Development of Fire Resistant Paint for Antarctica

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ABSTRACT

Antarctica with large desolate areas, snow and ice cover, few land marks and hostile weather represents extreme conditions of low temperature and high wind velocity. A fire proof paint which has fire retardant properties and simultaneously can withstand the Antarctic conditions was developed, evaluated and successfully applied to the wooden structure used in the permanent Indian Station at Antarctica.

INTRODUCTION

Antarctica with large desolate areas, snow and ice cover, few land marks and hostile weather represents extreme conditions of low temperature -65 to -70°C. A permanent Indian station at Antarctica has a wooden structure. Shri Ram Institute for Industrial Research, Delhi was assigned the job of making the wooden structure fire proof. With this in view, a study to synthesise and evaluate a suitable paint which has inherent properties of resisting the flames as well as fire retardancy and, at the same time, can withstand extreme low temperature was undertaken.

The temperature has a decisive effect on the matter and its properties, some materials which have very useful properties may be rendered useless in extreme cold or hot conditions. Hence, for the Antarctic conditions the choice of material is very critical. As there is a scarcity of water in this subcontinent, it becomes a most important feature that the material should make wooden structure fire proof and simultaneously, it can withstand the extreme low temperature conditions.

The major causes for the loss of life in wooden fire accidents are (Baker, 1981):

(i) Flame and its heat

(ii) Suffocation due to toxic gas concentration

(iii) Suffocation due to smoke

(iv) Suffocation due to oxygen shortage.

The major causes of the loss of life in afire involving wood appears to be the generation of carbon monoxide through thermal break-down of cellulose and partial oxidation of carbon (Dev. 1982, Stalker, 1971). The rate of thermal degradation of wood depends upon the heat transfer through the wood, type of char formed and the rates of diffusion of the gaseous decomposition products and degradation of products during their passage through the char. If the rate of heating of wood is very high, the cellulose material nearly completely vapourises during the pyrolysis process, leaving behind a comparatively small quantity of char material. The gases evolved on pyrolysis are highly inflammable hydrocarbon-rich mixtures.

To avoid the loss of life and money from a fire burning the wood, several flame retardent chemicals are mentioned (Pearson, 1984; Lee, 1980; Bhatnagar, 1982; Farcnik, 1977). These fire retardant chemicals can be divided into following four classes:

Class 1: Tetrakis (hydroxymethyl) phosphonium chloride, boric acid, calcium chloride, sodium tetraborate, ammonium pentaborate, magnesium silicate, antimony trioxide, ammonium polyphosphate, sodium silicate, potassium silicate, dicyanadiamide.

Class 2: **Ammonium sulphate, ammonium chloride, ammonium bromide, ammonium iodide, zinc chloride, aluminium chloride and diammonium phosphate.**

Class 3: **Ammonium formate, ammonium fluoride, sodium sulphate, sodium chloride, potassium chloride, potassium bromide and potassium nitrate.**

Class 4: **Potassium carbonate, sodium formate, trisodium phosphate and potassium fluoride.**

The samples of paint supplied by the Department of Ocean Development were decoded and a suitable paint which has inherent properties of fire retardancy and suitable for Antarctic conditions was successfully developed and evaluated at SRI. About two tonnes of this paint were synthesised and taken to Antarctica and successfully applied on the wooden structure. As reported by the Station Commander of the Indian Permanent Antarctic Station, this paint has given the desired results. This paper presents the details of synthesis and the evaluation work carried out on the fire proof paint at the Shri Ram Institute for Industrial Research.

MATERIALS AND METHODS

The paint supplied by the Department of Ocean Development was decoded by first separating *(i)* the organic compounds in the solvents like ether and methanol, *(ii)* polymer in solvents acetone and dichloromethane and *(iii)* the remaining portion was analysed for inorganic compounds.

Organic compounds were identified by using infra red spectro-photometer, nuclear magnetic resonance and melting point determination.

Polymer was identified by the infra red spectroscopy, differential scanning calorimeter and ignition test. Molecular weight was determined by light scattering and molecular weight distribution by gel permeation chromatography.

Inorganic compounds were analysed by atomic absorption spectroscopy for cations determination and by volumetric methods for anions.

Based on the various constituents present in the paint, flame proof paint for Antarctica was developed.

Synthesis of paint

Flame proof paint was synthesised in the laboratories of Shri Ram Institute by mixing Class I flame retardant compound, an antifreezing agent and a tinter. First the paste of the fire retardant solid compounds and tinter was made in water. The liquid flame retardant compound was then added to the paste slowly with stirring. Then to the obtained mixture, an antifreeze agent was added with stirring. A number of solvents as anti-freezing agents (Details given in Table I) can be used for making such paints. Antifreezing agents used in our studies were mainly diethylene glycol and dilute aqueous solutions of sodium chloride or magnesium chloride. The flame proof formulation developed have been protected by two patents (Indian patent) (Application No. 673 /DEL/85 and 674/ DEL/85 dated 19.8.85).

Properties of paint

Colour	:	White (Transparent or coloured material can also be made).
Density	:	1.35 kg/litre
Freezing point	:	-10 to -20°C
Application	:	By brush or spray coating
Coating	:	Two coatings are required

TABLE I

List of antifreezing agents

(a)	Glycols	
	(i)	Ethylene glycol
	(ii)	Propylene glycol
(b)	Ether derivatives of glycols	
	(i)	Methyl ether ethylene glycol
	(ii)	Ethyl ether ethylene glycol
	(iii)	Methyl ether propylene glycol
	(iv)	Ethyl ether propylene glycol
(c)	Aqueous solutions of	
	(i)	Sodium chloride
	(ii)	Potassium chloride
	(iii)	Magnesium chloride

Drying time : Touch dry 40 minutes, hard dry 2 to 5 hours
Finish : Smooth and matt
Storage life : Maximum one year

Evaluation of paint for fire retardant properties

The coatings of the synthesised fire retardant paint were applied on the following selected materials for typical applications:

(i) Plywood (3 mm) commercial grade
(ii) Particle board (12 mm)
Commercially available material for false ceiling, partitions and furniture etc.
(iii) Teak wood
Commercially available for door panels and furniture etc.

Painted and unpained specimens of special dimensions were prepared and subjected to standard tests which are :

(A) Fire test
(B) Ignitability test
(C) Fire resistance test
(D) Surface spread of flame test
(E) Specific optical density of smoke generated
(F) Fire retardancy of paint

Comparison of the behaviour of painted and unpainted specimens was done to draw an inference regarding the protection offered by the coating to the materials. The details of the methods of evaluations are given below :

(A) Fire test

This test was carried out to check the fire retardancy of the paint developed for wooden samples. Wooden samples of the size 20X5X0.3 cm were prepared. One half of the wooden sample was coated with the flame proof paint and the other half was left uncoated. The sample was exposed to flame (as shown in Fig. 1).

Fig. 1(a). **One half of the wooden sample has been coated with fire retardant formulations. When exposed to flame, the coated half stops the fire from spreading.**

Fig. 1(b). **After a while, the uncoated half is destroyed. Other half is protected by fire retardant coating.**

(B) Ignitability test (BS:476, part 6:1968)

A flame of LPG was allowed to play on the surface of the coated and uncoated specimens kept vertically for 10 seconds. The behaviour of the specimen was observed. On removal of the test flame if the material continues to burn for 10 seconds, and the flame reaches the edge of the specimen in any direction within 10 seconds the material was designated as not easily ignitable.

Specimens of the size 288X228 mm of the particle board (12 mm), plywood (1 mm) and teak wood, coated with fire resistance paint and uncoated (as controls) were subjected to the test.

(C) Fire resistance test (as per IS : 162)

This test was performed to check the fire resistancy of the coated wooden samples. Wooden samples were prepared of the size 150X25X13 mm. The coated panels were suspended vertically in a chamber and bunsen flame, 40 mm long, issuing from an orifice of 8 mm in diameter was placed below the test strip, the orifice being 25 mm from the end of the strip. Flame was allowed to play on the strip for 30 seconds and then removed. After the exposure was over, the surface of the specimen was cleaned to expose the wood. An approved sample was also tested in the same above manner and at the same time.

(D) Surface spread of game test (BS 476: Part 7: 1977)

The surface spread of flame test method compares the rate of spread of the flame over the materials with the surface exposed to the heating conditions. The specimen was mounted in a vertical position at right angle to the furnace. The face of the specimen was subjected to radiant heating,

the intensity decreasing along the length of the sample as depicted in Fig. 2. Immediately after the specimen was brought in the test position, a vertical luminous flame was applied at the hotter end for one minute. The test was continued for ten minutes and the time of spread of the flame was recorded along a line drawn parallel to the long axis, 75 mm from the bottom edge of the specimen. Particle board and plywood with single and double coats were tested. The surfaces of the material classified into one of the classes (shown in Table II) according to their observed behaviour under test.

TABLE II

Flame spread classification

Classification	Flame spread in first 1 min. 30 sec. mm	Final flame spread in 10 min. mm
Class 1	165	165
Class 2	215	445
Class 3	265	710
Class 4	more than Class 3 limits	more than Class 3 limits

(E) Specific optical density of time generated (ASTM E 662-79)

Measurements were made in terms of loss of light transmittance through a collected volume of smoke and effluent of a test specimen produced in a fixed volume chamber under controlled standardised conditions. The burning conditions were simulated by the smoke density chamber: radiant heating in the absence of ignition and flaming combinations in the presence of supporting radiations. The cumulative smoke observation measurements were made using a collimated light beam from a incadescent light source. The intensity of the light passing through the smoke was measured by a photomultiplier microphotometer system. The percentage transmittance values obtained were converted to specific optical density (DS).

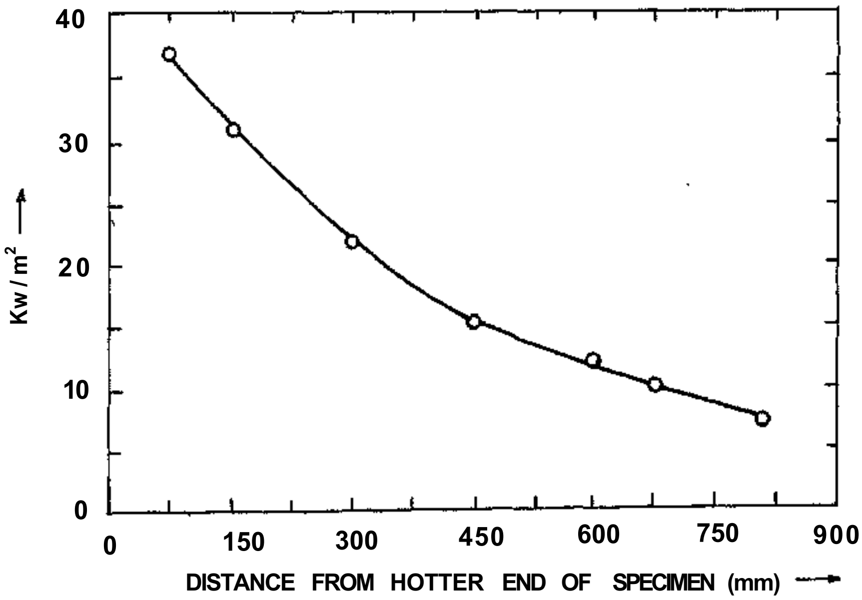

Fig. 2. **Intensity of the radiated heat incident on the specimen (surface spread of flame test).**

The concept of specific optical density permits studying the smoke characteristics of materials in terms of the area of specimen involved, the volume of the chamber and the optical path length of the light beam. Specific optical density provides the basis for predicting the smoke density which can be developed by the same product in the other fire involved areas in the other enclosure volumes.

The percentage transmittance and specific optical density were related by the following equation:

$$DS = G \log_{10} (100/T)$$

where DS is the specific optical density
G is geometrical factor for the chamber (=132)
T is percentage transmittance

(F) Fire retrardancy of paint (cabinet) (as per ASTM D 1360-79)

Relative fire retardant properties of a coating or a coating system on a wood surface were determined by this test. Specially this method determines the weight loss char index of the coated panel subjected to a flame. The specified quantity of the subject paint was applied on a wooden panel (300X150X6 mm) and weighed. These panels were placed at an incline in the cabinet and subjected to flames from an alcohol cup. The difference in weights of a panel before and after the exposure gave the weight loss. The average of six panels was taken and the results were reported as mean weight loss. The panels after the exposure were cut along the maximum length and width of the attack. The maximum length, width and depth of the affected portion of the panel were used to calculate the char index.

RESULTS AND DISCUSSION

(A) Fire test

It was observed that the fire spreading was stopped in the coated half while the uncoated half was completely burnt (as shown in Fig. 1). Hence, it was concluded that paint has protected the wooden structure and has self-extinguishing properties.

(B) Ignitability test

The results of the test have been summarised in Table III. All the three materials with and without coating were classified as 'Not easily ignitable' and no conclusion could be drawn as to the protection offered by the paint. This test was a preliminary check only.

TABLE III
Ignitability test results on materials coated with fire proof paint and unpainted materials

Materials	Thickness	Classification
Particle board	12 mm	Not easily ignitable
Plywood	3 mm	-do-
Teak wood	-	-do-

(C) Fire resistance test

It was observed that charred or scroched area in the coated wooden samples was not greater than that in the approved sample.

(D) Surface spread of flame test

The results of this test on the coated and uncoated materials are tabulated in Table IV and the flame spread observed is shown in Figs. 3 and 4. Coated particle board was observed to attain a surface spread of flame classification class 1 while uncoated specimen was classified as class 3. Similarly, uncoated plywood was classified as class 4 while plywood with a single coating and double coatings were classified as class 3 and class 1 respectively.

TABLE IV

Surface spread of flame test results.

Materials	Paint applied in 230X900 mm specimen	Classification
Particle board	Uncoated	Class 3
"	Coated (56 gm)	Class 1
Plywood	Uncoated	Class 4
"	Single coated (25 gm)	Class 3
"	Double coated (50 gm)	Class 1

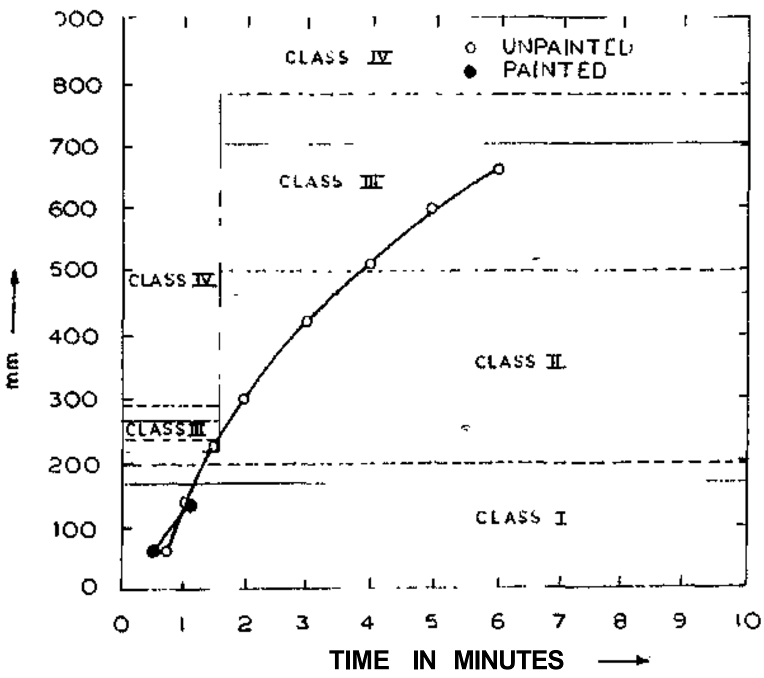

Fig. 3. **Surface spread of flame test on particle board.**

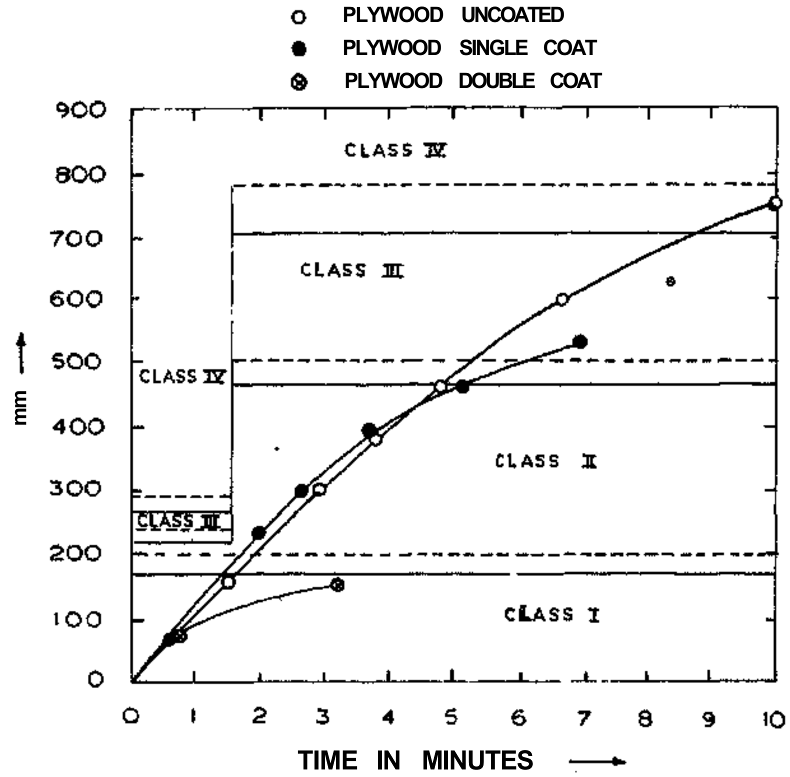

Fig. 4. **Surface spread of flame test on plywood.**

(E) Specific optical density of smoke generated

The results of the tests are tabulated in Table V and are expressed as the maximum specific optical density (DM), i.e., maximum (the peak) value of DS *vs.* the time curve. The DS time plots are given in Figs. 5 and 6. It was observed that under the flaming exposure conditions DM values were as follows:

(i) The particle board painted and unpainted 132.5 and 252.0 respectively.

(ii) The plywood painted and unpainted 62.7 and 72.5 respectively.

It may be concluded from the above results that the application of fire proof paint on the particle board as well as plywood resulted lower values of the specific optical density of smoke generated.

TABLE V

Smoke density test results

Materials		Thickness (mm)	Exposure	DS	Time of DS occurrence (Min)
Particle board	Uncoatcd	12	Flaming	252.0	16.8
	Coated	12	-do-	132.5	15.0
Plywood	Uncoated	3	-do-	72.5	16.5-17.0
	Coated	3	-do-	62.7	15.0-15.5

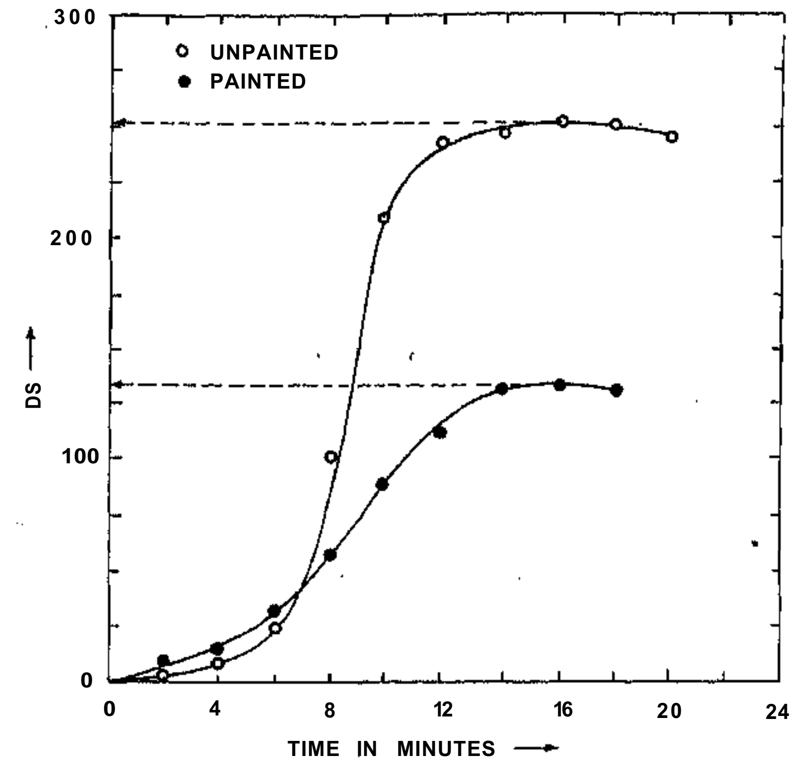

Fig. 5. Smoke density test on particle board (12 mm).

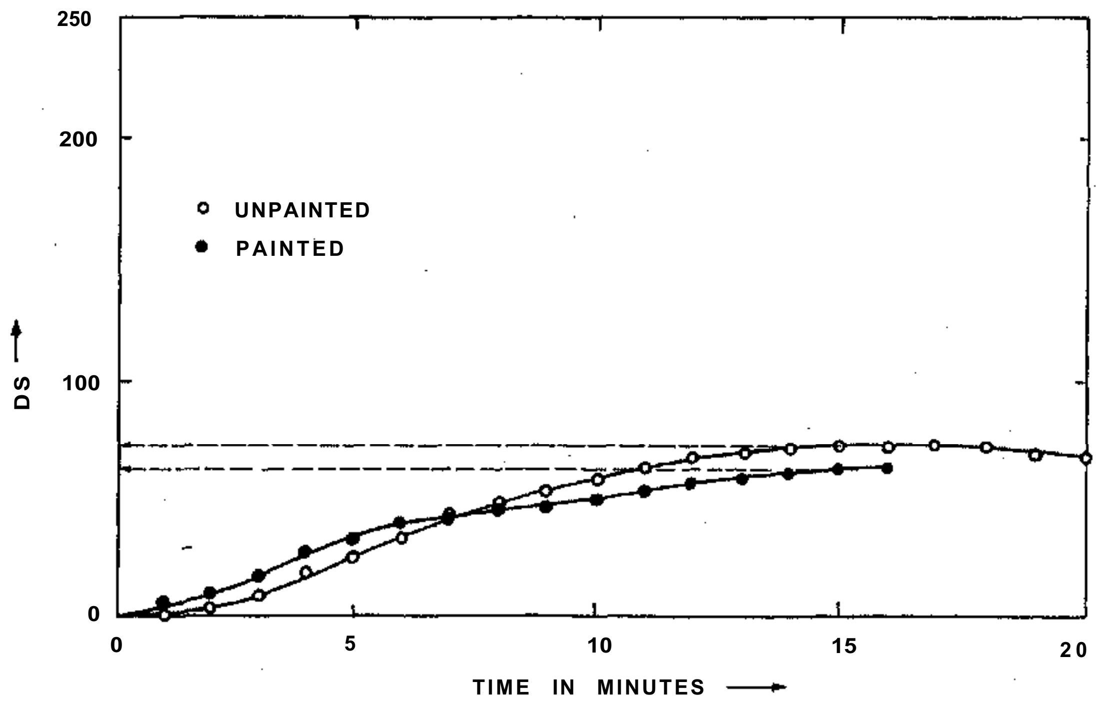

Fig. 6. Smoke density test on plywood (3 mm) flaming exposure.

(F) Fire retardancy of paint (cabinet method)

The results of the panels coated with 10.4 gm of the paints are given as below:

Mean weight loss 9.6 gm.

Mean char index 23.7 c.c.

CONCLUSIONS AND SCOPE FOR FUTURE WORK

During the study of Game retardant formulations developed for making the wooden structure fire proof at Antarctica, it was found that these coatings on wooden samples when applied gradually degrade/deteriorate, hence lose their flame properties after about six months depending upon the weathering conditions. More work has to be carried out to improve the fire retardant properties of the developed paint so that these formulations will remain unchanged when applied and do not lose their flame properties at least after about one year. From the studies carried out so far, we conclude and suggest that the coating should be applied after every six months interval.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the constant guidance and encouragement received from Dr. J.K. Nigam, Director, Shri Ram Institute for Industrial Research, Delhi. It is a pleasure to thank Dr. S.Z. Qasim, Secretary, Department of Ocean Development for his encouragement, co-operation and guidance throughout. Authors also wish to thank Col. P. Kumaresh, Leader wintering team for applying the paint to the wooden structures of Indian Antarctic Station and sending us the results.

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