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# REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1575.

Examination of Spacing Washers from
Canadian Dry Pin Track.

(Copy No. 14.)

## Abstract

Tests attempting to determine the nature and cause of failure of spacing washers used in the Canadian Dry Pin track are described and their implications discussed. Recommendations for improving the performance of the washers and increasing their service life are given.

Bureau of Mines
Division of Metallic
Minerals

Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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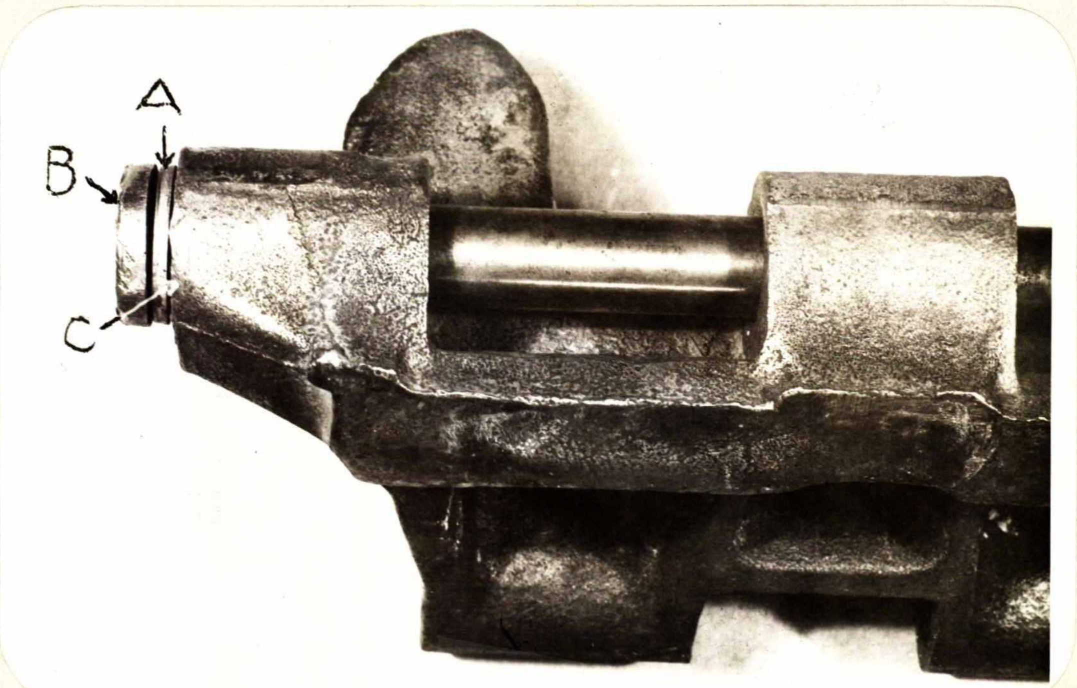
### Introduction:

In the last week of October and all of November of 1943, numerous washers failed in the Canadian Dry Pin track. The severity of the routine inspection test was increased during this period in order to check on pin performance. It was found that the washers would not stand up under these conditions. As a result, on December 2nd, 1943, seven broken and twelve new spacing washers were received from the Hull Iron and Steel Foundries Limited, Hull, Quebec, through Mr. V. W. G. Wilson of the Army Engineering Design Branch, Department of Munitions and Supply, Ottawa. It was requested that the washers be analysed chemically and checked for hardness. This request was covered by Requisition No. 618, AEDB Lot No. 505, Report 23 5C, Div. 2, Test No. 28, submitted by the Directorate of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario. It was further requested verbally that, if possible, the cause of failure be determined.

Application and Method Of Installation:

The spacing washer in the track acts as a cushion in order to minimize the shock on the rivetted end of the pin which has been cold-worked in rivetting and so may possibly be brittle. The method of installation is shown in Figure 1, the spacing washer, A, separating the rivetting washer B (held by the rivetted end of the pin) from the link end C. If operation is correct, the washer floats loosely between the link surface and the rivetting washer. It is then subject to no direct tensional stress and little wear if all irregularities have been removed from the link surface. It is, however, unlikely that the washer is free-floating throughout the life of the track, due to accumulation of dirt and pebbles, tightening-up of the pin and link assembly, etc.

Figure 1.

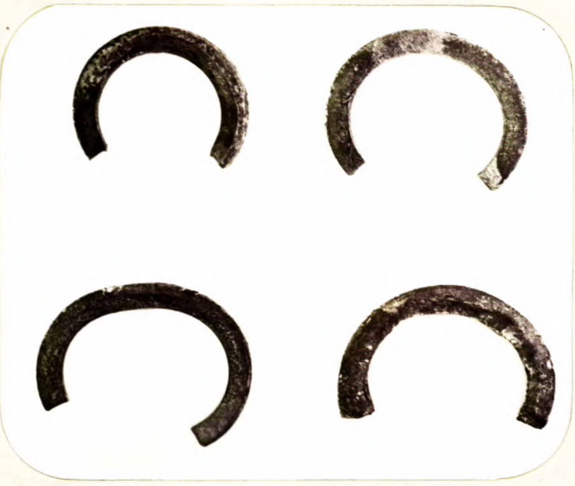



METHOD OF INSTALLATION OF SPACING WASHER.

Macro-Examination:

The broken washers had failed in two places. Some were deformed very little, while others had been bent out of round (possibly to remove them from the track). There were no noticeable signs of wear on any of the samples submitted. The fractures were dirty and nothing could be determined from them. Figure 2 shows four broken washers.

Figure 2.



BROKEN WASHERS.

(Approximately $\frac{3}{4}$ full size).

-

From the new washers it could be seen that they had been sheared from one-eighth inch plate. They are one-and-a-quarter inches outside diameter and seven-eighths inch inside diameter. The shearing left sharp edges and a slight burr. A new washer is shown in Figure 5 at number 1.

Preliminary Tests:

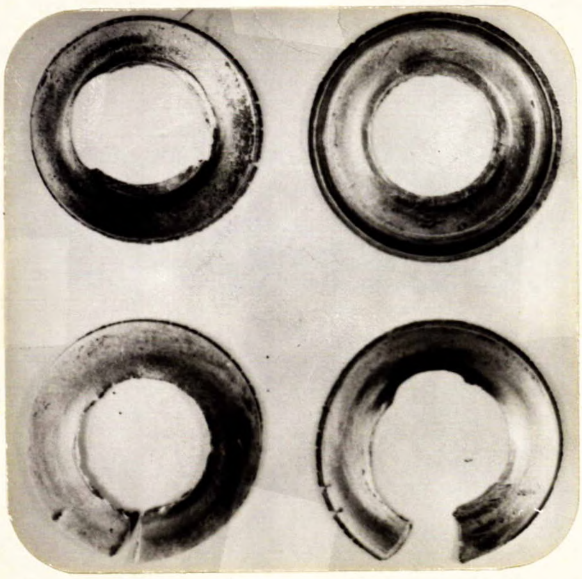
A few preliminary tests were carried out to endeavour to duplicate the manner in which the washers failed and so to determine, if possible, the cause of failure.

(Continued on next page)

(Preliminary Tests, cont'd) -

1. A punch was made up so that the washers could be hammered flat. After pounding to the breaking point a comparison between these washers and those broken in service was made, in order to determine whether this action was taking place in the regular assembly as a result of hammering between the link and the rivetting washer. Figure 3 shows four washers after having been subjected to several hundred blows using the punch with a two-pound hammer.

Figure 3.



FLATTENED WASHERS.

(Approximately ¾ full size).

Compare with Figure 2.

2. The washers fitted on the pins quite loosely, so one was put on a pin and squeezed in a vise until it was jammed on the pin. It was then hammered with a one-pound hammer. No cracks were seen. Number 2 of Figure 5 shows this washer.

3. One washer was compressed in the vise until flat. Some

(Preliminary Tests, cont'd) -

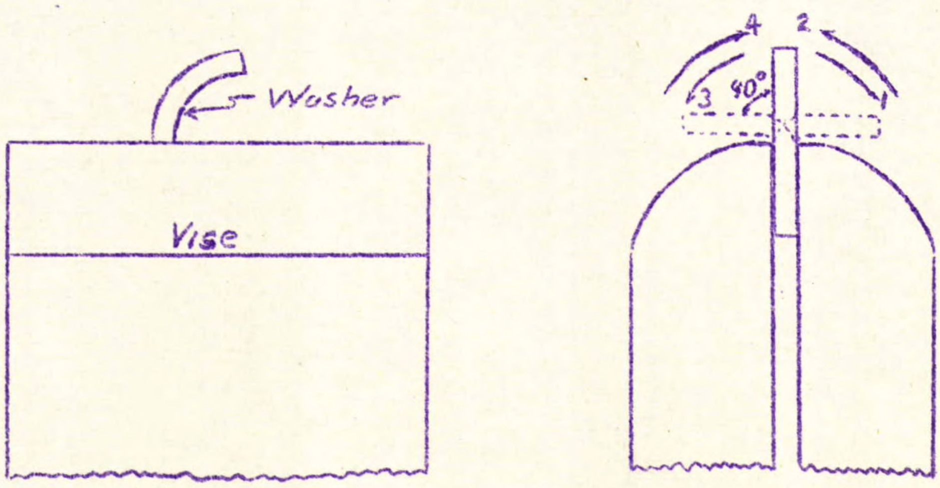
small cracks occurred towards the end of bending. No. 3 of Figure 5 shows this washer.

4. Washers were gripped in the vise and hammered in all directions. They had to be deformed much more than is possible in service before cracks could be produced.

5. Ten new washers were magnafluxed circumferentially and examined for transverse cracks but none was observed.

6. It was suspected that the washers may have been embrittled by hydrogen, and so three broken washers and three new washers were subjected to a repeated bend test, a diffusion treatment, and a second repeated bend test to attempt to detect any brittleness. The washer was gripped in the vise as shown in Figure 4 and bent backwards and forwards with a pair of pliers. The number of flexes required to break the washers was noted and is recorded below, in Table I. The washers were then given a diffusion treatment by heating at 700° F. for twenty hours and the bend tests repeated, the number of flexes required to cause failure again being noted and recorded in Table I.

Figure 4.



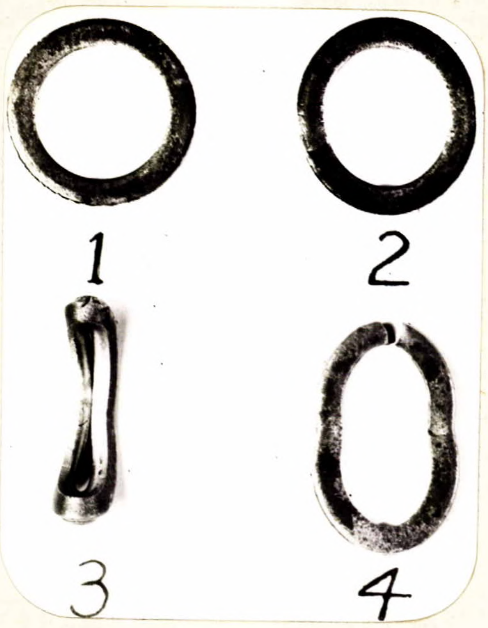

METHOD OF TESTING WASHER BY REPEATED BENDS.

(Preliminary Tests, cont'd) -

TABLE I.

| Washer No. | NUMBER OF FLEXES TO FAILURE Before diffusion | After diffusion | Remarks |
|---|---|---|---|
| 1 | 7 | 17 | Broken washer. |
| 2 | 13 | 19 | " " |
| 3 | 10 | 13 | " " |
| 4 | 16 | 24 | New washer. |
| 5 | 26 | 19 | " " |
| 6 | 19 | 18 | " " |

Figure 5.




CANADIAN DRY PIN TRACK WASHERS.

(Approximately $\frac{3}{4}$ full size).

1. New washer.
2. Washer after hammering on pin.
3. Washer after flattening in vise. Note small cracks.
4. Washer after pulling in tensile machine with U-bolt holder.

-

Hardness:

New Washers -

| Washer No. | Rockwell 'B' | V.P.N. equivalent |
|---|---|---|
| 1 | 73-80.5 | 128-147 |
| 2 | 71-78 | 124-140 |
| 3 | 72-79 | 126-143 |
| 4 | 58-67 | 98-114 |
| 5 | 57-66.5 | 97-113 |

Broken Washers -

| Washer No. | Rockwell 'B' | V.P.N. equivalent |
|---|---|---|
| 1 | 44-58 | 75-93 |
| 2 | 81-83 | 149-156 |
| 3 | 67-71 | 114-124 |
| 4 | 76-81.5 | 134-152 |

Some washers were tumbled together to eliminate the sharp corners and so raise the fatigue strength. Results of hardness tests were as follows:

| Washer No. | Rockwell 'B' | V.P.N. equivalent |
|---|---|---|
| 1 | 80-87 | 146-170 |
| 2 | 76-81 | 134-149 |
| 3 | 80-84 | 146-159 |
| 4 | 76-81 | 134-149 |

Heat Treatment:

Nos. 2, 3 and 4 of the new washers listed above were heated for 15 minutes in a neutral atmosphere in a Vapocarb furnace at 1625° F. and quenched in oil. After hardness tests, the results of which are listed below, Nos. 2 and 3 were drawn at 1000° F. for 30 minutes.

(Continued on next page)

(Heat Treatment, cont'd) -

Hardness After Quench -

| | | | |
|---|---|---|---|
| No. 2 | - | 43-46.5 Rockwell 'C', | 428-478 V.P.N. equivalent. |
| No. 3 | - | 42-44.5 Rockwell 'C', | 420-445 V.P.N. equivalent. |
| No. 4 | - | 76-79.5 Rockwell 'B' | 134-144 V.P.N. equivalent. |

Hardness After Tempering -

| No. | Rockwell 'C' | V.P.N. equivalent |
|---|---|---|
| 2 | 17-19 | 212-220 |
| 3 | 15-19 | 202-220 |

Tensile Tests:

Two methods of gripping the washers in the Baldwin-Southwark testing machine were used. In the first method the washer is held in U-bolts and in the second it is held in the standard grips. In calculating the ultimate stress an area of 0.0233 square inch was used. Tensile tests were performed on new washers as received, on washers heat-treated by these Laboratories, and on washers which had been tumbled together. The results are listed below. No. 4 of Figure 5 shows a washer after being pulled while held in the U-bolts.

| Type of Washer and Method of Gripping | | Load at failure, pounds | Ultimate strength, p.s.i. |
|---|---|---|---|
| New washer held in U-bolts | - | 1132 | 48,750 |
| " " " " " | - | 1133 | 48,750 |
| New washer held in grips | - | 1166 | 50,000 |
| Heat-treated washer No. 2 held in grips | - | 2740 | 117,000 |
| Heat-treated washer No. 3 held in grips | - | 1916 | 82,000 |
| Tumbled washer No. 1 held in grips | - | 1174 | 50,400 |
| Tumbled washer No. 2 held in grips | - | 1150 | 49,400 |

-

Chemical Analysis:

Drillings from two new washers, Nos. 1 and 5, from the heat-treated washers Nos. 3 and 4, and from two broken washers were analysed chemically. The analysis of the two broken washers was reported in P.M. Lab. Report No. 6828, December 4th, 1943, issued by these Laboratories. It is included here in order to give a complete record. The results of the analysis are as follows:

| WASHER | | Carbon, per cent | Manganese, per cent |
|---|---|---|---|
| No. 1 | - | 0.25 | 0.47 |
| No. 3 | - | 0.30 | - |
| No. 4 | - | 0.12 | - |
| No. 5 | - | 0.08 | 0.37 |
| Broken No. 1 | - | 0.22 | 0.33 |
| Broken No. 2 | - | 0.074 | 0.21 |

Microscopic Examination:

(a). One new washer and one heat-treated washer were sectioned transversely and prepared for metallographic examination. On viewing the unetched specimens it was seen that the steel was fairly clean and free from inclusions. The samples were then etched in 2 per cent nital. Figure 6 shows the structure as received and Figure 7 the structure after the heat treatment described earlier in this report. Both photomicrographs are at X250 magnification. It will be seen that both washers contain approximately 0.25 per cent carbon.

(Figures 6 and 7 appear on next page)

(Microscopic Examination, cont'd) -

Figure 6.

X250, nital etch.

SECTION AT SURFACE OF NEW WASHER (SAE 1025).

Note partial surface decarburization.

White constituent - ferrite.
Black constituent - pearlite (unresolved at this magnification).

Figure 7.

X250, nital etch.

STRUCTURE OF HEAT-TREATED WASHER (SAE 1025).

Tempered martensite.

(b). Three new washers were sectioned transversely and prepared for metallographic examination. After etching with 2 per cent nital the amount of decarburization at the surface was measured microscopically. The following results were obtained:

| Washer No. | | Depth of decarburization, in inches |
|---|---|---|
| A | - | 0.025 |
| B | - | 0.015 |
| C | - | 0.025 |

The microscopic examination showed that the steel in these washers contained approximately 0.10 per cent carbon. It was therefore very difficult to obtain accurate measurements for the depth of decarburization, especially as the decarburization varied from point to point on the surface of the washers.

(Continued on next page)

(Microscopic Examination, cont'd) -

It should therefore be borne in mind that the above results are average ones and are only approximate.

(c). All seven of the broken washers were sectioned longitudinally through the fractures and the specimens prepared for metallographic examination. On etching with 2 per cent nital and viewing with the microscope, it was seen that four of the washers contained approximately 0.10 per cent carbon and three approximately 0.25 per cent carbon. Figure 8, at X250, shows the structure at one corner of the fracture of one of the latter washers. Figure 9, at X100, shows the structure at the surface of a low-carbon washer.

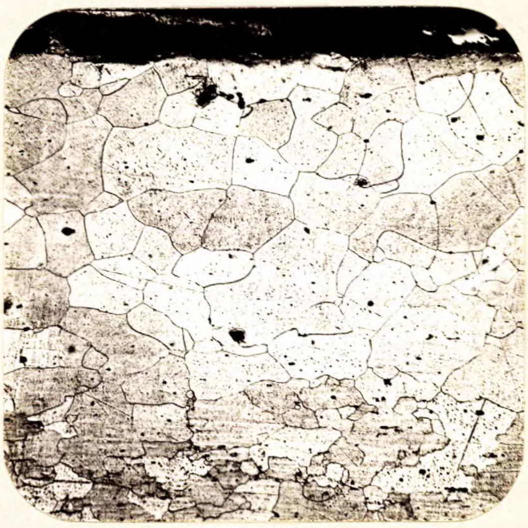
Figure 8.

X250, nital etch.

STRUCTURE AT FRACTURE OF SAE 1025 WASHER.

Note evidence of cold work and "burring".

Figure 9.



X100, nital etch.

STRUCTURE AT SURFACE OF LOW-CARBON WASHER.

Note larger grain size at surface, and decarburization.

Discussion:

In the absence of any positive evidence from the preliminary tests attempting to establish the cause of failure, it seems that there are three possible ways in which the washers

(Discussion, cont'd) -

could fail; namely, due either to fatigue, or to impact, or to a shearing action that occurs as a result of irregularities remaining on the links after grinding or of the presence of some foreign material in the washer-pin assembly. The laboratory tests show that considerable distortion accompanies cracking in compression or tension, and as the failed washers show little distortion this would appear to eliminate straight tensional or compressional stresses as the cause of failure. Further, since the material would be expected to have a fairly high impact resistance, failure due to direct impact seems unlikely. It is thought, therefore, most probably that the washers failed in fatigue. Failure in shear, as mentioned above, is a possibility, but, if fatigue failure is assumed, and the washers are treated to raise the fatigue strength, the resistance to shear will automatically be increased and the tendency to fail in this manner lessened.

Chemical analysis and microscopic examination show that the washers have been made from steels of two compositions corresponding approximately to SAE 1010 and SAE 1025 specifications. Originally the spacing washers used in the Canadian Dry Pin track were of SAE 1010 steel, but when numerous failures occurred with these washers the SAE 1025 washer which had been used in the Valentine track was tried. It was found to be less prone to failure than the SAE 1010 washer but still not satisfactory.

It may be that the washers have been embrittled in some way. In the test for hydrogen embrittlement, four of the six samples tested showed an increase in the number of flexes required to produce failure after the diffusion treatment, one showed a slight decrease, and another showed a definite decrease. This would tend to indicate that some improvement was gained by

(Discussion, cont'd) -

using the diffusion treatment. The fact that the one washer showed a decrease in the number of flexes required may well have been due to the difference in severity of bending before and after diffusion. However, since the test is rather a qualitative one, no definite conclusions can be drawn from it.

The large ferritic grain size and the decarburization at the surface of the SAE 1010 washers would be expected to have an adverse effect on the fatigue strength, and hence the service life, of the washers. Ferritic grain growth would be aided by decarburization. Large ferritic grain size in low carbon steels will cause brittleness. Therefore, due to this brittleness, surface cracks might well have been caused by impact, lowering the fatigue strength of the washers. There was no great amount of distortion at the fractures of the low-carbon washers.

The large ferritic grain size at the surface observed in the low-carbon washers was not seen in the SAE 1025 washers. However, the partial surface decarburization observed on some of the washers examined (see Figure 6) would tend to lower the fatigue strength, and hence the service life. These washers showed more evidence of cold-working at the fracture than the SAE 1010 washers.

Resistance to shear, like fatigue strength, is proportional to the hardness and tensile strength, which in the case of these washers are low. Therefore, to increase the service life the tensile strength (and as a result, the hardness) must be increased. The microstructure of the SAE 1025 washers as received shows them to be in the normalized condition (see Figure 6). The tensile strength could then be increased by a suitable heat treatment. The SAE 1010 washers could not be improved by heat treatment, due to too low carbon

(Discussion, cont'd) -

content, and so are not suitable. Tumbling the washers to remove the sharp edges and burrs caused by shearing would be expected to increase the fatigue strength somewhat, since these are stress raisers and as such tend to lower the fatigue strength.

From the results of these tests it seems that the best carbon steel for these washers would be SAE 1025 or SAE 1030 heat-treated to 26 to 31 Rockwell 'C'. This would give approximately 110,000 to 125,000 pounds per square inch tensile strength and, as a result, a much higher resistance to shear and a higher fatigue strength would be obtained than is the case at present without too great a lowering of the impact strength. The washers could be sheared from plate, as in present practice, tumbled together to round over the sharp edges, and heat-treated. Any surface decarburization should be eliminated in the heat treatment, as it would lower the fatigue strength. It is felt that a washer made in such a way would give satisfactory life. It is recommended, as a further safeguard, that in assembling the track the washers should be free to turn and not jammed between the rivetting washer and the link surface. Also, the link surface should be carefully ground to remove any irregularities.

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CONCLUSIONS:

1. The washers examined are made from steels of two ranges of composition corresponding approximately to specifications for SAE 1010 and SAE 1025.

2. The washers probably failed due to fatigue.

(Continued on next page)

(Conclusions, cont'd) -

3. The washers are in the normalized condition.

4. The surfaces of the washers are partially decarburized and, in the case of the SAE 1010 washers, exhibit ferritic grain growth. All this lowers the fatigue resistance.

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Recommendations:

1. In order to improve the performance of the washers and to increase their service life they should be made from SAE 1025 or SAE 1030 steel heat-treated to 26 to 31 Rockwell 'C'.

2. Any surface decarburization should be eliminated by the heat treatment.

3. The track should be assembled so that the spacing washers are free to turn and not jammed between the link surface and the rivetting washer.

4. The link surface which will be in contact with the spacing washer should be carefully ground to remove any irregularities which might tend to jam the washer and shear through it.

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