File.

FILE COPY

O T T A W A October 10th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1719.

Metallurgical Examination of Ford and Chevrolet Exhaust Valves.

(Copy No. 10.)

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

CANADA
DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA October 10th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1719.

Metallurgical Examination of Ford and Chevrolet Exhaust Valves.

Origin of Material and Object of Investigation:

On July 27th, 1944, three exhaust valves--two Ford (Figure 1) and one Chevrolet (Figure 2)--were submitted for examination by Professor J. U. MacEwan, Consultant to the Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario, under Requisition No. 656 (A.E.D.B. Lot No. 549, Report No. 31, Sec. E. Test No. 1). The covering letter, dated July 17th, 1944, requested

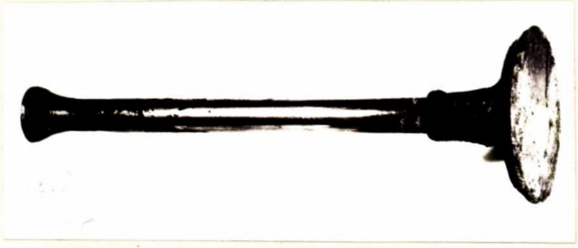
(a) Chemical analysis of the scale, and

(b) Micro-examination of metal in valve head underneath scale,

in order to determine the mechanism of failure of the valves.

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

Figure 1.



FORD EXHAUST VALVE.

(Approximately 1/2 size).

Figure 2.

CHEVROLET EXHAUST VALVE.

(Approximately 1/2 size).

Chemical Analysis:

Samples of scale scraped from the valve heads were analysed. The results are given in Table I.

Table I. - Analysis of Valve Scale.

		Ford	Chevrolet
		- Per Cent -	
Lead	-	61.5	53.4
Barium	-	8.3	2.3
Chromium	-	Nil.	Present.
Nickel	-	Nil.	"
Iron	-	Nil.	"

Samples were cut from the two types of valves, for chemical analysis. The results are given in Table II.

Table II. - Analysis of Valves.

		Ford	Chevrolet
		- Per Cent -	
Carbon	-	0.36	0.75
Manganese	-	0.99	0.44
Silicon	-	2.36	2.41
Nickel	-	7.60	1.25
Chromium	-	14.64	19.05
Molybdenum	-	0.07	Nil.
Tungsten	-	Nil.	Nil.
Cobalt		Nil.	Nil.

Hardness Tests:

Hardness tests were made on cross-sections of the valve heads, using the Vickers hardness tester with the 20-kilogram load. The results are as follows:

		Vickers	
Chevrolet	-	298	
Ford	-	286	(Average)

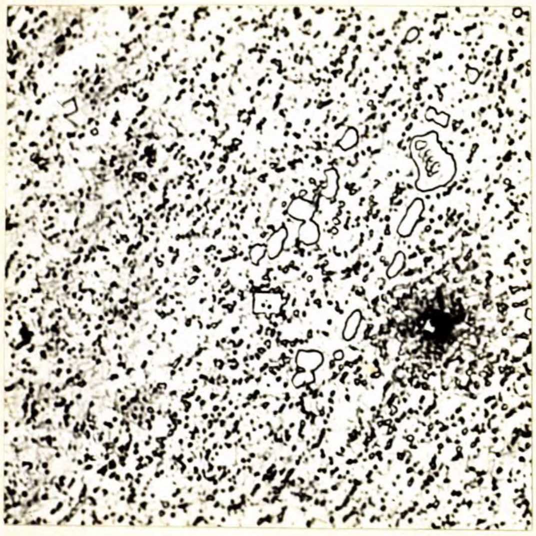
Magnetic Properties:

The two types of valves were tested with a horseshoe magnet to determine their magnetic properties. The Ford valve was found to be practically non-magnetic, whereas the Chevrolet valve was quite magnetic.

Microscopic Examination:

Sections of the two valve types were polished and etched for microscopic examination. Figures 3 and 4 are photomicrographs at a magnification of X750, showing the microstructures obtained on etching in Vilella's reagent.* Figure 3, taken from the Ford sample, shows carbides in a background of austenite. Figure 4, taken from the Chevrolet sample, shows the microstructure, which consists of carbides in a ferrite background.

Figure 3.

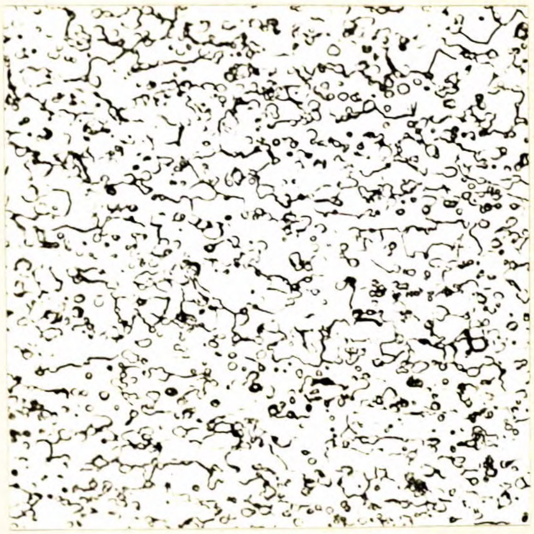


X750, Vilella's etch.

FORD VALVE.

Carbides in a background of austenite.

Figure 4.



X750, Vilella's etch.

CHEVROLET VALVE.

Carbides in a background of ferrite.

* Vilella's Etching Reagent:

Picric acid - -	1 gram
Hydrochloric acid -	5 cc.
Alcohol - -	100 cc.

Discussion of Results:

In the following discussion, excerpts will be taken freely from the pamphlet "Exhaust Valve Materials for Internal Combustion Engines", by S.D. Heron, O.E. Harder and M.R. Nestor, published by the American Society for Testing Materials, Philadelphia, Pa.

The results of the chemical analyses made on the valve heads show that the Ford valve is made of material which was probably intended to conform within the limits of Alloy #12, as given in the pamphlet. These limits are as follows:

	Chromium	Nickel	Carbon	Silicon
		- Per cent -		
Alloy #12 (austenitic)	- 17.5-20.5	7-9	0.30-0.45	2.5-3.25

It is to be noted, however, that the chromium content, 14.64 per cent, is less than the limits called for and may or may not be intended as such.

The Chevrolet valve is made of material falling within the limits of Alloy #4, which are as follows:

	Chromium	Nickel	Carbon	Silicon
		- Per cent -		
Alloy #4 (martensitic)	- 19-23	1.0-2.0	0.6-0.85	1.25-2.75

The magnetic tests, which showed that the Ford valve was non-magnetic and the Chevrolet valve quite magnetic, substantiate the results of the chemical analyses.

Examination of the microstructure just below the scale showed no discernible difference from that of the metal proper. No evidence of intergranular corrosion was observed.

The hardness tests substantiated the findings of the microscopic examination; that is, that the microstructures of the Ford and Chevrolet valves were, respectively, austenitic and ferritic.

The chemical analyses of the scale prove that both types of valves were subjected to fuels containing sub-

(Discussion of Results, cont'd) -

stantial quantities of lead compound. The barium found in both valve scales comes from the additives in the heavy duty oils. The fact that some nickel, chromium and iron were found in the scale from the Chevrolet valve indicates that corrosion was taking place. These elements were not evident in the scale scraped from the Ford valve.

The following exerpts were obtained from the pamphlet mentioned:

> Increasing the anti-knock fluid addition greatly increased the severity of exhaust valve service. Lead oxide attack was largely responsible for increased corrosion on exhaust valves that occurred with the use of leaded fuels. Lead compound attack could always be recognized as it led to the formation of a black magnetic oxide, while the scale formed solely by the action of heat was yellow and non-magnetic.
>
> Exhaust valve burning always occurred as a result of valve sticking or poor valve seating, for the hot gases escaping past the valve outlets raise its temperature to the burning point (1500°+ F.). Valve sticking can occur as the result of the presence of oil decomposition products in the valve guides.
>
> The metallurgist has reached his limit in exhaust valve material development, and improvements in exhaust valve performance are now largely the responsibility of the designer. One of these consists in ensuring certain valve rotation by employing the "clearance principle", that is, a device which enables the valve to be under no spring tension for a split second during the period in which the valve stem seat is closing up the free space between it and the end of the valve stem. Another improvement in design makes less likely the valve's sticking, by reducing valve guide temperatures. This is accomplished by recessing the valve guide below the surface of the engine block as against the usual practice of having a valve guide protuding beyond the engine block.
>
> It is generally agreed that austenitic alloys are superior to the martensitic type of steel.
>
> <u>Austenitic</u> (Ford) -
>
> These steels have relatively poor burning resistance, but have better hot strength than any of the martensitic steels.
>
> <u>Martensitic or Pearlitic</u> - (Chevrolet) -
>
> Can be quenched to produce fairly hard to very hard surfaces. All these steels lose hardness if the operating temperature exceeds about 900° F. At 1500° F. to 1600° F. these steels are all relatively lacking in strength and hardness.

Conclusions:

1. No evidence of intergranular corrosion was found on either type of valve examined.

2. Failure was probably caused by the combined action of high temperatures and a highly corrosive lead compound medium.

3. The austenitic type of valve material (Ford) is considered superior to the martensitic type (Chevrolet).

4. Improvement in valve performance is largely a matter of design to prevent valve sticking, rather than the selection of metallurgical materials.

ooooooooooo
ooooooo
oo

AF:LB.