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TESTS OF DUPONT ALUMINUM PAINT P-100P8497 IN THE FIREROOM OF THE USS EUGENE A. GREENE (DD711)

By J. A. Sanderson

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Approved by:

E. O. Hulburt
Supt., Physical Optics Division

Commodore H. A. Schade, USN
Director, Naval Research Laboratory

ABSTRACT

Hot surfaces, including asbestos-lagged pipes, in the after fireroom of the USS EUGENE A. GREENE (DD711) were painted with a high quality low emissivity aluminum paint (DuPont P-100P8497), and measurements of the emission of radiation by these surfaces were made at sea with the superheated steam at 800° F. The primary purposes of the test were to observe the durability of the paint under actual service conditions and to observe any obvious benefits of the painted surfaces to the comfort of fireroom personnel. A later report on these properties of the paint will be made by the GREENE. The principal observations described in this report are:

(a) The sensation of radiant heat from the water level gauges at about 400° F was considerably reduced, an opinion concurred in by water tenders. Physical measurements of uncertain accuracy indicated that the emissivity of the painted water level gauge was about 0.40.

(b) The measured emissivities of other aluminum-painted metal surfaces were 0.30 to 0.50. The heat sensation was considerably reduced by the use of the paint.

(c) The boiler front offered conditions of uniform temperature and smoothness favoring precision. The emissivity of the boiler front painted with the standard aluminum paint was about 1.0, but with the new paint under test, about 0.18.

(d) The emissivities of aluminum-painted asbestos surfaces were measured to be 0.50 to about 1.0. The uncertainties of the measurements on asbestos surfaces were large.

(e) The emissivity of the stainless steel economizer housing, unpainted, was 0.77 which is higher than that of most of the painted surfaces.

These measurements do not establish the true physiological value of painting all hot surfaces with a bright aluminum paint. It is clear that use of the paint reduces the radiation by an amount that is perceptible to fireroom personnel. It is recommended that adequate supplies of aluminum paint of this quality be made available for further large scale experimentation by those in charge of air conditioning measures.

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INTRODUCTION AND SUMMARY

Authorization. The original investigation of low emissivity aluminum paints was authorized by BuShips Project Order 514/43 of 12 January 1943, now closed. The measurements to be described were requested by BuShips 336 by telephone.

This report describes an experiment in which the hot surfaces in the after fireroom of the USS EUGENE A. GREENE (DD711) were painted with a high quality, low emissivity aluminum paint with the object of reducing the radiant heat intensities to which fireroom personnel are subjected. The paint was developed by the DuPont Company, Philadelphia Laboratory, and it was identified by the DuPont code number P-100P8497. While the detailed composition of this paint is not known to the writer, it undoubtedly will be made available by the DuPont Company. It is understood that the paint contains no unusual ingredients; the excellent optical (and mechanical) properties were achieved by proper blending of usual vehicles and aluminum flake with the purpose in mind of producing a paint of low emissivity, i.e., of high reflectivity for heat radiation. This paint, therefore, is of a quality to which all Navy heat resisting aluminum paints can be raised. The paint was similar to DuPont paints previously tested and described in reference (1).

Procedure. Observers included representatives of Materials Laboratory, New York Navy Yard, COTCLant, DuPont (Mr. P. F. Sanders), the GREENE and NRL. An important purpose of the test is to observe the durability of the paint and the more noticeable advantages or disadvantages of its use, and a report on these items by the Commanding Officer was requested by reference (2).

The GREENE was taken to sea from New York on 10 September 1945 running at standard cruising speed of 15 knots with one boiler in the after fireroom in operation and with steam superheated to 800° F. When equilibrium had been established, the temperatures of hot surfaces were measured to determine which of them should be painted. These measurements were made with a contact thermocouple pyrometer (Pyrocon) loaned by the Materials Laboratory, New York Navy Yard. They need not be listed in detail; those given below were typical:

- Feed discharge to boiler, asbestos-lagged 120° F. 176 - 100°F
- Water level gauges, rough bronze casting - 270 to 420° F at various points. 330 → 400 390
- Steam drum, asbestos-lagged 140° F. - 150
- Main steam line near main valve, asbestos-lagged, 140° F. 123
- Economizer, stainless steel, 160° F. - 142
- Mud drum, granular pigment paint, 190° F. 160 146
- Face of Boiler No. 4, painted with standard aluminum paint, 140° F. 140 147
- Fuel oil valve to burners, 140° F. 132 138

During this short cruise the outside air temperature was 78° F, and air temperatures within the fireroom were 78° F to 109° F in various locations.

The ship returned to New York, all fires were killed, and after the surfaces were cool the paint was applied by brushing by New York Navy Yard painters under the general supervision of Mr. P. F. Sanders, the DuPont Company. The paint was applied to all hot surfaces, i.e., to all surfaces which had been observed to be above about 120° F, except the stainless steel front of the economizer. The asbestos-lagged surfaces had been painted with white fire retardant paint, and the aluminum paint was applied directly over this. It is probable that a more effective low emissivity coating would result if an additional coat of fire retardant paint or clear varnish were applied to the asbestos surface before applying the aluminum paint. However, the aluminum painted surfaces were quite bright and, it is interesting to note, esthetically pleasing to those who chose to comment on its appearance.

A list of all surfaces painted was given by reference (3).

After 48 hours drying time, the ship again was taken to sea on 15 September under the same operating conditions and a number of measurements of the heat radiation from the hot surfaces were made by means of a total radiation pyrometer consisting of a radiation thermocouple at the focus of a concave mirror. Thermocouple voltages were measured by means of a suitable d. c. amplifier. All measurements were made relative to a small blackened can filled with water and containing a thermometer; hence, there were no errors arising from the variable ambient temperature.

Contact temperatures were measured at the same time by means of the contact pyrometer, and from the two measurements: radiation temperature by means of the radiation pyrometer and true temperature by means of the contact pyrometer: it should have been possible to measure the emissivity of the various painted surfaces. Indeed, it subsequently was found in laboratory tests that the two separate instruments produced values of contact temperature and radiation temperature which led to consistent and correct values of the emissivity of various smooth, uniformly heated surfaces. However, the measurements obtained aboard ship were not of the accuracy required for precise determinations of the emissivity of the painted surfaces for two reasons: (a) The contact pyrometer measured the temperature of a small area less than one-eighth inch square with indeterminate accuracy due not so much to the inaccuracy of the instrument as to the variability of the thermal contact between the small thermocouple and the slightly rough surfaces to which it was applied. On the other hand, the radiation pyrometer measured the radiation temperature of an area of 2 or 3 square inches and the radiation from both the hills and valleys of slightly rough surfaces entered into the measurement while the contact pyrometer was undoubtedly in closer contact with small surface projections than with surface depressions. (b) The true surface temperature varied considerably between different areas of most of the surfaces. Hence, while each instrument produced the correct answer for the quantity it measured, the two separate temperatures did not relate to identical surface conditions. Therefore, the measurements of radiation and contact temperatures were not suitable for a precise evaluation of the emissivities.

CHAPTER I

SUMMARY OF RESULTS

The principal effects of the aluminum paint and additional implications of the experiments are summarized below.

Water Level Gauges. The rough bronze castings supporting the gauge glasses were at temperatures of 270° F to 420° F, depending on the part of the gauge measured. The aluminum paint brought about a remarkable reduction in the heat sensation experienced by all technical and ship's personnel who made estimates of the discomfort produced by standing before the gauges. Reference (8) stated that at least until the ship had reached Norfolk after the tests were completed, the water tenders felt that the paint brought about an improvement. The physical measurement of the intensity of the radiation from these surfaces was uncertain because of the variation in temperature over the surface. The result was, however, that the emission of heat by the painted surfaces was 0.40 times that of the unpainted castings.

Recommendation. All bronze castings for water level gauges or other metal parts at temperatures near 400° F should be buffed smooth and nickel- or chromium-plated at the time of manufacture. These surfaces are the most noticeable hot surfaces in the fireroom, and the large ventilation pipe opening near the water tender's station is evidence of his danger from heat. Plating of future gauges is not unreasonable; the writer has seen nickel plated radiators in the wardroom of an older destroyer where the opposite treatment should have been employed.

All existing water level gauges should be painted with low emissivity aluminum paint preferably equal to that used in this test; or, as second best choice, with an aluminum paint incorporating any suitable vehicle and Type A aluminum powder or paste (Alcoa 321 powder or the equivalent paste); or, as third and poorest choice, they should be painted with present heat resisting aluminum paints containing Type B powder. Any of these measures will improve the water tender's situation, and the first, buffing and plating, will be the most effective.

Mud Drum. This surface was painted gray and was at about 190° F. After the aluminum paint was applied the measured radiation intensity was 0.30 to 0.41 times the intensity from the gray paint. Aluminum paint over a smooth metal surface is recommended.

Economizer. This stainless steel surface was not painted. The emissivity was 0.77. This surface would have been improved by being coated with the new paint.

Boiler Face. The original aluminum paint on the boiler face was grayish. The measured emissivity was 1.0. After being painted with the new paint, the emissivity was measured to be 0.18. The conditions of this measurement were more nearly comparable to laboratory conditions than any others encountered: the surface was at fairly uniform temperature and it was fairly smooth. The measured value of 1.0 for the existing aluminum paint must have been too high. But if that value was too high, then the emissivity 0.18 of the new paint was also too high since in this case the result was obtained by a comparison of radiation intensities "before and after" repainting for equal contact temperatures of the boiler face.

Values, Steel Girders and Other Metal Surfaces. These surfaces were in general irregular in shape and rather large temperature gradients existed over them; measurements of the radiation intensity from them were in general uncertain, but values of 0.50 were usually obtained.

Recommendation. That all hot metal surfaces be painted with low emissivity aluminum paint wherever this will not interfere with the mechanical function of the part.

Asbestos-Lagged Surfaces. Measurements of the radiation from these surfaces were extremely doubtful. It was here that observed contact temperatures were most likely in error because of the softer, less solid contact between thermocouple and surface and because of the poorer conductivity of the asbestos which, perhaps, reduced the rate of flow of energy to the contact thermocouple perceptibly. Whatever the true emissivity of these bright aluminized surfaces was, measured values were in the range 0.50 to 1.0; i.e., sometimes a measurable effect of the paint could not be detected. Since these surfaces were rarely above about 140° F, the simple test of comparing the heat sensations produced by the white-painted and aluminum-painted asbestos surfaces five days apart in time did not produce a striking result as it did in the case of hotter surfaces.

It should be appreciated that the accuracy of emissivity measurements depends upon the accuracy of the temperature measurements. Since temperatures enter as the fourth power in the computation of emissivity, an error of, say 10 percent, in temperature leads to an error of 40 percent in emissivity.

The emissivities of aluminum painted asbestos surfaces measured under laboratory conditions by comparison of the radiation from the surface with the radiation from a black body at the same temperature were given in references (4) and (5). From reference (4) the emissivity of asbestos painted with one coat of aluminum paint containing 3/4 pound of Type A powder per gallon was 0.41 and for two coats, 0.32. When the asbestos had previously been varnished to smooth it the emissivity of the aluminum-painted surface was 0.33 for one coat.

From reference (5) a certain DuPont aluminum paint on Navy asbestos produced a surface of emissivity 0.30. Hence, an improvement will usually be obtained by painting the asbestos surfaces with aluminum paint. (In this connection, it is not clear why these surfaces are at present painted with white fire retardant paint unless for the sake of appearance. Reference (4) made a particular point of the fact that white granular pigment paint is a good emitter of long wave length heat radiation.)

Recommendations. These general rules for asbestos-lagged surfaces may be laid down:

(a) Asbestos-lagged surfaces in the neighborhood of cooler surfaces should be painted with aluminum paint. For example, overhead steam pipes above a cooler deck or near a cooler bulkhead will be less noticeable if painted with aluminum paint.

(b) Asbestos-lagged.surfaces, such as the steam drums or overhead pipes athwart ship along the passages between the steam drums and the boilers should be painted with aluminum paint, subject to the reservation following.

(c) Large areas of warm surfaces such as the front of the steam drums may be so located relative to much hotter surfaces such as the water level gauges that when coated with aluminum paint they reflect radiation from the hotter objects instead of absorbing it. In this event, the better system might be to leave the asbestos-lagged surface unpainted in order to utilize its absorbing power. Each situation of this sort would require special consideration, but there will be relatively few of them.

In general, the radiation density within spaces where there are large temperature differences between the "hot" and the "cold" surfaces will be reduced by the application of aluminum paint.

CHAPTER II

CONCLUSIONS

The general problem of reducing the emission of radiation by hot surfaces need not be reviewed. It has been discussed in references (4), (5), and (6) and, without question, it is well understood by the Air Conditioning Section of BuShips. The desirability of smooth plated surfaces on small really hot objects has been emphasized in a number of reports. This report may be concluded with a summary of the developments in heat resisting aluminum paint since the beginning of the problem in January, 1943.

(a) It has been repeatedly shown that aluminum paint containing the equivalent of Navy Type A aluminum powder or paste, or the equivalent of Alcoa Standard Varnish powder produces a paint of lower emissivity than paint containg Type B, Extra Fine Lining, powder. In fact, The Aluminum Company of America handbook on aluminum paints recommends the equivalent of Type A powder. The Navy heat resisting aluminum paints contain Type B powder and the emissivity is relatively high.

(b) The several DuPont aluminum paints which have been tested in the laboratory and the particular DuPont paint No. P-100P8497 which was used in the test at sea do not, so far as can be learned, depend so much upon the use of new or obscure ingredients for their excellent optical properties as they depend upon the proper choice of aluminum powder or paste (the equivalent of Navy Type A is thought to have been used) and upon the proper choice and ratios of thinners with the end in mind of producing excellent leafing capacity. The addition of excess stearic acid described in reference (1) performs the important function of maintaining the leafing capacity of the ready mixed paint for several months. Equivalent aluminum paints probably can be compounded by any competent paint manufacturer following guidance which the Navy should provide.

(c) It appears that no standard service test has been made on these low emissivity DuPont paints. The final result of the present test which will be supplied by the report of the Engineering Officer of the GREENE will supply important information on the durability of the paint in actual service. In numerous applications of the paint to a variety of hot objects around the laboratory, there has been no evidence that the paint is less durable than other highly pigmented aluminum heat resisting paints. Observation of the durability of the paint on actual fireroom surfaces relative to the durability of other aluminum paints will be more conclusive than more casual observations in the laboratory.

(d) Further large scale experimentation on the use of low emissivity paints within ships seems to lie within the province of the Air Conditioning Section of BuShips where both the physical and physiological aspects of the problem are understood.

(e) In the last two years this Laboratory has received requests for information from branches of the Navy and the Army which had practical uses for a low emissivity paint. It has only been possible to refer these organizations to the DuPont Company. It appears to be highly desirable that a suitable specification be prepared in order that adequate Naval supplies of the material may be available for use (d) above and other uses.

REFERENCES

1. NRL ltr. S19(422) of 24 April 1944 to BuShips.

2. BuShips ltr. JJ52-(19)(336) of 13 Sept. 1945 to Commanding Officer, USS EUGENE A. GREENE (DD711) requesting report on the special paint at the time of next repainting.

3. COTCLant ltr. S19-5/L5-2/RD238 to Commander in Chief, US Fleet. This letter gave references authorizing the test and supplied a list of the surfaces painted.

4. NRL Report No. H-2024 of 2 March 1943, "The Optics of Paints: The Emissivity of Navy Aluminum Paints Type A and Type B and of Inside Granular Pigment Paints."

5. NRL ltr. S19(422) of 16 April 1943 to BuShips, Encl. (A) "The Reduction of Heat Radiation from Pipes and Boilers in Ships", a report by A. H. Pfund.

6. NRL report H-2122 of 22 July 1943, "The Optics of Paints: The Emissivity at 700° F of Sherwin-Williams, McCloskey and DuPont Heat Resisting Aluminum Paints."