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DEPARTMENT OF MINES AND RESOURCES

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Ottawa, August 15, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2089.

Investigation of Hard Drawn Spring Wire
As Used in the Twin Pin Clothes Pin

(Copy No. 6.)

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

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

O T T A W A, August 15, 1946.

# R E P O R T

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### As Used In The Twin-Pin Clothes Pin

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**Origin of Material:**

On July 18, 1946, these Laboratories received a request for assistance in evaluating the suitability of clothes pin spring wire, from Mr. C. R. Crocker, Regional Representative, Department of Reconstruction and Supply, through the Technical Information Service.

In the accompanying letter dated July 6, 1946 from Mr. Crocker and a subsequent communication from Mr. S. A. Hardisty, Manager, Twin-Pin Company, Limited dated July 22, 1946, it was revealed that:

1. The wire was purchased from the Steel Company of Canada as "14 gauge, galvanized, wiped clothes pin spring wire, 55/60 carbon".

..... 2.

(Original of Material Cont'd)

2. The spring for the clothes pin was formed in a machine constructed by Mr. Hardisty.

3. That after some months the spring becomes slack and the clothes pin falls apart.

Information was requested regarding the suitability of the wire for this type of clothes pin and the bending of spring wire and machines used for this purpose.

Object of Investigation:

To evaluate the spring wire in respect to its suitability for this design of clothes pin.

PROCEDURE:

1. Visual Examination:

Figures 1 and 2 are photographs of the spring wire as formed and in the assembled clothes pin. It was noted that some springs appeared weak and others strong in the assembled pin. Figure 3 is a photograph showing the permanent set induced in the spring form as a result of the assembling operation. Some of the springs failed in the forming operation. Figure 4 is a photograph of a typical failure.

2. Chemical Analysis:

Table I lists the results of the chemical analysis of samples from two different coils. For comparison purposes only A.S.T.M. Specification A-227-41 for hard drawn spring steel wire is also given.

TABLE I

| Chemical Analysis | 1. | 2. | A.S.T.M. A-227-41 Analysis Spec. |
|---|---|---|---|
| Carbon | +0.51 | 0.68 | 0.45 - 0.75 |
| Manganese | 1.08 | 1.07 | 0.60 - 1.20 |
| Phosphorus | 0.015 | 0.008 | .045 max. |
| Sulphur | 0.031 | 0.028 | .050 max. |
| Silicon | 0.16 | 0.19 | 0.10 - 0.30 |

+ - Carbon content is only approximate due to difficulty in shearing small samples for analysis.

3. Microscopic Examination:

Transverse and longitudinal sections were taken from both satisfactory and unsatisfactory spring wire, mounted, etched and examined under the microscope. Figure 6 is a photomicrograph of the normal sorbitic structure of the transverse area. Figure 7 is a photomicrograph of the longitudinal area showing the elongated grains of a typical hard drawn structure. No differences were noted in the microstructure between the satisfactory and unsatisfactory wire examined.

4. Physical Tests:

Both hardness and tensile tests were taken on various conditions of the wire. The results are summarized in Table II below. All hardness readings were taken on a Vickers Hardness Testing Machine (30 Kilos load) and the results obtained converted to Rockwell "C" Scale values and approximate tensile strengths. Tensile tests were performed after galvanizing had been removed from the test pieces on a 20,000 lb. Baldwin-Southwark Tensile Machine (2,000 lb. scale) and values obtained converted to approximate Rockwell "C" hardness numbers.

TABLE II

| Condition of the Wire | Vickers Nos. | R"C"Nos. by conversion | Estimated tensile strength by conversion. | Tensile Strength (actual tests) p.s.i. |
|---|---|---|---|---|
| (a) Coil wire prior to straightening and forming (as rec'd). Satisfactory springs were subsequently formed from this wire with normal breakage | (1) 420-434 | 42-44 | 196000-204000 | |
| | | 47 | | 231,000 |
| | | 47 | | 231,000 |
| | | 48 | | 234,000 |
| | | 48 | | 234,600 |

TABLE II (cont'd)

| Condition of the Wire | | Vickers Nos. | R"C"Nos. by conversion | Estimated tensile strength by Conversion p.s.i. | Tensile Strength (actual tests p.s.i. |
|---|---|---|---|---|---|
| (b) Coil wire after straightening and prior to forming | | | 49<br>49 | | 241,000<br>243,000 |
| (c) Spring wire from assembled pins which appeared weak and likely to fail in service | | 402-454<br>406-457<br>409-429<br>406-422 | 41-45<br>41-45<br>41.5-43<br>41-42<br>45 | 189,000-212,000<br>189,000-212,000<br>193,000-200,000<br>189,000-196,000 | 210,000 |
| (d) Springs which were slack in the assembled pin: A-readings on the working arm. B-the critical bend where the wire passes under the pin. C-readings on the wire passing under the pin | A<br>B<br>C<br>A<br>B<br>C | 467-449<br>467-470<br>459-473<br>432-449<br>441-462<br>444-470 | 44.5-46<br>44.5-46<br>45-46<br>43-44<br>44-44.5<br>44.5-46 | 208,000-220,000<br>216,000-220,000<br>212,000-220,000<br>200,000-208,000<br>204,000-216,000<br>208,000-220,000 | |
| (e) Wire from a coil in which there appeared to be an unusual number of fractures in forming. | | | 49<br>49 | | 238,000<br>237,400 |
| (f) Springs which fractured in forming. Low reading close to the fracture, high reading in the unaffected wire | | 409-444<br>409-439 | 41-4[illegible]<br>41-44.5 | 189,000-212,000<br>189,000-212,000 | |

A.S.T.M. A-227-41 specifies tensile limits of 210,000 to 254,000 p.s.i. for 14 gauge, hard drawn spring wire. The A.S.M. Handbook, 1939 Edition (page 984) lists a hardness range of Rockwell "C" 41 to 45 for hard drawn spring steel used in cold forming small helical coils. Compare the results obtained with both of these specifications.

Physical Test #1. and chemical analysis result #1 were both obtained from the same coil. Similarly test (e) and analysis #2 were obtained from the same coil. Apparently difficulty in producing satisfactory pins increased with the increased carbon content, although the wire still fell within the limits of A.S.T.M. Specification A-227-41.

5. Design:

The stress analysis of this type of clothes pin was determined. Assuming 14 gauge hard drawn spring wire conforming to A.S.T.M. Spec. A-227-41 it can be shown that the maximum safe working stress with intermittent loading is approximately 48,000 p.s.i. This is a torsional shear stress acting at the critical point where the wire passes under the pin. The actual working stress which is developed at this point was found to be approximately 200,000 p.s.i., almost four times greater than the safe allowable stress. (See Appendix X) Attention is also called to the sharp right angle bends at points A and B (see figs. 1, 4) and the resulting deformation on the inside of the bend (fig. 5)

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Discussion:

It was reported that some difficulty is experienced in assembling the clothes pin i.e. breakage of the wire in the forming operation and slackness of the spring in the assembled clothes pin. In addition, the service life of this type of clothes pin was reported to be somewhat shorter than that normally expected.

No differences were noted in the microstructure between satisfactory and unsatisfactory wire. The wire has a normal patented and cold drawn structure.

The chemical analysis revealed nothing unusual, A.S.T.M. Specification A-227-41 being very similar. The physical tests also fall within the limits of either this specification or the physical requirements of a typical specification for a hard drawn spring steel used in cold-forming small helical coils.+ However, a definite tendency was noted between the increased carbon content, the hardness and the number of failures in the forming operation. It is reported that an increase in the number of failures in forming occur as the carbon content increases. With satisfactory wire, the hardness values were R "C" 41-45 and the carbon content approximately 0.55 per cent. When the carbon content increased to 0.68 per cent with a corresponding increase in hardness to R "C" 49, the number of failures in the forming operation also increased. Note however that the wire still falls within the limits of ASTM A-227-41. It would appear that although the wire still conforms to specification, it is not the most suitable for this particular application; its suitability decreasing as the composition of the wire approaches either limit of the specification. Wire of higher carbon content will cause the failure in forming while that of lower carbon content will permit permanent set and slackness in the assembled pin.

..... 7.

+ A.S.M. Handbook, 1939 Edition, Pages 983-4.

The design develops a high working stress (torsional shear) at the critical bends where the wire passes under the pin. It can be shown that the actual working stress (200,000 p.s.i.) is far in excess of the maximum safe working stress (48,000 p.s.i.) for hard drawn spring wire loaded intermittently and conforming to ASTM A-227-41. The sharp right angle bends at points A and B (fig. 1.) act as stress raisers, i.e. actually raise the stress at these corners above the apparent maximum stress being applied and increase the probability of failure at A and B. This is substantiated in figures 4 and 5, photographs of a typical failure. A larger radius at these points would help to counteract this stress-raising effect. When the service stress accompanies the assembling and forming stresses, if fracture has not occurred, short service life will result. The type of failure will be determined by (a) the magnitude of variable stresses and/or (b) whether the wire is on the high or low side of the chemical specification.

Conclusions:

1. The wire has a normal patented and cold drawn structure. No differences were noted in the microstructure between satisfactory and unsatisfactory wire examined.

2. The chemical and physical properties of this wire conforms to A.S.T.M. Specification A-227-41 and in the samples examined were consistently within these limits.

3. It would appear that the wire supplied is according to specification but for this particular application is not the most suitable. Unsatusfactory springs occur when the wire varies from the average to the low or high limits of the specification.

(Conclusions cont'd)

4. Several undersirable features were noted in the design. It develops a high working stress (torsional shear) greatly in excess of the maximum safe working stress. Hence a short service life may be expected. The stress-raising effect of the sharp 90° bends further aggravate this condition.

5. With wire of high carbon content, the likelihood of failure occuring in the forming operation is increased. With wire on the low side of the carbon range and in conjunction with the severe stresses outlined in the discussion, slackness will occur in the assembled pin.

Recommendations:

The performance of the spring wire with this particular design would be improved partially by:

(a) A larger bend radius at the points A and B (fig. 1.) consistent with satisfactory assembling.

(b) Changing to an oil-tempered spring wire or a cold drawn wire of heavier gauge with the same or higher physical properties. The ability of the forming machine to bend the wire, the recoil in forming and the pressure required to spread the jaws of the assembled pin are limiting factors. Trial lots would determine the suitability of the wire. Since the product is in the low price field, the cost factor would be the prime consideration in changing to a different gauge or wire.

However, in view of the undesirable features of the design, it is felt that the remedial effect of the above suggestions would be very slight. With a change in design to incorporate a helical coil at the point where the wire

(Recommendations cont'd)

passes under the pin, better performance would be assured since:

1. The working stress would be reduced considerably to within safe limits.

2. The stress-raising effect of the sharp 90° bends would be totally eliminated at that critical point.

A further advantage to such a change in design would be the utilization of a less expensive wire than is now used.

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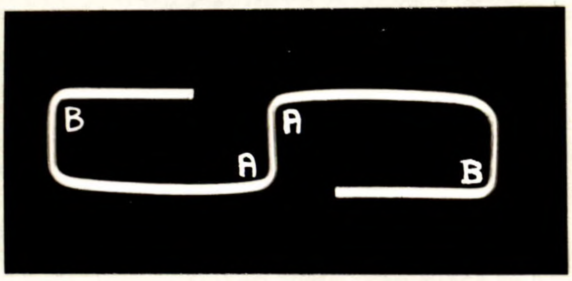
KBY:EF

(Figures 1 to 7 follow,)
(on Pages 10 and 11. )

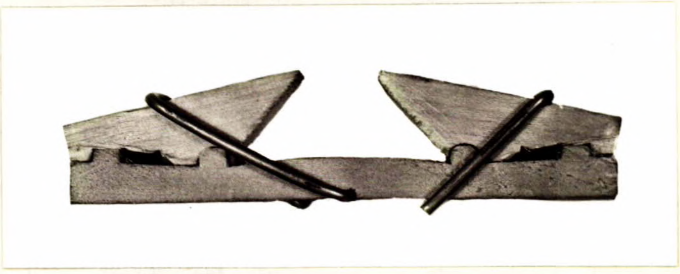
Figure 1.




CLOTHES PIN SPRING AS FORMED .
(Note the sharp 90° bends at A and B)

-

Figure 2.



ASSEMBLED CLOTHES PIN.

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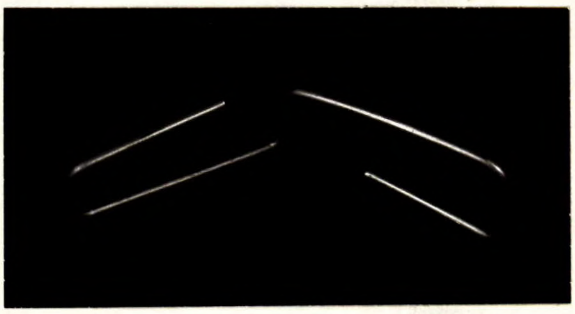
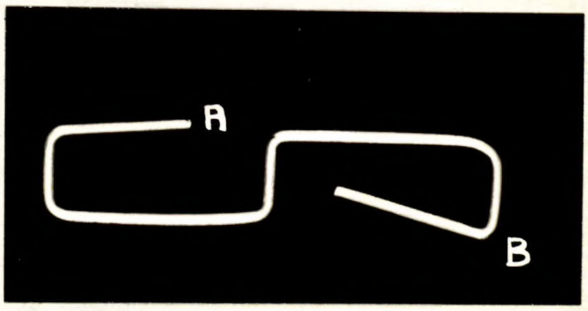
Figure 3.



THE SET INDUCED AS A RESULT OF THE ASSEMBLY OPERATION.

-

Figure 4.




TYPICAL DEFECTIVE SPRING FROM THE FORMING OPERATION.

(Compare with Figure 1 - note cracks at A and B)

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Figure 5.

THE FRACTURE AT POINT A.

(Note deformation on inside of the bend)

(See Figure 4.)

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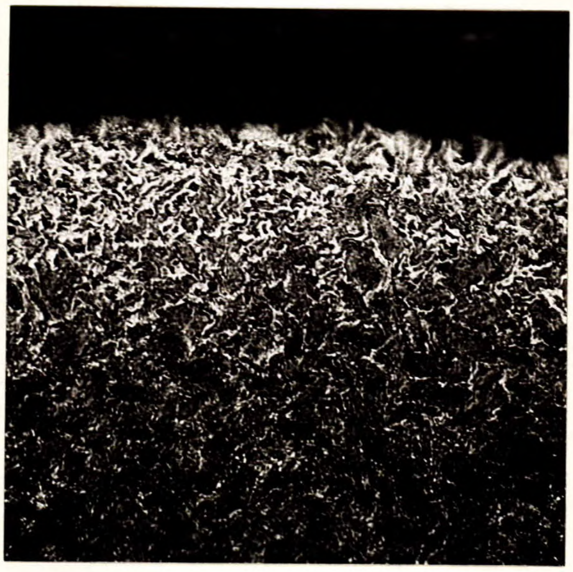
Figure 6.



X500, nital etch.

TYPICAL SORBITIC STRUCTURE OF TRANSVERSE AREA (near the surface of the wire).

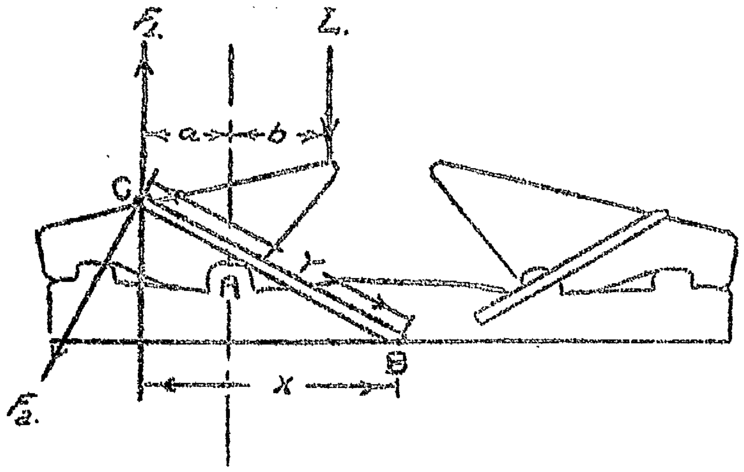
Figure 7.

X500, nital etch.

TYPICAL LONGITUDINAL AREA (elongated grains are characteristic of a cold drawn structure).

(An Appendix follows, on Page 12 to 15.)

# APPENDIX




SKETCH "A"

Referring to the above sketch, it is seen that the total stress acting on point B is composed of a torsional shear stress (the working stress) and static residual stresses developed in the forming and assembling operations. Of these, the working stress is the most important since in the assembled pin, it alone varies.

When the load is applied at L, the wire is twisted at B. When the torque is removed and if the torsional yield point has not been exceeded, the resiliency of the wire will return the spring to its former shape. However, with repeated applications of the load the torsional yield point is exceeded, permanent set occurs and the wire slackens, rendering the clothes pin useless.

The load L required to spread the jaws of the pin was found for both jaws on six clothes pins, selected at random from a dozen ready for market. These readings were 10# - 16# (12 readings, ave. = 13#).

Assuming the average pin using this type and size

(Appendix, cont'd) -

of wire requires a load of 13 lbs.

If $L$ = applied load
$F_1$ = resultant reacting force about A,
$F_2$ = resultant force on the spring at C.

Taking moments about A

$$L \times b = F_1 \times a,$$
$$13\# \times \tfrac{1}{3} = F_1 \times 7/16",$$
$$F_1 = 14.9 \text{ lbs.}$$

Taking moments about B

$$F_1 \times X = F_2 \times Y$$
$$14.9\# \times 1\text{-}3/8" = F_2 \times 1\tfrac{1}{2}"$$
$$F_2 = 13.55 \text{ lbs.}$$

The stress concentration is at point B of the wire. Part of the force $F_2$ is taken up by the deflection of the arm "Y". Therefore it will give an added measure of safety to our calculations if "Y" is considered a stiff member and that the whole of $F_2$ is transmitted directly at B.

$$\text{Therefore Torque} = F_2 \times Y = 13.55 \times 1\tfrac{1}{2}". = 20.4 \text{ in lbs.}$$

The reaction of the wooden slot in which the spring fits counteracts the bending effect of $F_2$ on the wire passing under the pin. Hence at B only the torsional effect need be considered.

The torsion formula $T = \frac{S_s J}{r}$ where $T$ = Torque in in.-lbs.
$S_s$ = max. unit shearing stress in p.s.i.
$J$ = polar moment of inertia
$r$ = radius of the wire, ins

For a solid circular section $J = \frac{\pi r^4}{2}$

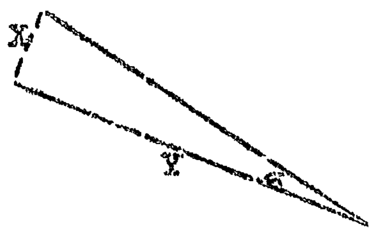
and 14 gauge wire has a diameter = .080"

$$\text{Therefore } S_s = \frac{T \times r}{J}$$
$$= \frac{20.4 \times .04}{\frac{\pi (.04)^4}{2}}$$
$$= \underline{\underline{204,000}} \text{ p.s.i.}$$

= unit shear stress actually developed in the spring
= unit working stress

(Appendix, cont'd) -

(2) As a check on the value obtained for $S_s$ (204,000 p.s.i.), the deflection of point C was roughly measured for both jaws of six pins. It was roughly estimated that C moves a distance of greater than 3/10" at right andles to "Y" when the jaw is spread i.e. x = .30 or higher.




When X = only .291 ins.

then $\alpha = \tan^{-1} \dfrac{.291}{1.375}$

$= 12°$

Also $S_s = \dfrac{r \theta E_s}{l}$

where r = radius of the wire
= .04"
$\theta$ = angle of twist in radians
$E_s$ = shearing modulus of elasticity
= $12 \times 10^6$
l = length of the arm that is twisted
= ½", the length of the arm passing under the pin since only one jaw is being operated at a time.

If Y moves through 12°

$\theta = \dfrac{12 \times \pi}{180}$

= .209 radians

and $S_s = \dfrac{.04 \times .209 \times 12{,}000{,}000}{.5}$

= 200,000 p.s.i.

This value is a close check on the previously estimated working stress.

(3) The following quotations are extracted from "The Design of Machine Members" by A. Vallance, (p. 164)

(a) "Tests indicate that the yield stress in torsion is approximately 45% of the ultimate strength in tension for oil-tempered wire and 35% for hard drawn wire."

(b) "The safe working stress should not exceed 80% of the torsional yield stress and if the spring is continuously subjected to rapid load fluctuations, the working stress must

(Appendix, cont'd) -

be reduced 25 to 50%."

Consider 14 gauge hard drawn spring wire conforming to A.S.T.M. Specification A-227-41. The tensile strength would fall between 210,000 p.s.i. and 254,000 p.s.i. If on the lower limit

$$\text{the torsional yield stress} = \frac{35}{100} \times 210{,}000 = 73{,}500 \text{ p.s.i.}$$

and therefore the safe working stress for intermittent loading

$= \frac{80}{100} \times 73{,}500 \times \frac{75}{100} = 44{,}000$ p.s.i. or lower, depending upon the value between 25 and 50% arbitrarily selected.

Similarly, if on the upper limit,
the safe working stress = 53,300 p.s.i.

Therefore the safe working stress lies between 44,000 p.s.i. or possibly lower (see above) and 53,300 p.s.i. A figure of 48,000 is arbitrarily selected.

Compare, the safe working stress (48,000 p.s.i. approx.) with the actual working stress (200,000 p.s.i. approx.).

Ottawa, Ont.
August 15, 1946.
KBY:LB.