ALTERNATIVE DAILY COVER MATERIALS AND SUBTITLE D - CONTROL OF FIRES

A SUMMARY OF TECHNICAL INFORMATION FROM THE PUBLIC DOMAIN

Compiled and Edited by
Paul A. Kittle, Ph.D.

Rusmar Incorporated
West Chester, PA

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EXECUTIVE SUMMARY

(1) RCRA Subtitle D requires all daily cover materials to control fires.

(2) Fires generally have two modes: the flaming mode, and/or the surface combustion mode, and both of these modes can be operative simultaneously.

(3) Fires can be extinguished by cooling.

(4) Fires can be extinguished by oxygen dilution.

(5) Fires can be extinguished by fuel removal.

(6) Flaming mode fires can be extinguished by chemical flame inhibition.

(7) There are no circumstances where fires are controlled by adding combustible substances to the fire zone.

(8) ASTM E1354 Cone Calorimeter evaluations define that at least one comparative set (conventional and flame retardant) of tarpaulins/geotextiles offered as alternative daily cover materials are combustible, and that the differences in combustibility between the conventional material and the flame retardant material are insignificant.

INTRODUCTION -
The RCRA Subtitle D regulations - Criteria For Municipal Solid Waste Landfills (1) become effective on October 9, 1993. Of specific interest is paragraph 258.21, Cover Material Requirements, which state:

> **(a) Except as provided in paragraph (b) of this section, the owners or operators of all MSWLF units must cover disposed solid waste with six inches of earthen material at the end of each operating day, or at more frequent intervals, if necessary, to control disease vectors, fires, odors, blowing litter, and scavenging.**

> **(b) Alternative materials of an alternative thickness (other than at least six inches of earthen material) may be approved by the Director of an approved State if the owner or operator demonstrates that the alternative material and thickness control disease vectors, fires, odors, blowing litter, and scavenging without presenting a threat to human health and the environment.**

> **(c) The Director of an approved State may grant a temporary waiver from the requirement of paragraph (a) and (b) of this section if the owner or operator demonstrates that there are extreme seasonal climatic conditions that make meeting such requirements impractical.**

In some segments of the solid waste disposal industry these pending rules are being overlooked in that polyethylene, polypropylene, and other "plastic" tarpaulins/geotextiles are being used as daily cover, even though it is clear that these materials are generally flammable (2,3,4,5).

The identification and disclosure of the flammability characteristics of the tarpaulins/geotextiles commonly used for alternative daily cover materials has generated considerable discussion between the national, state, and local solid waste regulators and the manufacturers of these "flammable plastic" materials (6,7). The tarpaulin/geotextile counter argument proposes that these flammable materials will interfere with oxygen transport to the fire zone, thereby qualifying them as alternative daily cover materials capable of meeting the RCRA Subtitle D regulations for "control of fires". This position is clearly inadequate in that the melting points of the tarpaulins/geotextiles are quite low, and the manufacturer's own flammability data show that in a fire condition these materials melt easily (6,7).

The objective of this document is to review the commonly accepted techniques used for fire control, and, further, to suggest that adding flammable materials to the combustion zone is not an acceptable fire control technique, but exactly contrary to the acceptable technique called "Extinguishment by Fuel Removal".

The information herein presented has been extracted from literature available in the public domain and has been properly referenced for ease of subsequent access (8).

THEORY OF FIRE CONTROL

A composite definition derived from various dictionaries is that combustion is a reaction which is a continuous combination of a fuel (reducing agent) with certain elements, predominantly oxygen, free or combined (oxidizing agent). This combination exists with other elements, including fluorine and chlorine. The quality, which all these reactions have in common, is that they are exothermic, that is, the combustion process liberates heat.

For the purpose of this discussion, fire is referred to in its most usual form, involving rapid oxidation at elevated temperatures accompanied by the evolution of heated gaseous products of combustion and the emission of visible and invisible radiation.

The combustion process occurs in two modes: (1) the flaming type (including explosions); and, (2) the flameless surface type (including glowing embers).

For sustained burning, the flaming mode requires relatively high burning rates, expressed in terms of heat energy released per unit time, coupled with "acceptable" heat loss due to effluent gaseous combustion products and radiation. For equilibrium conditions, the heat energy generated and the heat energy lost to the environment, both of which are measured on a time basis, must balance. If the heat generation rate is in excess, the fire will grow; conversely, if the heat loss rate is in excess the fire will diminish. Obviously, the process is highly heat dependent.

One method of fire control does upset this heat balance. Water, the mainstay of fire fighting, can be applied to flaming mode fires and, as a result, increase the heat loss to the environment, allowing the fire's intensity to diminish. In addition to lowering the temperature, flaming mode fires can be

controlled by restricting the fuel supply (less reducing agent), restricting the oxygen supply (less oxidizing agent), and, finally, by inhibiting the combustion chain reactions. Altogether, flaming mode fires have four controlling influences.

By contrast, the surface combustion mode has only three controlling influences: temperature lowering, fuel restriction, and oxygen restriction.

These two modes are not mutually exclusive; they may occur singly or in combination. Flammable liquids and gases burn in the flaming mode only. Most solid plastics can be construed as 'frozen flammable liquids,' and, as such, will melt with sufficient thermal feedback prior to burning. The commonality of this variety of fuels is that they must vaporize and be diffused with oxygen immediately before burning.

Examples in which both modes exist are: solid carbonaceous fuels such as coal; solid carbohydrates such as sugars and starches; solid cellulosic/lignins such as wood, straw, brush, and similar vegetable materials; and thermosetting plastics which do not melt. With these latter materials, the early stages of combustion start in the flaming mode, due to the destructive distillation, with a gradual transition occurring toward the surface combustion mode, during which both modes are simultaneously in action. Ultimately, the flaming mode is terminated with the residual surface combustion mode existing alone. Examples in which the surface combustion mode exists alone are pure carbon, other readily oxidizable nonmetals, such as sulfur and phosphorus, and readily oxidizable metals, such as magnesium, aluminum, zirconium, uranium, sodium, and potassium.

EXTINGUISHMENT BY COOLING

Under fire conditions, water, applied as a straight stream or in a wide angle spray pattern, is the most effective means of removing heat from ordinary combustible materials, such as wood, straw, paper, cardboard, and other materials used in the construction and furnishing of buildings. The extinguishing mechanism depends upon cooling the solid fuel, thereby reducing and ultimately stopping the rate of release of combustible vapors and gases.

This cooling action also results in the formation of steam which, in compartment or structural fires, serves to partially dilute the ambient oxygen concentration. However, the effect is transitory, and, in outside fires, nonexistent.

The efficiency of an extinguishing agent as a cooling medium depends upon the specific and latent heat, as well as upon the boiling point. The superior properties of water can be attributed to the relatively high values of the specific heat, latent heat, and availability. Unfortunately water is heavy and a burden when transported from any significant distance. Its cooling action is performed by means of sequentially conducting, evaporating, and converting heat away from solid surfaces, which are burning or are hot from exposure.

Since heat is continuously being carried away by radiation, conduction, and convection, it is only necessary to absorb a small proportion of the total heat being evolved by the fire in order to extinguish it by cooling.

EXTINGUISHMENT BY OXYGEN DILUTION

Oxygen may be present as free gaseous oxygen in the atmosphere, or combined, as in the form of hypochlorites, chlorates, perchlorates, nitrates, chromates, oxides, and peroxides. The term "dilution" can only be applied to the gaseous state, because, in the combined state, oxygen is bonded into the molecule and no dilution is possible. Hence, chemicals in this category will always present a high level of hazard, and the oxygen dilution technique is useless in fighting fires with high concentrations of these materials present.

Since equal volumes of gases contain the same number of molecules, it is possible to compute gas densities from the molecular weights, as well as to rationalize that the percentage of oxygen in a space will be reduced when "foreign" gases, carbon dioxide or nitrogen, are injected into the same space. Steam may accomplish the same result, as already mentioned above. The necessary degree of oxygen dilution varies greatly with the particular fuel. For instance, wood is known to continue to burn at oxygen levels as low as 4-5%. By contrast, hydrocarbon gases usually will not burn when the oxygen level is below 15%. This observation correlates well with the chemistry of the fuel source.

Fires in closed spaces will, of course, consume oxygen, however, this cannot be relied on to achieve self-extinguishment, since combustion in oxygen-deficient atmospheres results in the copious generation of flammable gases due to incomplete combustion. This result can lead to an explosion when additional ventilation provides a new oxygen source.

A typical example of the effective use of the oxygen dilution principle is carbon dioxide being discharged in total flooding of closed spaces. In local application of carbon dioxide systems, the flame velocity, which varies with the fuel source, is suppressed. The residual velocity of the carbon dioxide/air gas stream, if properly applied, will overcome the flame velocity dynamically and will result in rapid extinguishment through the combined action of oxygen dilution and flame "blow-out".

EXTINGUISHMENT BY FUEL REMOVAL

A chemist would define a fuel as a reducing agent. A reducing agent is a substance which can reduce an oxidizing agent, losing one or more electrons in the process. The oxidizing agent acquires the transferred electrons. The net result of the electron transfer is:

(1) the reducing agent has been oxidized; and,
(2) the oxidizing agent has been reduced.

In all cases this electron transfer event emits heat and/or light energy. When this event occurs under "normal" conditions, it is combustion (controlled, like in a furnace or an engine), or commonly referred to as a fire (uncontrolled, like a forest fire or structure fire).

It is important to recognize that the oxidation/reduction always occur together - they may not occur separately - with the terms, oxidation and reduction, being relative.

For the flaming mode of combustion, it is necessary for solid and liquid fuels first to be vaporized, with the solid fuels being distilled pyrolytically, and the liquid fuels being evaporated. In some instances, such as the case of thermoplastics (polyethylene and polypropylene tarpaulins/geotextiles are thermoplastics), the solids are melted or fused, after which they vaporize. Flaming mode combustion follows vaporization.

The surface or glowing mode of combustion does not require this gasification because combustion occurs directly at the solid interface with the air; thus, burning rates are small compared with the flaming mode. Examples are wood, charcoal, coke, and combustible metals.

It is obvious that many materials can be classed as fuels having wide ranges of ignition temperatures, lower and upper flammable

limits in air, flash points (if liquid), compounded in some instances with chemical activity (decomposition), and solubility in water, which influences the type of fire control.

For solid fuels, another important influence on fire intensity (BTU/time unit) is the fuel array (dust, splinters, shavings, logs, or timbers), and whether that array is horizontal, vertical, cribbed, or piled. In each condition, the same fuel will have entirely different burning characteristics, but the fuel value, total BTUs available, will not be affected by the orientation.

From a chemical viewpoint, fuels can be categorized as follows:

(1) Carbon and other readily oxidizable nonmetals such as sulfur, phosphorus, and arsenic;

(2) Compounds rich in carbon and hydrogen (hydrocarbons);

(3) Compounds containing carbon, hydrogen, and oxygen, such as alcohols, aldehydes, organic acids, cellulose, and lignin (wood and vegetable material);

(4) Many metals and their alloys (including sodium, potassium, magnesium, aluminum, zinc, titanium, zirconium, and uranium).

Fuel removal can be accomplished literally by removing the fuel indirectly by shutting off the fuel vapors from combustion in the flaming mode, or, in the non-flaming mode, by covering the glowing fuel. Some special examples are:

(1) Large tanks of liquid flammables have been extinguished by the expedient of pumping the liquid from the burning tank to an isolated, safe tank;

(2) If a flammable liquid, like oil, has a flash point higher than the ambient storage temperature, then proper agitation of the liquid to raise the cooler bottom portion to the top, and correspondingly to displace the hot upper layer to the bottom of the tank, will result in starving the flames from the vapors.

(3) Forest fires are often interrupted and stopped by means of a fire break across the advancing flame front - removing the fuel source.

(4) The only practical method of extinguishing deepseated fires in silos and piles of solid combustible is removal of the fuel.

(5) The covering of liquid and solid burning fuels with blankets of fire fighting foams made by the aeration of solutions of water and foam concentrates. This method of fire attack has become standard procedure for aircraft crashes, large tank farms, and oil tanker fires.

(6) The covering of burning metals by various materials that are inert with respect to the specific metal involved. Examples are dry petroleum coke, various inorganic salts used singly or in eutectic proportions, sand, coal, foundry fluxes, soda ash, and similar materials.

EXTINGUISHMENT BY CHEMICAL FLAME INHIBITION

Extinguishment by cooling, extinguishment by oxygen dilution, and extinguishment by fuel removal are applicable extinguishing methods for all classes of fires of the flaming and glowing modes. Extinguishment by chemical flame inhibition applies to the flaming mode only. Since extinguishment by chemical flame inhibition applies only to the flaming mode of combustion, and that mode is minimal in most landfill type fires, this mode of extinguishment will not be discussed in this document.

THE USE OF FLAME RETARDANT MATERIALS (7)

Improvements in ignition control of materials have come about as a result of flame resistant treatments developed for both natural and synthetic polymeric materials. It is also possible to design polymeric systems in which a substantial fraction of the material is unavailable as fuel. Examples abound - filled polymers, halogenated monomers and polymers, and polymers based upon other chemistry than simple hydrocarbons.

However, it is important to recognize that claims for flame resistance have little meaning beyond the test method which was used to evaluate fire performance. Therefore, materials which resist ignition or behave acceptably in small scale tests, may be wholly inappropriate for use when more severe, or substantially different, fire conditions are encountered. The present state of materials fire testing makes it important that materials be tested under conditions which simulate, as closely as possible, expected real fire scenarios (2,3,7).

Flame spread tests are probably the best known fire performance tests. The most widely used of these are the Steiner Tunnel Test (ASTM E84), and the Radiant Panel Test (ASTM E162). These tests attempt to simulate the spread of fire (note that flame spread

tests involve materials already burning, thereby defining that these materials are combustible) across a plane surface and may include the imposition of a known external radiant flux (2,3,7).

In 1981 it was recognized that the role of tests defining the heat release rates during combustion would likely become important in evaluating the combustion characteristics of potentially flammable substances. However, at that time no standard tests existed (2).

In 1991, the National Fire Protection Association reported that several tests had been developed for determining the heat release rates during combustion. Two standard tests now exist: ASTM E906 (NFPA 263), Method for Testing for Heat and Visible Smoke Release Rates for Materials and Products, and ASTM E1354, Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products, Using an Oxygen Consumption Calorimeter. These tests measure the rate at which heat is produced as a function of imposed radiant energy. Because of the importance of an imposed radiant energy flux in real fire hazards, these measurements promised to be of increased importance in predicting fire hazards (2,3,7).

In actual fact, this was an astute prediction, as shown by the fact that Underwriter's Laboratories retrofitted their Steiner Tunnel Test (ASTM E84) facility with instrumentation to allow heat and smoke release data to be obtained along with the normal Steiner Tunnel Test information (9).

Ideally, fire resistant treatments should be detectable as diminished heat release measurements. At present, this appears to be true only for a few materials, notably wood impregnated with fire resistive compounds. Generally, decreased heat release is affected by the selection of materials which are inherently of low combustibility, such as concrete, metal, glass, and the like. Some success has been obtained in recent years with fire resistant coatings contributing to a material's lowered flame spread (2,3,7).

Unfortunately the materials being offered to the sanitary landfill alternative daily cover market as "flame retardant" do not seem to deliver very much benefit over those more conventional materials which are not classed as "flame retardant". Comparison sets of materials are not readily available since not many tarpaulin/geotextile providers offer the "same" material in both a "flame retardant" and a conventional, which must be called flammable, by default,

versions.

One tarpaulin/geotextile manufacturer, Cormier Textiles Products, Inc., Sanford, Maine, does supply their polyethylene tarpaulin material, WP-1440 in both a flammable and a flame retardant version, WP-1440-FR. Samples of both of these materials have been subjected to the ASTM E1354 Cone Calorimeter evaluation. In fact, since the results from both samples were so similar, suggesting no noticeable flame retardant behavior, a second sample of the WP-1440-FR was tested. It is noteworthy that both "flame retardant" samples were obtained from the Commonwealth of Pennsylvania, Department of Environmental Resources, where they had been submitted for consideration as alternative daily cover material. More importantly, the fact that the solid waste rules in Pennsylvania define that daily cover material must be non-combustible, makes these results even more outstanding. The ASTM E1354 Cone Calorimeter data are shown on the next pages - (1) the Cormier Textiles WP-1440, with an ignition time of 31 seconds, and the maximum heat release rate at 60 seconds after the start of the test; (2) the Cormier Textiles WP-1440-FR, sample #1, with an ignition time of 39 seconds, and a maximum heat release rate at about 65 seconds after the start of the test; (3) the Cormier Textiles WP-1440-FR, sample #2, with an ignition time of 39 seconds, and a maximum heat release rate at about 75 seconds after the start of the test; and (4)the heat release rates of all three samples plotted on the same scale so that the comparisons are more easily made.

It is important to note that all of these evaluations were done in triplicate using 25 KW/sq. meter as the radiant flux, exactly the same as the previously developed data. The evaluations were performed by Underwriters Laboratories.

CONCLUSIONS

(1)RCRA Subtitle D requires all daily cover materials to control fires.

(2) Fires generally have two modes: the flaming mode, and/or the surface combustion mode, and both of these modes can both be operative simultaneously.

(3) Fires can be extinguished by cooling.

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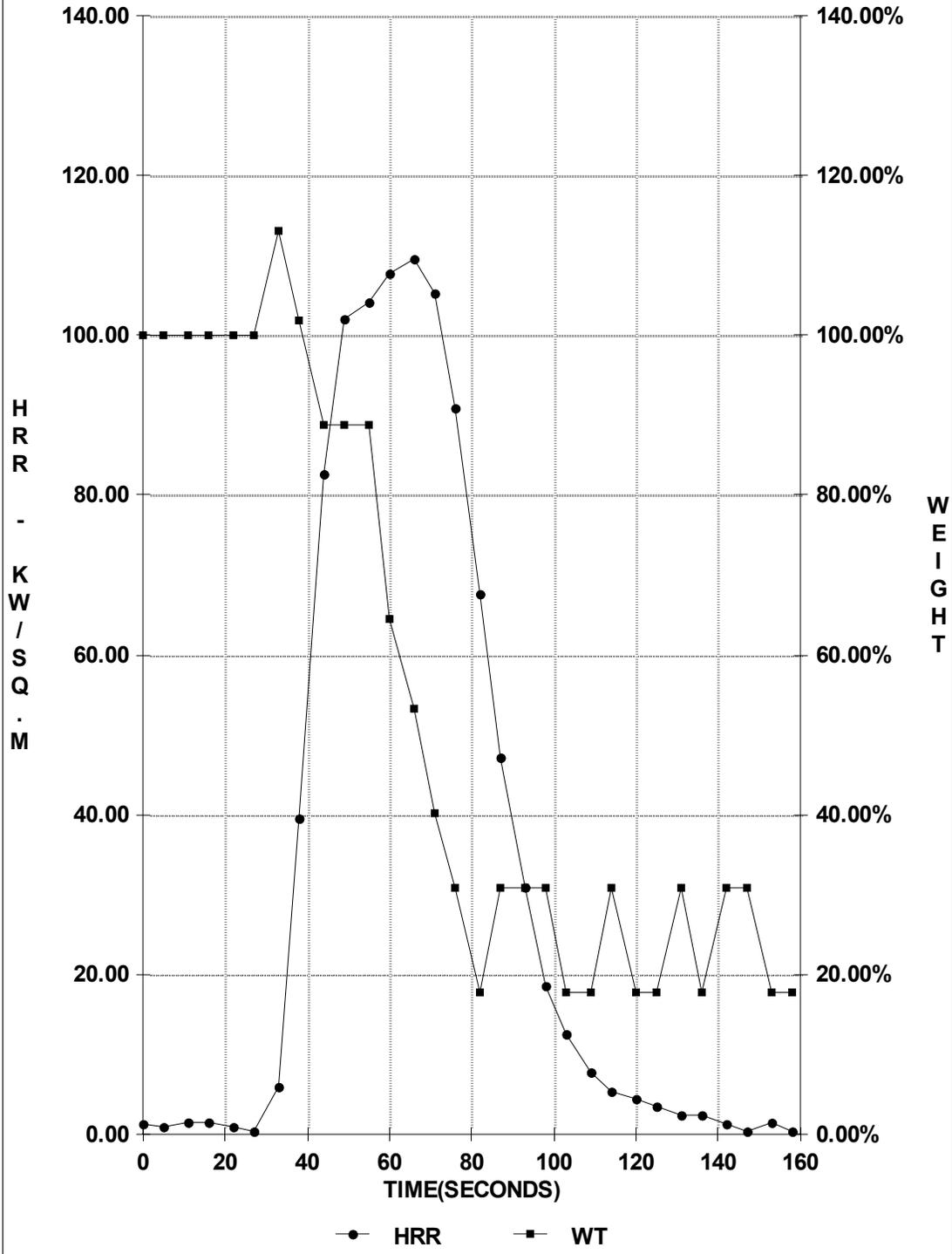
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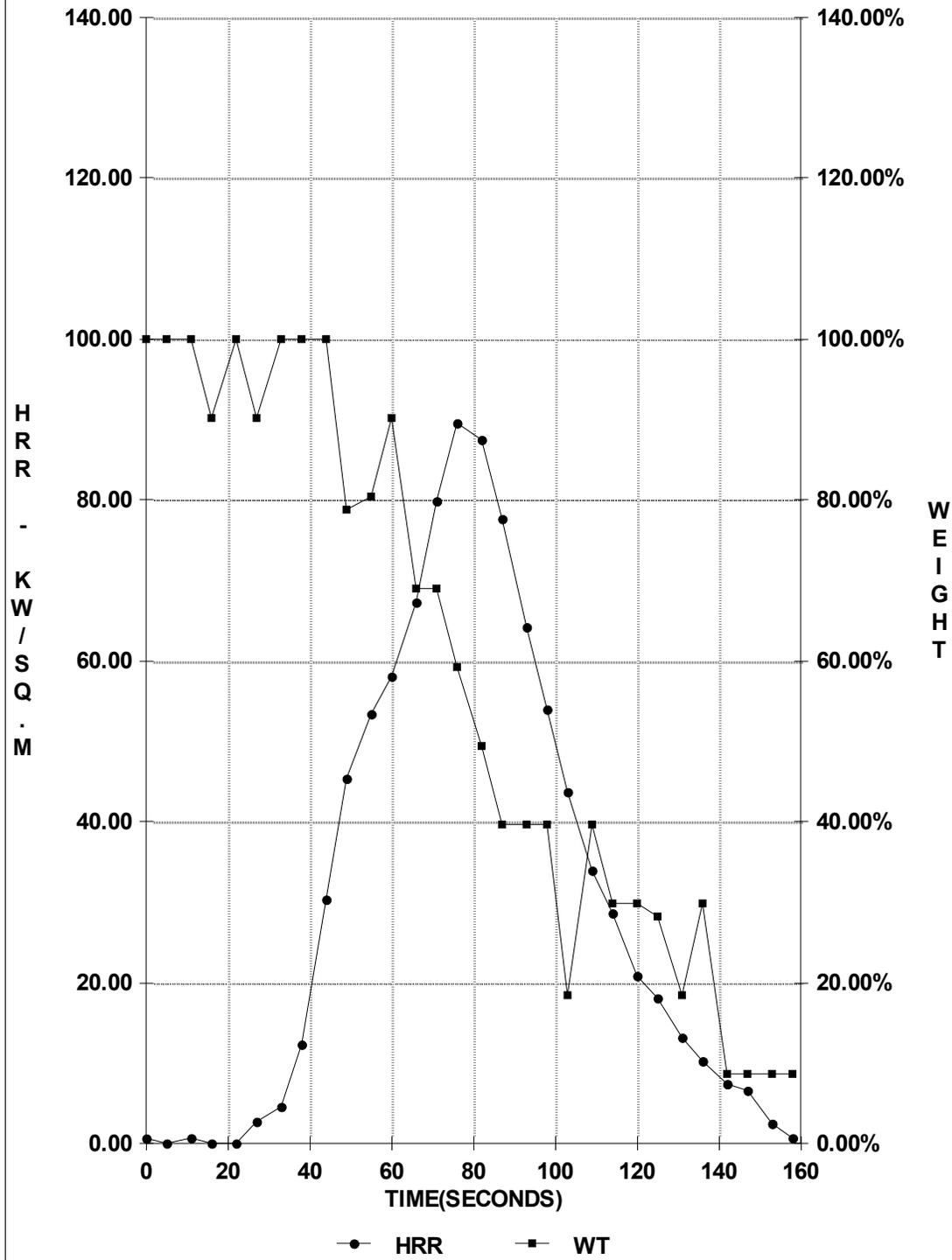
CORMIER 1440; IGN TIME = 31 SECONDS
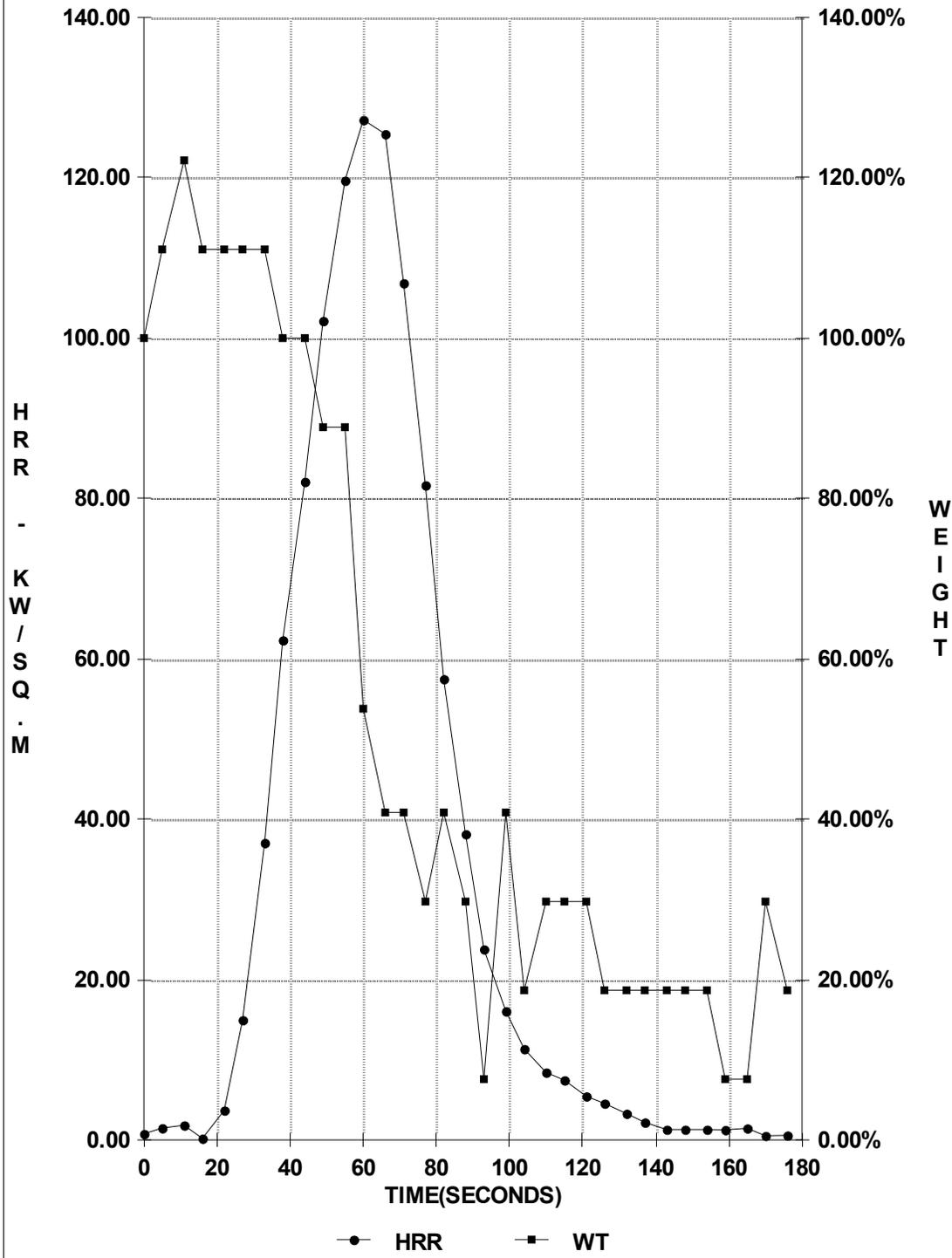
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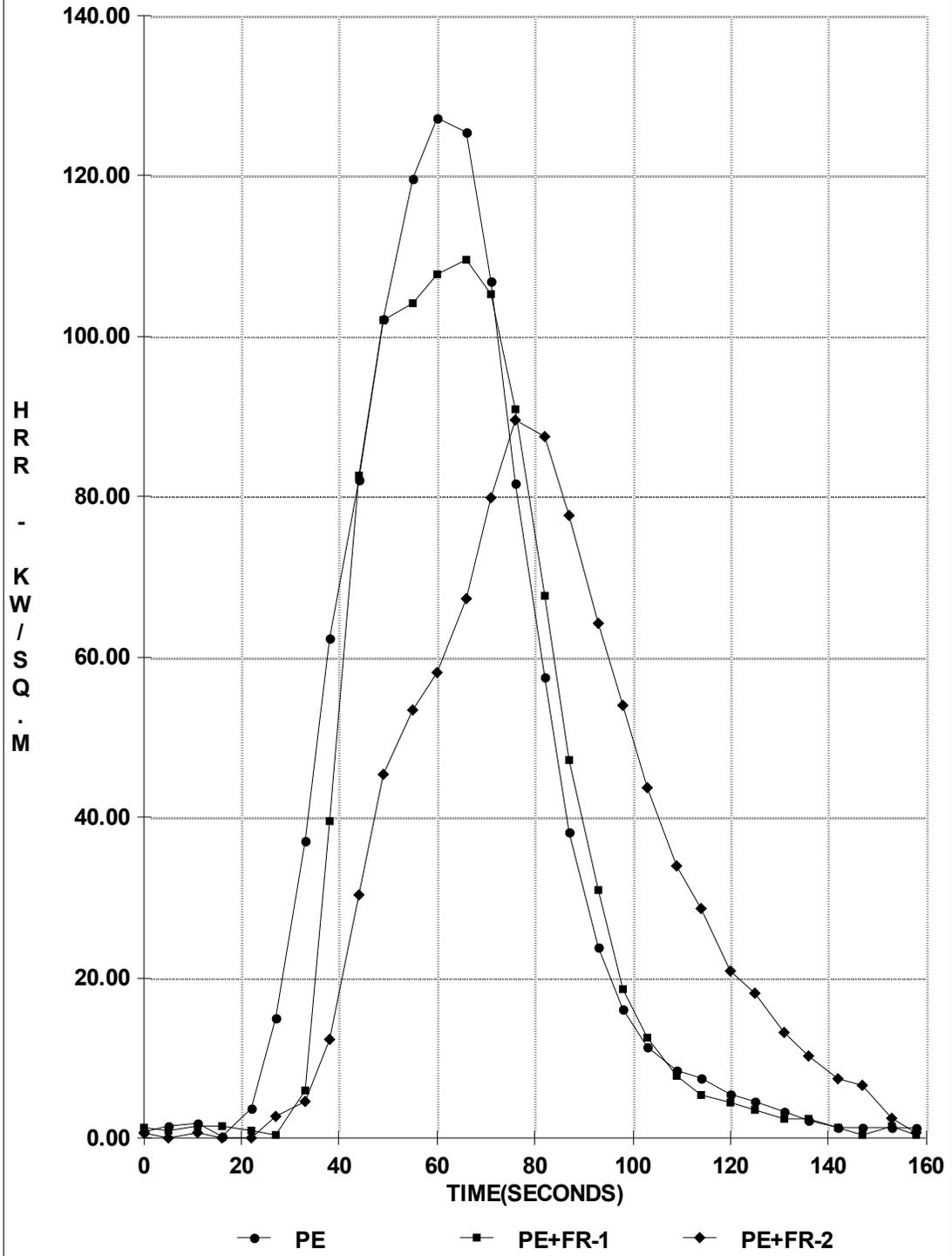
CORMIER 1440-FR-1; IGN TIME = 39 SECOND

Figure showing HRR (KW/SQ.M) and WEIGHT (%) versus TIME (SECONDS). Legend: HRR, WT.

ASTM CONE CALORIMETER TEST

CORMIER 1440-FR-2; IGN TIME = 39 SECOND

ASTM CONE CALORIMETER TEST

TREATED AND UNTREATED P/E TARPS

PE ● PE+FR-1 ■ PE+FR-2 ◆

REFERENCES -
(1) Code of Federal Regulations, Protection of Environment, 40, Part 258, Criteria For Municipal Solid Waste Landfills, Revised as of July 1, 1992.

(2) Clarke, Frederick B., "Fire Hazards of Materials: An Overview", in Fire Protection Handbook, Fifteenth Edition, National Fire Protection Association, Quincy, MA, 1981, pages 4-2 to 4-8.

(3) Clarke, Frederick B., "Fire Hazards of Materials: An Overview", in Fire Protection Handbook, Seventeenth Edition, National Fire Protection Association, Quincy, MA, 1991, pages 3-15 to 3-20.

(4) Cohn, Bert M. "Plastics", in Fire Protection Handbook, Fifteenth Edition, National Fire Protection Association, Quincy, MA, 1981, pages 4-68 to 4-83.

(5) Cohn, Bert M. "Plastics", in Fire Protection Handbook, Seventeenth Edition, National Fire Protection Association, Quincy, MA, 1991, pages 3-101 to 3-120.

(6) Kittle, Paul A. and Schmidt, C.E., Comparison of Long Duration Foam, Synthetic Tarpaulins, Geotextiles, and Soil as Subtitle D Compliant Daily Cover Materials for Sanitary Landfills, presented at Waste Tech '93, Marina Del Rey, CA, January, 1993.

(7) Flammability of Plastics & Polymers Used As Alternate Daily Covers, A Summary of Technical Information from the Public Domain, Compiled and Edited by Paul A. Kittle, April, 1993.

(8) Haessler, Walter, "Theory of Fire and Explosion Control", in Fire Protection Handbook, Fifteenth Edition, National Fire Protection Association, Quincy, MA, 1981, pages 3-24 to 3-29.

(9) Information obtained from Underwriters Laboratories' Fire Protection Group.