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of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1774.

Metallurgical Examination of Two Volute Springs for Medium Tanks.

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Origin of Material and Object of Investigation:

On August 30, 1944, Prof. J. U. MacEwan, Division of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario, submitted Requisition No. 671 (Lot No. 564, Report No. 101, Test No. 5) requesting the examination of two volute springs from current production. The information desired was (a) chemical analysis, (b) hardness survey through a cross section of each coil, and (c) amount of decarburization. The springs were received on November 1, 1944.

The springs were arbitrarily numbered 1 and 2, as no distinguishing marks could be found on them. Each coil was then numbered, the smallest being number 1.

Chemical Analysis:

The following are the results of the chemical analysis:

	SPRING NO. 1	SPRING NO. 2	NE 9262
	- Per Cent -		
Carbon -	0.61	0.60	0.55-0.65
Manganese -	0.84	0.91	0.70-1.00
Silicon -	2.09	2.10	1.80-2.20
Sulphur -	0.026	0.037	0.040 max.
Phosphorus -	0.005	0.004	0.040 max.
Chromium -	0.30	0.27	0.25-0.40
Nickel -	Nil.	Nil.	--
Molybdenum -	Nil.	Nil.	--

Both springs were of NE 9262 steel.

Depth of Decarburization:

The depth of decarburization was determined microscopically. Results are shown below. These readings were taken on the crown or rounded top of each coil.

Coil No.	SPRING NO. 1	SPRING NO. 2
1 -	0.170 mm.	0.210 mm.
2 -	0.185 "	0.340 "
3 -	0.190 "	0.095 "
4 -	0.215 "	0.120 "
5 -	0.235 "	0.125 "
6 -	0.210 "	0.220 "
7 -	0.210 "	0.170 "

Hardness Surveys:

Hardness surveys were taken on cross-sections of all the coils, using the Vickers hardness tester with a 30-kilogram load. The distance of each impression from the outside edge of the coil was measured. Results are shown in Table I.

(Table I comprises Page 3.)
(Text continues on Page 4.)

TABLE I. - Vickers Hardness Surveys (30-kilogram load) on Volute Spring Coils.

(Distances are in millimetres from outside edge.)

SPRING NO. 1.

Coil No. 1*		Coil No. 2		Coil No. 3		Coil No. 4		Coil No. 5		Coil No. 6		Coil No. 7	
442	0.3	465	0.4	431	0.9	473	0.9	454	0.3	508	0.3	449	0.2
468	1.0	496	1.0	481	1.3	473	1.1	487	0.8	527	1.1	493	0.8
468	1.9	487	2.0	493	2.0	487	1.5	481	1.4	537	2.1	493	1.3
468	3.0	484	2.6	487	2.9	493	2.1	476	2.1	517	3.1	493	2.0
473	3.9	476	3.3	487	3.3	465	3.0	478	3.2	537	3.9	487	2.8
473	4.2	467	4.2	490	4.4	481	4.4	476	4.2	530	4.9	484	3.4
459	4.8	470	4.9	490	5.0	493	5.9	476	5.2	523	5.9	490	4.1
		473	5.8	490	5.8	446	7.1	476	6.2	533	7.0	487	4.9
		465	6.4	490	6.3	432	8.2	470	7.1	537	8.0	487	5.8
		473	7.1	487	7.0	446	9.1			527	8.9	484	6.6
		422	7.9	496	7.8	434	9.7			537	9.7	478	7.8
				490	8.7					465	10.2	481	8.5
				487	9.0							481	9.3
				490	9.5							465	10.0
				449	10.0								

SPRING NO. 2.

Coil No. 1		Coil No. 2		Coil No. 3		Coil No. 4		Coil No. 5		Coil No. 6		Coil No. 7	
317	0.2	380	0.2	481	0.3	493	3.4	473	0.3	478	0.5	360	0.2
425	0.9	433	0.9	496	1.0	493	4.3	483	0.9	498	1.3	483	0.8
446	1.4	401	1.5	483	2.0	493	5.3	503	1.3	488	2.1	483	1.6
468	2.0	493	2.3	483	2.6	508	6.6	493	1.9	503	2.9	483	2.2
478	2.5	489	3.3	478	3.4	508	7.4	473	2.4	493	4.1	478	3.0
473	3.0	503	3.9	478	4.5	530	7.9	483	3.1	493	5.4	483	3.9
464	3.4	508	5.0	473	5.7	519	8.4	483	4.1	493	6.8	478	4.3
478	3.9	437	5.7	483	6.7	508	8.8	473	5.1	488	7.8	473	5.1
464	4.3	459	6.1	498	7.2	508	9.0	483	6.0	488	8.6	488	5.8
		488	6.9	488	8.1	498	9.3	483	7.0	488	9.9	488	6.3
				478	9.0	498	9.5	508	8.0			498	7.0
						498	9.8	483	8.5				
								464	9.1				
								478	9.7				

* These readings were taken beyond the soft zone.

(Hardness Surveys, cont'd) -

Under the microscope it was discovered that the No. 1 coil of Spring No. 1 was not martensitic near the top. A hardness survey was run from the edge to show the gradation in hardness. These results are shown below. They were obtained on the Vickers hardness tester, using a 30-kilogram load.

V.P.N.		Distance from top, in millimetres
390	-	0.6
390	-	1.0
409	-	1.5
429	-	2.0
433	-	2.7
442	-	3.2
446	-	3.9
455	-	4.7
455	-	5.0

From the results in Table I, it can be seen that the hardness was uniform across each coil. The depth of the soft zone in Coil 1-1 was about 5 millimetres. Beyond this the hardness of the coil was similar to that of the other coils, as was the martensitic structure.

Microscopic Examination:

The structure of the No. 1 coil of Spring No. 1 was studied more thoroughly under the microscope. The structure is shown in Figure 1.

(Continued on next page)

(Hardness Surveys, cont'd) -

Figure 1.

X100, nital etch.
STRUCTURE OF COIL 1-1.

At higher magnifications it was found that the structure consisted of a drawn martensite (and ferrite in the decarburized zone) with the softer quench products ranging from bainite to fine pearlite. This is shown in Figure 2.

Figure 2.

X1000, nital etch.
STRUCTURE OF COIL 1-1.

Conclusion:

Apparently the carbon content gradient in from the top of the coil, together with critical cooling conditions, resulted in the formation of soft products near the tip of the coil. Otherwise the springs were satisfactory in structure. The decarburization must be considered a defect.

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