

"FIRE RETARDANCY USING APPLIED MATERIALS"

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Dr. Rubin Feldman is the founder and president of Thermo Systems, Inc. in St. Louis, Missouri. The company produces Thermo-Lag which he originally developed for the National Space program. It has been used on all space vehicles for space shots as an inner heat shield since 1960.

Prior to his present position, Dr. Feldman was the chief Thermo-Dynamicist at Emerson Electric Company in St. Louis for 15 years.

Dr. Feldman received his PhD in chemical engineering from Johns Hopkins University.

## A B S T R A C T

The last decade has witnessed many advances in the technology of fire protection. Archaic building codes are gradually being revised to conform to the rapidly developing state-of-the-art. Factory Mutual and the Underwriters' Laboratories, the traditional test agencies upon whose listings all major insurance companies rely, are continuously updating their simulation procedures to bring them on par with new developments.

THERMO-LAG represents an example of advanced technology transfer from the Little Joe, Surveyor, Comsat, re-entry and Apollo age to everyday fire protection needs. Utilizing the TSI-patented principle of sublimation cooling for thermostatic temperature control, THERMO-LAG meets a wide range of fire retardancy and heat transmission control requirements. Properties vary from flexible tape for conduits and electrical cables to rigid coatings for column protection, with a broad spectrum of sublimation temperatures available. THERMO-LAG can be applied in the field or in the factory, utilizing mass production techniques, yielding a product that is reliable, effective, widely available and low in cost.

C O M M E R C I A L   T H E R M O - L A G   M A T E R I A L S  
F O R   P R O T E C T I O N   F R O M   F I R E

DESIGNATION	DESCRIPTION	APPLICATION	MAJOR END USE
THERMO-LAG 220	Coating - Fire Retardant	Brush Roll Spray	Fire Retardant Warehouse Shelves, Containers (Wood and Cardboard)
THERMO-LAG 220	Concentrate	Pressure Spray Trowel Roll	Heat Transmission Control . . . . Hollow Metal Structures . . . . Safes
THERMO-LAG 330	Coating - Fire Retardant	Brush Roll Spray	Same as 220 - in Areas where Special Adhesion and Chemical Resistance are Required
THERMO-LAG 330	Tape - with Contact Adhesive	Wrap Roll	Conduit . . . Wire Bundles . . . Areas where Instant Fireproofing is Required
THERMO-LAG 330	Concentrate Coating	Pressure Spray Trowel Roll	Heat Transmission Control . . . Beams, Columns, Joists, etc. (Style and Functional)

S E L E C T E D   T H E R M O - L A G  
C H A R A C T E R I S T I C S

	MATERIAL	
	THERMO-LAG 220	THERMO-LAG 330
	PAINT MASTIC	PAINT MASTIC TAPE
<b>UL RATINGS OBTAINED IN ASTM E84 TUNNEL:</b>		
FLAME SPREAD	0	5
FUEL CONTRIBUTED	0	0
SMOKE DEVELOPED	0	0
SPREAD RATE — SQ. FT./GAL.	250	250
<b>MATERIAL REQUIRED:</b>		
WOOD	0.005 INCH	0.005 INCH
CARDBOARD	0.005 INCH	0.005 INCH
PAPER	LESS THAN 0.005 INCH	LESS THAN 0.005 INCH
PLASTIC	0.005 INCH	0.005 INCH
STEEL*	TO SUIT NEEDS	TO SUIT NEEDS
OTHER SUBSTRATES	INQUIRE	INQUIRE
<b>SOLVENT OR THINNER:</b>	WATER	MEK OR TOLUENE
<b>APPLICATION:</b>	BRUSH, SPRAY ROLLER, DIP, TROWEL	BRUSH, SPRAY ROLLER, DIP, TROWEL
<b>COLOR:</b>	TO SUIT NEEDS	TO SUIT NEEDS
<b>SUBLIMATION TEMPERATURE:</b>	220°F	400°F
<b>WASHABILITY:</b>	EXCELLENT	EXCELLENT

\*RESULTS FROM ASTM E119, FM STD 4975 AND OTHER TESTS, AVAILABLE UPON REQUEST.

A D V A N T A G E S  
O F  
T H E R M O - L A G

- PERFORMANCE
  - SAFETY IN USE
    - LOW COST
    - EASE OF APPLICATION

U.L. LISTED



TESTED  
AND  
APPROVED

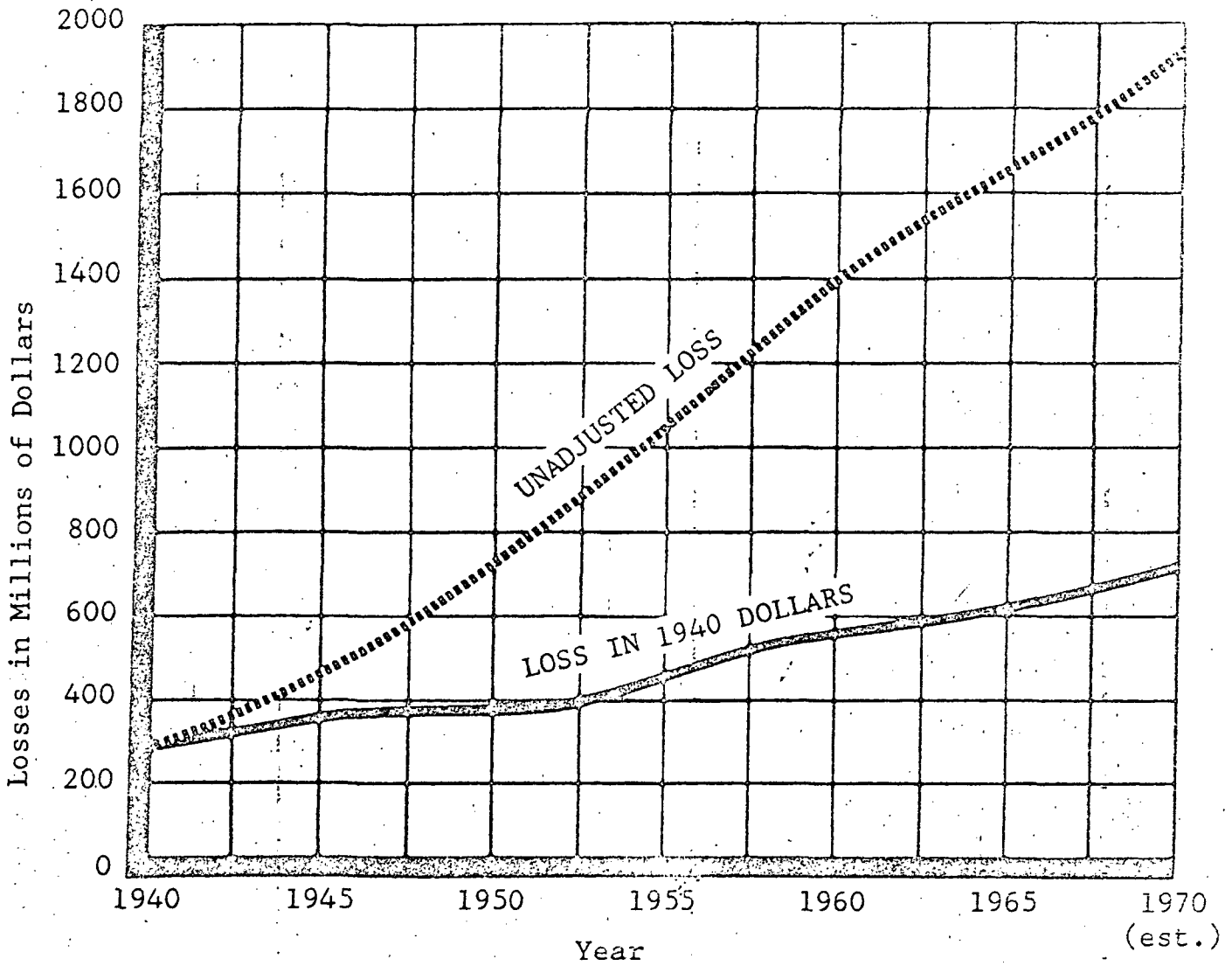
## FIRE RETARDANCY AND HEAT TRANSMISSION CONTROL USING APPLIED MATERIALS

### Introduction

Ever since man moved out of his fireproof cave he has had fire problems. Unharnessed fires have been violently destructive. The burning of Rome and the Great Fires of London and Chicago are but three examples of devastation wrought by the raging monster.

Progress has been made slowly in man's efforts to protect his property from the ravages of fire. Eliminating all timber and using heavy masonry walls, Catullus constructed a "fireproof" repository in 78 B.C. But fireproof constructions scarcely advanced beyond that point during the next two thousand years. It is only in comparatively recent times that the practice of fire protection began to develop into a science. Present methods and experience make hit-or-miss or arbitrary fire protection procedures totally unnecessary. Their deployment, however, is tangled up in the labyrinths of archaic regulations and building codes.

The need for more effective fire protection is brought sharply into focus by the gruesome statistics published by the National Fire Protection Association. In 1970 the property damage due to fire is estimated to exceed \$2 billion,



FIRE LOSSES, SHOWING EFFECT OF INFLATION  
 (EXCLUSIVE OF FOREST FIRES)



with another half billion dollars lost in forest fires, aircraft fires, motor vehicle fires, and other non-building losses. Every two seconds a fire breaks out in the United States; every two minutes someone's home goes up in flames; and every forty minutes someone dies in a fire. Fire injuries are substantially more frequent than deaths.

The three worst residential loss-of-life fires in 1970 occurred in hotels, killing a total of 67 people and injuring many more. At the Ozark Hotel in Seattle, 20 people died on March 20; in the Tonet Square Hotel in Los Angeles, 19 people died on September 13; and in the Pioneer Hotel in Tucson, 28 people died on December 20. All three fires had two things in common: all were believed to be of incendiary origin and none employed fire retardant materials where they should have.

Only a few days ago, on Friday, May 14, a fire occurred at the Ambassador Hotel and Residence in St. Louis. Before rescue could be effected, four people were dead and many more injured. The fire, which was of incendiary origin, started in a third story room. The room employed wood paneling. The fire quickly spread along its surface to that of the walls down the corridors, causing heavy damage and making rescue of those trapped in their rooms extremely difficult if not impossible.

But this is 1971--and such tragedies are no longer inevitable. Science is no longer devoted to alchemy or

the search for the philosopher's stone to turn lead into gold. Space age technology has landed us on the moon . . . and taught us to combat the inferno-like heating of re-entry conditions. The knowledge of heat control utilized in aerospace applications has resulted in the development of highly efficient fire retardant and heat transmission control materials. Some of these are highly competitive in price-- costing no more than ordinary good quality paint.

### Fire

What, then, is a fire? A fire may be defined as "rapid oxidation with the evolution of light and heat." Combustion in the broadest sense includes not only the chemical combination of fuel with oxygen, but also in combination with other oxidizing agents such as chlorine. Hence combustion may occur not only in the atmosphere of oxygen, but elsewhere.

Ignition of a combustible material will occur only where there is a sufficiently high temperature and a sufficient quantity of heat and oxygen to initiate self-sustaining combustion. Fire will not propagate from point of ignition if heat is carried away faster than it is produced, as the temperature will be decreased and the fire will go out. Heat may be carried away from a point of ignition by radiation, conduction, and convection. In the case of a log touched by a match, conduction may start

at the point where the match flame touches the wood. The flame of the match may produce a temperature of 2000°F or higher, but it does not produce enough heat to start sustained burning of the wood. Heat will be conducted and absorbed by the body of the log and incendiary heat will be lost by radiation and convection.

The same match, when dropped on a material of better insulative qualities and lower mass (such as cardboard boxes), will after a short time initiate combustion, which will rapidly spread. In the case of a single log, even if sufficient temperature is attained to initiate local combustion, the fire may go out because of rapid loss of heat by radiation and convection. If two or three logs are placed together, however, the radiation and convection from one to the other will tend to keep the wood hot and fire will readily continue.

The same principles apply in the case of a fire, particularly one contained in close quarters. Consider, for example, the case of a fire in a corridor or typical room. Assuming that there is adequate air supply to sustain combustion, fire in such a space--with combustible surfaces on several sides, each side reradiating heat to the other--produces a much more severe fire than a similar area of combustible surface in the open. Protecting these surfaces with a fire retardant will, of course, greatly minimize if not completely eliminate the potential of fire spread.

When a combustible material is still more finely divided, in the form of dust flying in the air, ignition can occur from a minute heat source. The same is more pronounced in the case of flammable gases and vapors, where the combustible material is divided into individual molecules. This explains why a fine cloud of combustible dust, gases or vapors can be ignited by a very small source of heat, such as a spark.

With some fires where the air supply is restricted, a considerable quantity of carbon monoxide may be produced. The carbon monoxide may subsequently come in contact with additional oxygen and ignite to form carbon dioxide and further spread the flame; hence the necessity to restrict the size of open spaces susceptible to fire by means of fire walls and openings protected by fire doors.

### Building Codes

"In a general sense building codes are designed to provide rules for public safety in the construction of buildings to the extent which can be applied as law under the broad authority of the police power," states the NFPA. They thus comprise minimum standards consistent with reasonable public safety. They do not necessarily provide complete safety or ideal conditions. By their very nature they may adequately cover structures of common types only, with less applicability to large manufacturing buildings and major structures of unusual design.

Building code requirements vary widely in different parts of the United States and Canada. In many areas there are no building codes as such, or there are only incomplete or absolute requirements. The following five principal codes are in circulation in the United States and Canada:

National Building Code (1st Edition 1905)  
Uniform Building Code (1st Edition 1927)  
Southern Standard Building Code (1st Edition 1935)  
Basic Building Code (1st Edition 1950)  
National Building Code, Canada.

These are in addition to a number of state codes. All are markedly informal in arrangement, and most features are prepared in such different manners as to make comparisons difficult. All are revised and re-issued periodically.

The general practice is to specify minimum requirements for the protection of structural members, partitions, etc., in terms of specific materials or combinations of materials. These requirements are then expressed in terms of time of ultimate fire resistance, or, in other words, the time period during which the construction member should stand up to a fire of given intensity before specific damage occurs as determined by applicable standards.

In the past it has been standard building code procedure to place restrictions upon the use of combustible materials for the interior finish only in assembly occupancies and in buildings of fire resistant construction.

However, the situation has changed with the development of many new types of finish materials, some of which are highly combustible and already proven to be dangerous, creating a need for more careful regulation. Buildings which would appear to be fire safe can be rendered unsafe through the use of hazardous types of finish materials. Under present building codes, the use of combustible finishes, regardless of degree of hazard, considered too dangerous for use in fireproof or fire resistant buildings, are permitted in non-fire-resistant structures. Such procedure is obviously unsound in principle and very dangerous.

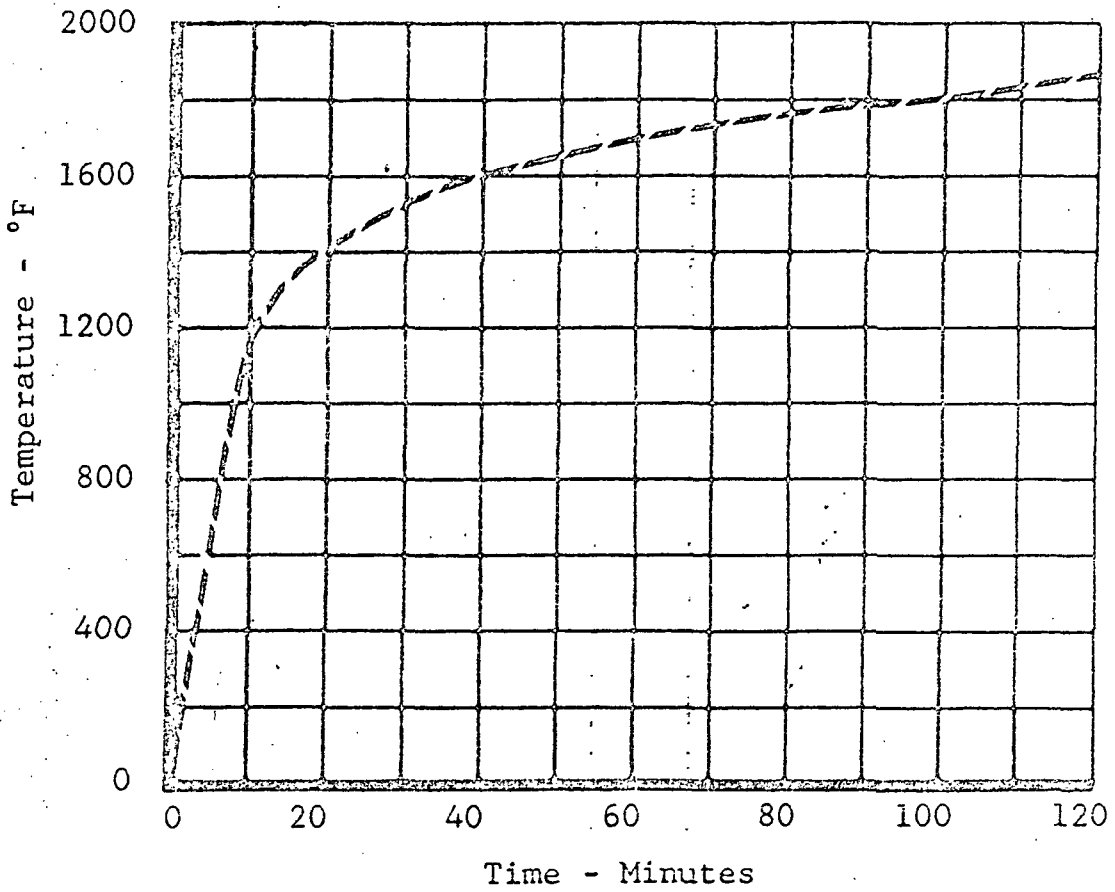
#### Test and Approval Methods

The regulation of interior finish materials has been given considerable study by building code and fire authorities in the last several years. Performance standards have been developed to measure the relative hazard of these materials with respect to surface burning characteristics. One standard method of test for surface burning characteristics of building materials (ASTM E-84) has become widely recognized in modern building codes throughout the country. The ASTM test represents the conditions of a vigorous incipient fire and determines relative fire hazard of the material by evaluating the rate of flame spread along the surface of a 20-25 foot long test sample under a standard exposure fire. The test establishes relative hazard represented by the finish material according to numerical

flame spread, the lower rating indicating less hazardous finishes (0 for asbestos cement and 100 for untreated Douglas fir).

Another procedure is followed by the Factory Mutual Corporation by the use of a calorimeter in which a precise measurement of heat contribution in addition to flame spread is evaluated and comprises a key standard in the rating of materials, particularly in the area of activities covered by Mutual Insurance Companies. The relative fire hazard of finish materials, as classified by the numerical flame spread and heat and smoke contributed ratings of the Underwriters' Laboratories and Factory Mutual, represents a national endeavor toward the creation of realistic test conditions.

It has become standard practice in building codes to specify the degree of fire protection that must be provided by the various structural parts of the building according to the hours of fire resistance which they are capable of developing under standardized conditions of fire exposure. ASTM E-119 procedure and adaptations thereof comprise the recognized standard by which the duration and intensity of fires are classified and on which recognized fire resistance ratings of materials of construction are based. For illustration, see the standard time-temperature curve depicted on the following page.



FIRE SIMULATOR TIME-TEMPERATURE CURVE

PER ASTM E-119



In order to establish the fire resistance rating of any building assembly of construction, a specimen of prescribed size must be exposed to a standard fire. The fire resistance rating of a construction assembly or material is determined by the length of time that it successfully performs during the fire exposure. The condition of performance or construction of a material during a fire test varies with expected function of the material and assembly. For instance, wall, floor and roof panels must also withstand exposure without allowing the passage of flame and without transmitting heat through the construction to raise the temperature of the un-exposed surface more than 250°F above its initial temperature. In order to qualify for fire ratings of one hour or more, walls and partitions must also withstand a prescribed exposure to a hose stream of specified pressure immediately after fire exposure, thereby establishing the integrity of the construction to the effect of cooling.

#### State of the Art Materials

Until very recently, when the accelerated rate of the transfer of aerospace developed technology to everyday fire protection needs occurred, commonly used materials of construction included gypsum, vermiculite, perlite, mineral fiber, concrete, masonry, metal lathe and plaster and many other combinations. Although the materials in themselves are relatively inexpensive, brute force techniques employed

in their utilization and the common cumbersomeness associated with in situ installations makes the installed cost very high indeed, the cost of building in many cases prohibitive. This coupled with an increase in inflation, particularly in the area of labor, has resulted in serious slumps in the building industry by making many types of institutional and commercial buildings prohibitive for many uses.

During the last two decades, plastics have encroached into many traditional areas of building construction. They are essentially composed of organic material easily susceptible to combustion. The stress on fire protection has thus become even more apparent. State-of-the-art fire protection or fire retardance includes the use of externally applied coatings.

Replacing sometimes highly flammable finish materials with coatings or paints which inhibit rather than contribute to the spread of fire is both possible and practical. Using these coatings permits much greater flexibility in choice of building materials, allowing lightweight and low cost constructions otherwise impossible because of their extreme susceptibility to fire. For example, in addition to a number of plastics, cardboard has been introduced into building construction. A "paper" bridge is only one dramatic example of innovative and imaginative engineering utilizing cardboard as a structural material.

One noteworthy means of protection is offered by intumescence. In essence, intumescence is provided by coatings in various thicknesses which offer a measure of thermal protection to surfaces to which they are applied. Prior to the occurrence of fire, such coatings are indistinguishable from conventional products. Upon heating, however, they decompose, bubbling and foaming to form a thick, not easily combustible, multi-cellular insulative barrier. The materials are useful for short periods of time, measurable in minutes. However, for sustained protection of an hour or more, the required material thickness of one-half inch or more is prohibitive.

A major disadvantage of intumescent materials is the propensity of the active ingredient to leach out under exposure to humidity or rain. The coatings are thus rendered ineffective for protection from fire after extended periods of time.

In still other applications, emphasis has been placed on chemical equilibrium shifts of the material surface via high concentrations of halogens--notably fluorine. Such methods provide adequate short term protection from fire but greatly increase the toxicity hazard due to the introduction of inherently poisonous gases.

## THERMO-LAG

A more advanced means of fire protection is offered by a family of paintlike materials utilizing the principle of sublimation for thermostatic temperature control. These materials, marketed under the trade name of THERMO-LAG, have proved effective in numerous aerospace applications over the past decade and more recently for protection from the ravages of fire.

A sublimate, by definition, is a material which undergoes a transition from a solid into a vapor at a fixed temperature. THERMO-LAG materials utilize a family of subliming agents to attain different levels of temperature control. The materials operate in the facsimile of a water jacket - as long as the THERMO-LAG is there, the temperature of sublimation cannot be exceeded. Some typical temperatures of sublimation are 220°F, 400°F, 550°F and 800°F.

As the material sublimates, undergoing the transition from a solid into a vapor, it absorbs a considerable amount of heat at the same time. This process is similar to that of boiling water. It takes approximately 1 Btu/lb. to raise the temperature of water by one degree. It takes 980 Btu/lb. to boil water off, without elevation in temperature. In the case of THERMO-LAG, it takes approximately 750 Btu/lb. to vaporize it. At higher temperatures the THERMO-LAG vapors undergo additional decompositions; larger THERMO-LAG molecules break up into smaller ones. The result is the

absorption of extremely high levels of heat energy, as high as 6000 Btu/lb. under some conditions. The heat energy absorbed by the THERMO-LAG vapors is no longer available to impinge upon the structure protected by the THERMO-LAG coating. The result is actual heat blockage: heat is prevented from penetrating to the surface of the material.

Decomposition has to take place within the coating itself; once it gets into the fire it is of little value. When a missile travels at extreme velocity through the air, it produces a boundary layer of air which sort of drags along with the missile. This layer of stagnant air in itself provides an effective means of insulation, protecting the re-entering missile to a considerable extent from the aerodynamic heating. When THERMO-LAG gases inject into this boundary they, too, absorb a considerable amount of heat energy. They further stretch the boundary layer by physical extension of its volume, improving its effectiveness as insulation.

In the case of a fire, where there is no high velocity speed, a boundary layer must be created. This is accomplished from the principle of intumescence. Because THERMO-LAG produces a rather voluminous amount of gaseous matter, it is also used as an intumescent agent. Upon exposure to heat, the initial thickness of THERMO-LAG is increased many times, performing an action comparable to that of intumescent coatings. However, the passage of the cooling gases produced

by the sublimate do more than stretch the intumescent multi-cellular layer. They also block a considerable amount of heat by coming into contact with the foamed-up THERMO-LAG structure, using the heat from the fire for decomposition of the mass. This heat is thus rendered unavailable to penetrate the un-vaporized material.

It is a well-known fact that an important component of a fire is radiation. However, ordinary commercial fire retardant materials or heat transmission materials, such as used on steel, have not utilized this technology. The important criterion here is to absorb the minimum and reflect the maximum amount of heat energy by radiation. In aerospace jargon, this means producing a low alpha over epsilon ratio. This has been accomplished by THERMO-LAG materials, comprising a significant advance in the state-of-the-art for fireproofing and fire retardant materials.

In simplest form, THERMO-LAG is used for commercial applications in coatings applied approximately 0.005 inches thick. This is comparable to two coats of paint. In this thickness, THERMO-LAG can be used to protect materials such as cardboard, wood, plastics and other combustibles from burning. Two THERMO-LAG formulations have been selected for commercial use: THERMO-LAG 220 and THERMO-LAG 330, subliming at 220°F and 400°F respectively.

THERMO-LAG 220 is a water-based material; THERMO-LAG 330 is solvent based. Both are quick drying; both have

been evaluated by the Underwriters' Laboratories. In addition, THERMO-LAG 220 is one of the few materials ever approved for protection of combustibles by Factory Mutual Research Corporation in Boston.

THERMO-LAG 220 has a flame spread of 0, a fuel contributed rating of 0, and a smoke developed rating of 0, as determined by the Underwriters' Laboratories in ASTM E-84 tunnel tests. THERMO-LAG 330 has a UL rating of 5 flame spread, 0 smoke developed and 0 fuel contributed. (The ratings are determined on a comparison basis, with asbestos board the standard for 0 and untreated Douglas fir being given a rating of 100.)

The application of THERMO-LAG, particularly on materials such as cardboard, is indeed dramatic. When a coating of 0.005 inches is applied to the cardboard, the exposure to a typical flame will not cause the cardboard to combust, regardless of the duration of exposure. After some time (in the standard two-coat thickness of 0.005 inches, from twelve to seventeen minutes), dehydration will cause the cardboard to become brittle and crumble, but it will not combust.

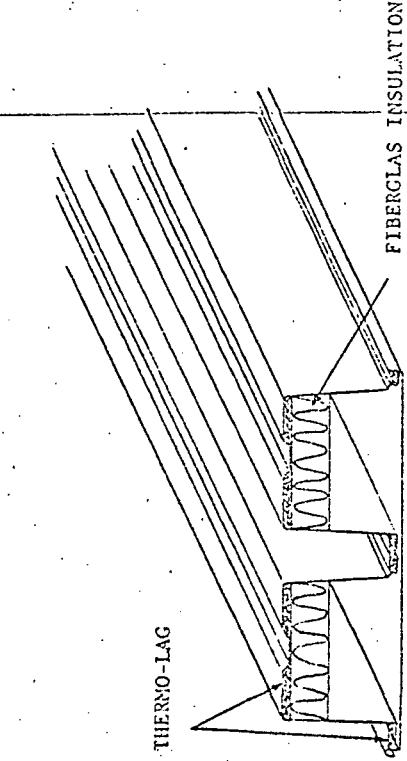
Present applications of THERMO-LAG extend from warehouse complex containers and shelves through other industrial and institutional use where a low flame spread is vital. Many items are being introduced on the market which have been rendered non-combustible by the application of THERMO-LAG.

In the case of structural steel applications, the particular utility of THERMO-LAG is its economy of application. It can be applied during production, minimizing the requirement for less reliable and more costly field application. A fire wall is a typical example of factory-applied fire protection. THERMO-LAG can be sprayed or otherwise dispensed in small thicknesses to the interior of the structure. The resultant product is lightweight, efficient and economical. For example, one-half inch of THERMO-LAG dispensed in one application performs the same function as four layers of one-half inch gypsum board. The applied cost is considerably lower, as continuing process equipment can replace the less efficient in situ installation, where considerable cutting, drilling, fitting in place, etc., is required.

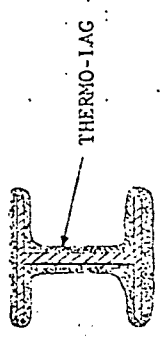
A schematic depicting some typical metal constructions employing THERMO-LAG as well as a figure showing a typical temperature response are included on the following pages. Please note the asymptotic temperature behavior of THERMO-LAG to the 220°F level. In addition to fire protection, THERMO-LAG also offers significant sound deadening, stiffening of low gauge partitions, stability, and flexibility in design.

A considerable amount of testing has also been done in the area of roof tops and structural beams and columns. THERMO-LAG in a thickness of approximately 0.150 inches will

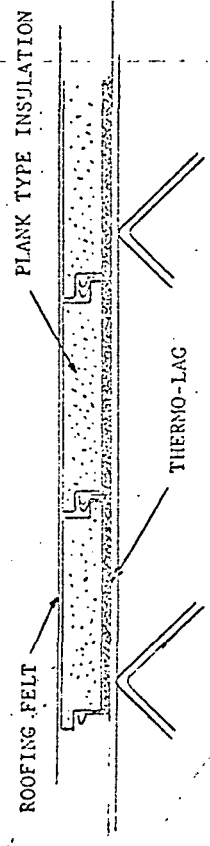




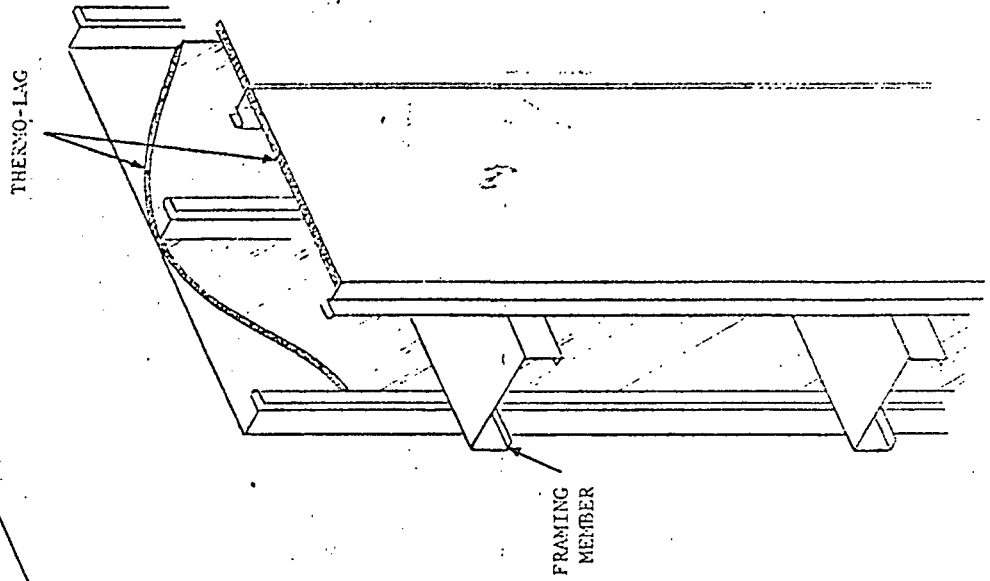
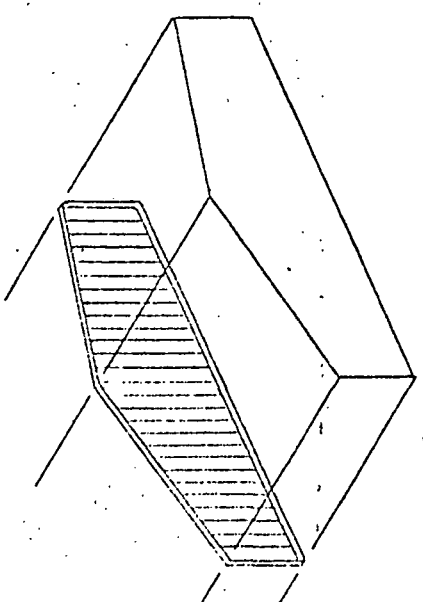
STRUCTURAL BEAMS



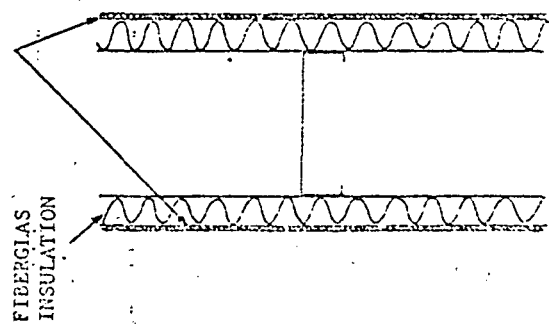
PRE-INSULATED ROOF - PLANK TYPE



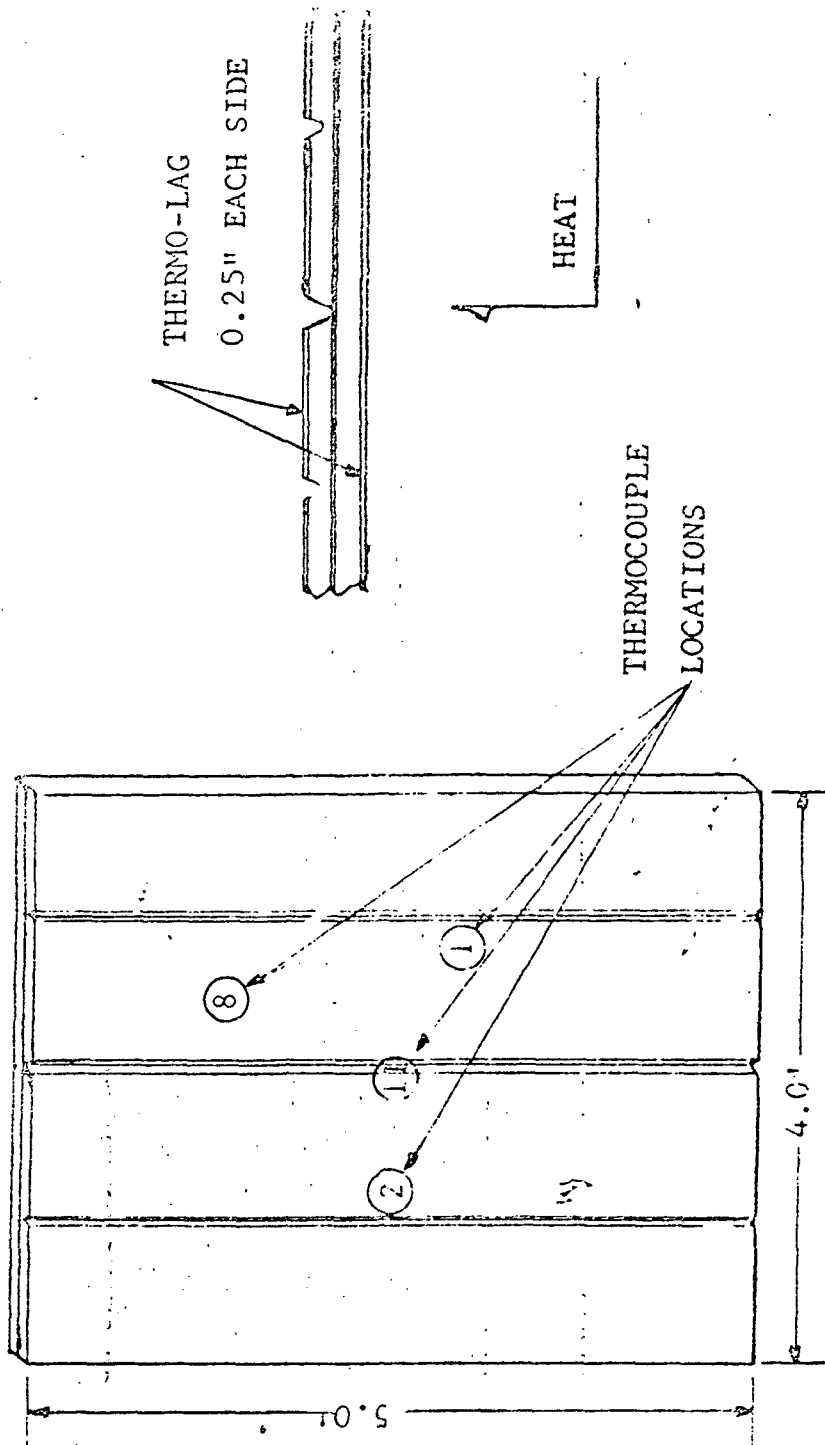
PLAN VIEW



THERMO-LAG

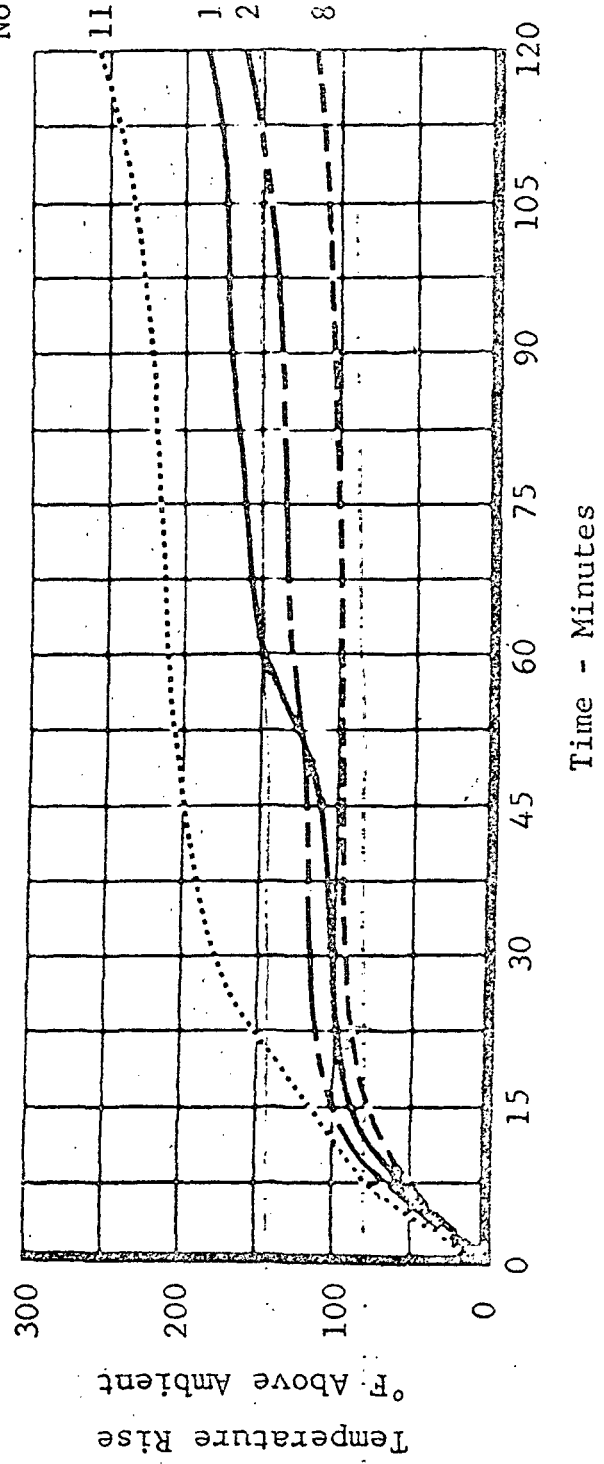


... VERTICAL SECTION



S K E T C H   O F   T E S T   S P E C I M E N

Thermocouple  
No.



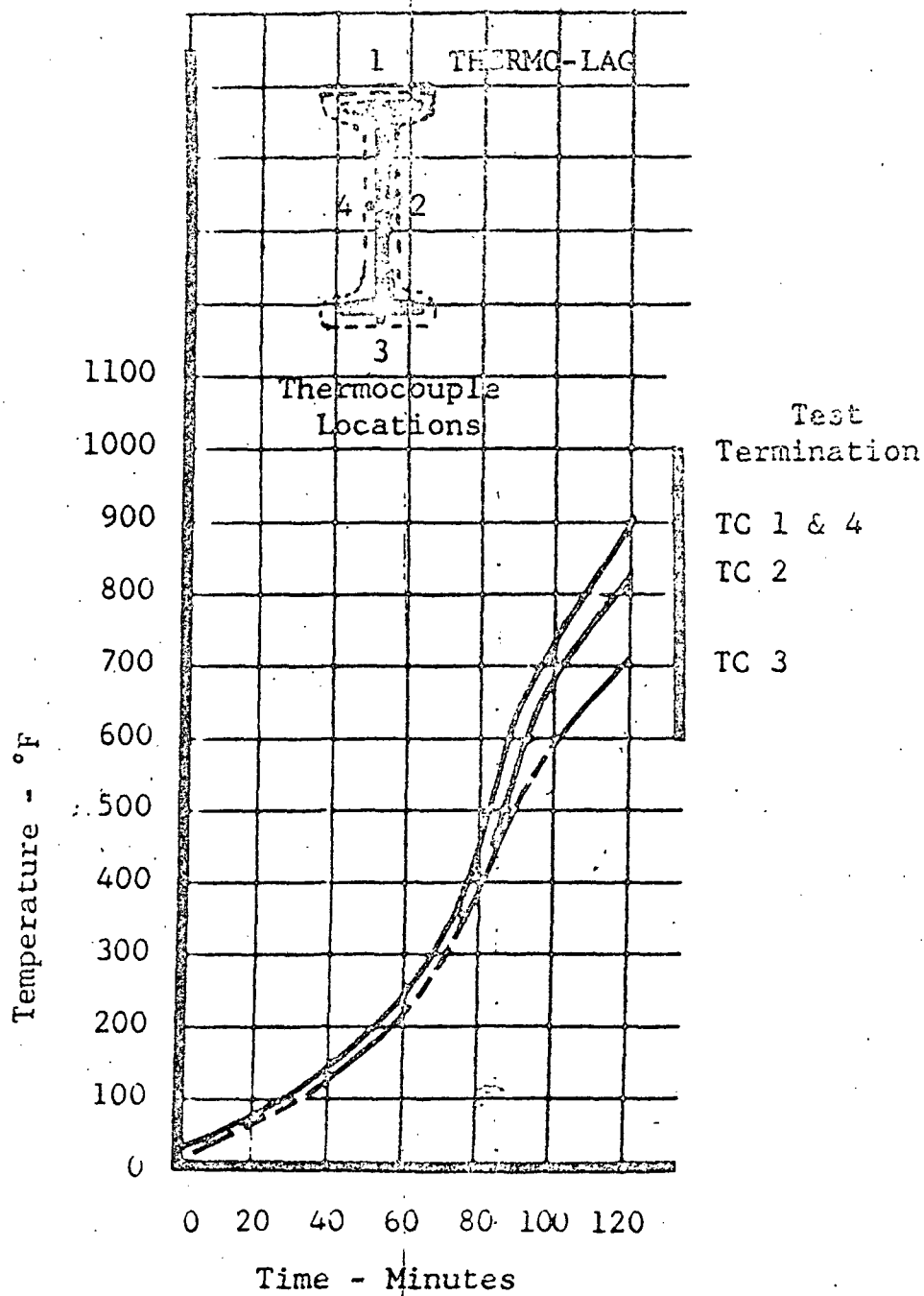
THERMAL RESPONSE OF STEEL WALL

give two hours' fire protection, comparable to that provided by four inches of concrete and 0.500 inches of a state-of-the-art intumescent coating. The total applied cost of THERMO-LAG is thus appreciably lower.

Structural segments have been subjected to simulated fire tests in accord with ASTM E-119 procedures, with the results as depicted on the following page. Please note that none of the thermocouples exceed a temperature rise of 1000°F in the prescribed time limit.

Still another revolutionary development in THERMO-LAG materials is "instant fireproofing" via flexible, pressure sensitive tapes. The tapes are a three-part system consisting of a given thickness of THERMO-LAG, a contact adhesive for easy application and a vapor barrier which provides a protective and decorative finish. This system will prove effective for the protection of electrical circuitry and small diameter items requiring low cost but effective fire protection.

THERMO-LAG has also undergone a considerable amount of environmental testing. Weatherometer for accelerated life; humidity; salt spray; impact; abrasion--these are but a few of the exposure tests that have been performed. A complete report on tests performed in accord with Federal Test Standard 141a is available upon request.



TRANSIENT RESPONSE - 16" STEEL BEAM  
 PROTECTED WITH 0.150" THERMO-LAG

## Conclusion

In summation, THERMO-LAG represents an example of advanced technology transfer yet to come in many other areas. Aerospace developed technology for protection from intense heat is effectively utilized in commercial THERMO-LAG fire retardant materials. Properties range from rigid to a pliable tape, with thermostatic temperature control capabilities as low as 200°F upward to 1000°F.

THERMO-LAG not only provides a unique method of fire retardancy and heat transmission control but also one that is more economical, efficient and reliable than conventional materials. THERMO-LAG is adaptable in use, permitting factory as well as field installation, resulting in broader use via wider availability and in appreciably reduced costs.