. In the area of attack, the material has been thinned to approximately one-half of its original thickness, considerable grain boundary attack is evident.

Aluminum and Kirksite gave similarly harmful results. Here, the destruction of the base metal's protective coating was not as rapid and consequently the rate of attack was somewhat reduced. The molten aluminum reacted with Rene' 41 and formed a hard and brittle product with a tendency to crack and spall.

Again the mode of attack was intergranular, but the depth of penetration was not as great as that of lead. The results, however, were none the less serious. In some cases the attack was not visible without the use of high power magnification. On examination, however, these specimens exhibited the same intergranular corrosion and brittle behavior.

The attack by Kirksite at 1975°F was the least destructive to the base metal. In this case, the attack was accompanied by a chemical reaction on the surface of the metal, which produced a non-protective, objectionable oxide film which appeared to add to the general loss in mechanical properties.

Similar tests with these materials at lower temperatures, such as those required in precipitation hardening (1400°F for 16 hours) or those to be encountered in service gave comparable results, but reduced in intensity. The attack was progressive, but it was found to stop at temperatures below the melting point of the soft metals. With each incident of exposure, the attack proceeded further.

At these lower temperatures, the attack by aluminum seemed most severe and was followed in intensity by lead and Kirksite. Contact with coatings and paints which contain low melting metallic pigments (such as the silicone-aluminum base paints) should, therefore be avoided and any traces of these removed from Rene' 41 parts which are to be subjected to elevated temperature exposure either during the course of manufacture or during service.

To prevent these types of attacks, it has been necessary to insure that all Rene' 41 parts are free of low melting metallic materials prior to thermal exposure. Tools made of these materials are no longer used in the fabrication of Rene' 41 unless properly protected so that direct contact with the part is impossible. In addition all applicable Republic Aviation Corporation processing specifications have been amended to keynote this danger and the following statement has been incorporated in the manufacturing operation sheets:

"Special care must be used during the manufacturing of this part to avoid contamination by lead, zinc, magnesium, aluminum, tin and alloys of these metals, including Kirksite, in all stages of manufacture".

Since these precautionary measures were initiated there has been no loss due to this type of attack.

C. Investigations are being conducted in areas of production and tooling where it is believed that manufacturing proficiency can be improved and cost reductions effected. Programs have been initiated into the following:

1. Forming and Tooling

- a. The effects of elevated temperature upon parts manufacture

Remarks: Preliminary investigations have indicated that springback is decreased and multi-stage forming with attendant re-solution annealing is eliminated in some cases when parts are hot formed. In addition, there is evidence that post formed trimming of parts can be avoided since parts have been satisfactorily formed from developed flat patterns. It may also be possible to pierce attaching holes in contoured flanges in the flat blank, thereby reducing the amount of assembly drilling.

b. Employment of cast mated die sets

Remarks: In conjunction with elevated temperature forming cast Beryllium Copper mated dies have been employed, forming developed blanked parts under comparatively low pressures with a minimum of flange distortion or concave curling. This type of die has the potential of eliminating costly multi-stage dies which have been used to form parts with dissimilar flange angles, joggles, etc..

2. Cleaning and Descaling

- a. The use of chemical methods of scale removal.
- b. The use of anti-oxidate and oxidation retarding coatings.

3. Welding

Evaluation of spotwelding for assembly manufacture

Remarks: Rene' 41 specimens have been spotwelded for test data. A program is in progress to spotweld combinations of specimen gauges, as well as joining Rene' 41 to Inconel X.

DRILL DRIVER FOR KELLERMATIC

VIEW 1: BUSHING TIP
 MATERIAL: NAT'L-TOOL-STEEL H. T.-Rc 61-65
 Dimensions: .0003, -.0000, .2501, .25 TYP, .005 RELIEF, .5003 DIA., 1.37, .56, .3748, .0000, -.0003 DIA.
 Feature: DRILL 3/8(.375)x1.20DF.

VIEW 2: DRIVER
 MATERIAL: NAT'L-TOOL-STEEL H. P.-Rc 57-60
 Dimensions: 2.12, 1.88, 1.78, .1285 DIA REAM S.F. FOR NO.30 DRILL, .2500, .0000, .0003 DIA., 4.00, 600, .34 DIA., 1/16 DIA KNOCK OUT HOLE, 6-40 x .12 LG. SEC. SET SCR.
 Feature: SPIRAL OIL GROOVE (R.H.) .03 WIDE x .010 DP x 1.68 LG. .200 PITCH

VIEW 3: DRILL MODIFICATION
 Dimensions: 5, 16

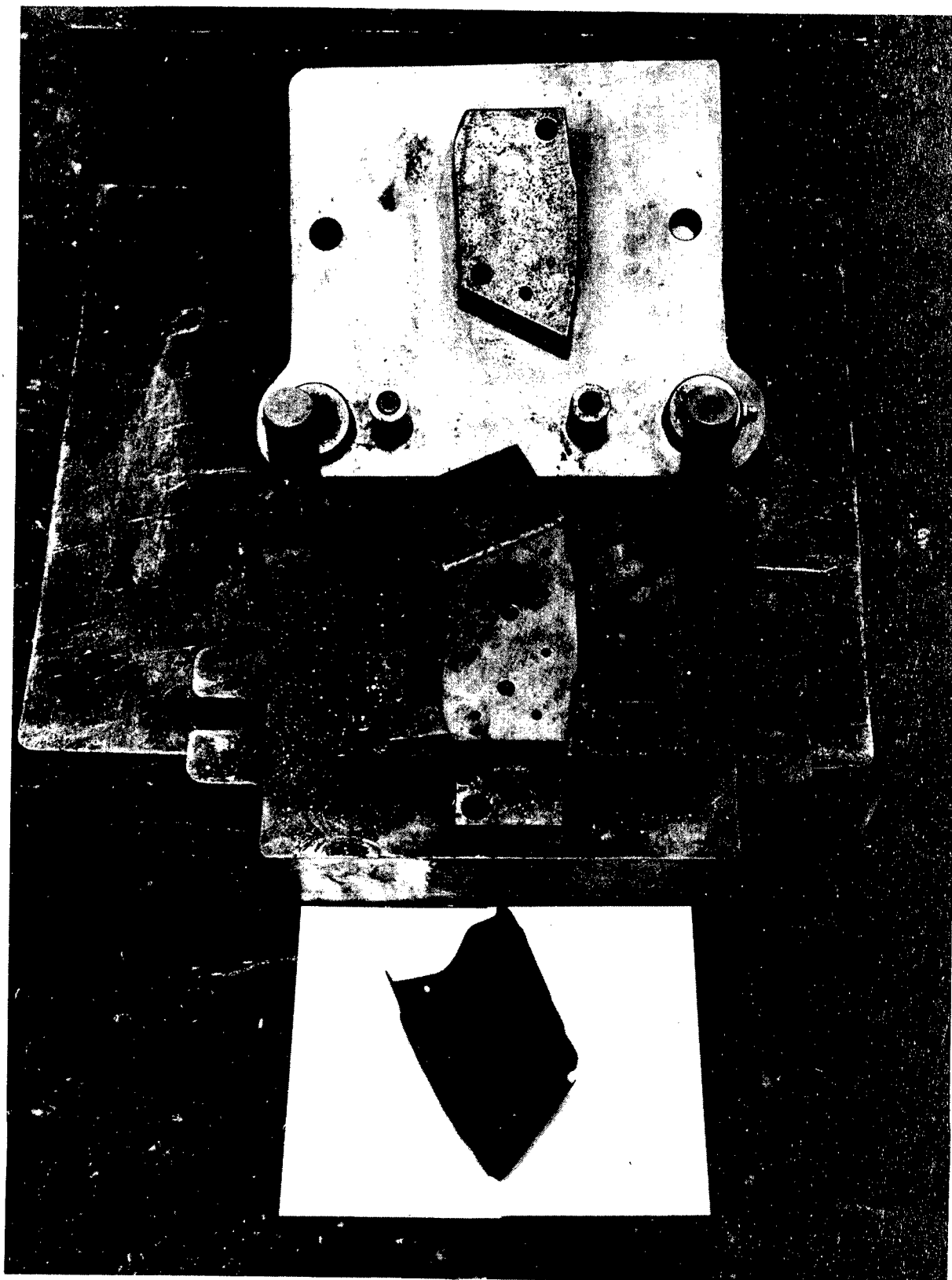
NOTES:
 1) Surfaces marked [concentric symbol] are to be concentric within .001 total indicator reading.
 2) Centers permissible
 3) Sizes shown are for No 30 (.1285) drills on Speed Brake Door
 4) Break all sharp edges

NAT'L-TOOL-STEEL
H. F.-Rc 57-60

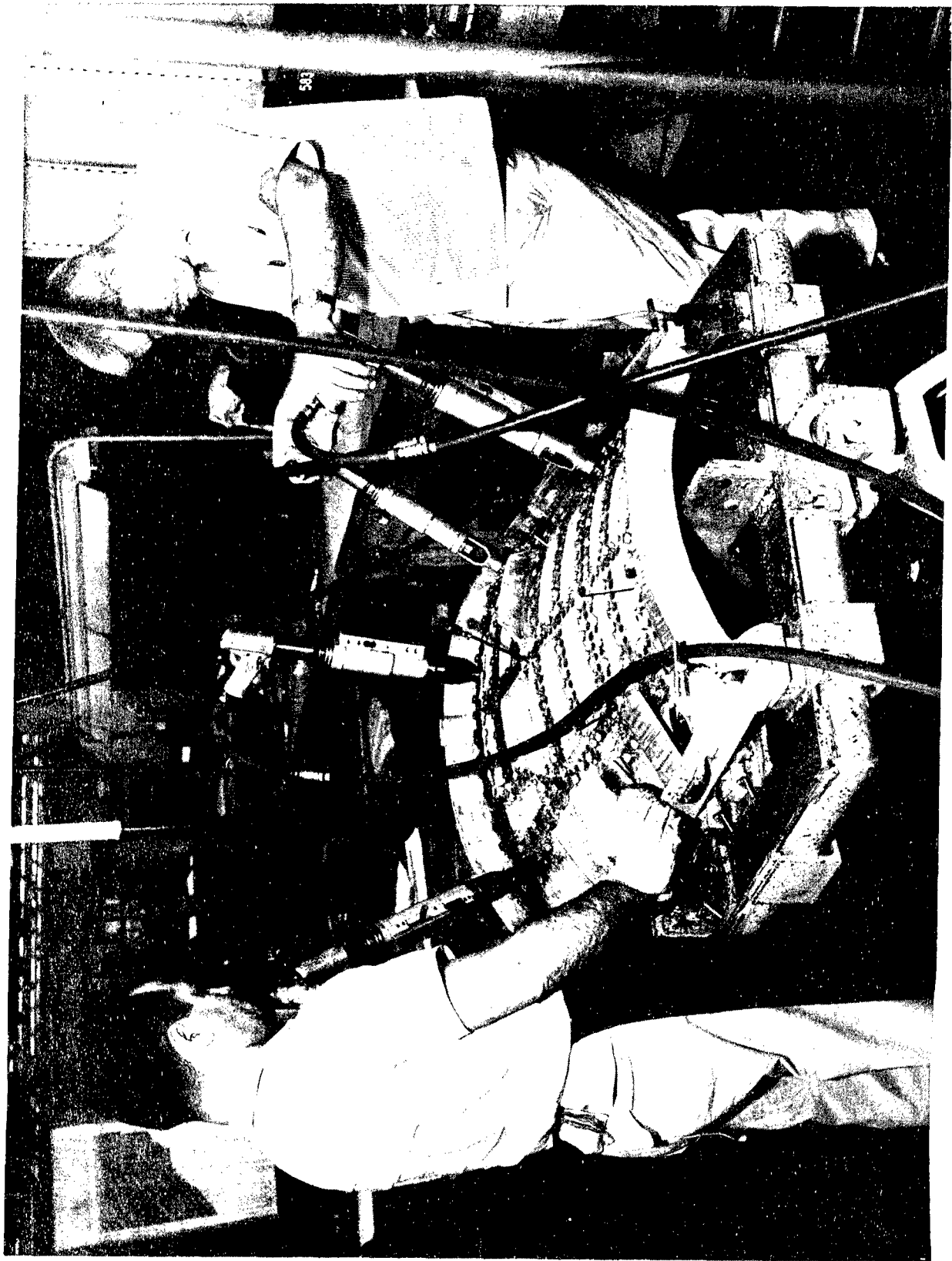
DRILL MODIFICATION

- 1) Surfaces marked are to be concentric within -.001 total indicator reading.
- 2) Centers permissible
- 3) Sizes shown are for No 30 (.1285) drills on Speed Brake Door
- 4) Break all sharp edges

REF MRP DWG 2224

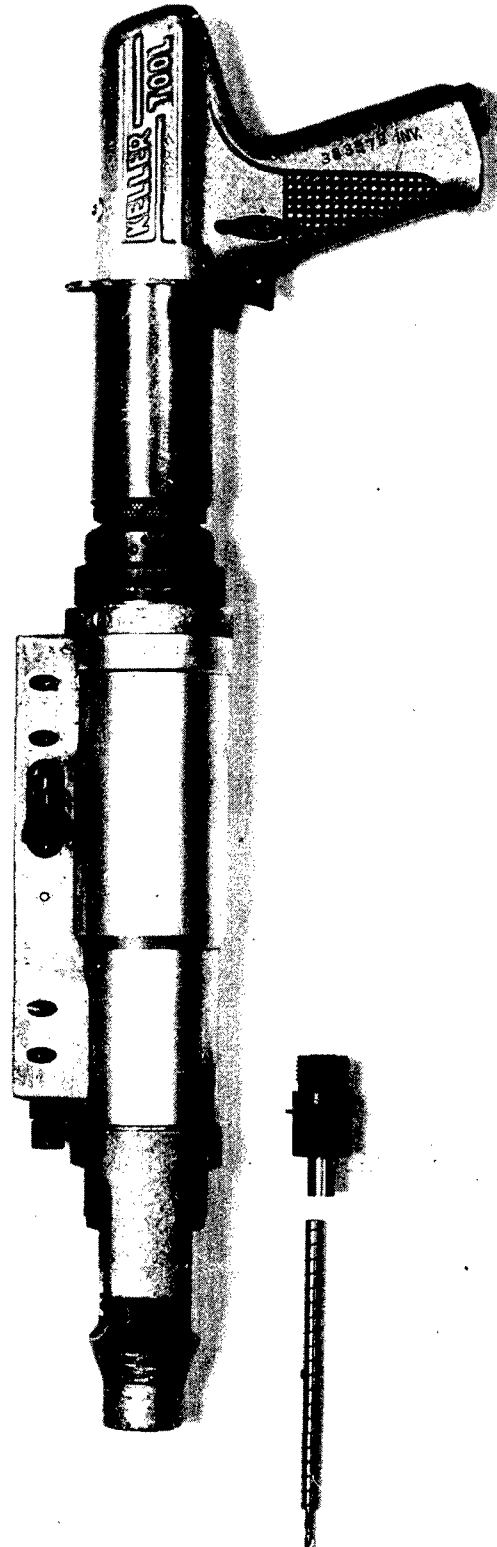


PHOTOGRAPH #1
FORM DIE FOR 1ST STAGE FORMING OF SPEED BRAKE RIBLET. PART FINISH FORMED
ON COMPOUND CAM ACTION FORM DIE

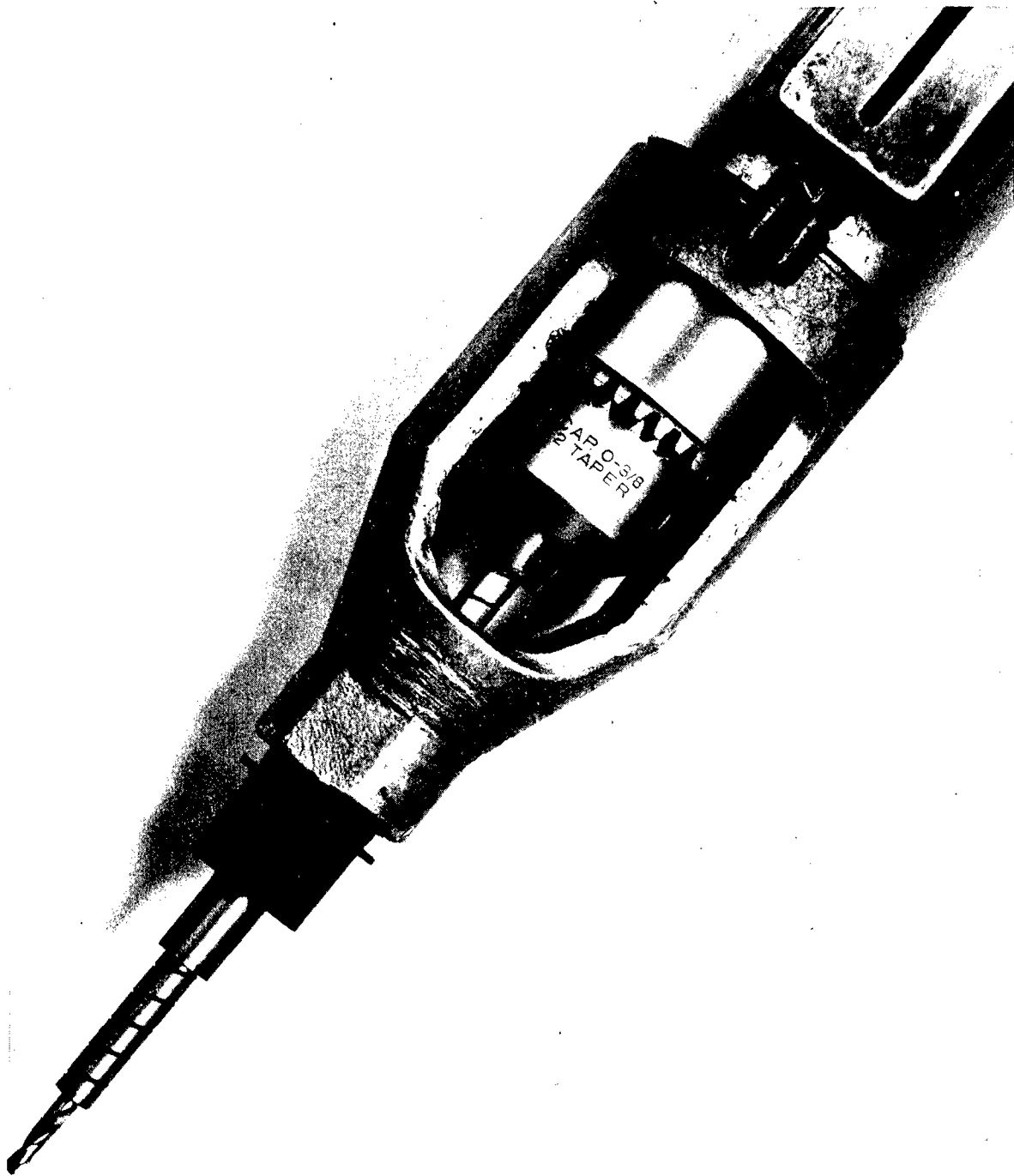


PHOTOGRAPH #2

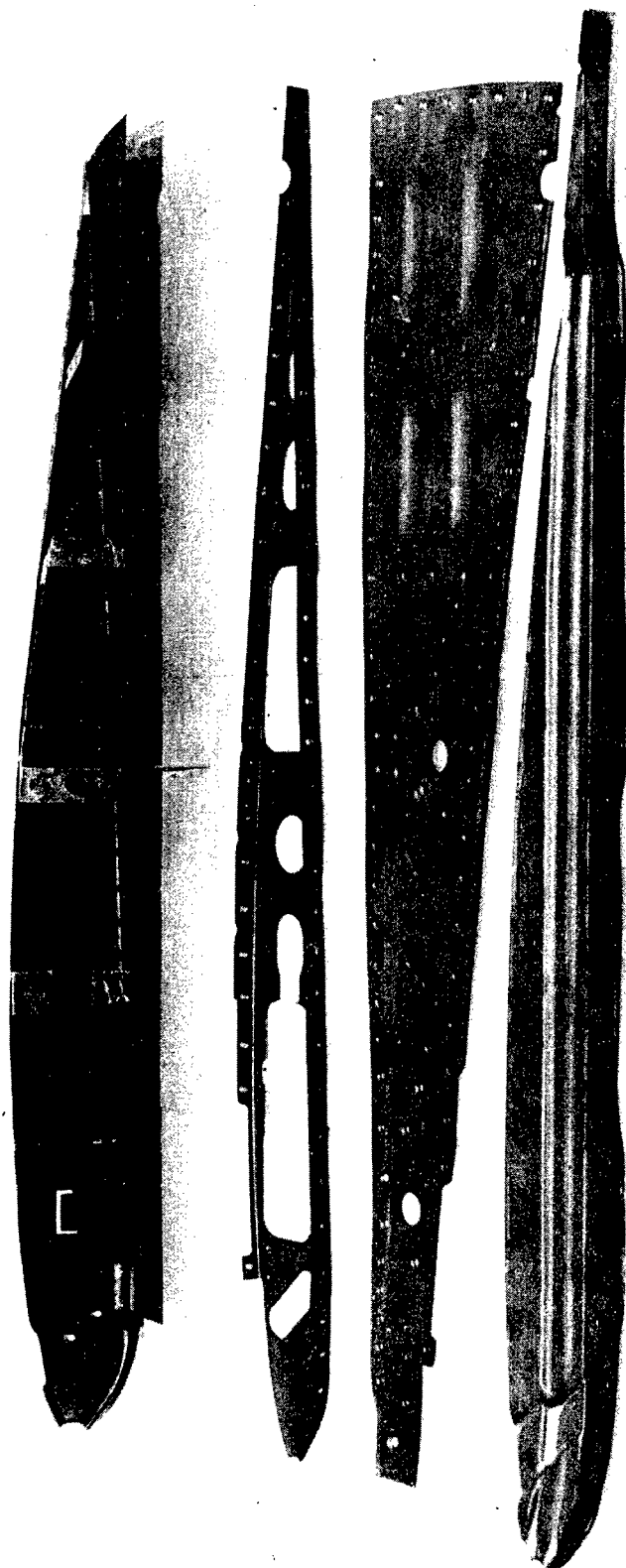
2ND STAGE ASSEMBLY FIXTURES AND DRILL RACK WITH CONSTANT FEED AND SPEED DRILL MOTORS



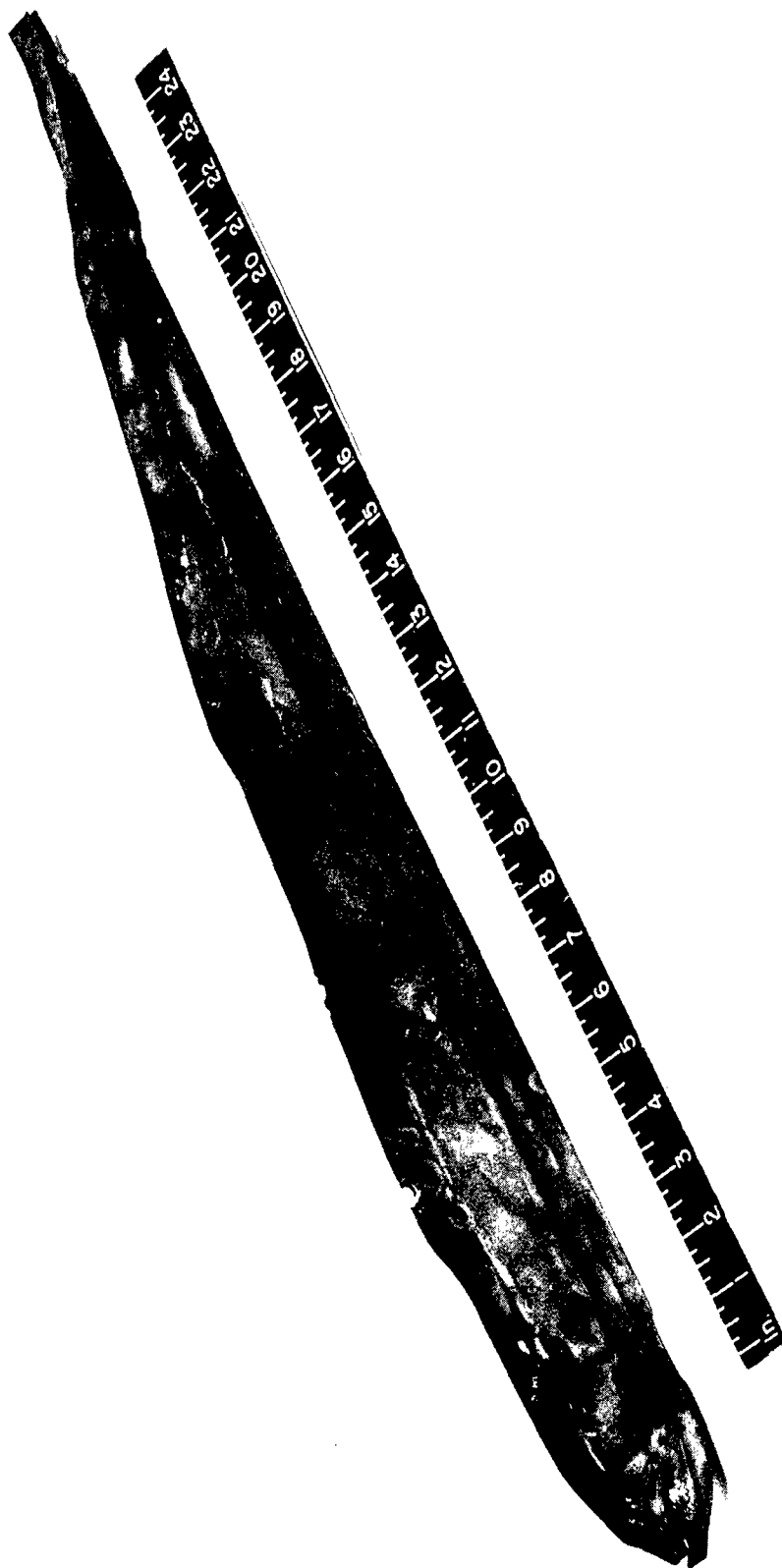
PHOTOGRAPH #3
KELLERMATIC CONSTANT FEED AND SPEED AIR DRILL WITH DRILL
DRIVER AND ADAPTER



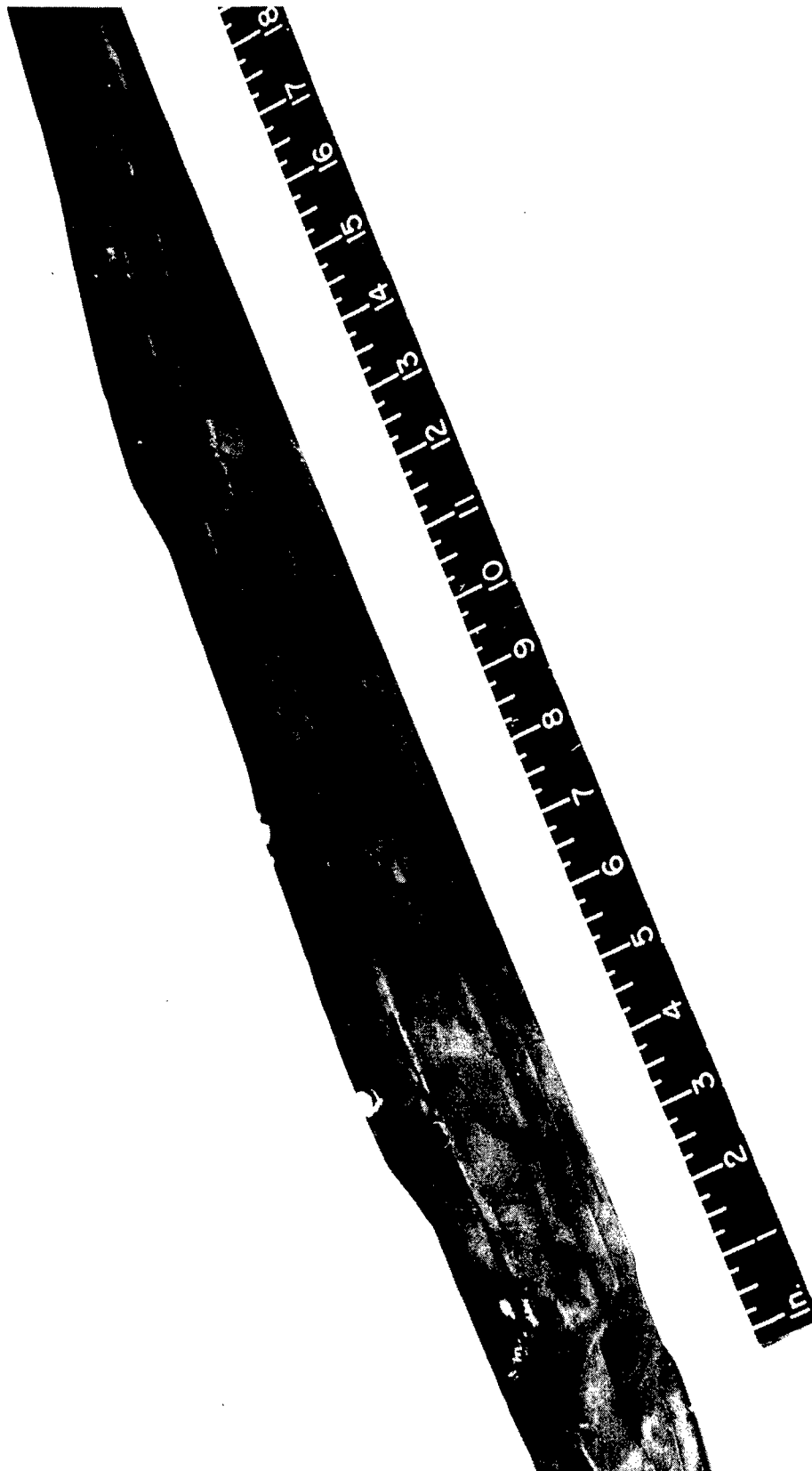
PHOTOGRAPH #4
KELLERMATIC CONSTANT FEED AND SPEED AIR DRILL WITH DRILL
DRIVER AND ADAPTER



PHOTOGRAPH #5
RENE' 41 SPEED BRAKE SLIDING SHIELDS

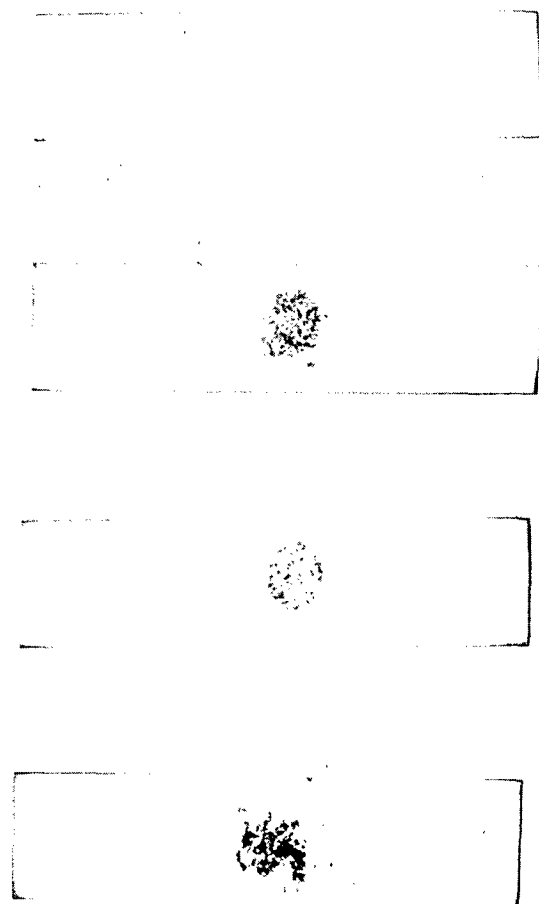


PHOTOGRAPH #6
RENE' 41 PART FORMED WITH LEAD DROP HAMMER DIES AND PROCESS ANNEALED
AT 1975°F FOR 30 MINUTES



PHOTOGRAPH #7
CLOSE UP VIEW OF THE PART SHOWN IN PHOTOGRAPH #6
NOTE THE EXTENT OF THE EFFECTED ZONES SURROUNDING THE DISINTEGRATED METAL.
THESE AREAS ARE TYPICAL FOR THIS TYPE OF ATTACK.

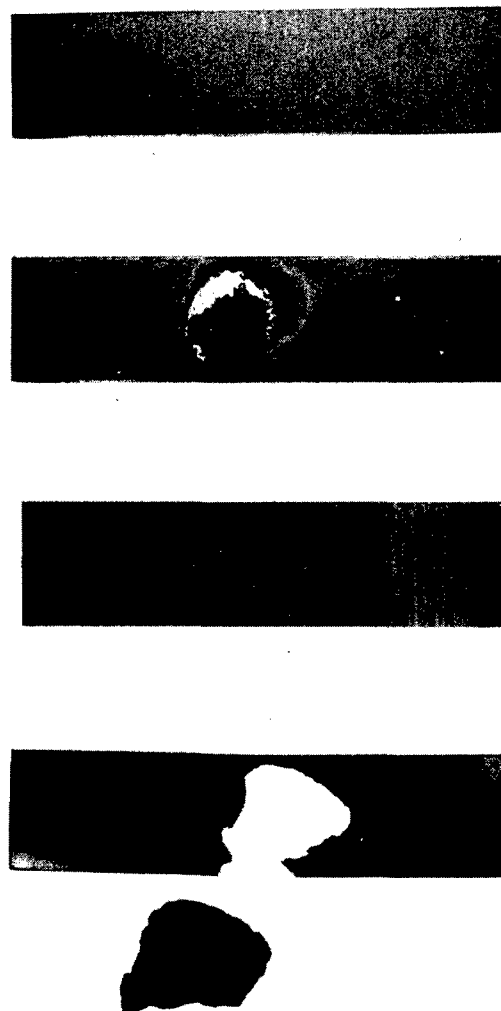
RENE' 41



LEAD ALUMINUM KIRKSITE CONTROL

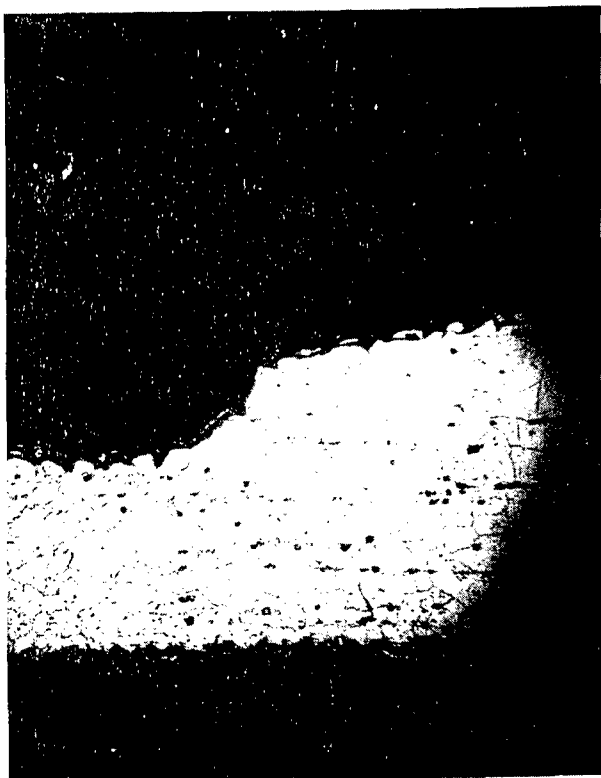
PHOTOGRAPH #8
 RENE' 41 TEST SPECIMENS IN CONTACT WITH TYPICAL AIRCRAFT TOOLING MATERIALS
 PRIOR TO ELEVATED TEMPERATURE EXPOSURE

RENE' 41



LEAD ALUMINUM KIRKSITE CONTROL

PHOTOGRAPH #9
 RENE' 41 TEST SPECIMENS SHOWN IN PHOTOGRAPH #8 AFTER EXPOSURE AT THE SOLUTION ANNEALING TEMPERATURE (1975°F) FOR THIRTY MINUTES. NOTE THE EXTENT TO WHICH THE ATTACK HAS PROCEEDED IN THE CASE OF THE LEAD AS COMPARED WITH THE ALUMINUM, KIRKSITE AND CONTROL SPECIMENS.



PHOTOGRAPH #10A
 RENE' 41 ATTACKED BY LEAD AFTER EXPOSURE AT 1975°F
 FOR 30 MINUTES. NOTE THE SEVERITY OF ATTACK AND THE
 DEGREE OF INTERGRANULAR CORROSION AS COMPARED WITH
 10B (CONTROL).



PHOTOGRAPH #10B
 RENE' 41 CONTROL SPECIMEN. SOLUTION ANNEALED
 1975°F THIRTY MINUTES.

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