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REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1832.

Metallurgical Examination of Two (X.C.R. and T.P.A.) Exhaust Valves and a Valve Seat.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA April 6, 1945.

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Description of Material and Object of Investigation:

On February 17, 1945, four samples for examination were received from the Inspector of Electrical Engineering, Signals and Engineering Branch, Inspection Board of United Kingdom and Canada, 479 Bank Street, Ottawa, Ontario. The samples, shown in Figure 1, were identified as follows:

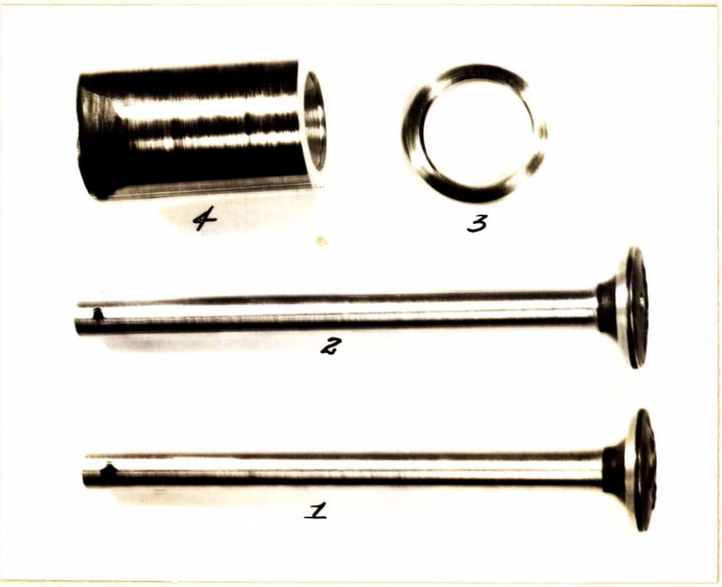
1. Silchrome X.C.R. exhaust valve.
2. T.P.A. austenitic valve.
3. Valve seat.
4. Bar stock from which valve seat was cut.

The covering request letter, dated February 16, 1945, File No. 4/14/10/6, stated that the valve seat was alleged to be austenitic steel. A chemical analysis of the three steels was requested.

(Continued on next page)

(Description of Material and Object of Investigation, cont'd) -

Figure 1.



EXHAUST VALVES, VALVE SEAT, AND BAR STOCK.

(Approximately ¾ actual size).

Magnetic Tests:

The magnetic properties of the components submitted, obtained by testing with a horseshoe magnet, are as follows:

TABLE I. - Magnetic Properties.

X.C.R. valve	strongly magnetic.
T.P.A. "	slightly magnetic.
Valve seat and bar stock	non-magnetic.

Hardness Examination:

The results of hardness readings obtained on the Vickers hardness tester, using 20-kg. load, are as follows:

TABLE II. - Hardness Values.

	Vickers	Rockwell "C" (Converted)
X.C.R. valve	404-412	41-42
T.P.A. "	228-243	19-21
Valve seat	232-257	19-23
Valve seat bar stock	256-260	23-24

Chemical Analysis:

The results of chemical analyses are compared in Table III with the specifications for similar type alloys, as given in Reference 1.

TABLE III. - Chemical Analysis.

	X.C.R. Valve	Alloy No. 25	T.P.A. Valve	Valve Seat Bar Stock	Alloy No. 15
	-(Per Cent)-		-(Per Cent)-		
Carbon	0.36	0.40-0.50	0.46	0.41	0.40-0.50
Silicon	0.89	1.0 max.	0.70	0.53	0.30-0.80
Manganese	0.35		0.46	0.51	
Nickel	4.36	4.5-6.0	13.62	13.90	13.0-15.0
Chromium	23.85	23.25-24.25	13.55	13.82	13.0-15.0
Molybdenum	2.40	2.5-3.5	0.24	0.34	0.50 max.
Tungsten	-	-	1.55	1.95	1.75-3.0

Microscopic Examination:

Figures 2 and 3 are photomicrographs, at X1000 magnification, of a sample cut from the X.C.R. valve. Vilella's etching reagent[*] was employed to produce the microstructure in Figure 2, whereas a ferricyanide etch[**] was used in Figure 3. The latter reagent, which is a modification of Murakami's reagent, is intended to differentiate between ferrite and sigma phase by turning the former yellow and the latter light blue. However, in this case the effect was to increase the definition between the ferrite and austenite constituents. The black areas are probably etching pits.

Figures 4 and 5, both at X1000 magnification, show the microstructure of the T.P.A. valve and the valve seat bar stock, respectively. In both cases the structures consist of austenite and carbides. The grain size of the bar stock is considerably larger than that of the T.P.A. valve, indicating that the bar had been finished rolled at a temperature higher

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[*] Vilella's Reagent:
(HCl - 5 c.c.)
(Picric acid - 1 gram)
(Alcohol - 1 c.c.)

[**] Ferricyanide etch:
(Potassium ferricyanide - 30 grams)
(Potassium hydroxide - 30 grams)
(Water - 60 c.c.)

(Microscopic Examination, cont'd) -

than that used in the final forging of the valves.

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Discussion:

Silchrome X.C.R. Valve.

The X.C.R. valve, made from a high chrome-nickel-molybdenum steel, conforms with the specifications of Alloy No. 25, which comes under the group classified as "Transformation Hardening, Age Hardening, or Precipitation Hardening" steel (see Reference 1). The heat treatment for this steel consists of quenching into water from 2000° F., followed by reheating to 1400° F. and holding at that temperature for about 16 hours. As a result of the latter operation, the hardness is increased from 25 Rockwell "C" to over 40 Rockwell "C".

According to the ternary diagram given in the A.S.M. Handbook (1939), page 407A, fig. 1, the constituents for this steel on water-quenching from 2000° F. should be ferrite and austenite. Under equilibrium conditions, reheating at 1400° F. should result in the elimination of the austenite phase. However, because of the extreme sluggishness of the steel, the austenite remains present after the second heat treatment, and the constituents evident under the microscope are ferrite and austenite (see Figure 3). This was confirmed by X-ray diffraction tests. The increased hardness on annealing at 1400° F. is probably due to the precipitation of submicroscopic particles of carbides which cannot be discerned under the metallurgical microscope.

The following excerpt is taken from Reference 1:

> "Recently, a high chromium-nickel-molybdenum steel (Alloy No. 25) has been introduced and is capable

(Discussion, cont'd) -

> of hardening to over 40 Rockwell 'C' ......"
>
> "Alloy No. 25 has excellent resistance to burning and its wear and scuffing resistance are in outstanding contrast to the austenitic steels. It is always used in the hardened condition and occasionally develops a condition of pronounced brittleness in the valve head. This brittleness is probably due to phase changes resulting from repeatedly passing through the temperature zone from 1400 to 1600° F."

T.P.A. Exhaust Valve and Valve Seat.

Chemical analyses and magnetic and hardness tests indicate that the T.P.A. valve and the valve seat (see Figures 4 and 5) are made from essentially identical material. The microstructure consists of austenite and carbides. These steels belong to the austenitic group, and fall within the limits of the specifications for Alloy No. 15 (see Reference 1). The following is taken from the same reference:

> "Alloy No. 15 is the most widely used steel for aircraft exhaust valves, and its use is almost exclusive in this country. Its burning resistance is poor, and it would probably be unusable but for the fact that it is almost universally used with internal cooling and with a seat facing of cobalt-chromium-tungsten alloy."

CONCLUSIONS:

1. The Silchrome X.C.R. valve was manufactured from a steel which comes under the "Transformation Hardening, Age Hardening, or Precipitation Hardening" group.

2. The T.P.A. valve and the valve seat are practically identical in composition and are of the "austenitic" variety.

REFERENCES.

1. "Exhaust Valve Materials for Internal Combustion Engines," by S.D. Heron, O.E. Harder and M. R. Nestor. (In copyrighted 'Symposium on New Materials in Transportation' published by the American Society for Testing Materials, Philadelphia, Pa., 1940.)

2. "The Trend in Poppet Valves," by A. T. Colwell. Ontario Research Foundation, Toronto 5, (1939).

3. "Constitution of Iron-Chromium-Carbon Alloys," by Walter Crafts. A.S.M. Handbook, 1939, page 407 A.

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AF:GHB.

Figure 2.

X1000, Vilella's etch.*

SILCHROME X.C.R. VALVE.

Ferrite and austenite.

Figure 3.

X1000, ferricyanide etch.**

SILCHROME X.C.R. VALVE.

Ferrite and austenite. The black areas are probably etching pits.

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* Vilella's Reagent:

(HCl - 5 c.c.)
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(Alcohol - 1 c.c.)

** Ferricyanide etch:

(Potassium ferricyanide - 30 grams)
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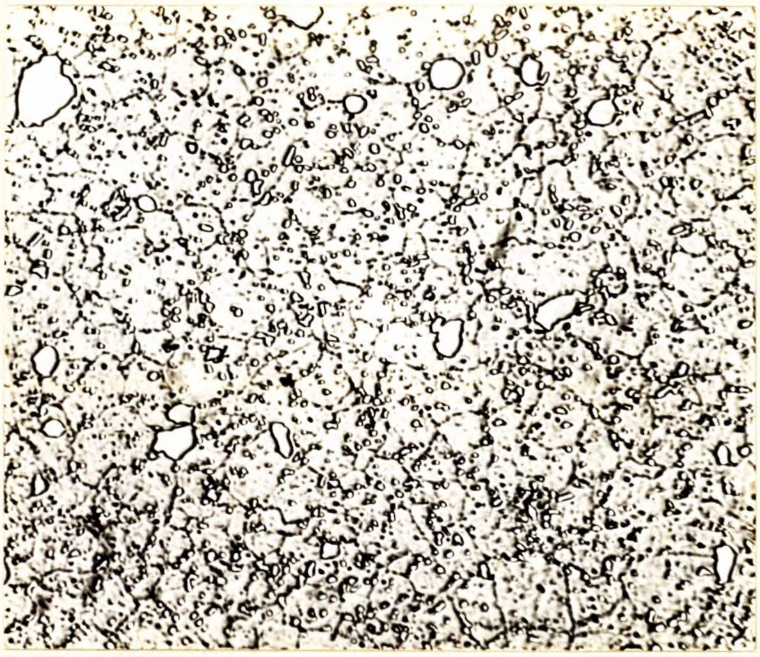
Figure 4.



X1000, Vilella's etch.

T.P.A. VALVE.

Austenite and carbides.

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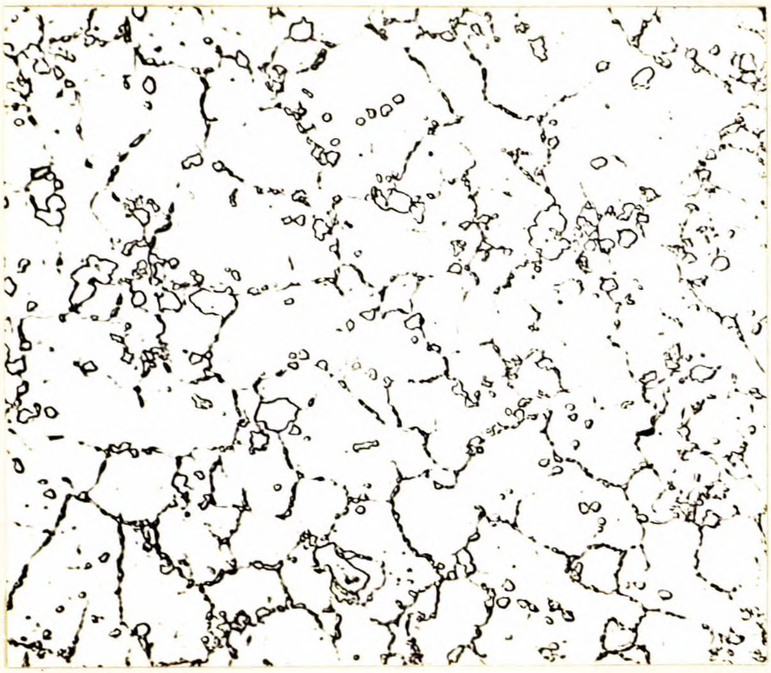
Figure 5.



X1000, Vilella's etch.

VALVE SEAT.

Austenite and carbides.

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AF:GHB.