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REFINEMENT IN BLACK CHROME FOR USE AS A SOLAR SELECTIVE COATING

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16. Abstract

The NASA Lewis Research Center previously determined that a widely available commercially electroplated decorative finish known as black chrome has desirable solar selective properties (NASA TM X-71596). Black chrome is significant as a solar selective coating because the current extensive use of black chrome in the electroplating industry as a durable decorative finish makes black chrome widely available on a commercial scale and potentially low in cost as a solar selective coating. In the work described in this report black-chrome deposits were modified by underplating with dull nickel or by being plated on rough surfaces. Both of these procedures increased the visible absorptance from that reported in NASA TM X-71596. There was no change in the infrared reflectance for the dull-nickel - black chrome combination from that reported for the bright-nickel - black-chrome combination. However, the bright-nickel - black-chrome coating plated on rough surfaces indicated a slight decrease in infrared reflectance. As integrated over the solar spectrum for air mass 2, the reflectance of the dull-nickel - black-chrome coating was 0.077, of the bright-nickel - black-chrome coating plated on a 0.75-μm (30-μin.) surface was 0.070, of the bright-nickel - black-chrome coating plated on a 2.5-μm (100-μin.) surface was 0.064. The corresponding values for the bright-nickel - black-chrome coating on a 0.0125-μm (0.5-μin.) surface, two samples of black nickel, and two samples of Nextrel black paint were 0.132, 0.123, 0.133, and 0.033, respectively.

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SUMMARY

The NASA Lewis Research Center previously determined that a widely available commercially electroplated decorative finish known as black chrome has desirable solar selective properties (NASA TM X-71596). Black chrome is significant as a solar selective coating because the current extensive use of black chrome in the electroplating industry as a durable decorative finish makes black chrome widely available on a commercial scale and potentially low in cost as a solar selective coating.

In the work described in this report black-chrome deposits were modified by underplating with dull nickel or by being plated on rough surfaces. Both of these procedures increased the visible absorptance from that reported in NASA TM X-71596. There was no change in the infrared reflectance for the dull-nickel - black-chrome combination from that reported for the bright-nickel - black-chrome combination. However, the bright-nickel - black-chrome coating plated on rough surfaces indicated a slight decrease in infrared reflectance.

As integrated over the solar spectrum for air mass 2, the reflectance of the dull-nickel - black-chrome coating was 0.077, of the bright-nickel - black-chrome coating plated on a 0.75-micrometer (30-μin.) surface was 0.070, of the bright-nickel - black-chrome coating plated on a 2.5-micrometer (100-μin.) surface was 0.064.

The corresponding values for the bright-nickel - black-chrome coating on a 0.0125-micrometer (0.5-μin.) surface, two samples of black nickel, and two samples of Nextel black paint were 0.132, 0.123, 0.133, and 0.033, respectively.

As integrated over the black-body spectrum for 121° C (250° F) from 3 to 15 micrometers, the reflectance of the dull-nickel - black-chrome coating was 0.92, of the bright-nickel - black-chrome coating on a 0.75-micrometer (30-μin.) surface was 0.88, and of the bright-nickel - black-chrome coating on a 2.5-micrometer (100-μin.) surface was 0.86. These reflectance measurements indicated ratios of absorptance to emissivity for dull-nickel - black-chrome coatings of 10.9, for bright-nickel - black-chrome coatings on 0.75- and 2.5-micrometer (30- and 100-μin.) surfaces of 7.8 and 6.6, respectively, for bright-nickel - black-chrome coatings on 0.0125-micrometer (0.5-μin.) surfaces of 9.8, for two samples of black nickel of 13.8 and 8.0, and for one sample of black paint of 1.00.

INTRODUCTION

Flat-plate solar collectors have the potential for achieving higher temperatures if the surface which absorbs the solar radiation is so conditioned that it has a minimum infrared emissivity and a maximum absorptance in the visible spectrum, that is, solar selective properties. Previously known solar selective coatings are black copper oxide and electrodeposited black nickel (ref. 1). In addition, the NASA Lewis Research Center has found that a commercial electroplated decorative finish known as black chrome has the required high absorptance in the visible spectrum and low emissivity in the infrared spectrum to make it a desirable solar selective coating.

Other necessary properties of a practical solar selective coating are availability, ease of application, low cost, and long-term durability under solar radiation. Since black chrome is an inorganic coating, it is not susceptible to photodegradation. Nor is black chrome susceptible to oxidation or degradation in humid atmospheres. In addition, black chrome is widely used in the electroplating industry as a durable decorative electroplated finish. This use is significant for possible solar application because the current wide availability makes possible a lower cost. The black chrome plated by many electroplaters is secured as a proprietary mixture from the Harshaw Chemical Company.

To investigate the possibility of producing black chrome with absorptance enhanced over that of the black chrome reported in reference 2, black chrome was plated over dull nickel and also over rough surfaces. In contrast, the black chrome of reference 2 was plated over bright nickel on steel buffed to a root-mean-square roughness of less than 0.0125 micrometer (0.5 μin.). Visible and infrared spectral reflectances were measured to determine the quality of the solar selective coating which was produced by these changes.

This report describes the method of producing the plating substrate surface, the black chrome, and the results of measurement of the spectral reflectance.

PROCEDURE

Black-Chrome Preparation

The black-chrome deposits used in spectral measurements of solar selective properties were electroplated on 10- by 15-centimeter (4- by 6-in.) test panels by the Harshaw Chemical Company. The panels were 0.875-millimeter- (0.035-in.-) thick cold-rolled steel buffed to a root-mean-square roughness of less than 0.0125 micrometer (0.5 μin.). For those panels for which a rough surface was desired, the panel was grit-blasted prior to plating to obtain the required surface roughness. The panels were plated by the following process:

(1) The panels were cleaned with electrolytic chelating cleaner at 88° C (190° F) and 750 to 860 amperes per square meter (70 to 80 A/ft^2). Two cycles were used with an acid dip between them.

(2) The panels were nickel plated.

(a) Bright nickel was applied with Harshaw Chemical Company ZODIAC for 15 minutes at 430 amperes per square meter (40 A/ft^2) to deposit approximately 0.0125 millimeter (0.0005 in.) of nickel.

(b) Dull nickel was applied with Harshaw Chemical Company NUSAT for 15 minutes at 430 amperes per square meter (40 A/ft^2) to deposit approximately 0.0125 millimeter (0.0005 in.) of nickel.

(3) Black-chrome plating was done with Harshaw CHROM-ONYX at 24 volts and 2150 amperes per square meter (200 A/ft^2) for 3 minutes.

(4) The panels were rinsed with water.

(5) The panels were rinsed with alcohol.

(6) The panels were dried in air.

Each panel was wrapped in tissue paper and stored until measurements were completed.

The black-nickel solar selective coatings used for comparison with the black chrome were secured from outside sources.

Spectral Measurements

The spectral reflectance from 0.35 to 2.1 micrometers of all samples was measured by using normal illumination and diffuse viewing with a CARY-14 spectrophotometer having a spherical diffuse reflectance attachment. A magnesium oxide surface prepared at the Lewis Research Center was used as a standard. All measurements reported for 0.35 to 2.1 micrometers are total diffuse reflectance.

The spectral reflectance from 3.0 to 15.0 micrometers was measured with a WILLEY-318-S spectrophotometer which uses a spherical diffuse reflectance attachment. Evaporated gold film was used as a standard. All measurements are total diffuse reflectance.

TEST RESULTS

The application of the black chrome to the dull nickel or the rough surfaces is as convenient and feasible as the application to the bright nickel which was described previously.

The general appearance of the black-chrome - dull-nickel coating is that of a matte diffuse surface, as contrasted with the mirrorlike surface of the black-chrome - bright-nickel combination. The general appearance of the black-chrome - bright-nickel coating on the rough surfaces is that of a shiny but rough surface, as contrasted with the dull flat appearance of the black-chrome - dull-nickel combination.

The results of the spectral measurements of reflectance shown in figure 1 are for black chrome on dull nickel and for black chrome on bright nickel on both 0.75- and 2.5-micrometer (30- and 100-μin.) rough surfaces. Reflectances are presented from 0.35 to 15 micrometers. The corresponding reflectances, as integrated over the solar spectrum for air mass 2 were 0.077, 0.070, and 0.060. Also shown for comparison are reflectance curves for black chrome on bright nickel on a 0.0125-micrometer (0.5-μin.) surface and for Nextel black paint.

The reflectances of the same black chromes are plotted in figure 2 on a scale expanded by a factor of 5 to show in detail the differences between surfaces. The roughening of the surface under the black chrome, either by underplating with dull nickel or by physical abrasion of the substrate, decreases the reflectance in the visible spectrum by approximately a factor of 2. The reflectance of the black-chrome - dull-nickel coating is indistinguishable from that of the black-chrome - bright-nickel coating on roughened substrates. However, the infrared reflectance of the black-chrome - bright-nickel combination on the rough surfaces is lower than that of black chrome on either dull or bright nickel on a buffed substrate. The values for the reflectances of these materials from 0.35 to 2.1 micrometers as integrated over the solar spectrum for air mass 2 are given in table I together with the corresponding reflectances from an integration over black-body conditions from 3 to 15 micrometers. The corresponding α/ϵ ratios are also presented in table I. The reflectances of black-chrome - dull-nickel coatings and of two samples of black nickel are shown in figure 3 from 0.35 to 15 micrometers and in figure 4 on a scale expanded by a factor of 5 from 0.35 to 2.1 micrometers.

It is thought that the increased absorptance of the black-chrome - dull-nickel and the black-chrome - bright-nickel coatings on rough surfaces is due to a physical effect of "light traping." However, the roughness produced in the dull nickel is evidently of such a small scale that it has no effect on the infrared reflectance, whereas the larger scale roughness produced by grit blasting produces a Hohlraum effect for the infrared reflectance.

SUMMARY OF RESULTS

A study was made of refinements in black chrome for use as a solar selective coating. Electroplated black chrome was formed on both dull nickel and mechanically roughened surfaces. Spectral reflectance measurements from 0.35 to 15 micrometers indicate that black chrome on both dull nickel and roughened surfaces had increased absorptance over that of black chrome plated over bright nickel. Moreover, while the black chrome on a rough surface showed an infrared reflectance which was inferior to that of black chrome on bright nickel plated on a buffed substrate, the black chrome on dull nickel showed an infrared reflectance equal to that of black chrome on bright nickel. The absorptance-emissivity ratios determined for the black chrome on dull nickel, on bright nickel, and on surfaces of 0.75- and 2.5-micrometer (30- and 100-μin.) roughness were 10.9, 9.8, 7.8, and 6.6, respectively. The results indicated that the solar selective properties of black chrome can be further optimized from those reported previously by underplating the black chrome with dull nickel.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, October 17, 1974,
506-23.

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2. McDonald, G. E.: Spectral Reflectance Properties of Black Chrome for Use as a Solar Selective Coating. NASA TM X-71596, 1974.

TABLE I. - VISIBLE ABSORPTANCE AND INFRARED EMISSIVITY OF SOLAR SELECTIVE COATINGS

Coating	Absorptance, α (a)	Emissivity, ϵ (b)	Ratio of absorptance to emissivity, α/ϵ
Black chrome on dull nickel	0.923	0.085	10.9
Black chrome on bright nickel	.868	.088	9.8
Black chrome on bright nickel (0.75-μm (30-μin.) surface roughness)	.930	.12	7.8
Black chrome on bright nickel (25-μm (100-μin.) surface roughness)	.936	.14	6.6
Black nickel 1	.877	.066	13.3
Black nickel 2	.867	.109	8.0
Nextel black paint	.967	.967	1.0

[a]Based on spectrum weightings for solar air mass of 2.

[b]For 3 to 15 μm of sample; based on spectrum weightings for 121° C (250° F) black body.

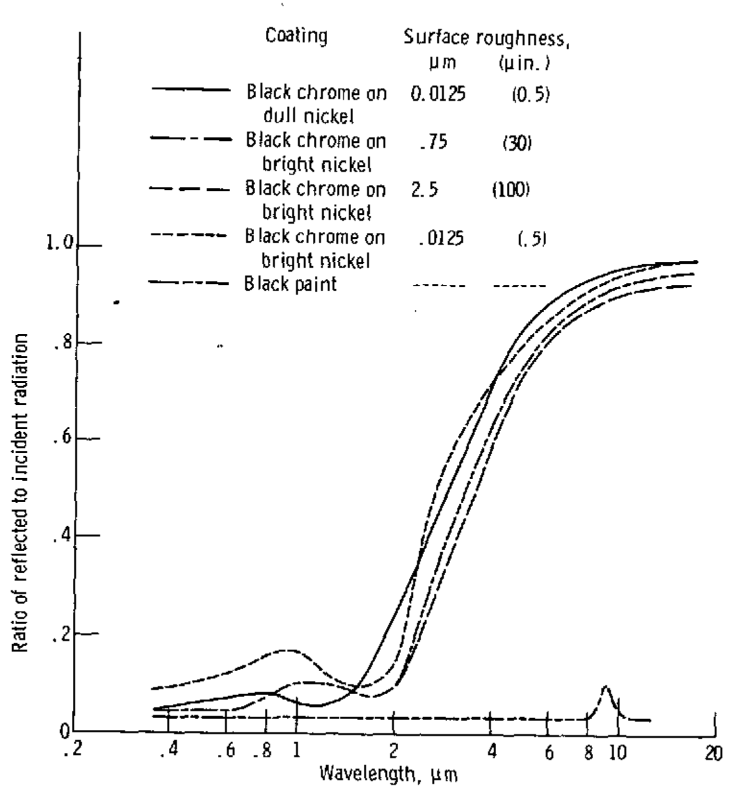

Figure 1. - Reflectance of black chrome on various surfaces and of black paint.

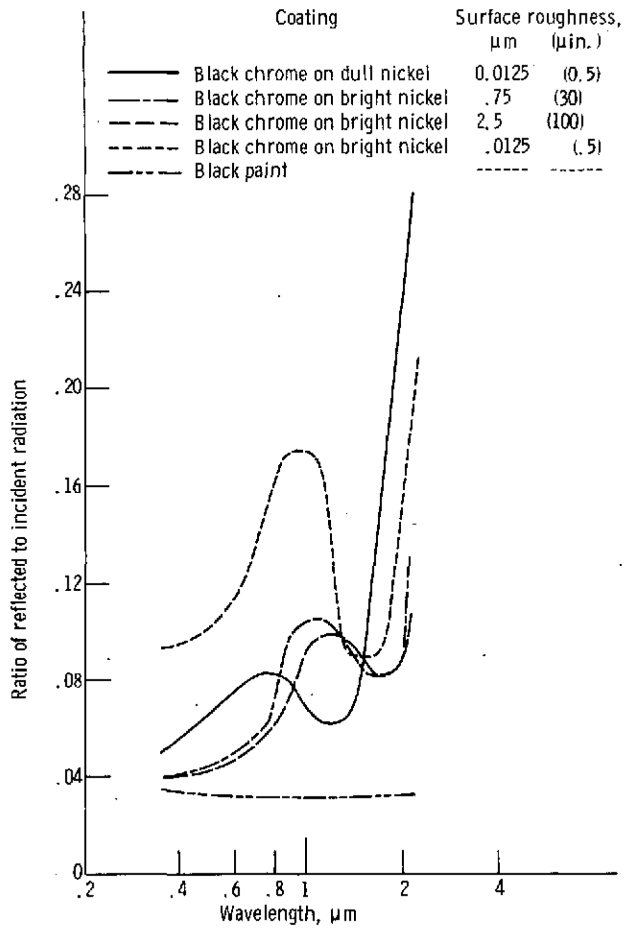

Figure 2. - Reflectance of black chrome on various surfaces and of black paint plotted on expanded scale.

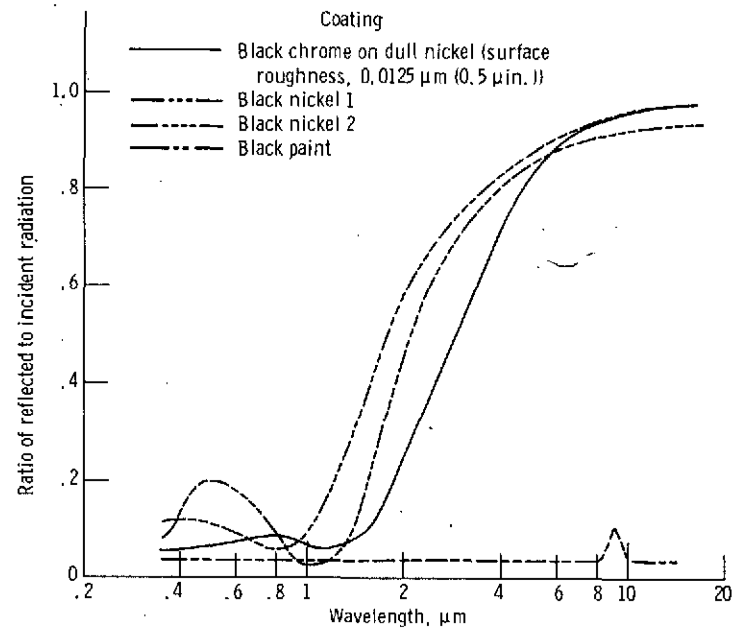

Figure 3. - Reflectance of black-chrome - dull-nickel coating, black nickel, and black paint.

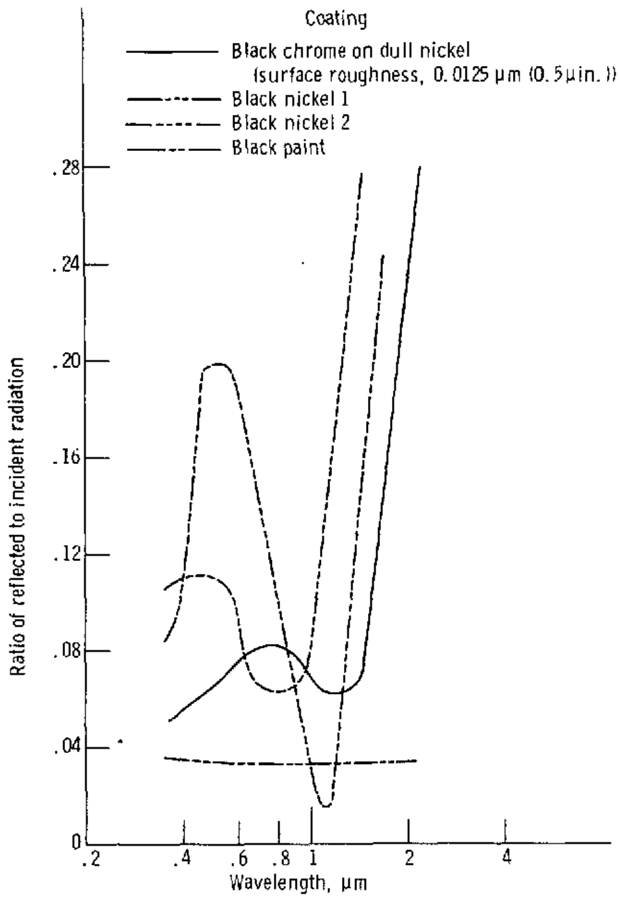

Figure 4. - Reflectance of black-chrome - dull-nickel coating, black nickel, and black paint plotted on expanded scale.

NASA-Langley, 1974