DEVELOPMENT OF IMPROVED METHODS, PROCESSES, AND TECHNIQUES FOR PRODUCING STEEL EXTRUSIONS

L. M. Christensen

NORTHROP CORPORATION
Norair Division
Contract AF33(600)-36713

Interim Engineering Report No. 14
1 October - 31 December 1962

The loss of load carrying capability in the point and shoulder area of drawn sections is critical when working with thicknesses of .05 and less. Sections of .06 thickness and larger are not appreciably affected because the few thousandths of an inch removed per side for the point is a progressively smaller percent of the load-carrying cross-section.

BASIC INDUSTRY BRANCH
MANUFACTURING TECHNOLOGY LABORATORY

Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

ABSTRACT SUMMARY
Interim Technical Progress Report

INTERIM REPORT NOR-63-9
December 1962

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To make it possible to obtain repetitively successful results, preliminary draw dies should be designed without restraint at the extremities. Edges should be sized as a final step in the series of reductions.

Best prospect for eliminating deficiencies of point reliability in PH15-7MO is by transforming the metallurgical structure of the point and shoulder area from austenite to martensite. This will increase the strength level in the area of smaller cross section without affecting deformation characteristics of the shape to be drawn.

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FOREWORD

This Interim Technical Progress Report covers the work performed under Contract AF33(600)-36713 from 1 October 1962 through 31 December 1962. It is published for technical information only and does not necessarily represent the recommendations, conclusions, or approval of the Air Force.

This contract with Northrop Corporation, Norair Division, Hawthorne, California, was administered under the direction of Mr. T. S. Felker of the Basic Industry Branch (ASRCTB), Manufacturing Technology Laboratory, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

L. M. Christensen of Northrop Norair's Materials Sciences Laboratory was the engineer in charge. Major subcontractor was Allegheny Ludlum Steel Corporation, Watervliet, New York, with Mr. R. P. DeVries in charge of the subcontract engineering effort. Reporting to Mr. DeVries is Mr. J. H. Rice in charge of both extruding and warm drawing operations.

The primary objective of the Air Force Manufacturing Technology 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 Technology development required on this or other subjects will be appreciated.

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PUBLICATION REVIEW

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____
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I INTRODUCTION

This report is the thirteenth in a series of interim engineering reports concerning a program for the development of an improved, commercially feasible extruding process, coupled with post extrusion cold and warm drawing, to produce ultra-thin airframe-quality steel extrusions that are comparable in quality to their aluminum alloy counterparts.

The reporting period covered in this document extends from 1 October 1962 through 31 December 1962.

Included in this report is a summary and evaluation of warm drawing process technique development for both H-11 and PH15-7MO materials. Details of an extended effort to fully optimize the process is delineated with an emphasis on "pointing" procedure and metallurgical control.

Further experience and conclusions relating to the sporadically encountered chevron type defect in both materials is summarized. A recent revision to the objectives and scope of the contract is also included.

A change in mode of preheating from induction to a resistance type furnace is described.

For the benefit of the reader, Appendix I contains summaries of the Interim Engineering Reports which have been previously published on this contract.

II CONTRACT SUMMARY

The following brief summary of the primary contract work statement elements is presented for continuity of this report:

<u>Phase I</u> Survey of the aircraft and extrusion industries to select shapes, alloys, and specifications for the extrusions to be developed in this program.

The three subcontractors chosen to participate in the development of experimental techniques to produce the simplest shape in two selected alloys were:

Allegheny Ludlum Steel Corp., Watervliet, N. Y.
Harvey Aluminum, Torrance, California
C. I. E. P. M., Paris, France

<u>Phase II</u> Development and Optimization of cold and warm draw techniques for the .06 thick Tee shape which was developed in Phase I.

<u>Phase III</u> Development of both extrusion and draw techniques for an actual B-70 Weapons System structural shape in PH15-7MO steel alloy.

<u>Phase IV</u> Development of both extrusion and draw techniques for the same B-70 shape as Phase III except that the material shall be A-286.

<u>Phase V</u> Development of production methods for heat treatment of steel extrusions.

Allegheny-Ludlum Steel Corporation has been chosen as the subcontractor for the development activity of Phase II.

III CONCLUSIONS

1. The loss of load carrying capability in the point and shoulder area of drawn sections is critical when working with thicknesses of .05 and less. Sections of .06 thickness and larger are not appreciably affected because the few thousandths of an inch removed per side for the point is a progressively smaller percent of the load carrying cross section.

2. To make it possible to obtain repetitively successful results prelimary draw dies should be designed without restraint at the extremities. Edges should be sized as a final step in the series of reductions.

3. Best prospect for eliminating deficiencies of point reliability to PH15-7MO is by transforming the metallurgical structure of the point and shoulder area from austenite to martensite. This will increase the strength level in the area of smaller cross section without affecting deformation characteristics of the shape to be drawn.

4. More refinement of pointing techniques and a better understanding of the metallurgy involved in the various processing steps will be necessary before warm drawing can be considered optimized.

5. The newly installed resistance heat furnace which has replaced induction heating as a means of preheating the drawing stock has been demonstrated to be more reliable but less flexible for this type of application.

6. Steel extrusion of the target configuration can be adequately and satisfactorily stretch straightened without resorting to application of heat during the stretching operation.

7. Chevron type defects which have occurred on both H-11 and PH15-7MO are caused by lubrication failures which are often associated with metal pileup and resultant uneven draw forces.

IV COLD AND WARM DRAWING DEVELOPMENT

OBJECTIVE

Extrusions for advanced design aerospace vehicles, often require a drawing operation following extrusion to obtain the required finished size. This is so for two reasons: first, sectional thinness and/or tolerances required are beyond that which can be obtained by the most advanced extrusion processes; secondly, tensile and yield strength of some alloys are improved by cold working of the metal prior to heat treatment. The varied designs to be encountered with the special aircraft shapes necessitate a directed study into the fundamentals of cold and warm drawing processes. To date, the process of metal-working has been an art, one of trial-and-error. A concerted effort will be made to reduce the variables to predictable facts. The entire scope of Phase II will be directed towards development of all precepts and facets of drawing operation as necessary to bring the extrudable product to an even thinner and closer tolerance article for use in airplanes, where weight and structural integrity are being utilized to a degree not before contemplated. These purposes will best be served by utilizing the typical advanced design extruded shape which formed the basis of development of advanced extruding techniques in Phase I. Using the Phase I "T" shape, complete details and precepts will be investigated and parameters established to yield the following specific target goals in addition to the basic configuration shown in Figure 1:

a. Minimum length of 20 feet.
b. Thickness of flange and section of .040 ± .003.
c. Radius between flange and section of .060 ± .010.
d. Surface finish of 63 rms or better.
e. Straightness of .0063-inch/linear foot.
f. Twist one quarter degree/linear foot, 2-1/2° max.
g. Angularity ± 1° at any point of measurement.
h. Flatness of .002-inch/inch cross-wise dimension.
i. Aircraft and missile quality mechanical properties required in the as-drawn condition.

DRAWING FACILITY & EQUIPMENT

Basic equipment chosen for experimental use in developing parameters and techniques of warm drawing at the Watervliet, New York, facility of Allegheny Ludlum Steel Company was a 100,000 lb. chain driven draw bench. To provide the necessary preheat of the stock prior to drawing, an induction heating unit was installed. For this, a Lepel 100 KW induction heater was rented by Allegheny Ludlum through the Titanium Metals Corporation of America and was to be utilized both on Norair's steel warm-drawing program and on Republic Aviation's titanium warm-drawing program. To transmit the heat into the work piece, Lepel also supplied a spiral wound, 25 turn work coil,which was mounted adjacent to the draw die. Temperature is sensed by an Infra-Red Pyrotel Unit aimed at the exit-aperture end of the work coil.

For full details and photographs of the above and other auxiliary equipment, see previous Interim Engineering Report #12.

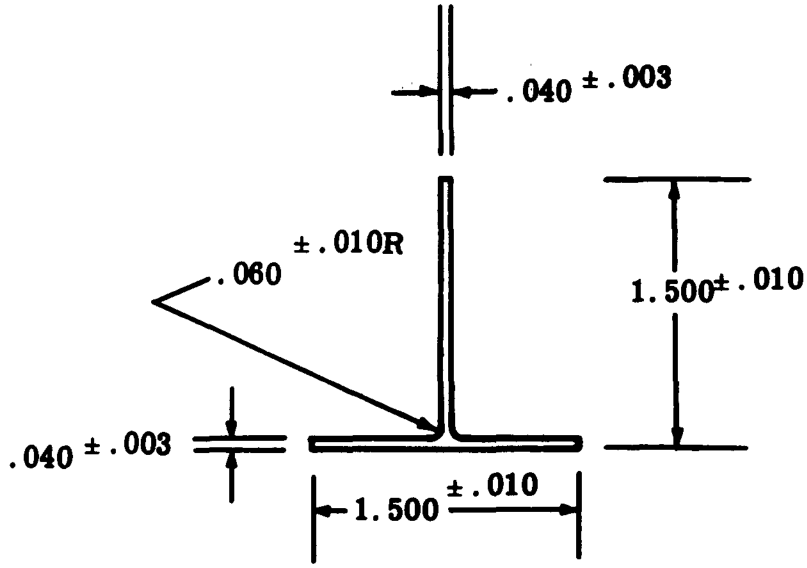


FIGURE 1 CONFIGURATION OF WARM DRAWN PHASE II TARGET SHAPE TO BE PRODUCED IN H-11 AND Ph15-7Mo STEELS

DIES

The same Tungsten Carbide dies that were previously used for drawing the H-11 alloy were utilized in the current investigation of drawing PH15-7MO except that the inserts were shipped back to American Carbide to have the fillet radius area enlarged from .06 to .09 to avoid the build-up of excess metal which had been previously encountered.

A photo of this sectional die is shown in Figure 2.

Drawings of this die assembly were included in an earlier report, but a clearer interpretation of the assembly could be gained by including a photograph. The sections marked with a "C" denote tungsten-carbide material, while sections marked with "S" or unmarked are of H-11 tool steel. A cover plate is placed over the assembly of blocks to hold them firmly in place. The cover also adds rigidity during the drawing operation. Further reduction can be obtained by changing to thinner shims between the tungsten-carbide inserts.

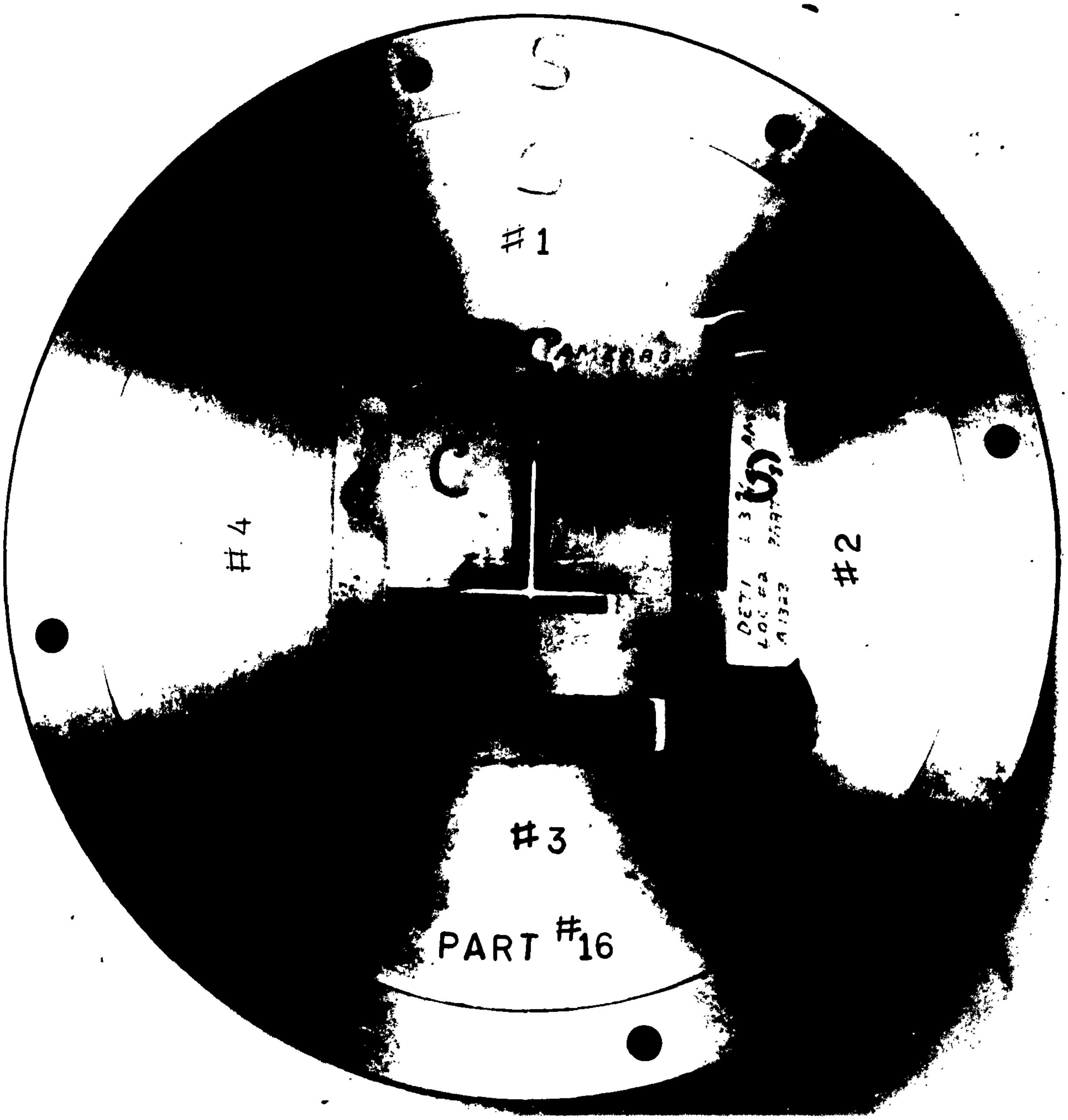


FIGURE 2 DIE ASSEMBLY FOR 0.060 INCH SECTION THICKNESS

V EVALUATION OF PROCESS DEVELOPMENT

The scheduled conclusion of Phase II effort was very successful from the technological standpoint of achieving a final product which conformed to target specifications. However, the amount of final product yielded, particularly on PH15-7MO alloy, was so small that the process could hardly be considered optimized. It was demonstrated conclusively that the process is technically feasible and the potential benefits in quality of product and advancement of the state-of-the-art are substantial.

Surface quality and dimensional integrity of the .04 thick warm-drawn shape is excellent; the surface is consistently smoother than 63 rms and within ± .003" tolerance. This means that we are now approaching feasibility of usage in the as-extruded and drawn condition of the multitude of ultra-thin PH15-7MO sections such as those which have been designed for the RS-70 weapons system. To date these sections have had to be laboriously and expensively machined from oversized extrusions or from bar. Since the vast majority of the RS-70 shapes have members as thin as .030 to .050 thickness, the optimization of .040 thick shapes under this project promises a tremendous savings. The current technical status of this development is best summarized by stating that the feasibility is conclusively proven but not yet perfected to the point of assuring an adequate predictability.

ANALYSIS OF THE PROBLEM

In order to start the drawing operation, it is necessary to prepare the section by what is called "pointing". This means that the first six inches must have its thickness reduced sufficiently to allow it to pass unrestricted through the draw die so that it can be grasped on the far side of the draw die by gripper jaws. The trolley which holds the gripper jaws then is pulled down the bed and the deformation of drawing starts at the shoulder of the point where it contacts the bearing area of the draw die. In drawing a section of normal thickness of .25 of an inch, the few thousandths of an inch that are removed for the point is a small comparative percentage as opposed to a section which is only .05 thick, in which case a substantial percentage of cross-sectional area is lost. Which means that there is a significant loss in draw carrying capacity in the pointed area. The periphery of a thin section is nearly as great as that of a thick section, so that the draw load remains nearly the same. This is true because friction accounts for at least 90% of the draw load. With a marginal relationship, irregularities in the point area such as scratches, undercutting, or machining marks which are normally of no consequence,become critical and often result in point breakage.

Such difficulty was encountered in the development of the warm-drawing techniques with a starting quantity of twelve lengths of PH15-7MO. After processing them through the various experiments with repointing after each of the four draws the quantity remaining through the last .043 pass was two lengths of only three feet. Reasons for this high mortality were as follows, with points being experimentally prepared by various methods:

a. Point failure due to excessive grinding in point preparation.

b. Point failure due to undercutting at the liquid-air interface in the pickling solution.

c. Point failure due to lack of straightness in machining points.

d. Point failure due to excessive deformation in the fillet or edges of the extrusion.

e. Arcing in the work coil due to liner failure with the consequent stoppage of drawing.

f. Point failure due to overheating vagaries of the induction heater.

g. Cracking during straightening.

h. Slight misalignment of draw dies, causing a bending moment on point.

A reviewal of these causes leads to the supposition that, with a subsequent order, many of them would be eliminated entirely and the balance would be substantially reduced. This however, is an opinion and needs to be substantiated by test to be able to say the process is predictably reproducible.

CONCLUSIONS

An analysis of the results and difficulties encountered in the foregoing effort which were delineated in detail in previous interim report #13 yields the following conclusions:

(1) Both H-11 and PH15-7MO have been successfully warm drawn through four successively smaller draw dies to a thickness of .040 ± .003.

(2) Though technically successful, the warm drawing process cannot be considered optimized because of a high attrition rate in "point" preparation.

(3) The loss of load carrying capability in the point and shoulder area is critical when working with sections of .05 thickness and less. Sections of .06 and larger are not appreciably affected because the few thousandths of an inch removed per side, for the point, is a progressively smaller percent of the load carrying cross section.

(4) A potential solution to this critical problem is the successful development of a means of raising the strength level appreciably in the point and shoulder area only. This investigation is under way at Norair and appears promising.

(5) Intermediate annealing between draw passes appears beneficial in reducing draw loads when working with such thin sections.

(6) The amount of deformation around the periphery of the cross section must be relatively equivalent to avoid excessively uneven draw loads and metal pileup.

(7) Designed experiments with straightening of PH15-7MO disproved a previously held belief that chevron defects were attributed to uneven residual stresses induced by gag straightening. The conclusion is now reached that chevrons are caused by lubrication failure.

(8) Constant speed, constant power input with the induction heater is a satisfactory means of obtaining temperature control within limits liberalized by necessity to plus or minus 50°F.

VI ADDITIONAL PHASE II EFFORT

It is therefore, the opinion of the contractor that further refinement of specific techniques should be effected to consider the process optimized. The best techniques developed in the preceding effort, plus the incorporation of new variations will be utilized. The add-on effort will primarily incorporate much greater emphasis and care in precision pointing operation and a broader and more metallurgically oriented approach to the development.

The previously available extrusion stock was depleted because of the high mortality rate due to point breakage. It will be necessary therefore, to extrude more billet material to supply ample stock for the ensuing program.

The following is a breakdown of detail planning for the next series of experiments:

1.0 PROGRAM PLAN OF PROPOSED ADDITIONAL PHASE II EFFORT

1.10 PROCUREMENT

1.11 EXTRUSION DIES

Dies shall be procured to the design configuration and material used in the last extruding effort, except that outside corners shall be full round. They shall be procured from the Ferndale plant of Allegheny Ludlum Steel Corporation and shall be of X-ray quality.

1.12 BILLETS

Six billets of PH15-7MO shall be procured from Armco Steel Corporation. Billets shall be airmelted to North American Aviation's chemistry limits. The delta ferrite content shall not exceed 20%. The following examinations shall be performed in a similar manner to that used in the last billet procurement.

a. Micro
b. Macro
c. Chemistry

1.20 EXTRUDING

1.21 GENERAL

The extruding operation should be performed in the same manner, conditions, and criteria as utilized in the November 1961 effort. Billet heating techniques, time-at-temperature, die lubricant, container lube, billet lube, container temperature, etc. shall all be identical.

Before attempting actual extruding, dry runs shall be made as necessary to refamiliarize the crew with billet handling and loading techniques.

1.22 TEMPERATURE RECORDING

If possible, the Pyrotel unit from the Lepel induction heater shall be set up and utilized to record extrusion exit temperature readings in place of the 35 mm cameras previously used.

1.23 TESTING OF EXTRUSIONS

Each extrusion shall be subjected to the following tests:

a. Micro for delta ferrite at each end.
b. Hardness at each end as extruded.
c. Mechanical properties in an as-extruded condition, one longitudinal specimen from each end.
d. Mechanical properties heat treated to RH 950 -- 3L and 3T from each end (F_{ty}, F_{tu} and % E). Also micros and R_c.

All test bars shall be prepared in accordance with specimen drawing to be furnished by Norair.

All sections to be stretch straightened.

1.30 PRELIMINARY THERMAL TREATMENT EXPERIMENTATION

One extrusion shall be selected on the basis of best conformance to dimensional control and cut and prepared as required to furnish stock for experimental operations covered under 1.30, 1.40, 1.50, and 1.60.

The purpose of the following experiment is to determine the effect of 1950 F treatment on the amount of delta ferrite.

Heat treat as-extruded material at 1950 F for:

a. 1/2 hour, 1 hour, 2 hours, 4 hours (W.Q.).
b. Determine delta ferrite by micro and R_c.
c. Subcool to -100 F and -320 F and determine amount of austenite and martensite by micro, hardness and magnetic permeability.

1.40 PRELIMINARY METALLURGICAL TESTS

Purpose is to determine the austenitic stability characteristics of a 1950 F solution annealed material with time-at-temperature determined from 1.30 above.

a. Reduce 10% in rolling mill at 600, 800, 1000, and 1200 F and obtain micros, hardness, and magnetic permeability checks for each.

b. Reduce 40% in rolling mill at 600, 800, 1000, and 1200F and obtain micros, hardness, and magnetic permeability checks for each.

c. From the above data plot the percent reduction versus hardness and percent martensite for each temperature of reduction.

d. Evaluate to determine optimum drawing temperature.

1.50 PRE-DRAW PREPARATION

1.51. THERMAL TREATMENT

Cut balance of selected extrusion into two pieces and solution anneal according to heat treatment determined in 1.30 above.

a. 1950 F followed by water quench.
b. Obtain micro and hardness.

1.52 POINTING

Due to the critical nature of this operation all efforts in this section shall be performed wholly by Allegheny technicians rather than operating shop personnel.

a. Perform auxiliary straightening operation in point area to obtain optimum straightness and flatness.

b. Chemically machine points with solution formula to be furnished by Norair.

c. Prepare points to sufficiently small size to accommodate all four draw operations.

d. Mask off applicable area to prevent chemical action at the liquid to air interface.

e. Prepare point with a tapered shoulder 1.00 in length.

f. On one of the two sections subcool the point area and half of the shoulder to effect an austenitic to martensitic transformation.

g. Take micros and hardness transverse.

h. Measure and record range of thickness over point area.

1.60 EXPERIMENTAL WARM DRAWING

1.61 LUBRICATION

The same lubricants and method of application shall be used as determined to be most dependable in previous effort. Extreme care should be exercised to insure adequate and even coating of lube to reduce friction. The importance of this cannot be over-emphasized because more than 90 percent of the draw load is caused by friction. If the lubrication is inferior the draw load will rise drastically and pull off the points.

1.61 LUBRICATION (continued)

An increasing draw load drastically accelerates the stress when based on ultra-thin sections. If the draw load can be kept below 10,000 lbs., then an austenized point of .036 thickness (sufficient for final pass) would involve a stress of 122,000 PSI. Since the PH15-7MO material is good for about 150,000 PSI the points should hold. However, notch effects and dynamic loading make it marginal, depending on severity.

1.62 ALIGNMENT

Before drawing, dies should be carefully checked for alignment to minimize bending moments that would otherwise be involved. Permanent type shims shall be provided and utilized as necessary. Strain gages shall be re-calibrated and the trolley and gripper head lined up properly.

1.63 DRAW TEMPERATURE

a. Draw temperature shall be as determined from 1.40 and incorporated on the basis of constant power and constant speed.

b. Before starting the induction heater, the console should be vacuumed and the cooling system flushed out.

c. Sighting area of the Pyrotel unit shall be 5/8 of an inch up from the base on the vertical leg.

1.64 WARM DRAWING AT OPTIMUM TEMPERATURE WITHOUT INTERMEDIATE THERMAL TREATMENT ON 1950 F SOLUTION ANNEALED MATERIAL

Record pertinent criteria for each draw on data sheet shown in Figure 3.

a. 1st pass -- Micro R_c draw load
b. 2nd pass -- Micro R_c draw load
c. 3rd pass -- Micro R_c draw load
d. 4th pass -- Micro R_c draw load

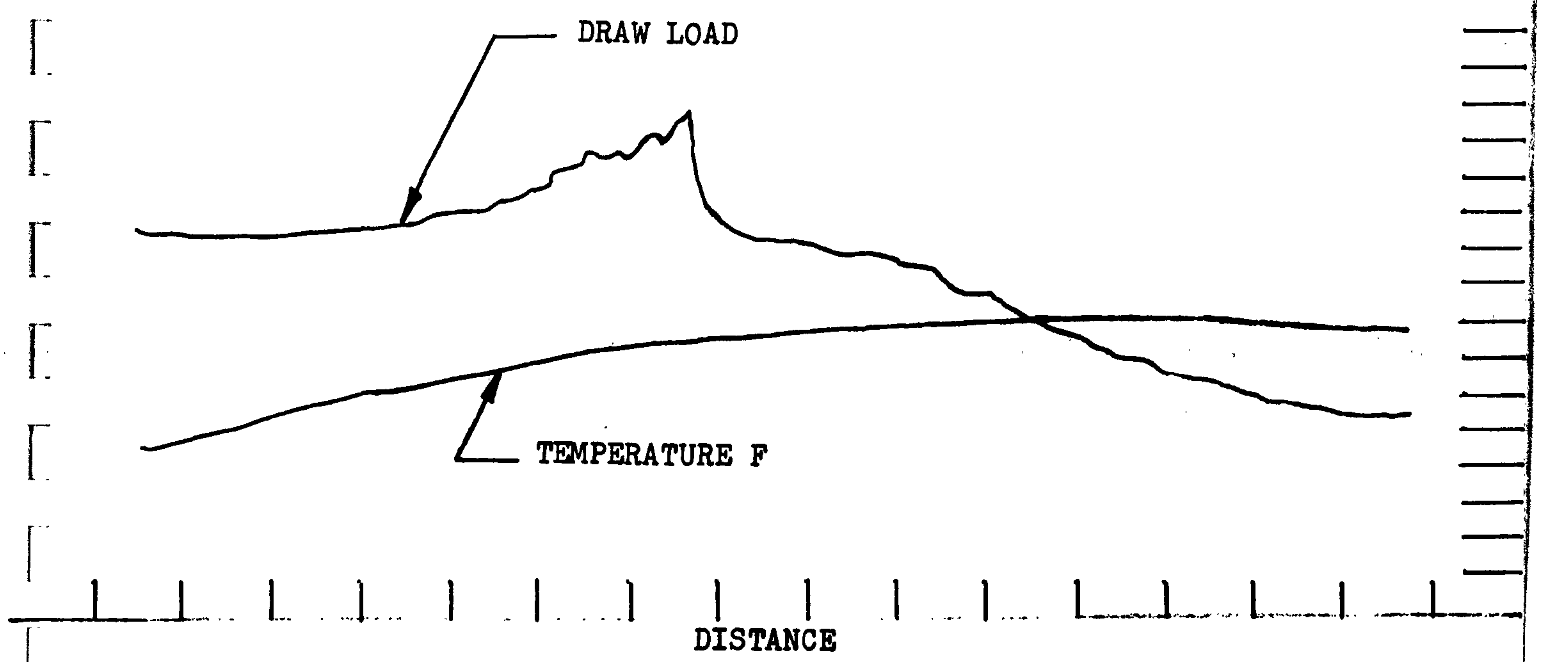
1.65 WARM DRAWING AT OPTIMUM TEMPERATURE WITH INTERMEDIATE THERMAL TREATMENT ON 1950 F SOLUTION ANNEALED MATERIAL

Record pertinent criteria for each draw pass on data sheet shown in Figure 3.

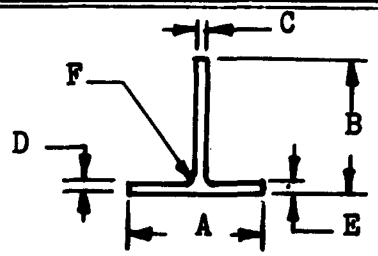
a. 1st pass -- Micro R_c draw load
Stress relief 4 hours at 1200 F
Micro and R_c

b. 2nd pass -- same
same
same

DRAW NO.
DATE:



EXTRUSION NUMBER	
MATERIAL	
LENGTH (STARTING)	
LENGTH (DRAWN)	
DIE TEMP	
PREHEAT TECHNIQUE	
DRAW SPEED	
DRAWN THICKNESS ATTEMPTER	
HEAT TREAT CONDITION	
HARDNESS BEFORE DRAW	
HARDNESS AFTER DRAW	
LUBRICATION	
TYPE OF POINT PREPARATION	
TEMP & METHOD OF STRAIGHTENING	
RESULT	



DIM.	MEASUREMENTS AT 18" INTERVALS											
A												
B												
C												
D												
E												
F												

FIGURE 3 DATA SHEET FOR DRAWING OF STEEL TEE SHAPE

1.65 WARMDRAWING AT OPTIMUM TEMPERATURE WITH INTERMEDIATE THERMAL TREATMENT ON 1950 F SOLUTION ANNEALED MATERIAL (Continued)

c. 3rd pass -- same
same
same

d. 4th pass -- same
same
same

1.66 IN PROCESS STRAIGHTENING

Straightening as necessary shall be performed by stretch straightening.

1.70 HEAT TREATMENT OF EXPERIMENTALLY DRAWN SHAPES

a. The two .043 thick warm drawn tee sections from Section 1.60 shall be heat treated to the RH-950 condition.

b. Determine F_{ty}, F_{tu}, and %E in both longitudinal and transverse directions. Eighteen specimens will be required with three samples each (L & T) from the two ends and from the center plus micros and R_c.

1.80 PILOT PRODUCTION WARM DRAWING

From the above program select the optimum process to be used on the remaining five extrusions. Use data sheet shown in Figure 3 to record all pertinent criteria.

1.90 HEAT TREATMENT OF PILOT PRODUCTION QUANTITY

a. Heat treat to RH-950 condition.

b. Determine mechanical properties -- nine longitudinal and nine transverse specimens from each tee section plus micros and R_c.

VII REVISION OF PROGRAM OBJECTIVES

The program,as outlined in Section II Contract Summary, has been revised during this reporting period. The first change is a revision to Phase III "Development of Both Extrusion and Drawing Techniques for an Actual RS-70 Weapons System Structural Shape in PH15-7MO Steel Alloy." The contract did call for a pilot production quantity of thirty shapes to be produced after proper experimentation in order to substantiate optimization of process techniques. The change reduces this quantity from 30 to 10 in order to avoid an excessive buildup of costs. There is no change in the contract requirement of shipping the pilot production quantity to North American Aviation for their evaluation.

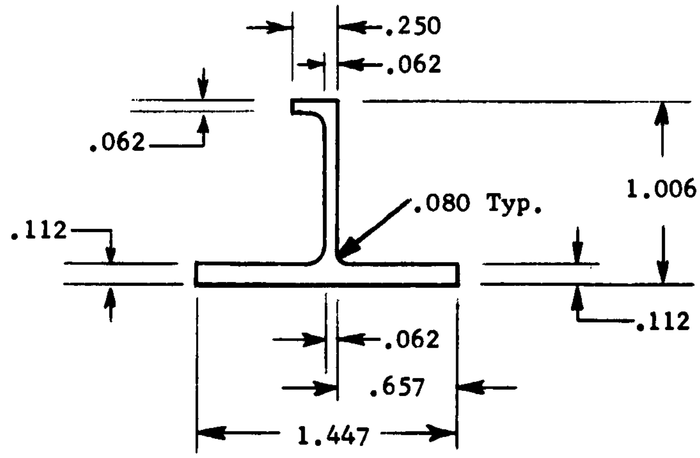
The second contract change is the complete deletion of Phase V requirements. Phase V called for development of production methods for heat treat optimization in full 20 foot lengths. There are few facilities capable of this type operation. However, the large gantry type furnace at Lindberg Steel Treating Company in Melrose Park, Illinois, appeared very adequate and satisfactory for this purpose. Instead of heat treatment of the sections in full 20 foot lengths, foot long specimens will be cut from various locations along the length and heat treated separately, tested and evaluated concurrently with each of the phases to follow.

VIII SELECTION OF PHASE III SHAPE

Inasmuch as the next series of experiments which are listed in Section VI of this report are expected to consummate Phase II, preliminary planning for Phase III has been instituted. Since the contract calls for selection of an actual RA-70 weapons system shape, North American Aviation was contacted to ascertain the scope of potential target selections. After extensive perusal and conferences with the ASD Project engineer and Allegheny Ludlum, a very representative, yet challenging, target shape was selected and is shown in Figure #4. At first glance it does not appear too different from the present Phase II shape shown in Figure 1. However, the closing hook at the top of the vertical leg greatly increases the complexity of the drawing operation. In addition, the variation in thickness is a new variable and challenging to both the extruding and drawing operations.

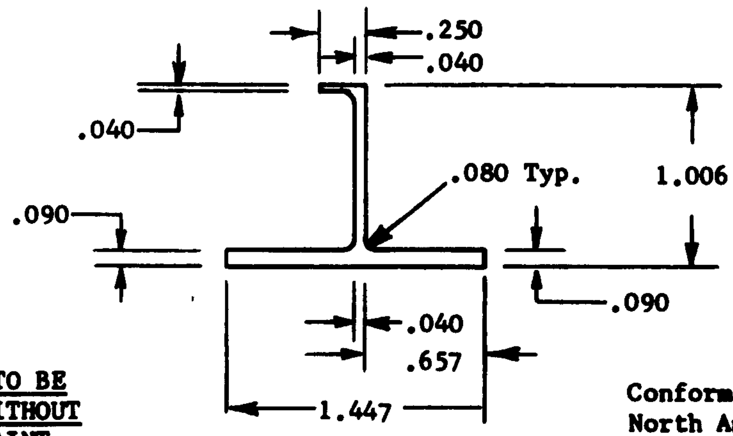
The shape represents a wide and extensive number of variations of the same basic configuration used in the RS-70.

A solution to previous difficulty of metal pileup on the edge will be effected by designing the preliminary dies without construction at the extremities.



EXTRUDED SHAPE

PH15-7MO STEEL



DRAW DIES TO BE DESIGNED WITHOUT EDGE RESTRAINT

Conforms to North American Aviation Shape No. 64E6

DRAWN SHAPE

FIGURE 4 TARGET SHAPE FOR PHASE III

IX CHANGE OF MODE OF PREHEAT FOR DRAWING

Previous to this reporting period, the selected means of inducing heat into the section ahead of the draw die, has been by means of a 100 KW Lepel induction heater. The history of Phase II development has been replete with unexpected and unforeseen difficulties connected with the very critical requirements of inducing and controlling proper levels of temperature into these very thin sections. These difficulties have been of a nature which included both equipment breakdown and operational character. The critical deficiency appears to be an inability to closely control the temperature over the length, under the dynamic conditions of the gripper die hookup and draw speed. The most recent difficulty has been failure and replacement of a time relay motor which controlled sequencing of the main generator. Repeated arcing of the induction coil has occurred through the Fiberfax liner. This is sometimes caused by deterioration of the liner as the result of cutting and abrasion of the passing edges. Various liners and cements have been tried without material improvement. Repeated arcing has necessitated the replacement of the 25 turn copper coil. A new work coil is currently being fabricated which will have 11 more turns.

Because of the tenure and multiplicity of difficulties connected with the induction heater, an alternate means of heating has been developed and installed. It is a resistance type muffled furnace which was designed by TMCA and constructed at Allegheny Ludlum in Watervliet. It is composed of a stainless steel tube 3 inches in diameter which is resistance heated by water cooled clamps attached to each end of the tube. Power is supplied by two 1500 Amp DC welding generators. Amperage is supplied at low voltage to reduce arcing. The heated tube is encased by K-33 insulating brick and magnesia blocks along its entire length and periphery. The refractory material is covered by a 3/16 inch thick mild steel plate.

Preliminary runs on the furnace, show good reliability with a temperature variance from the radiant heat of $\pm$ 50° F. A comparison of the two means of heating indicates the resistance furnace to be more reliable but less flexible than the induction mode of heating. Chief drawback is the fact that temperature at the draw die can be controlled primarily by draw speed.

Pictures and drawings of the new heating setup will be included in the next report. Tentative plans call for utilization of the resistance furnace until or unless the new coil for the induction heater exceeds expectations.

X EXTRUSION BILLET ANALYSIS

In ordering PH15-7MO extrusion billet for the new effort, Allegheny Ludlum found that it could not be obtained from eastern seaboard sources within a reasonable length of time, so Norair undertook the procurement of same. A satisfactory commitment was obtained from a Los Angeles source, and a forged bar of 3½ inch diameter was ordered under North American Aviation's material specification NAA LB0160-123. Also stipulated was the requirement that the ferrite content should not exceed 20%. Previously used material at Allegheny Ludlum was approximately 40% in ferrite and was believed to be detrimental in both processing and in obtaining satisfactory mechanical properties.

Vendor's Test Results, furnished with the incoming billet stock, certified that the material was capable of meeting physicals in the following condition:

Heat No.	Condition	Yield	Tensile	Elong % In Inches	% Red of Area
ARMCO 31436	TH-1050	195,000	196,000	16.2	40.0
	RH-950	222,000	223,500	11.1	37.0

The chemistry was as follows:

C	Mn	P	S	Sil	Ni	Cr	Mo	Al
.057	.61	.015	.012	.35	7.26	14.95	2.24	1.09

The ferrite content was listed as 10%.

Following receipt of the billet stock with the above listed test results the stock was sent to Norair"s Material Science Laboratory for recheck and further analysis. The bar was cut in half and samples taken from each end and the center. Chemistry, micro and macro samples were prepared and evaluated. The material was adjudged to be satisfactory. Results with photos will be included in the next report.

XI PROGRAM FOR NEXT REPORTING PERIOD

Early in the reporting period a new extrusion effort is scheduled to provide additional stock for optimizing the warm drawing techniques. This will be followed immediately by a thorough metallurgically oriented investigation to perfect pointing procedures, to determine effects of preliminary and intermediate thermal treatments and to ascertain austenitic stability characteristics at various temperatures and percentages of reduction. There will be a considerable amount of in-process testing to evaluate the effect or lack of same with each of the processing parameters.

Requirements for the selected RS-70 Phase III shape have been determined, and tooling such as draw dies, etc., have been tentatively planned. After approval of completion of Phase II by ASD the Phase III development of extruding and drawing techniques for the RS-70 shape will be instituted.

The non-induction coil will be shipped to Allegheny Ludlum, set up, calibrated, and evaluated for re-instatement as the means of heating for the warm drawing cycle.

APPENDIX I

SUMMARY OF PREVIOUS

INTERIM REPORTS

APPENDIX I

Summary of previous Interim Reports published under Contract AF33(600)-36713.

Interim Engineering Report No. 1, NAI-58-656, included a full discussion on the surveys of both the airframe and the steel extruding industries. Also included was the basis for selecting the Phase I shape, the target specifications, and the initial three participating subcontractors.

Interim Engineering Report No. 2, NAI-58-876, included a full discussion of Allegheny Ludlum's equipment, extruding precepts, and facilities, as well as reporting the first half of their experimental extruding effort. It covered only the preliminary large diameter container pushes at Harvey Aluminum because at the close of the report period their small diameter container had not been completely fabricated. Interim Report No. 2 did not include any technical data from C. I. E. P. M. because Sejournet's extruding effort did not begin until after the issuance of that report.

Interim Engineering Report No. 3, NOR-59-246, included a detailed description of the last half of Allegheny Ludlum's effort since the first portion was covered in Report No. 2. The extruding effort by C. I.-E. P. M. (Sejournet) was included in its entirety with extensive inspection data obtained from their several extrusions. No coverage was given to Harvey Aluminum's effort because Harvey was late in submitting their report.

Interim Engineering Report No. 4, NAI-59-354, included a complete tabulation of detailed inspection and evaluation of samples submitted from each of the three participants. Such items were listed as dimensional variation, surface roughness, and inclusion count. Also included was the complete presentation of the entire Phase I effort for Harvey Aluminum. A discussion and summation of the scheduled Phase I effort was presented together with details of an extended development effort for Phase I with Allegheny Ludlum as subcontractor.

Interim Engineering Report No. 5, NOR-59-504, included details of the design and utilization of a radiation shield for heating and handling of billets. Also included was information and technical substantiation for a high-heat container liner which was conceived and fabricated primarily for extruding A-286 material. The report presented details of an extruding effort with the high-heat liner which was foreshortened due to premature container and stem failure. Efforts to replace these failed major components was underway when the steel strike halted all activity.

Interim Engineering Report No. 6, NOR-60-106 includes activities starting from the end of the steel strike on 7 November 1959. After resumption of work schedules, some time was consumed in reactivating the plant and facilities during which a new liner and new stems were being finished. Extruding of A-286 was again attempted with the high heat liner and again resulted in gross failure of tooling. Subsequently, PH15-7MO was substituted for A-286.

Another extruding effort was made with H-11 and the new PH15-7MO using a container liner at the more conventional 900°F temperature. It was anticipated that extruding of A-286 will possibly be resumed at a later stage in the program.

Interim Engineering Report No. 7, NOR-60-253, completely summarized Phase I effort. A major extruding effort was planned and effected using H-11 and PH15-7MO. A new stable die material was used extensively which, in the previous period, had indicated promise. A new higher melting point glass was used with billets that received a longer soak period at temperature. Results were deemed to be an unprecedented success in efforts to produce super thin (.06) thicknesses of aircraft type shapes in difficult-to-form alloys.

Interim Engineering Report No. 8, NOR-61-199, includes mechanical property test results showing low longitudinal tensile values in the leg section in the evaluation of Phase I extrusions in both H-11 and PH15-7MO materials. It includes extensive metallurgical studies by both Northrop and Armco Steel Corporation which suggest that the low properties resulted from diffusion of the nickel lubricant material into the surface of the extrusions. It also covers program planning for Phase II to resolve this problem as well as further improvement of extruding techniques. Also included is planning for cold and warm drawing to yield sections of .04 wall thickness.

Interim Engineering Report No. 9, NOR-61-245, shows results of Phase II extruding effort to improve the producibility of the process, eliminate low mechanical properties, and provide extruded stock for cold and warm drawing experimentation. Details of the extruding effort with some clad and some unclad billets in both H-11 and PH15-7MO is covered.

Interim Engineering Report No. 10, NOR-62-19, comprises full details of final extruding effort to provide stock for Phase II drawing experimentation. The effort showed good reproducibility and proved the feasibility of eliminating the nickel plate previously used. It also delineates the details and difficulties of setting up and preliminary calibration of the induction heating apparatus for warm drawing.

Interim Engineering Report No. 11, NOR-62-77, provides a full description of the warm drawing facility and equipment used for developing techniques for very thin H-11 and PH15-7MO airframe shapes. Precise dimensional data is presented in graphic form on extruded stock to be drawn. Some of the difficulties encountered in pointing and gripping are given with the remedial action which was requied. The extensive problems connected with obtaining a uniform preheat with the induction heater are covered and the resultant corrective action of using constant power and constant speed.

Interim Engineering Report No. 12, NOR-62-170, summarizes details of development of process techniques for warm drawing H-11 from an as extruded thickness of .065 through four reductions to a thickness of .040. Also discussed are details of a chevron type defect which developed sporadically during the reducing passes. The report contains dimensional inspection results of the fully drawn sections.

APPENDIX I (Continued)

Interim Engineering Report #13, NOR-62-216, contains similar data to Report #12 except that the experimental material involved is PH15-7MO instead of the H-11 contained in Report #12. Results of processing technique development of PH15-7MO is given in detail, summarized and evaluated. Further discussion of the chevron type defect which has been encountered with both types of material is also included.

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