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- Lift with protected lobby does not provide adequate safety in comparison to stair for the entire building population. Overall risks of lifts with protected lobby were slightly higher than the risks of stair system.
- A combined system of lifts with protected lobby for one-fourth of population and stair for three-fourth of population can provide adequate safety in comparison to individual system alone (lifts or stairs).
- Lifts with double protected lobby provides a better performance.

The MODA method provides a versatile means for risk assessments. It is based on a comparative study of multiple options and incorporates multiple risk attributes into the evaluation. In its application to fire risk assessment, the method is linked to other means of evaluations such as the ASET/RSET analysis, stochastic modeling and safety index analysis. The MODA method involves the ranking of level of importance for multiple risk attributes. This ranking is still by and large empirical and, to a degree, subjective. Further research is required to establish a statistical database which can be used to justify the ranking. Input from multiple stakeholders in the fire engineering brief process, as recommended by the International Fire Engineering Guidelines, can also be adopted as a way to minimise subjectivity in the ranking.

The current study did not include the cost-effectiveness analysis in the risk assessment, although in theory such an inclusion is achievable.

REFERENCES

[1] Klote, J.H., (1982), "Elevators as a Means of Fire Escape",

[2] Pauls, J.L., Gatfield, A. J. and Juillet, E., (1991), "Elevator Use and for Egress: The Human Factors Problems and Prospects",

[3] Bukowski, R.W., Burgess, S.R., Reneke, P.A., Editors (2003), "Collected Publications Related to the Use of Elevators during Fires",

[4] Kuligowski, E., (2003), "Elevators for Occupant Evacuation and Fire Department Access",

[5] Kuligowski, E., and Bukowski, R.W., (2004), "Design of Occupants Egress Systems for Tall Buildings",

[6] So, A., and Yu, J. (2003), "Lift Logic", Fire Prevention Fire Engineers Journal, August Issue, Gloucestershire, UK,

[7] Ebihara, M., Sekizawa, A., Nakahama, S., Notake, H., Ikehata, Y. (2004), "Analysis on Efficiency of Evacuation Using Elevators in a High-Rise Building", Human Behavior in Fire: Public Fire Safety - Professionals in Partnership.

[8] ABS (2004), "Housing and Lifestyle: High Rise Living", Australian Bureau of Statistics, Report No. 4102.0.

[9] Miller, I., (2005), "Human Behaviour Contributing to Unintentional Residential Fire Deaths 1997-2003", New Zealand Fire Service Commission Research Report Number 47.

[10]Koshak, J. (2003), "Elevator Evacuation in Emergency Situations", ASME, p. 1-6.

[11]Allen, T., (2004), "Early Evacuation Elevator Operation", Use of Elevators in Fires and Other Emergencies

[12]Klote, J.H. (2003), "Analysis of the Life Safety Consequences of Smoke Migration through Elevator Shafts", American Society of Mechanical Engineers,

[13]Aloi, S. and Rogers, J. (2002), "Reach of the Sky", Fire Prevention & Fire Engineers Journal, Volume 62, No. 219, FPA, London, UK.

[14]Bukowski, R. W., (2005), "Protected Elevators For Egress And Access During Fires In Tall Buildings",

[15]Nakahama, S., Ebihara, M., Sekizawa, A., Ikehata, Y., Notake, H., (2005), "Examination of Feasibility of Elevator Evacuation Based on Risk Assessment".

[16]ABCB, (2005), International Fire Engineering Guidelines, Australian building code Board, Canberra, Australia.

[17]Clemen, R.T., (1996), "Making Hard Decisions: An Introduction to Decision Analysis", 2nd Edition, Belmond, California Duxbury Press.

[18]Balson, W. E., J. L. Welsh, D. S. Wilson, (1992), "Using Decision Analysis and Risk Analysis to Manage Utility Environmental Risk",

[19]French, S., (1996), "Multi-Attribute Decision Support in the Event of a Nuclear Accident", Journal of Multi-Criteria Decision Analysis 5,

[20]Dyer, J., Edmunds, T., Butler, J., Jia, (1998), "A Multi-Attribute Utility Analysis of Alternatives for the Disposition of Surplus Weapons-Grade Plutonium", Operations Research 46 p. 749-762.

[21]Lee, W. B., Lau, H., Liu, Z, and Tam, S., (2001), "A Fuzzy Analytical Hierarchy Process Approach in Modular Product Design", Expert System, 18 (1), p. 32-42, doi:10.1111/1468-0394.00153

[22]Edwards, W., (1977), "Social Utilities", Decision and Risk Analysis Powerful New Tools for Management,

[23]Saaty, T.L. (1980), "The Analytic Hierarchy Process", McGraw-Hill, New York.

[24]Sekizawa, A., Nakahama, S., Notake, H., Ebihara, M., and Ikehata Y., (1996), "Study on Feasibility of Evacuation using Elevators in a High-rise Building", University of Tokyo, Taisei Corporation and Shimizu Corporation.

[25]Rockwell, (2000), "ARENA 5.0 Version", Rockwell Software Inc., USA.

[26]Mori Building Co. Ltd and University of Hong Kong, (2002), "A Survey on Residents' Responses to High-Rise Living in Hong Kong", Mori Building.

[27]Cornell, C.A. (1969), "A Probability-Based Structural Code", ACI Journal, Volume 66(12), p. 974-985.

[28]McGrattan, K.B., Forney, G.P., Floyd, J.E., Hostikka, S. and Prasad, K., (2004), "Fire Dynamics Simulator - Version 4.07", Fire Research Division, NIST, USA.

STUDIES ON BITUMENISED MUD BASED CABLE FIRE STOP

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INTRODUCTION

Electrical cables are extensively used in all major industries. Increase in power generation and its distribution systems have resulted in an increase in the power that would be fed to a fault. As the modern production facilities demand long runs of power and control cables all over the plant area a fire incidence in the vicinity of the cables may result in the initiation of fire which may spread along the cables laid in the tray. Poly vinyl chloride (PVC) occupies a premier position in the field of cable insulation and sheathing on account of its economy and excellent electrical and handling properties.

Though poly vinyl chloride is self extinguishing in case of a fire it may burn with copious amount of smoke and fumes which have corrosive and toxic effects. Industries such as power stations, fertilizer plants, cement plants, refineries, petrochemicals etc. are immensely prone to fire accidents as they use PVC insulated electric cables extensively in bulk and long runs. Fire once initiated can spread to hitherto remote locations. A major contributor to the spread of fire is the unsealed inter-connecting penetration openings in walls and floor. Even an improperly sealed opening creates a chimney effect and causes spread of flame and smoke in a few seconds. Equipment machinery and structure also suffers damage due to the high concentrations of smoke, corrosive fumes and toxic gases. The problem is further multiplied as these gaseous combustion products render fire fighting difficult. Thus besides the loss of life the financial loss in terms of property, machinery and production (generation of power) may amount to hundreds of crores of rupees due to these fires which involve large amount of cables. Electrical fires are a cause of concern today because of the difficulty in fire fighting and controlling such fire. To reduce fire spread through electrical cables all openings in wall, ceilings or floors through which cables or cable tray penetrate should be provided with an effective non-combustible insulating materials called 'fire stop'.

The firestop is a specific construction consisting of the materials, which fill the openings around penetrating items such as cables, cable trays conduits, Ducts and pipes and their means of support through the wall or other openings to prevent spread of fire. Various types of proprietary seal systems are available. The materials used there in are not available indigenously. Literature reveals that the existing cable firestop systems have certain limitations as far as the site requirements related to ageing, water permeability and operations like removal and insertion of cables are concerned[1]. Therefore, it is worthwhile to develop suitable firestop with indigenously available material in order to reduce the fire hazard in electric cables.

The present article deals with the development and evaluation of firestop system based on bitumenised mud slurry.

EXPERIMENTAL

Commercially available materials such as wheat straw, kerosene oil, mud or soil having 20-25 percent clay and 40-50 percent sand and bitumen of 80 /100 penetration grade were used in the present study.

CONSTRUCTION OF FIRESTOP SYSTEM

The concrete slab (100 x 100 x 20 cm) for fire stop system was constructed with cast able refractory containing mainly silica, alumina , cement with reinforcement of 6 mm dia. M.S. rods having lifting Bolts on both sides. An opening of 50 x 50 x 20 cm was incorporated in the slab for fixing the cable tray and filling materials. The constructed slab was cured for 28 days.

A ladder type M.S. tray of size 150 x 32 x 5 cm was prepared. 31 PVC insulated electric cables of 19 mm diameter, single strained, 2-core aluminum conductor were fixed in the tray. It was passed through the center of aperture so as these penetration items protruded approximately 32 cm from exposed face into the furnace and 98 cm away from unexposed face of fire stop. After fixing the cable tray a shuttering of non- combustible material board was provided at lower side to retain the filling materials i.e. bitumenised mud.

Slurry of 1.8 kg of wheat straw, one cubic foot (cft) of soil having 20-25 percent clay and 40-45 percent sand with water was prepared and kneaded daily for about a week. A solution containing bitumen of 100/80 penetration grade and kerosene oil (100: 20, w/w) was prepared by mixing these properly. 1.5 kg of this solution was added to one cubic foot of the slurry and mixed thoroughly [2]. The slurry thus prepared was filled in the cavity. A wire mesh of size 1.5 mm diameter was provided at a depth of 10-12 cm from the top which acts as a reinforcement to the filling material. The opening was filled completely with bitumenised mud and then dried completely in atmospheric conditions. A non combustible board was also fixed on the top of the cable fire stop system. The construction details are shown in Figure 1.

EVALUATION OF FIRE STOP SYSTEM

Temperature Measurement

The fire performance of cable fire stop system was evaluated following UL: 1479-1983, ASTM E 814, ISO: 834-1975, BS: 476 part 8: 1972 standard procedures [3-6]. Specimen was heated in a furnace which is capable of producing a positive pressure and standard heating conditions. The temperature of the furnace was controlled to vary with time as far as possible in accordance with the standard time Temperature curve. The actual temperature verses time recorded during test is represented graphically (Figure 2.). The accuracy of the temperature was controlled within the tolerance limit according to the standard. Temperature was measured at different position on the unexposed side of the cable fire stop specimen. Position of thermocouples is given in Table 1 and Figure 1. The temperatures at different positions recorded during evaluation are given in Table 2 and averages of the temperatures recorded were plotted against time (Figure 2). The physical observations were also carried out at different time intervals following ISO: 834- 1975 standard procedure. The data of physical observation is recorded in Table- 3.

Hose Stream Test

The intention of the hose stream test is to ascertain whether the fire stop assembly maintains its stability on application of water jet after withstanding the fire for the specified fire rating duration. During hose stream test the temperature of the furnace followed the standard time temperature curve which was exactly similar to the one used for carrying out the fire-rating test. The fire stop was subjected to the action of hose stream test within five minutes after the furnace was shut off. The stream was delivered Through 63 .5 mm hose and discharged through a 28.6 mm discharge tip of the standard taper, smooth bore pattern without a shoulder at the orifice .The nozzle orifice during test was kept at 6.1 m from the center of the exposed surface of the fire stop .The water pressure and duration of application maintained according to the standard.

Oxygen Index Test [7]

When fire retardant materials are subjected to a test to evaluate their flammability it becomes almost impossible to rate them in order of their performance because in each case the specimen is found to perform in a similar fashion. They do not burn and so can not be graded. Oxygen Index test is a method that allows fire retardant materials to be thus graded. Basically this method was developed For assessment of combustion of plastics but now it is often used as an R&D tool in case of Fire retardant/ resistant materials. Specimens are subjected to a test flame under artificially created atmosphere where the concentration of oxygen can be varied; in O_2-N_2 atmosphere; from 0-100%. The higher the concentration of oxygen required for a material to burn, the greater is its flame retardancy. The only limitation is the size of the test specimen.

Since a 19mm dia. Sample can not be subjected to test in the Oxygen Index test apparatus, specimens were prepared by coating cable 8 mm dia. cables sufficient quantity of bitumenised mud plaster so as to achieve a dry coating thickness of 2 mm. The top edge of the specimen was also coated with the same thickness of bitumenised mud plaster. Specimens were subjected to test under oxygen rich O_2-N_2 mixture which was allowed to flow upwards through a glass chimney. Oxygen concentration was increased in small steps from 21% onwards and a test flame applied to the top edge of the specimen till a sustained flaming for three minutes duration or 75 mm length was observed (Table-4).

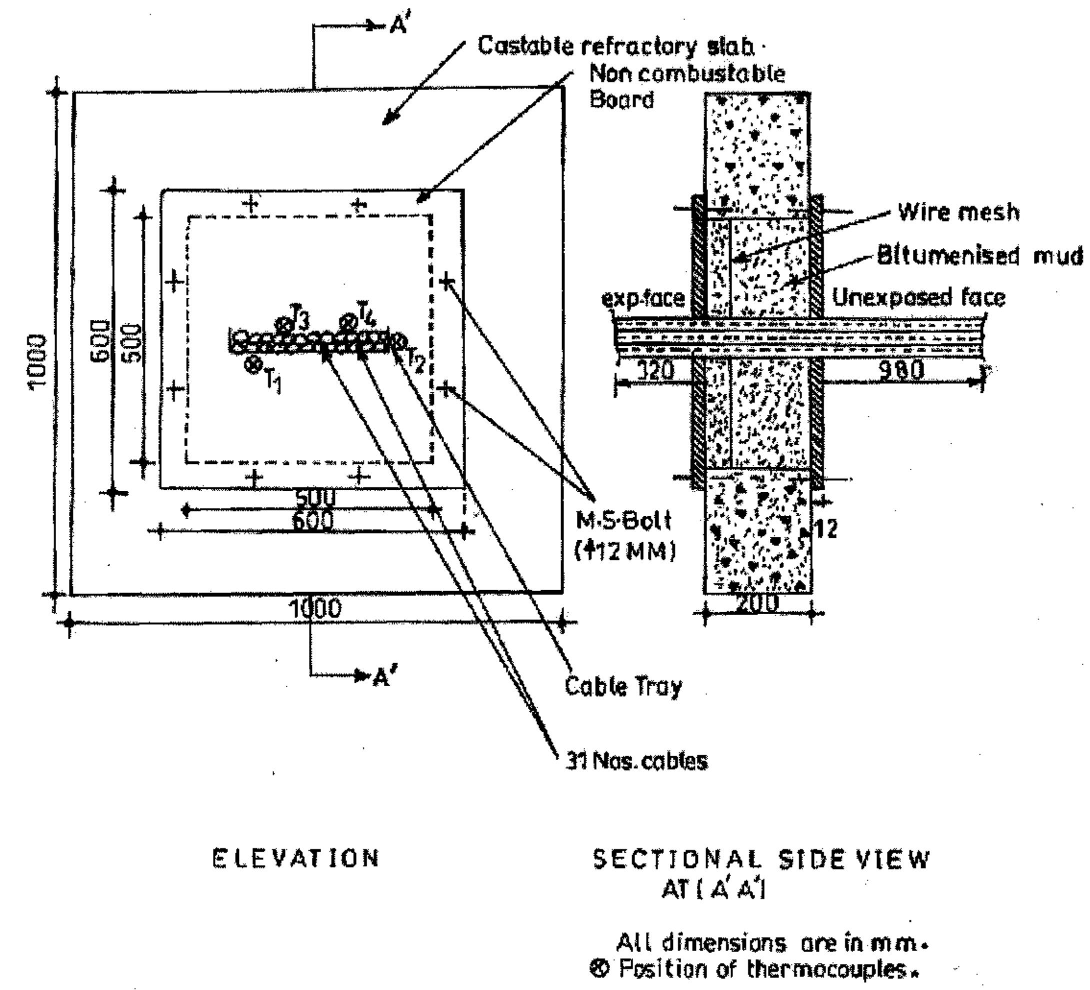
RESULTS & DISCUSSION

The actual course of furnace temperature-time pattern is very important from the fire resistance evaluation point of view for any specimen. Therefore, actual temperature time pattern of furnace during evaluation of fire stop was recorded. It is observed that actual furnace temperature was found well within the limit of standard furnace temperaturE (Figure 2). The bitumenised mud based cable fire stop specimen was exposed in the calibrated furnace

For 150 minutes duration. Temperatures on unexposed face at different positions (Table 1) at different time intervals were recorded in Table 2. Data states that the temperature on the unexposed face is rising steadily up to 75 minutes and there after up to 120 minutes it raises slightly at a faster rate but after this period it rose very quickly. The average temperature of the unexposed face clearly indicates that the maximum temperature attained in 120 minutes was (77.8 °C) which is well below 163 °C, The temperature considered important from thermal insulation point of view in accordance with BS 476 [8]. From Table 2 it is observed that maximum rises only 89.9°C, 67.3 °C, 77.4 °C, and 80.5 °C respectively at T_1, T_2, T_3 and T_4 thermocouple position at 120 minute which are far below the failure temperature i.e. 163 °C above the initial temperature. However, failure temperature of 163 °C reached within 150 minutes of exposure. The sudden rise in temperature may either be due to insulation failure or attainment of the uniform temperature gradient across the thickness of the material.

In bitumenised mud, fibers from decayed wheat straw act as reinforcement to the soil thereby increasing the cohesion and the strength of the mud mortar. The period for which wheat straw is decomposed play an important role in the performance of mud mortar. It is experimentally established that wheat straw gets disintegrated during a period of 12 days in winter as well as rainy season while 8 days are required during summer season.

During hose stream test, no opening that could permit a projection of water from the stream beyond the unexposed side is noted. Physical observations were also carried out along with the instrumental observations. The course of physical observation makes the thing as clear as crystal as to study the relevant physical parameters in depth with the understanding that the course of experimental events has occurred in variance to time.



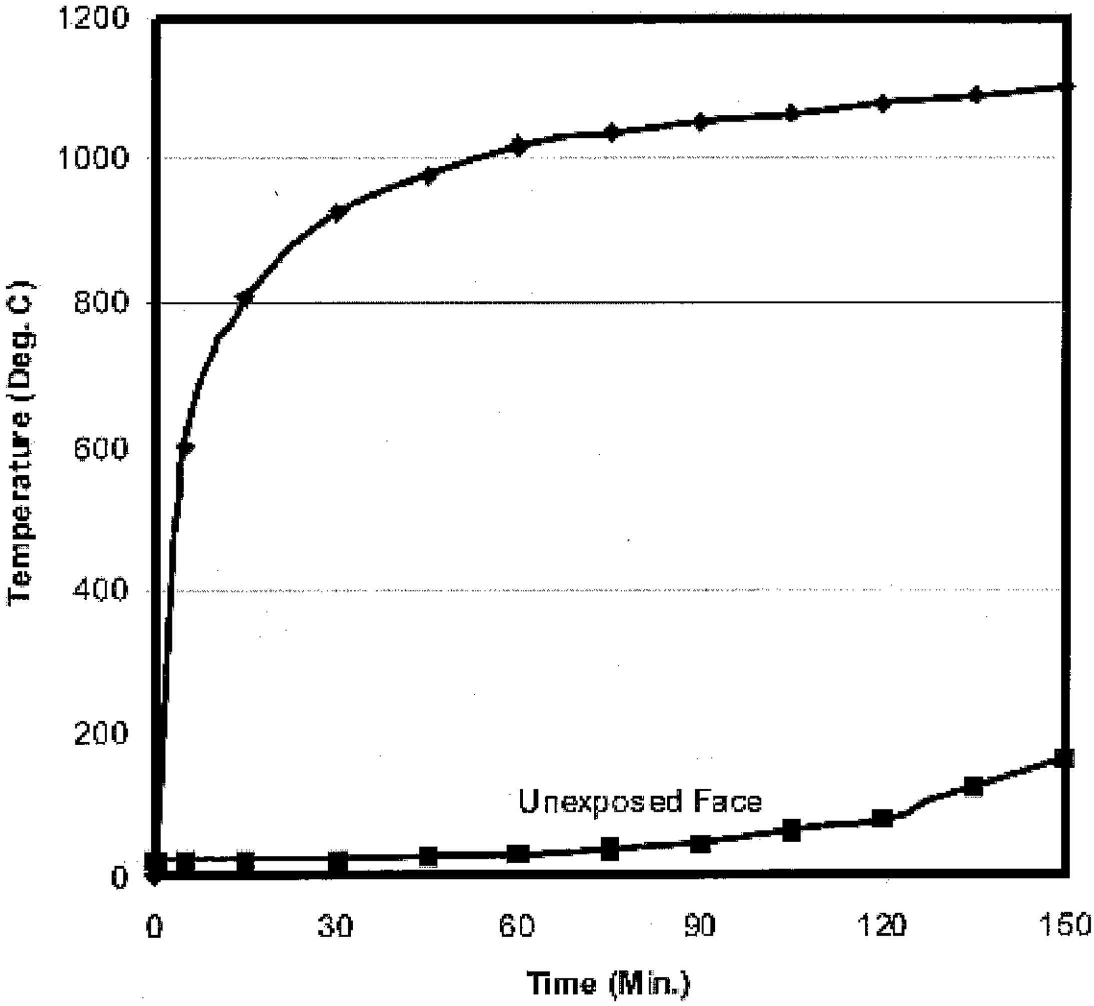
It is noted from the physical observations that no smoke was evolved up to 120 minutes exposure and no change in cotton pad test was noted. After this exposure, little quantity of smoke was observed on unexposed face of fire stop system. However, cotton did not catch flame during cotton pad test when conducted following standard procedure. Maximum temperature rise was noted at the T_4 Thermocouple position with no change on cotton pad test, however, vigorous smoke evaluation was observed on unexposed side specimen at 150 minute. It may be due to the burning of some cable after failure of insulation.

When the bitumenised mud coated cable specimens were exposed to Oxygen Index test it was observed that they were resistant to any flaming for quite high concentrations of oxygen in the O_2-N_2 mixture. At a concentration of 85 and higher small flame were Observed but they were not able to sustain for sufficient duration to help in arriving at any conclusion. Experiments were conducted up to an oxygen concentration of 92% as now the mixture becomes very rich. Till the end of experimentation no flaming for 3 minute duration or 75 mm length was observed (Table-4). In fact as the oxygen concentration increases beyond 85% the flame becomes blue & its size decreases hence experiments were not conducted beyond this oxygen concentration.

CONCLUSION

To reduce the fire hazards in electric cables bitumenised mud based cable fire stop have been studied. The experimental studied on the fire resistance evaluation of specimen have conclusively demonstrated that the specimen is found to be quite effective for at least two hours fire resistance rating.

Figure 2-
Standard Time Vs Temperature compared with the average temperature on the unexposed face of specimen



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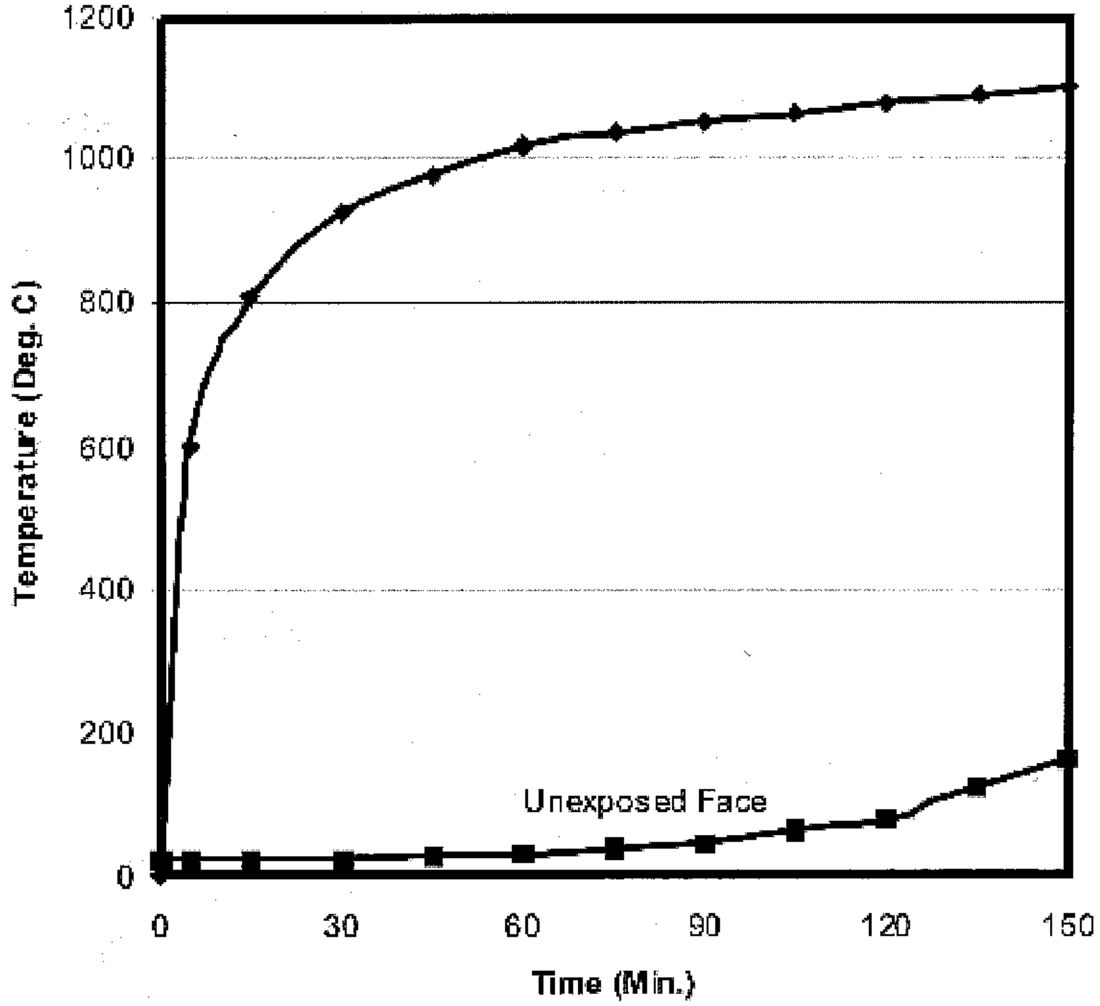

Table-1

Thermocouple No.	Position
T_1	25 mm away from Fire stop material on the board
T_2	25 mm away from unexposed face material on the cable tray
T_3	25 mm away from unexposed face material on 19 mm dia., 2 cores, single strained, aluminum conductor, PVC insulated, armoured, power cable.
T_4	25 mm away from unexposed face material on 19 mm dia., 2 cores, single strained, aluminum conductor, PVC insulated, Armoured, power cable.

TABLE - 2
Unexposed Face Temperature at Different Thermocouples

Time (min.)	Unexposed Face Temperature (°C)			
	T_1	T_2	T_3	T_4
00	21.8	21.6	21.8	21.6
15	22.6	22.3	22.6	22.3
30	22.8	24.4	24.3	23.3
45	23.3	25.1	28.8	26.8
60	25.3	25.9	35.1	33.4
75	28.1	30.6	41.7	41.7
90	38.4	36.9	49.9	51.6
105	61.2	49.4	68.8	67.9
120	89.9	67.3	77.4	80.5
135	114.0	109.8	126.8	134.8
150	148.8	156.4	167.4	184.2

TABLE - 3
Physical Observations During Evaluation

Time (Min.)	Observations
00	Furnace was started at a pressure of ~1.5mm Wg.
15	No smoke observed on unexposed face.
45	Furnace pressure was noted 0.0 mm Wg and no smoke was observed on the unexposed side.
60	Maximum temperature on unexposed face noted 35.1 °C at thermocouple position T_3
90	Furnace pressure noted 0.5 mm Wg. No smoke unobserved face. No change during cotton pad test was observed.
120	Furnace pressure recorded +1mm Wg. Maximum temperature was recorded at thermocouple position T_1. No smoke on unexposed side was observed. No change in colour of cotton pad noted during cotton pad test.
135	Very small amount of smoke was observed on the unexposed face. No change in colour of cotton pad noted during cotton pad test
150	Vigorous smoke evolution observed. Rate of rise of temperature found very fast. Some change in colour of cotton pad noted during cotton pad test. Maximum temperature observed at thermocouple position T_4. Furnace shut off and hose stream test was carried out. During hose stream test no opening was noted that would permit any projection of water.

Table – 4
Observations of Limiting Oxygen Index Test

Oxygen Concentration	Flame length (mm)	Flame Duration (sec.)
21.0	Nil	Nil
30.0	Nil	Nil
40.0	Nil	Nil
50.0	Nil	Nil
60.0	Nil	Nil
70.0	Nil	Nil
80.0	2-3	5
85.0	3-5	8

REFERENCES

1. R. K. Jain, Cable-fire safety management in power cable, *J. Indian Building congress*, 1996, Vol.2, No. 2,
2. N. K. saxena, *Development of some fire retardants for combustible materials* Ph.D. Thesis, Meerut University, 1987
3. UL:1497 *Standard for fire test of through penetration firestops*, Underwriters Laboratories Inc. USA, 1983
4. ASTM E 814 *Standard method of fire tests of through penetration fire stops*. American Society for Testing and Materials, Philadelphia, PA, USA, 2000
5. ISO:834 *Fire resistance tests: Elements of building construction*, International Standard Organization, 1975
6. BS 476 *Fire Tests on Building Materials and Structures: Part-8: Test methods and criteria for the resistance of elements of building construction*, British standard Institution, London, 1972
7. ASTM D 2863 *Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)*. American Society for Testing and Materials, Philadelphia, PA, USA, 1997