FLAME RETARDANT - FIRE RESISTANT CONVEYOR and ELEVATOR BELTING

A GENERAL OVERVIEW

of

MAJOR BURNING TEST PROCEDURES

for

BELT QUALIFICATION and APPROVAL

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October 1984

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ABSTRACT

Conveyor and elevator belts are made of organic materials and virtually any belt will ignite and propagate flame if the igniting fuel load is large enough and other conditions for combustion are present. Therefore belting may contribute to the ignition and propagation of fires which can present serious hazards to property and life, especially in confined environments and in those where volatile dusts, gases or vapors are present or combustible materials are carried. What then is meant by the classification given some belts . . . "Flame Retardant" or "Fire Resistant"? These labels designate specific belting styles whose flame retardant (fire resistant) properties have been improved markedly through extensive investigation of fires and development of belting constructions throughout the world during the past 30 years substantially reducing the potential contribution of belts to fire hazards. Such belting is now manufactured for these installations with a much greater fire resistant property than that of the ordinary rubber and cotton products of a few decades ago or of the standard undesignated belting made for general use today.

To distinguish and identify these flame retardant (fire resistant) belts, official regulatory agencies in the industrialized nations around the world have established a wide variety of burning test procedures, simulating to the extent considered practical, actual end use fire scenarios, to observe the burning performance of any belt. Standards of fire performance have been set forth in accordance with the results of these test procedures, and approval (or qualification) offered formally on the basis of such tests. Therefore, the terminology "flame retardant" ("fire resistant") applied to any conveyor belting advertised in promotional

literature and stamped on the covers of the belt itself, denotes satisfactory performance in accordance with the standards of such specified test procedures and identifies the improved flame retardant properties contrasted to those of any standard belting type which does not bear this classification.

All of these many flame retardant tests are not identical, for they do not follow exactly the same test procedures nor regard the same variables. However, every test in general use in the world today produces results which are sufficiently discriminatory to categorize belting qualitatively as of low fire resistance or high fire resistance character, and afford a rational basis for a "pass/fail" distinction.

Currently most countries require some form of "flame test", attempting to relate ignitability and flame propagation. Some are small scale, burning relatively small belt specimens in a laboratory chamber, permitting testing of many samples at reasonable cost. Some are large scale, testing full width samples of significant length in galleries simulating a mine entry or grain elevator leg, using high levels of ignition flux. In addition, practically all countries require a test of the belt's contribution to ignition in a stalled belt condition, described as a "drum friction test". No test or group of tests quantitatively consider all of the recognized variables of various fire scenarios. Reliable authorities conclude that it may never be possible to develop a totally conclusive test method to quantitatively measure with precision the final relative fire resistant properties of a wide variety of materials, since the combination of variables in an actual fire is almost limitless. However, by observing and understanding the flame retardant testing and approvals system prescribed by regulation or law or generally accepted within an industry, belt users may specify "flame retardant" belting to contribute to their overall fire prevention and fire control programs.

Demonstrable improvement in the levels of ignition heat flux, rate and extent of flame propagation, combustion heat release, and other factors cumulatively supporting flame retardance, has been accomplished through a complex design and engineering program in belt manufacturing. Obviously all of the other functional properties essential to the practical performance of the conveyor had to be regarded as well. The selection and arrangement of basic textile reinforcing yarns and elastomer components and the addition of various chemical flame inhibitors required for increased levels of flame retardance, generally predisposed some sacrifice in other belt properties such as abrasion and oil resistance or applicability in inclined installations. Improved flame retardance characteristically resulted in increased belting costs. So a factual assessment of many factors had to be made when adding this flame retardant property to belting.

It is recognized that any effective fire prevention and control program must be developed by management and supervision specifically for each unique installation, so widely varied are the operational conditions and resulting fire hazards. The selection of belting with flame retardant properties is only a small though significant facet of a totally integrated program. The installation of fire detection and suppression systems, use of adequate ventilation equipment, recognition and control of ignition sources, persistent personnel training in satisfactory housekeeping and maintenance routines, and many other detailed programs must be coordinated, always regarding the practical and most efficient operation of the facility. Selection of flame retardant belting must always be made in recognition and in support of all of these other interrelated programs. No total program can be regarded as totally fail-safe, so constant attention to all potentially contributive factors is imperative.

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BACKGROUND

In this century the belt conveyor has become the major component of bulk materials handling systems throughout the industrialized world. In the mining and processing of coal and other minerals, in the harvesting and storage of grain and a wide variety of agricultural commodities, and in the manufacture and distribution of an almost infinite number of products, conveyor belt systems have proven to be in many installations the most efficient means of moving materials over varying distances at controlled rates, and at lowest cost.

The very nature of many conveyor systems, however, demands consideration of potential fire hazard. Often the materials conveyed are themselves combustible under certain conditions, or may produce dusts or gases as they are handled which can be ignited, and possibly exploded. The conveyor may be operated in or through an environment where the electrical lighting or the operation and maintenance of the powered machinery might provide energy release in the form of a spark or arc to cause ignition and fire of the surrounding structures, which may be of wood or of other flammable material. The belting itself may be ignited under certain conditions and may support combustion and flame propagation in a major fire.

Fire originating from any source in the area surrounding conveying systems presents a serious hazard. A fire usually results in the loss of substantial amounts of the material being conveyed, the loss of production in the entire operation causing a costly shutdown of a major facility, and even present possibilities of injury or loss of life. A fire once started may be difficult to control and may propagate extensively, particularly in a confined environment; illustratively, the entries and cross-cuts of an underground coal mine, the horizontal enclosed belt tunnels and encased elevator legs of a grain elevator, or belts threaded through the entire operation of a package distribution center. Under such circumstances the products of combustion, most particularly carbon monoxide, might fill the work space with deadly gas in a very short time, thus presenting a serious hazard to the lives of the workers present.

Through the years serious fires have occurred in many belt conveyor installations throughout the world. To combat this hazard, long-range programs have been intensively promoted to identify the causes of explosions and fires and to minimize or remove every causative factor. For at least three decades industry itself, insurance underwriters, government regulatory agencies, and manufacturers of conveyor equipment, including those that produce conveyor belting, have cooperated in an allout effort to reduce the number and consequence of fires. Positive accomplishments in practically every industry can be commended. A prime example is the work done by regulatory agencies, mining associations, and manufacturers of conveying equipment in the underground mining area. Broad progams of fire prevention have been implemented, acccomplishing:

1. Installation of fire suppression systems, sprinkler protection and the like, to minimize propagation and damage.
2. Reduction of gas, vapor, and dust concentrations in the area by eliminating or reducing their production or by installing adequate means of removal with proper ventilation systems.
3. Control of ignition sources; isolation of electrical equipment, prevention of the accummulation of static charges, grounding all equipment, avoiding the build-up of frictional heat, and the rejection of foreign metal objects into the material flow.

4. Maximizing housekeeping and maintenance duties that relate to fire prevention and training workers and supervisors in fire detection and fire fighting techniques.

5. Consideration of fire prevention and control in the design and structure of all new and supplemental physical facilities.

6. Designing operational equipment with fire prevention in mind; providing the safest possible procedures for storing, handling, and using fuels and lubricating materials.

7. Development of conveyor belting itself with maximum flame retardant (fire resistant) characteristics, consistent with other essential functional properties; belting which may not be ignited by friction or throw off sparks or glowing particles that might ignite combustible materials in the environment; belting which is self-extinguishing in many practical circumstances or whose physical characteristics would minimize propagation and intensification of any fire.

It is encouraging to note in many publications very significant reductions in the incidence of fires and in the magnitude of damage reported resulting from these concentrated fire prevention programs, although reliable statistics on fire incidence in a wide variety of applications are not always readily available for broad quantitative analysis.

But despite this laudable improvement in the statistics reflected generally throughout the world, of which mining is only illustrative, there continue to occur serious explosions and fires even in recent years. There is great incentive toward further improvement in every area. During an eight-day period in 1977 five explosions and fires occurred in major grain elevators which resulted in 59 death and 48 injuries and created commodity losses, equipment and facility damages amounting to millions of dollars. A few months ago a disastrous fire ravaged a Japanese coal mine with a loss of 83 lives. Since the life and health of even a single human individual cannot be evaluated statistically, it is incumbent upon all agencies directly concerned to continue these programs well begun toward the final elimination of fire hazards.

CONVEYOR BELTING IN FIRES

Early in the investigations of incidents of explosion and fire, the particular conveyor belting itself in use at the time was identified in a small but significant number of the events as a possible contributor to fire propagation or as a possible source of ignition. Categorically, this involvement has been classified for investigation into one or more of three scenarios:

1. Exposure of the belt to a small intensive external fire, the belt igniting, and then propagating the flame to surrounding areas and materials. Generally the likelihood of this having occurred with a moving belt proved relatively remote, since the transmission of sufficient heat energy for ignition from a localized stationary flame to a moving belt was difficult to achieve. However, a stuck roller was found to generate sufficient frictional heat to ignite surrounding dust and when a belt was stopped the ensuing flame sometimes ignited that section of belting. In similar fashion, the belt rubbing against a stationary portion of the conveyor structure seemed to result in a sufficient distribution of heat energy generated along the moving belt that the belt would not burst into flame, but when

the belt stopped the concentration of heat ignited that small section of belt. In both instances of frictional heating this flaming section often resulted in extensive flame propagation.

2. In major conflagrations, involving outside sources of heat such as burning oil, chute lining, coal, or materials carried, or even components of the structure of the installation itself, the belt was found to add substantial heat energy as a fuel source, even propagating the flame beyond the area of influence of the primary fire.

3. When a belt was stalled (e.g. from a roof fall in a mine, clogging the boot in a grain elevator, or drive misalignment causing the belt to jam on one side in the belt takeup or other component part) the belting itself forced against a continuously rotating drive drum created excessive heat and ignited certain belt materials, even throwing sparks or glowing materials to the surrounding area, and igniting dusts or other flammable substances.

Each of these basic scenarios laid the foundation for effective improvement in the flame retardant (fire resistant) properties of belting.

As natural rubber covers and cotton belting carcasses have given way to belting reinforced with nylon and polyester yarns saturated and covered with polyvinyl chloride (PVC), neoprene (polychloroprene), or styrene-butadiene-rubber (SBR), compounded with additions of flame retardant materials, the belting industry has been able to develop belting products whose flame retardant properties are markedly improved. This transformation has contributed in a most effective way to the reduction of fires.

Many of the major industrialized nations have devised fire resistance test methods as a relative measure of the ability of a belting material to resist ignition and flame spread. These properties can be expected to vary with physical variables of belt width and thickness, relative space dimensions in which the belt is installed, ignitor heat flux (intensity and time of exposure), air velocity, burning orientation, as well as the critical heat flux characteristic of the belting material itself required to sustain burning. This critical level is in turn related to the heat release rate of the material under specified burning conditions, the direction and magnitude of air flow at the flame front, the radiation from adjacent structures back to the belt, and heat input from other burning materials. It is well to note that virtually all belting made of organic substances can be ignited and will propagate flame under certain conditions. The test conditions and procedures of both small-scale and large-scale tests prescribe arbitrarily selected physical conditions designed to simulate as nearly as possible a realistic typical scenario in an actual field application. Recognizing, however, the number of physical variables affecting ignition and flame spread which are present in an almost infinite variety of combinations in an actual conveyor belt system, test conditions can at best only generally approximate those which might be found in any specific fire.

Standards of performance based on the results of such tests are obviously established at any time to:

1. Sort out materials whose performance is definitely of low flame retardant level (e.g. that approximating the fire performance of dry red oak wood), from those which can be distinctly recognized as more highly flame retardant.
2. Encourage development of improved materials by gradually changing performance standards to embrace the practical levels of higher fire resistant products whose performance seems to reflect a significant improvement.
3. Establish a qualitative means of generally maintaining reasonably consistent fire retardant properties throughout production of "qualified" belting types in the entire industry.

Theoretically, such tests might well have sought to measure: self-sustained burning, ease of ignition, rate of heat release, critical radiant flux, smoke generation, and toxicity of combustion products; nevertheless, the current flame tests, both small-scale and large-scale, relate to only the self-sustained burning fire performance characteristic. (As will be noted later, the drum friction test does measure the ignition characteristic under one form of energy input.) Self-sustained burning must be recognized as an important parameter, but it must be realized that the probability of such performance for a given conveyor belt is a function of the characteristics of the ignition source and the operational environment as well as the properties of the conveyor belt itself.

SMALL-SCALE FLAME TESTING

In the United States, Great Britain, Germany and many other countries flame testing involves small belting specimens ignited by a carefully controlled heat source for a given period of time. The test purports to demonstrate the extinguishing properties of the belt material by noting the time required for the flame to go out after the heat source is removed, noting then also any occurrence and duration of glowing. This test prescribes a totally inadequate ignition heat source, is very dependent upon air velocity, demands a critical orientation of the test specimen, and is quite dependent upon sample width, length and thickness. Yet the test results clearly distinguish between low flame retardant belts of the natural rubber/cotton types and those purposefully made with PVC, neoprene or flame retardant SBR using nylon or polyester for reinforcement. Results consistently direct compounders to the use of adequate levels of flame retardant additives to pass this qualitative "go-no go" test. It is generally conceded that the uncontrolled variables present prohibit a realistic quantitative comparison among the highly fire resistant materials. A small-scale test is the only qualification presently required in the United States for underground mining by the Mine Safety and Health Administration provided the conveyor system is properly equipped with sprinklers, motion detectors, alignment devices and the like.

LARGE-SCALE FLAME TESTING

In large-scale tests, particularly promoted in Germany and followed in special studies in the United States and elsewhere, full width and relatively long samples of belting are suspended horizontally in simulated colliaries of full scale design and ignited at one end with large quantities of wood or other large sources of heat energy. Assuming a specific belt width, thickness, distance of belt to ceiling, ignitor input flux, and other physical variables, a belt "qualifies" if it does not propagate flame throughout its entire length after the ignition source has been burned out or removed. A scaled down but similar test, known as the "propane gallery test" is conducted in similar fashion. The interpretation of the results of these large-scale fire tests is similarly frustrating for more than very general classification because of the interaction of the influence of the many variables which will be found in a wide variety of end use conditions.

Illustrating the difficulties in specifying and controlling the variables involved in such tests, a representative variety of flame retardant belts was tested by one of the major fire insurance companies. No belt selected for study could be ignited under a set of assumed practical conditions when the belt was strung low in the entry. Changing only the height of the belt by lifting it to an optimum distance from the ceiling, substantially every full width belt ignited, with a reasonable heat flux input, and was eventually consumed. By arbitrarily selecting physical parameters such as ignitor heat flux and application area, belt width in relation to chamber width, air direction and velocity, and belt height in relation to the ceiling, a group of belt samples can be so tested in this manner so as to self extinguish before the flame spreads to the end of each sample. Thus "quantitative comparisons" are made between such belts. The validity of such comparisons as a measure of relative quantitative flame retardant levels in eventual practical applications obviously depends upon the accidental similarity between assumed physical conditions of the large-scale test and those actually encountered in the belt conveyor system in applications in the field.

PROPOSED METHODS

Recent work done by the US Bureau of Mines toward the development of a test method to overcome the limitations of existing laboratory scale methods and perfect the principles of large-scale testing seeks to measure both ignitability and flammability in quantitative terms. Fixing air velocity, ignitor heat flux, belt width and height of belt sample in a given test changer, data is developed, while thus controlling the burning of a belt sample, on flame spread rate, heat release rate and the critical ignitor heat flux. These three factors are then mathematically combined to give a flammability index. The object of this extensive work was to provide a more reliable measure of the potential fire hazard that may be practically encountered with conveyor belts. Once again, all of the variables are difficult to recognize and control. The data accumulated by this method is somewhat difficult to correlate with other tests and explain. Nevertheless, better than any method currently prescribed, this proposed test procedure seems sufficiently sensitive at least to discriminate clearly between belts of low and high fire resistance and may prove to be the forerunner of methods yet to come which will update the present flame tests in the world.

Interesting studies are considered in the field of measuring critical radiant flux as a possible quantitative indicator of a belt's flame retardant properties. Extinguishment of a fire in a section of belting occurs when the minimum heat flux into the substrate falls below some critical value dependent upon the properties of the belt itself. This is not unlike the small-scale flame test where extinguishment is influenced by feedback only from the flame front, in which comparisons are made by the number of seconds required for the flame to go out. In the proposed Critical Radiant Flux Test a radiant panel is so arranged as to enhance the heat feedback mechanism in a gradually diminishing fashion along the belt sample until the flame is extinguished, permitting comparisons measuring the critical radiant flux. It may give a more accurate means of comparing flame propagation and burning heat energy release values of various belting structures.

DRUM FRICTION TESTING

Most of the work in conveyor belting design has been concentrated on the first two scenarios (pages 7 and 8) to minimize the possible role of the belt itself in flame propagation. The third scenario (page 8), well illustrated by a stalled or stuck belt against which the drive pulley continues to turn, points to the hazard of possible fire generation within the belt itself. Improvement of belt properties in this type situation can thus be qualified as fire prevention rather than fire control. Statistical studies reveal that a very substantial portion of mine fires have been caused by friction in this manner. The National Coal Board investigating conveyor fires over a ten-year period preceding the 1950 Creswell Colliary disaster found that approximately one-third of all fires were generated in the belts which were caused largely by such frictional phenomenon. Investigations revealed that a stalled belt of the type generally used three decades ago could be readily ignited when held on a rotating drum, and glowing particles and sparks falling from a smoldering belt were capable of igniting coal dust. Belts which in themselves did not flame or glow could ignite coal dust sprinkled on them when the driving drum temperature reached approximately 300 degrees centigrade.

In a drum friction test, a section of belting is held wrapped around a rotating drum simulating the drive pulley in an actual installation. Provision for variation in tension, in speed of rotation, air flow at the drive, and time is provided. Conditions may then reproduce as nearly as possible some of the actual operating situations in a specific installation. A test is continued until the belt parts or a maximum allowable drum surface temperature has been exceeded.

To qualify,

a. the belt must show no evidence of flame or glow in the test specimen while the belting is in contact with the drum or in the parted ends after it has failed;

b. the drum temperature must not exceed a predetermined maximum temperature limit, determined by the minimum temperature of ignition of any dusts, gases, or flammable material likely to be present, and

c. no glowing particles of sparks may be thrown off into the environment.

The most obvious deficiencies in this test procedure as currently followed result from the use of a bare steel drum while most drive pulleys in actual use are "lagged" with a variety of elastomeric materials. Further, the actual interface is often covered with a contaminant layer of dust, crushed grain or coal, and the like, markedly altering the interfacial structure. The results of such a drum friction test therefore are not necessarily directly correlatable to other flame propagation tests of the types previously discussed. Nevertheless, the United Kingdom (National Coal Board), the European Economic Community, Canada, Germany, France, and many other countries have added such a drum friction test to their flame tests as an essential for belt qualification and some include the requirement that the belt must part during the course of the test.

CONCLUSION

Since virtually any conveyor or elevator belt may ignite and propagate flame, fire prevention and control programs for conveying systems in hazardous environments must embrace a total systems approach, including: belt slippage-sequence switches and/or motor torque detectors which will shut down the drive if the belt stalls, belt lateral motion detectors, automatic heat detection sensors to disclose any heated bearings, fire detection and extensive fire suppression and control equipment, and continuous personnel training in maintenance and housekeeping. Such are unfortunately mechanically vulnerable and subject to human error and must be constantly monitered.

As responsible management personnel in any operation where belt conveyors are used assess their fire hazard potential regarding existant operational conditions and requirements, a basic "Flame Retardant" belt should be installed as one means of reinforcing such a total fire prevention and control program. While there may be no such thing as "fire proof" belting, the informed user should find satisfaction in the apparent improvement which he can expect by specifying "Flame Retardant" when he purchases new or replacement belting.

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