CANADA

LABORATORY DEVELOPMENT OF CORROSION-INHIBITING COATINGS FOR MINE HOIST WIRE ROPE

W. Dingley

Extraction Metallurgy Division

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LABORATORY DEVELOPMENT OF CORROSION-INHIBITING COATINGS FOR MINE HOIST WIRE ROPE

by

W. Dingley*

ABSTRACT

Results of laboratory tests are given on a compound designed to protect zinc-coated steel wire mine hoist rope. In a preliminary screening test it was learned that a combination of a road-construction asphalt, zinc chromate and trichlorethylene gave better results than a number of compounds presently used for wire rope protection.

A second series of tests on zinc-coated wire from mine hoist rope, using various proportions of asphalt, zinc chromate and trichlorethylene, showed that coatings having an asphalt to zinc chromate ratio of about 1:1 gave best results. The asphalt-zinc chromate-trichlorethylene coating is recommended for both used and unused ropes.

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*Technical Officer, Pyrometallurgy and Corrosion Subdivision, Extraction Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

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MISE AU POINT EN LABORATOIRE D'ENDUITS DE PROTECTION CONTRE LA CORROSION DESTINÉS AUX CÂBLES D'ACIER DES MACHINES D'EXTRACTION

par

W. Dingley*

RÉSUMÉ

L'auteur rapporte les résultats obtenus au laboratoire en ce qui a trait à un composé destiné à protéger les câbles d'acier enduit de zinc qui servent dans les machines d'extraction des mines. Au cours d'un essai préliminaire à crible, il avait été établi qu'un mélange constitué d'asphalte destiné à la construction des routes, de chromate de zinc et de trichloréthylène donnait de meilleurs résultats qu'un certain nombre de composés présentement utilisés pour protéger les câbles d'acier.

Une seconde série d'essais sur le fil enduit de zinc dont on se sert pour fabriquer les câbles des machines d'extraction impliquait l'emploi, dans diverses proportions, d'asphalte, de chromate de zinc et de trichloréthylène, et l'auteur a constaté que les enduits où l'asphalte et le chromate de zinc se trouvaient dans une proportion d'environ un à un donnaient les meilleurs résultats. Il est à recommander d'utiliser l'enduit constitué d'asphalte, de chromate de zinc et de trichloréthylène sur les câbles aussi bien neufs qu'usagés.

*Fonctionnaire technique, Subdivision de la pyrométallurgie et de la corrosion, Division de la métallurgie extractive, Direction des mines, ministère des Mines et des Relevés techniques, Ottawa, Canada.

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INTRODUCTION

In the mines throughout the world there has been a great loss of time, material and human life, due to metal corrosion. Some idea of the importance of this problem may be obtained from the 75 different references to corrosion which appeared in the proceedings of the Institution of Mining and Metallurgy's conference on "Wire Ropes in Mines" which was held in 1950.[1] These references indicate that most of the corrosion in the hoisting ropes has been caused largely by the penetration of moisture between the individual wires.

Asphalt, bitumen, lanolin, oils, greases, and combinations of these compounds have been applied to ropes during manufacture and during service, to protect them from this moisture. Zinc and lead powders and colloidal graphite, suspended in lubricants, also have been used.[2] Chemical compounds with water-displacing properties have appeared more recently.[3] It now is well established that, in most mines, ropes consisting of zinc-coated steel wires give appreciably longer service than do those consisting of bare wires.[4] Zinc-coated wires are being used extensively in ropes which previously had been very difficult to protect owing to their closely woven nature, such as the one shown in Figure 1.

The work reported here was done in response to a request from a Canadian company for assistance in solving a difficult corrosion problem encountered in connection with their zinc-coated hoist ropes. In

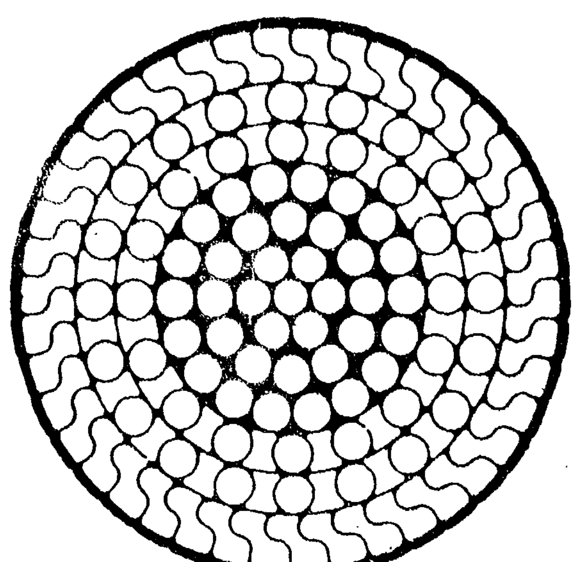


Figure 1--Locked coil wire rope (cross section).

spite of frequent applications of various types of compounds, corrosion had reduced the useful life of these ropes to 18 months.

Examination of an unused rope revealed a small amount of zinc and iron corrosion at numerous locations on individual wires that had been removed from the first, second and third rows. Examination of a used rope showed that quite severe corrosion had taken place on the outer surfaces of all the wires in the first row, and also that the zinc coatings on all of the wires in all of the rows had been almost completely consumed by corrosion. The rope compound found on the unused rope was not visible in the corrosion products from the used one. Compounds applied while the ropes were in service apparently had not penetrated further than the outer row of wires. Chloride was the predominant anion in the corrosion products.

In view of these findings a program was initiated to attempt to produce a compound that could be used on wire ropes to increase their resistance to corrosion under the conditions in this particular mine. The purpose of this bulletin is to outline the work done in the development of such a compound. The resulting coating material has shown exceptionally good results in laboratory corrosion tests, and arrangements are being made now to test it under actual conditions in the mine.

EXPERIMENTAL PROCEDURE

Specimen Preparation and Corrosion Test Method

Protective coatings investigated during this work were all tested by the same standard procedure so they could be arranged readily in order of merit. Each test specimen was prepared as follows:

1. A 6-inch length of zinc-coated wire, obtained from the first (outside) row of an unused rope (see Figure 1), was thoroughly brushed in suitably stabilized liquid trichlorethylene and then degreased in the vapor of the same material. It then was placed in a desiccator.

2. It was removed from the desiccator and hand-dipped in the coating material being tested.

3. It was hung vertically for 24 hours at room temperature (70°F) to allow volatile constituents of the coating material to evaporate.

Each test specimen so prepared was subjected to an intermittent immersion test in 5 per cent sodium chloride solution to determine its resistance to corrosion. Although these conditions obviously did not exactly duplicate conditions in the mines, they did include the frequent wetting and partial drying which usually take place in such an environment. It will be recalled, also, that chloride was the predominant anion in the water from the mine in question. Having found the coating with the best corrosion resistance in the laboratory test, it was planned to test it further in the mine to ensure that the results obtained in the laboratory were not misleading.

In this corrosion test, each coated specimen was suspended vertically from the arms of a dipping machine with vinylidine chloride cord. By this means it was dipped into and withdrawn from a 2000-ml glass beaker containing 1900 ml of 5 per cent sodium chloride solution, each complete cycle requiring one minute. The specimen was examined on each working day and a note was made of the time to first appearance of red iron rust and to general rusting. (General rusting was indicated by the appearance of rust spots on various parts of the surface of the specimen, and by a sudden increase in the amount of iron rust in the solution.)

Development of the New Coating Compound

During the first part of the investigation a considerable number of coating materials were compared in the laboratory test described above. These included three types of rope compound presently used and a wide variety of organic and inorganic materials known to protect metals against corrosion under certain circumstances. The best of the commercial rope compounds gave effective protection for only four hours in the laboratory corrosion test. Of the other materials investigated, a road-construction asphalt gave particularly good results as a base. It also was found that:

1. Chromates were the most effective of the additives tested, when an asphalt-base coating was used.

2. Trichlorethylene was an excellent thinner for the asphalt-chromate coatings, due at least partly to its good wetting properties and high volatility.

For these reasons it was decided to pay particular attention to combinations of asphalt, chromate and trichlorethylene during the latter part of the investigation.

Chromate Inhibitor Action Compared

The next step was to compare the inhibitor action of various chromates when used in combination with the asphalt and the trichlorethylene. As shown in Table 1, the two zinc chromate (zinc yellow) pigments tested proved to be much superior to a barium potassium chromate pigment and to chemically pure anhydrous sodium chromate. It also was observed that one of the zinc chromate (zinc yellow) pigments gave considerably better results

TABLE 1

Corrosion Resistance Imparted to Zinc-coated Steel by Chromate Compounds in Asphalt Coatings

(hours to first rusting in an intermittent immersion test using 5 percent sodium chloride)

Ratio (asphalt/compound)	Zinc Chromate Pigment A	Zinc Chromate Pigment B	Barium Potassium Chromate Pigment	Sodium Chromate (anhydrous) C.P.
5/1	96	72	60	60
2/1	500	200	-	-
5/4	500	200	85	180
5/12	420	235	-	-

Asphalt coating with no chromate - 48 hours.
Best rope compound used at mine - 4 hours.

than the other. Finally, the ratio of asphalt to chromate pigment appeared to be very important.

In the next phase of the investigation, experiments were performed to determine the preferred proportions of asphalt, the better zinc chromate pigment, and trichlorethylene in the coating mixture. Whereas mixing of the constituents in earlier experiments had been done comparatively inefficiently by hand, in these later experiments it was done much more effectively by an electric mixer (30 minutes at approximately 8000 revolutions per minute).

Mixtures of the asphalt and zinc chromate were made up in the following ratios: 1:0, 5:1, 2:1, 1:1, 2:3, 1:2, and 2:5. Each mixture was divided into 12 equal portions, and a different amount of trichlorethylene was added to each. Each of the resulting 72 mixtures was applied, by dipping, to a different set of three steel panels, each one inch square. After drying, the average weight of each of the 72 types of coating per unit of area was determined.

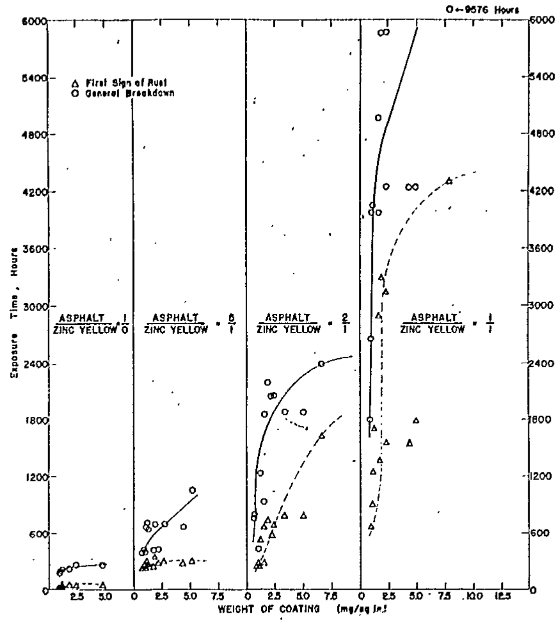
Each of the above-mentioned 72 coating mixtures was applied in the same way to a set of two zinc-coated steel wire samples taken from an unused mine hoist rope. After drying, the resulting specimens were subjected to the corrosion test already described. In Figure 2 the average number of hours to first rusting and the average number of hours to general rusting are plotted against the average coating weight, in the case of each of the 72 types of coating. It will be noted that in one case in which the asphalt/ zinc chromate ratio was 1:1, general breakdown did not occur even when the test had lasted 9576 hours. There also was a similar case when the ratio was 2:3.

In Figures 3 and 4 the compositions of these different types are plotted on ternary diagrams, which also show the weights of the coatings. The coatings having the best resistance to corrosion are indicated. The latter are listed in Table 2.

TABLE 2

Compositions of Coatings Most Resistant to Corrosion

Coating Composition (per cent by weight)			Ratio
Asphalt	Zinc Yellow	Trichlorethylene	Asphalt/Zinc Yellow
25.0	25.0	50.0	1:1
22.7	22.7	54.6	1:1
22.7	34.1	43.2	2:3
22.2	33.3	44.5	2:3
20.0	30.0	50.0	2:3
18.1	27.3	54.6	2:3



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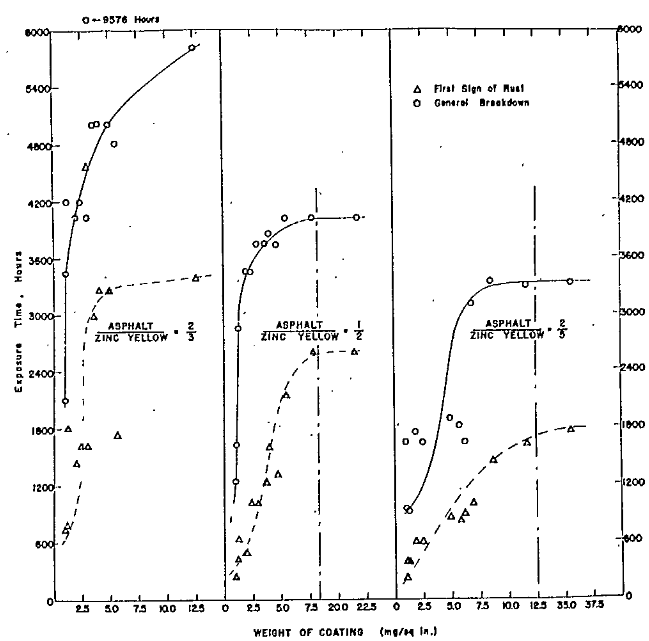

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Figure 2--Effect of coating weight on the time to first rusting and the time to general rusting, in the case of each of the seven ratios of asphalt and zinc chromate pigment.

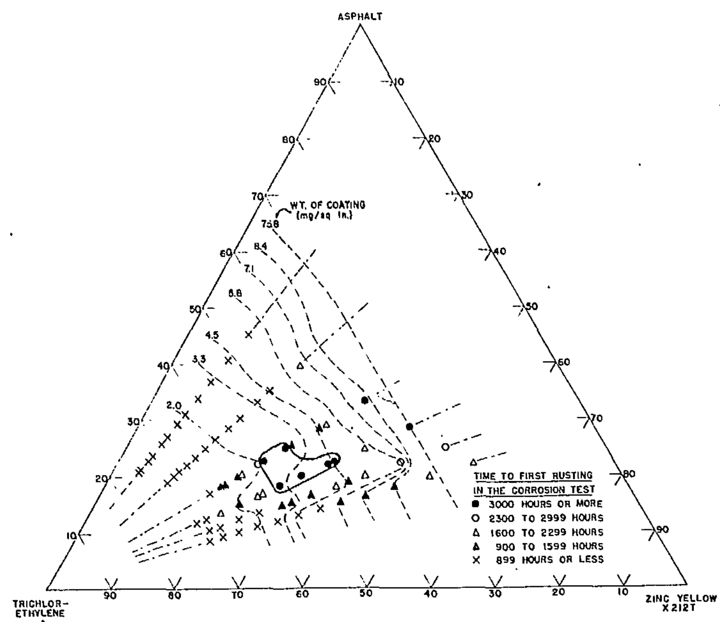

Figure 3--Time to first rusting of coatings produced from asphalt-zinc chromate pigment-trichlorethylene mixtures, on zinc-coated steel wire.

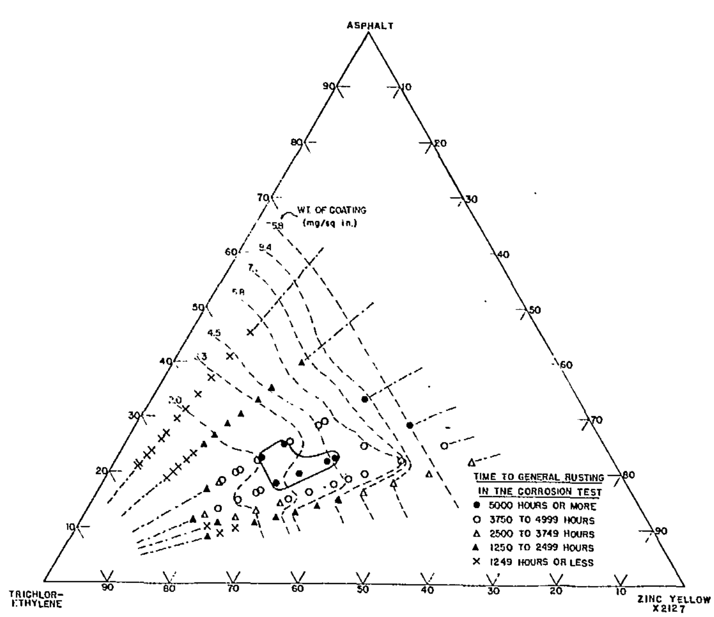

Figure 4--Time to general rusting of coatings produced from asphalt-zinc chromate pigment-trichlorethylene mixtures, on zinc-coated steel wire.

DISCUSSION

It should be emphasized that although early experiments were not as carefully controlled as the ones summarized in Figures 2 to 4, they provided an adequate over-all picture. In addition to showing that one zinc chromate pigment was superior to other chromates investigated as a corrosion inhibitor, results presented in Table 1 showed that the degree of inhibition afforded zinc-coated steel was greatest when the asphalt/zinc chromate ratio was about 1:1. Results obtained were inferior when this ratio was substantially increased or decreased. This was substantiated by the experiments summarized in Figure 2.

Data summarized in Figure 2 show that a coating with an asphalt/zinc chromate ratio of 1:1 possesses the best corrosion resistance per unit of weight. However, a coating with a ratio of 2:3 also resists corrosion exceptionally well.

Six of the eight coatings which resisted first rusting for more than 3000 hours had the three ingredients in fairly similar proportions (see Figure 3), and the same six coatings resisted general rusting for more than 5000 hours (see Figure 4). It is reasonable to assume, therefore, that any compound with a composition like that of any of these six would give excellent corrosion protection to galvanized mine hoist ropes. It should be pointed out that two highly resistant coatings located outside this preferred area were much thicker.

It may be added that the brushing, dipping and spraying characteristics of the best six coating compounds were very good. The coatings dried to touch quite rapidly and had excellent adherence when subjected to bend tests. They penetrated well into narrow recesses and joints, at least partly because of the excellent wetting properties of the trichlorethylene. It was found that this new compound could be applied over other types of rope compounds and still give considerable protection to the rope. It also could be applied satisfactorily to the surface of lightly rusted and of wet wires, and would impart somewhat improved corrosion resistance to wires in these conditions.

Because the zinc chromate pigment in the coating has a low solubility, it leaches out very slowly; so its inhibitor action continues over a long period.

Zinc coating applied to this particular type of mine hoist rope is designed to prevent the steel from corroding. That it does so is shown by inspection of used zinc-coated ropes from which the zinc is almost entirely removed in the process of protecting the steel.

The purpose of the new coating described in this article is twofold:

1. If the coating is applied at the time the rope is manufactured, it will reduce the rate at which the zinc corrodes, thus giving longer protection to the steel.

2. If the coating is applied to rope already in service, it will tend to protect any remaining zinc, and any steel surfaces that have become exposed, from further corrosion. The small amount of moisture passing through the coating will be inhibited by the slowly-dissolving chromate.

CONCLUSIONS

Data presented in this article, based on laboratory experiments, indicate that a compound containing asphalt, zinc chromate pigment and trichlorethylene in the proper proportions will increase substantially the corrosion resistance of closely woven zinc-coated mine hoist wire ropes; also that the compound has considerably greater protective value than the commercial rope compounds also tested during this investigation.

The new compound can be applied by conventional methods, has good wetting properties and adherence, dries rapidly, and can be applied over other rope compounds.

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(Editor's Note: See also "Corrosion and Protection of Mine Hoist Ropes" by F.L. LaQue, in Corrosion, Vol. 6, Jan. 1950, pp. 8-13.

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