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THE DEVELOPMENT OF HXW THERMAL COATING

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<p>This report describes the development of a coating for use on space vehicles to control their temperature while in a space environment. This is accomplished by varying the optical properties of the coating to control thermal absorption and emission rates of the vehicle surface.</p> <p>The inorganic coating described within this report has the capability of providing the necessary optical properties for thermal control and is also very stable in the environment of vacuum and solar radiation.</p> <p>The HXW coating is primarily a water suspension of synthetic mica that is gelled with a silicate solution. The products used in the coating are available from commercial sources and are relatively inexpensive for this type of coating.</p>					
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THE DEVELOPMENT OF HXW THERMAL COATING

SUMMARY

A vehicle in an earth orbit or on an interplanetary mission is an isolated body in thermal equilibrium with the space environment. Temperature control of the vehicle is largely established by external surface coatings which provide the correct balance between absorption from radiating energy sources, principally the sun, and emission due to the temperature of the vehicle itself. The optical properties of such coatings, in particular the solar absorptance and thermal emittance, are adjusted to meet the thermal requirements of the surface to be coated. In addition to the desired optical properties, thermal control coatings must exhibit favorable mechanical characteristics.

A thermal control coating designated as HXW has been formulated which gives improved optical properties over existing coatings and also exhibits favorable mechanical properties. The coating composition is based on a binder comprising a suspension of synthetic mica gelled with a suitable cation-containing solution, which is a solution of a soluble metal silicate. Zinc oxide or other pigments are normally added to the composition, depending on the optical properties desired. This coating has a wide variety of uses because of its variable optical properties and its stability to solar radiation.

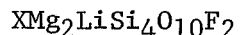
INTRODUCTION

This report presents the technical development of a coating referred to as HXW. This coating is formulated from commercially available products from Minnesota Mining and Manufacturing Company, New Jersey Zinc Company, and Philadelphia Quartz Company. The coating is versatile in that compositions can be "tailored" extensively for a variety of coating applications. Another advantage of the coating is that it is inorganic and, therefore, non-flammable. This report describes the formulation, grinding, and spraying techniques, and physical testing of the HXW thermal control coating.

GENERAL DESCRIPTION OF THE HXW COATING

This report is concerned not only with the coating called HXW but also with a binder which can form the basis for a wide variety of coatings by addition of selected pigments and other components. Gelation of synthetic mica or sodium-magnesium-fluorolithosilicate mineral in finely divided aqueous suspension by addition of a specified cation-containing solution produces a hard, durable material highly resistant to solar radiation and ideally suited for binder use. Although the theory is not completely understood, the formation of this material is believed to result from an exchange reaction between metal cations such as lithium or sodium in the mica or mineral component with cations in the gelant solution.

The principal component of the binder is a finely divided aqueous suspension of a reactive synthetic mica or a mineral of the trioctahedral montmorillonite type. These materials are characterized by their physical form of extremely thin platelets, their excellent capability for film formation in aqueous suspension, and their high degree of chemical reactivity, owing to the presence of low-atomic-number metals and fluorine. Synthetic micas which can be used are exemplified by the formula:



where X is sodium or lithium. Material of this type is obtained by chemical modification of naturally occurring micas such as phlogopite. Most naturally occurring micas are not suitable without chemical modification, although they have the same crystal structure as the synthetic mica shown above. The relatively high content of aluminum or potassium atoms in natural micas result in low reactivity and poor film forming properties, requiring that these elements be at least partially replaced by the more reactive lithium. In addition, hydroxy groups in the naturally occurring material are replaced by fluorine atoms. Synthetic mica with the formula shown above is available commercially from Minnesota Mining and Manufacturing Company under the trade name "Burnil Microplates" in the form of irregular platelets 20 to 100 angstroms thick, with their diameters greater than 100 times the thickness. They have a theoretical density of 2.7 g/cc, an index of refraction of 1.5, and a melting point greater than 1800°F. This synthetic mica or fluorolithosilicate is employed in the form of an aqueous suspension, having a concentration such as to allow mixing with the other components and subsequent application as a coating. A concentration of about 4 weight percent is suitable in most cases, although concentrations

from about 1.5 to 25 weight percent can be used. These materials form a thixotropic slurry in water, and higher concentrations may cause difficulty in attaining a homogeneous mixture and result in a marked reduction in film forming properties.

An aqueous solution containing metal cations in the form of a soluble metal silicate or sulfate is mixed with the synthetic mica suspension in an amount sufficient to provide the desired properties in the cured binder or coating. The metal cation source can be a soluble alkali metal silicate such as sodium, lithium, potassium, or aluminum silicate. In the case of alkali metal silicates, the properties and solubility vary with the ratio of alkali metal oxide to silica therein, but any water soluble form can be used. A silicate concentration of about 80 to 100 weight percent of the binder solution is preferred. The most desirable physical properties are obtained when using potassium silicate. The brand now used is "Kasil #6" from Philadelphia Quartz Company. This particular silicate contains 12.45 weight percent K_2O and 26.2 weight percent SiO_2 .

An aqueous solution of certain metal sulfates can also be used as the gelant. Sulfates of alkali metals including sodium, lithium, and potassium and of alkaline earth materials including calcium, magnesium, and the like, as well as aluminum sulfate are suitable for this purpose. Binders gelled with sulfate solutions show some advantages over silicate-gelled binders, for example, in the hiding power of the product coating, but silicate-gelled binders show much better adhesive properties.

The mechanical properties of the binder can be controlled by varying the relative amounts of the synthetic mica and gelant solution. For binders gelled with soluble silicate solutions, about 15 to 30 weight percent of dry gelant solids relative to the total dry solids weight of binder and other components can be used. At lower proportions, mechanical strength and durability are reduced, and at proportions over 30 percent the binder or product coating becomes brittle and more water soluble. For metal sulfate solutions, a gelant proportion of 25 to 32 weight percent of binder components can be used. As is the case for the silicate gelant, the binder becomes harder with increasing amounts of sulfate solution gelant.

The mixture obtained by combining the synthetic mica or fluorolithosilicate suspension and its gelant solution can be used without any other additives for some coating applications. Such a coating is highly durable and protective, but its optical properties, for example, a solar absorptance of 0.56 for a typical mixture, limit its use in unpigmented form.

For most applications, therefore, pigments or other additives are employed to impart the desired optical properties. The binder prepared as described above is broadly compatible with conventional pigment materials, and in particular oxide pigments such as zinc oxide, titanium dioxide, antimony trioxide, zirconium oxide, etc. For solar reflector type thermal control coatings, a pigment having maximum stability to solar radiation in vacuum is preferred, and zinc oxide and zirconium oxide are the most suitable in this regard. A pigment volume concentration of about 25 to 48 percent can be used, and best results with regard to optical properties are obtained at a concentration of 38 to 42 percent pigment.

For reflective coatings, all or part of the pigment component can be replaced by solid or hollow glass microspheres, such as are available commercially from Minnesota Mining and Manufacturing Company under the designation "Microballoons." Minimum particle size microspheres are preferred, and in particular those that have a diameter less than 10 microns, although those with a diameter of 35 to 45 microns can be used. Glass microspheres exhibit a high degree of stability in space environment and excellent reflective properties so that they are ideally suited for thermal control coating applications. In addition, coating weight is reduced since the glass microspheres are hollow and have a much lower density than oxide pigments. For best results, the glass microspheres are used in combination with a pigment such as zinc oxide, with the small pigment particles being interdispersed between the glass particles in the coating to provide maximum hiding power.

The optical properties of this type coating can be varied widely by selection of the appropriate pigment and coating thickness. A solar absorptance as high as 0.98 can be obtained by using a black pigment or as low as 0.17 can be obtained with zinc oxide. The minimum solar absorptance for the regular HXW white coating of 0.17 occurs at a minimum coating thickness of 12 mils. Figure 1 shows the coating thickness versus solar absorptance of the HXW coating over a sand-blasted aluminum substrate.

A typical batch of white HXW consists of 150 gm of ZnO, 150 ml of B-35A glass microspheres, 225 ml of HX-610 synthetic mica suspension, 150 ml of Kasil #6, and 200 ml of distilled water. The materials are mixed by conventional methods such as ball milling. The materials are added to the mill in the above order except water is added after the other materials have milled 2 hours. A satisfactory consistency for spraying is obtained by milling 3 to 6 hours in a porcelain ball mill at 70 percent critical speed defined by

$$\left[\text{rpm} = 54.2 / \sqrt{\text{mill radius (ft)}} \right].$$

The volume ratio of balls to materials in the mill is 1:2 and the total charge <50 percent of the mill capacity. It is preferable that the coating be prepared just prior to using; however, no problems have been observed as far as shelf life is concerned. The storable shelf life has been found to be in excess of 18 months. In using a previously prepared mixture, thorough mixing should be made prior to application.

Substrate preparation is a very important step in the application of the HXW coating. The HXW is primarily used on metal substrates. If the metal is bare it should be sandblasted with 80-100 grit silica and then cleaned with a detergent cleaner and water followed by acetone or freon. The coating has a much improved resistance to salt spray or high humidity corrosion if the substrate is alodined, anodized, or even primed with zinc chromate. The chromic acid anodize seems to be the best process to protect the substrate from corrosion.

The HXW formulation is applied by spray-painting using a conventional spray gun. The gas to the gun must be clean and free of oil. The application technique consists of spraying until a reflection due to the liquid is apparent. This is followed by air drying until the gloss is practically gone, at which time the spraying-drying cycle is repeated. The wet thickness of the HXW is approximately three times the cured thickness. After application, the coating is tack-free and it will dry in air at room temperature. However, a preferred curing cycle is 24 hours at room temperature, 8 hours at 170°F, and 16 hours at 250°F, the elevated temperature being used to insure complete curing and hardening.

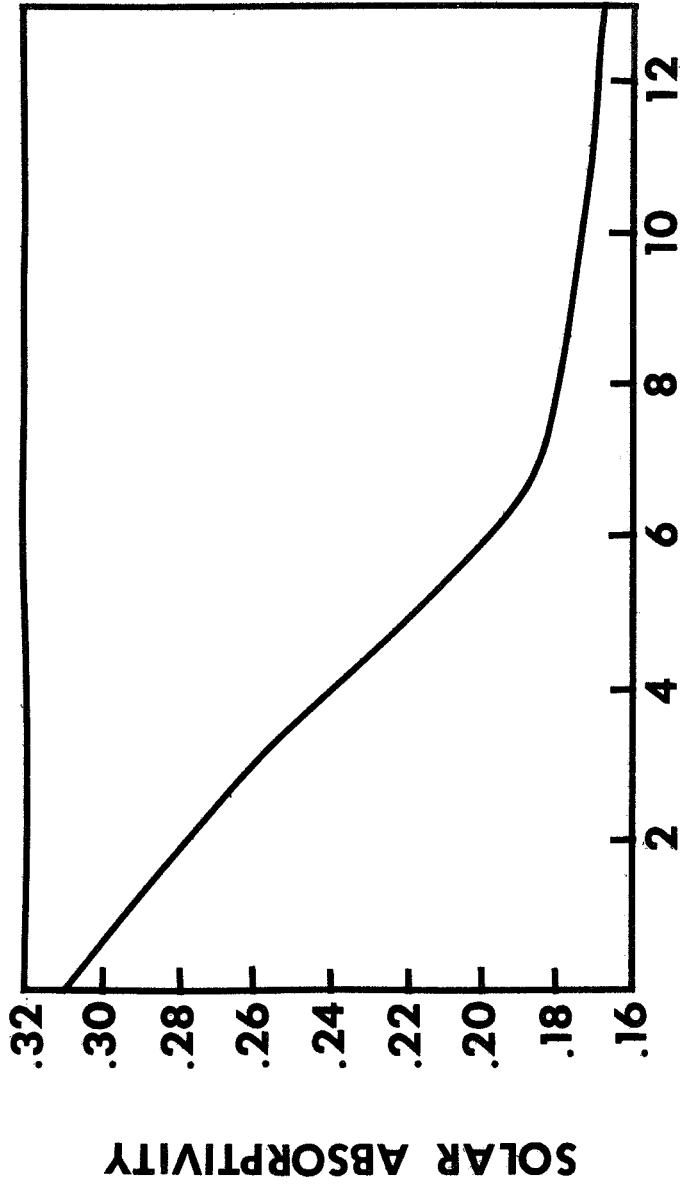
Optical stability of a thermal control coating is essential for exterior use on a space vehicle. The HXW coating, using zinc oxide as the pigment, has been exposed to ultraviolet radiation up to 1000 sun hours with a change in the solar absorptivity of 0.01 or less. Exposure of the coating to electron and proton radiation at a flux of 10^{13} electrons or protons per square centimeter at 1 mev energy level at 5×10^{-7} torr resulted in a solar absorptivity increase of 0.01 or less. These tests demonstrate the exceptionally good resistance of the coating to degradation of optical properties upon exposure to radiation in vacuum.

A primary concern of coatings for use on the interior of space vehicles is flammability. The HXW coating meets the requirements for Type I materials of MSFC-SPEC-101 and, therefore, is a non-flammable coating. This characteristic is basically due to the absence of organic material in the coating. It also meets the LOX compatibility specification (MSFC-SPEC-106B) meaning that it is compatible with high oxygen atmospheres or other hazardous environments.

Other merits of the HXW coating are its toughness, durability, and low offgassing qualities. This coating has also been found to be resistant to cracking or spalling when thermally cycled between 212°F and -320°F.

CONCLUSIONS

Based on the data obtained during the development program of the HXW, it appears that this coating has many applications in the thermal control of space vehicles. The optical properties of this coating are superior to many coatings of this type and its versatility will enable it to replace some types of coatings now in use. The coating is relatively cheap and the materials are available commercially. It is easy to prepare and no special precautions are necessary as far as hazards are concerned.



COATING THICKNESS (mils)

FIGURE 1

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APPROVAL

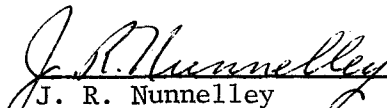
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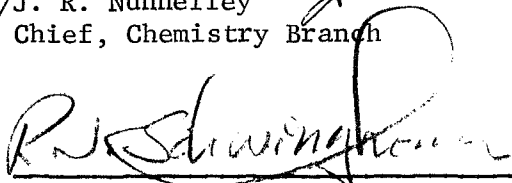
Roger J. Harwell

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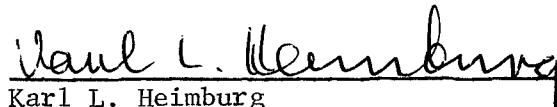
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