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**DEEP-HOLE DRILLING IN THE MANUFACTURE
OF VKF LAUNCHERS**

R. E. Johnson

ARO, Inc.

November 1966

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FOREWORD

The work reported herein was done at the request of Headquarters, Arnold Engineering Development Center, Air Force Systems Command, Arnold Air Force Station, Tennessee, under Program Element No. 65402234.

The results of tests were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of AEDC under Contract AF 40(600)-1200. The manuscript was submitted for publication on October 6, 1966.

This technical report has been reviewed and is approved.

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ABSTRACT

Every effort has been exerted to maintain the highest level of quality in the manufacture of hypervelocity launcher components in the von Kármán Gas Dynamics Facility (VKF). Since the manufacture of these components involves deep-hole drilling, the effect of this operation on the quality of the finished bores was not completely known. An investigation was undertaken to determine the effects of our range of boring operation on the component quality. This report describes the investigation and the results obtained.

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SECTION I

INTRODUCTION

After a launcher failure in the von Kármán Gas Dynamics Facility (VKF) in 1962, the Metallurgical Laboratory undertook quality control measures to prevent the reoccurrence of such failures. Precise control of heat treatment and resulting microstructure since that time has more than doubled the life of these high pressure components. Other factors in the quality control of these launchers have been considered. For example, deep-hole drilling and boring has to be carried out after final heat treatment at hardness levels up to approximately Rc 42; and it is known that deep-hole drilling of these high strength steels can result in over-heating of the steel surface, which may result in untempered martensite. The low ductility of the untempered martensite on the inside of the holes could result in cracking under the stresses imposed by firing conditions, thus, exposing the pressure chambers and launcher tubes to more severe hydrogen attack and stress corrosion.

The fear that the untempered martensite on the inside diameter of the gun bore could cause trouble was increased after the presentation of a paper at the Air Force Material Symposium at Miami Beach where examples of this problem were shown. The hardness values indicated were, however, higher than those of the VKF gun components. To assure that the same problems were not being created at AEDC, an investigation was initiated; and VKF gun steels were drilled and bored under the widest range of conditions used during manufacture. This program included:

- a. Range of Steels
- b. Cutter Materials
- c. Feeds and Speeds
- d. Coolants

The various specimens were subjected to microstructural and microhardness examination in the "as machined" condition. Duplicate sets of specimens were tempered after machining and re-examined. This report is a summary of the results of this investigation.

SECTION II

TEST PROCEDURE

2.1 GENERAL

Most of the gas launcher components at VKF are processed by conventional lathe and boring bar techniques, with tungsten carbide or high speed steel cutters being used. A gun drill is used, however, in processing some of the smaller bores. Gun drills differ from conventional drills in two major respects: (1) rotational speeds are up to three times higher than conventional drills, and (2) high pressure oil accomplishes the dual purpose of coolant and chip remover. Both of these methods of deep-hole drilling were evaluated as to the possibilities of their creating a martensitic layer on the bored surface.

2.2 RANGE OF STEELS USED

The steels used in this investigation were Nationalloy 7, 14, and Type 4340 steel. All these steels were drilled in the quenched and tempered condition.

2.3 CUTTER MATERIAL

The boring bar cutter materials used were Rex 95 high speed steel and tungsten carbide. The gun drills were proprietary and made of high speed steels. These cutters and drills were sharpened to the various configurations normally used by the machinists.

2.4 FEED AND SPEEDS

The lathe surface speeds used were 132 to 500 in./min. This range of speeds would cover the full range of speeds normally used in production machining. An 0.025 depth cut was employed in all boring tests. The gun drill surface speeds used were approximately 2400 in./min with feeds of 5/8 in./min.

2.5 COOLANTS

Only two types of coolants were used, oil and water soluble oil. Both of these were used in lathe bores, whereas only oil was used with the gun drill.

2.6 HONING

Honing was used only on gun drills in this program.

2.7 TEMPERING AFTER BORING

Tempering was carried out after some boring tests to determine if any change in surface structure was effected. The tempering temperatures used were equivalent to the tempering temperatures used in the initial specified heat treating operation. One set of tests was tempered at various times using a semi-log scale of time.

SECTION III RESULTS

Microhardness testing and microexamination were used to evaluate the different effects of deep-hole drilling. Microexamination proved to be the most effective even though it is difficult to distinguish between martensite and tempered martensite using light microscopic techniques. The following results were obtained:

- a. Microexamination revealed no martensite on any of the bored surfaces.
- b. Microhardness testing did reveal an increase in hardness near the bored surface, but microexamination revealed this to be caused by deformation.

- c. Microexamination revealed no discernible decarburization of the bored surfaces.

SECTION IV

DISCUSSION

There was much data developed during this program for evaluation of the various effects of deep-hole drilling. The methods of boring were calculated to produce all levels of surface heating encountered in the production of VKF launcher components. This data could be tabulated to show the exact range of conditions used; but since none of these data is associated with a martensitic layer on the launcher bores, only typical data for the various conditions will be presented.

The microstructure of the surface on one of the lathe-bore specimens is shown in Fig. 1. This specimen was machined so as to produce a maximum amount of heat. The conditions used for the machining were:

- a. Surface speeds - 500 in./min
- b. Tools - carbide
- c. Coolants - water soluble oil
- d. Cut - 0.025 in.
- e. Feed - 0.004 in.

The surface of the specimens contained no martensite needles except those formed during the initial quenching. If the boring had resulted in the formation of martensite, the orientation of the new martensite would have been different from that formed during heat treating. It should be noted, however, that machining did result in a disturbed layer extending approximately 0.005 in. deep. At the lower magnification, this disturbed layer appears to be martensitic. At magnifications in the range of 1000, however, it can be seen that the disturbed layer consists of the original tempered martensite needles curved during deformation of the surface. This deformation resulted in an increase in hardness at the surface, as would be expected. Microhardness readings showed Rc 42 (equivalent) near the surface as compared to Rc 37 of the quenched and tempered material.

The type of cutting tool had no discernible effect on the disturbed layer. Figure 2 is a photomicrograph of a disturbed layer produced in 4340 steel using a Rex 95 high speed cutter. A comparison of Fig. 1 with Fig. 2 shows that there is no difference caused by the two types of cutter materials.

The effect of lathe boring was compared with gun drilling on Type 4340 steel. Figure 3 is the microstructure of a bored surface produced with gun drilling. The only difference that could be noted in the methods of boring is that the disturbed layer is only approximately half as deep as that produced by lathe boring. This is attributed to the much higher surface speeds and comparatively lighter cutting pressures associated

with gun drilling. There was no evidence of new martensite in these specimens. The drilling conditions used on this specimen were:

- a. Surface speeds - 2400 in./min
- b. Feeds - 5/8 in./min
- c. Coolant pressure - 500 psi

The VKF launcher components are honed after drilling. Figure 4 shows a drilled surface after honing, and it is obvious that the more severe portion of the disturbed layer was removed.

It was thought that the disturbed layer might possibly contain some decarburization. Two methods were used to determine if any decarburization were present. One method was tempering after drilling, and such a surface is shown in Fig. 5. It can be seen that recrystallization did occur in the severely deformed surface (eliminating the white layer). This clearly demonstrates that decarburization was not present.

The other method used to determine whether decarburization was present was to austenitize one of the lathe bored specimens and water quench. The structure of the specimen is shown in Fig. 6. The structure of the 4340 steel is uniform through the layer disturbed by deep drilling. If this surface had contained any degree of decarburization it would have been evident in this test.

SECTION V CONCLUSION

The rate of surface heating in our deep drilling operations was not severe enough to result in either a martensitic or a decarburized layer.

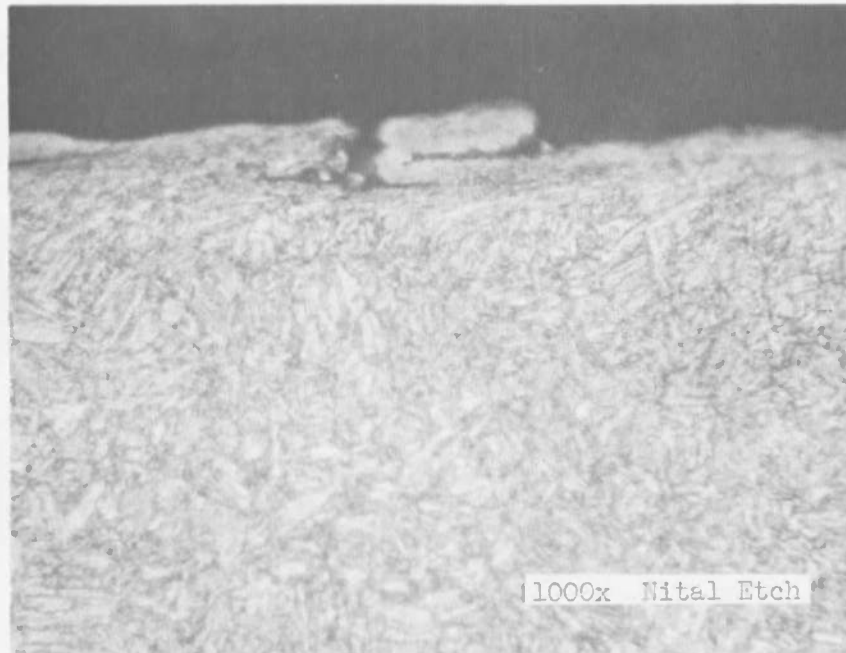


Fig. 1 Lathe Bored—A Carbide Cutter Was Used with Speeds and Feeds Required to Produce Maximum Surface Heating



**Fig. 2 Lathe Bored Using a Rex 95 High Speed Steel Cutter
(Disturbed Layer Appears the Same as in Fig. 1)**

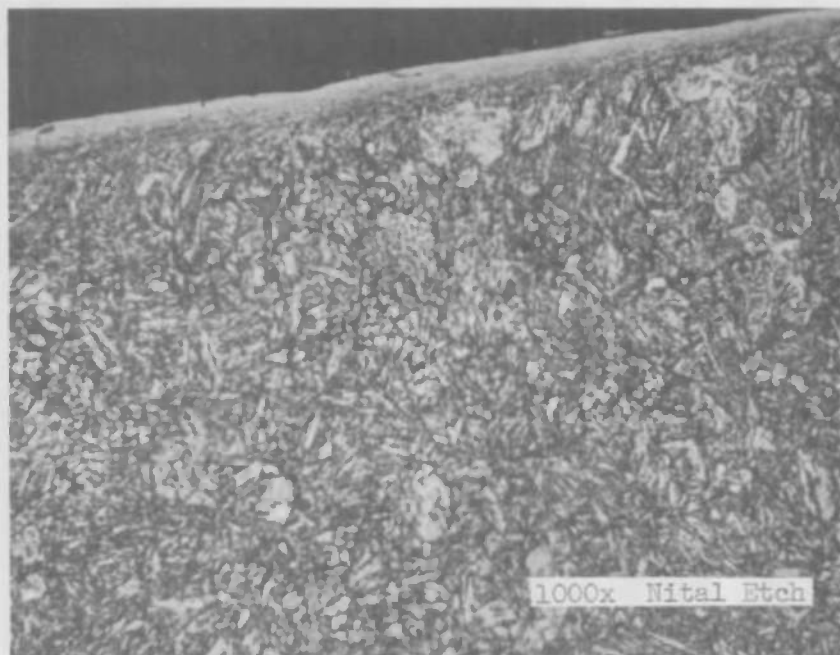


Fig. 3 Disturbed Layer Produced by Gun Drilling

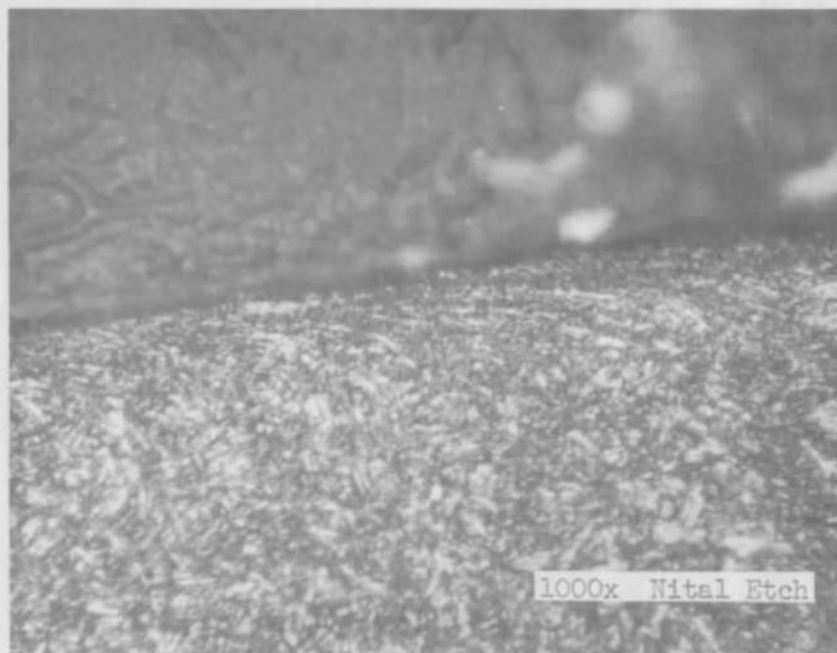


Fig. 4 Gun-Drilled Surface after Honing



Fig. 5 Gun-Drilled Specimen after Tempering at 1000°F for 1/2 hr



Fig. 6 Austenitized at 1425 for 20 min and Quenched in Water
after Lathe Boring

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(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Arnold Engineering Development Center, ARO, Inc., Operating Contractor Arnold Air Force Station, Tennessee		2a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b GROUP N/A	
3 REPORT TITLE DEEP-HOLE DRILLING IN THE MANUFACTURE OF VKF LAUNCHERS			
4 DESCRIPTIVE NOTES (Type of report and inclusive dates) N/A			
5. AUTHOR(S) (Last name, first name, initial) Johnson, R. E., ARO, Inc.			
6. REPORT DATE November 1966		7a TOTAL NO. OF PAGES 13	7b NO. OF REFS N/A
8a CONTRACT OR GRANT NO. AF40(600)-1200		9a ORIGINATOR'S REPORT NUMBER(S) AEDC-TR-66-220	
b PROJECT NO.		9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A	
c Program Element 65402234			
d			
10. AVAILABILITY/LIMITATION NOTICES Distribution of the document is unlimited.			
11 SUPPLEMENTARY NOTES Available in DDC		12. SPONSORING MILITARY ACTIVITY Arnold Engineering Development Center, Air Force Systems Command, Arnold Air Force Station, Tennessee	
13 ABSTRACT Every effort has been exerted to maintain the highest level of quality in the manufacture of hypervelocity launcher components at VKF. Since the manufacture of these components involves deep-hole drilling, the effect of this operation on the quality of the finished bores was not completely known. An investigation was undertaken to determine the effects of our range of boring operation on the component quality. This report describes the investigation and the results obtained.			

KEY WORDS

deep-hole drilling

launchers

hypervelocity

heat treatment

2. Launchers -- Barch 7
 3. Launchers -- "

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