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TESTING OF FLAME SCREENS AND FLAME ARRESTERS AS DEVICES DESIGNED TO PREVENT THE PASSAGE OF FLAME (DPPF) INTO TANKS CONTAINING FLAMMABLE ATMOSPHERES ACCORDING TO AN IMO STANDARD

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16. Abstract

Devices to Prevent the Passage of Flame (DPPF) include flame arresters, flame screens and pressure/vacuum valves which are used in venting systems on storage tanks and tanker vessels transporting flammable or combustible liquids. DPPFs are intended to prevent the propagation of flame into enclosed spaces containing explosive vapors/air mixtures. This report describes flashback and endurance burn tests to determine compliance of DPPFs to International Maritime Organization (IMO) Standard, MSC/Circ. 373, "Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers." This report presents data of flashback and endurance burn tests conducted on four (4) flame screen arrangements and ten (10) arresters.

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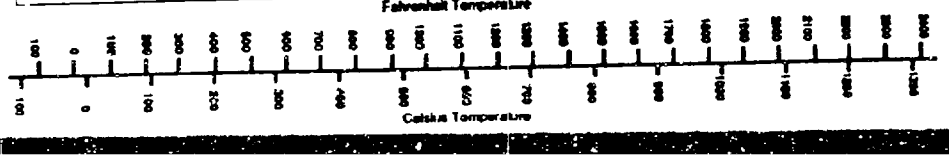
When you know (symbol)	Multiply by	To find (symbol)
Length		
inches (in)	2.540	centimeters (cm)
feet (ft)	30.48	centimeters (cm)
feet (ft)	0.3048	meters (m)
Area		
square inches (in²)	6.452	square centimeters (cm²)
square feet (ft²)	929.0	square centimeters (cm²)
square feet (ft²)	0.09290	square meters (m²)
Volume		
fluid ounces, US (fl oz)	29.57	milliliters (ml); cubic centimeters (cm³)
gallons, US liquid (gal)	3.785	liters (l)
cubic feet (ft³)	0.02832	cubic meters (m³)
cubic yards (yd³)	0.7646	cubic meters (m³)
Mass (weight)		
ounces, avoirdupois (oz)	28.35	grams (g)
pounds (lb)	0.4536	kilograms (kg)
Density		
pounds per cubic inch (lb/in³)	27.68	grams per cubic centimeter (g/cm³)
pounds per cubic foot (lb/ft³)	16.02	kilograms per cubic meter (kg/m³)
Pressure		
pounds per square inch (psi)	6895	pascals (Pa); newtons per square meter (N/m²)
pounds per square inch (psi)	0.0703	kilograms per square centimeter (kg/cm²)
pounds per square inch (psi)	51.71	millimeters of mercury (mm Hg) at 0°C
pounds per square inch (psi)	0.06895	bars (10^5 N/m²)
inches of water (in H_2O) at 60°F	1.867	millimeters of mercury (mm Hg) at 0°C
inches of water (in H_2O) at 60°F	248.9	pascals (Pa)
inches of water (in H_2O) at 60°F	0.002489	bars (10^5 N/m²)
inches of mercury (in Hg) at 32°F	3386	pascals (Pa)
inches of mercury (in Hg) at 32°F	0.03386	bars (10^5 N/m²)
Energy		
British thermal units (Btu)	1055	joules (J); newton-meter (Nm)
British thermal units (Btu)	0.2520	kilocalories (kcal)
Thermal Conductance		
Btu / hr - ft² - °F	0.0001356	calories / sec - cm² - °C
Btu / hr - ft² - °F	0.4882	calories / hr - cm² - °C
Btu / hr - ft² - °F	0.0005678	watts / cm² - °C
Heat Flow		
Btu / hr - ft²	0.00007535	calories / sec - cm²
Btu / hr - ft²	0.2712	calories / hr -cm²
Btu / hr - ft²	0.0003154	watts / cm²



Conversions from Metric Measures

When you know (symbol)	Multiply by	To find (symbol)
Length		
millimeters (mm)	0.03937	inches (in)
centimeters (cm)	0.3937	inches (in)
meters (m)	39.37	inches (in)
Meters (m)	3.281	feet (ft)
Area		
square centimeters (cm²)	0.1550	square inches (in²)
square centimeters (cm²)	0.001076	square feet (ft²)
square meters (m²)	1550	square inches (in²)
square meters (m²)	10.76	square feet (ft²)
square meters (m²)	1.196	square yards (yd²)
Volume		
milliliters (ml)	0.03381	fluid ounces, US (fl oz)
liters (l)	0.2642	gallons, US liquid (gal)
liters (l)	0.03531	cubic feet (ft³)
cubic centimeters (cm³)	0.06102	cubic inches (in³)
cubic meters (m³)	35.31	cubic feet (ft³)
cubic meters (m³)	1.308	cubic yards (yd³)
Mass (weight)		
grams (g)	0.03527	ounces, avoirdupois (oz)
grams (g)	0.002205	pounds (lb)
kilograms (kg)	2.205	pounds (lb)
Density		
grams per cubic centimeter (g/cm³)	0.03613	pounds per cubic inch (lb/in³)
kilograms per cubic meter (kg/m³)	0.06243	pounds per cubic foot (lb/ft³)
Pressure		
pascals (Pa); newtons per sq. meter (N/m²)	0.000145	pounds per square inch (psi)
bars (10^5 N/m²)	14.50	pounds per square inch (psi)
kilograms per square centimeter (kg /cm²)	14.22	pounds per square inch (psi)
millimeters of mercury (mm Hg) at 0°C	0.01934	pounds per square inch (psi)
millimeters of mercury (mm Hg) at 0°C	0.5357	inches of water (in H_2O) at 60°F
bars (10^5 N/m²)	401.8	inches of water (in H_2O) at 60°F
pascals (Pa)	0.00402	inches of water (in H_2O) at 60°F
pascals (Pa)	0.000295	inches of mercury (in Hg) at 32°F
bars (10^5 N/m²)	29.53	inches of mercury (in Hg) at 32°F
Energy		
kilojoules	0.9478	British thermal units (Btu)
kilocalories	3.968	British thermal units (Btu)
Thermal Conductance		
calories / sec - cm² - °C	7373	Btu / hr - ft² - °F
watts / cm² - °C	1761	Btu / hr - ft² - °F
Heat Flow		
calories / sec - cm²	13270	Btu / hr - ft²

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1.0 INTRODUCTION

The IMO fire safety requirements for tankers, contained in Part D of Chapter II-2, regulation 59 of the International Convention for the Safety of Life at Sea (SOLAS) 1974, and the 1983 Amendments (reference 1), requires that cargo tank venting systems be provided with devices to prevent the passage of flame (DPPFs) into the cargo tanks. The design and testing of these devices are to comply with the requirements established by IMO. Test standard MSC/Circ.373 (reference 2), was adopted by IMO in April 1984. The IMO standards are based on a German test with modifications.

Being a signatory to the Safety of Life At Sea (SOLAS) convention, the United States is obligated to use the IMO standard despite the fact that there are major differences between the present U.S. Coast Guard regulations and the IMO test. The new IMO criteria requires DPPFs to achieve the highest obtainable temperature on the tank side of the element before the time requirement for the endurance burn test is imposed. This is a major departure from the Coast Guard accepted test criteria which requires the arresting device prevent the passage of flame for one half of an hour or one hour depending on other variables.

With such a major departure from currently accepted criteria, it is incumbent upon the Coast Guard to validate, through testing, the adequacy of the new criteria with a Coast Guard-approved independent testing facility, before finalizing regulations which implement the new IMO standard. This project addresses the efforts to validate the IMO Standard, and consists of two separate reports. The first addresses the testing of flame arresters and flame screens, while the second will address the testing of pressure/vacuum valves.

2.0 OBJECTIVES

The principal objectives of this project are centered on the essential elements of the areas of test verification, test protocols, test availability and repeatability as follows:

Development of the detailed test procedures, specialized test apparatus and instrumentation required to conduct flashback and endurance burn tests in accordance with IMO Standard MSC/Circ.373.

Obtain a representative selection of currently available DPPFs (flame screens and flame arresters) and utilize these to verify that the newly developed test methods presented in IMO MSC/Circ.373 can be conducted satisfactorily. Determine if flame screens and flame arresters previously tested and approved as meeting U.S. Standards (reference 3) can pass the new IMO tests, and those which do not meet U.S. Standards do not meet the IMO Standards.

Identify at least one established independent testing authority with resources and facilities acceptable to U.S. Coast Guard, and which has the capabilities to perform both approval testing and follow-up production inspections of DPPF manufacturers on an ongoing basis.

These tests will be used to determine, 1) if the candidate flame screens and flame arresters will function in accordance with current IMO Regulations, and 2) if the IMO test parameters and procedures are considered adequate, as well as fair.

3.0 REVIEW OF FLAME SCREEN/FLAME ARRESTER REGULATIONS, STANDARDS AND TESTING PROTOCOLS

There exist several applicable national (U.S.) and international standards, regulations, and codes of practice pertaining to the selection, testing, installation and use of DPPFs on tankers.

The principal Codes and Standards, the authority having jurisdiction where applicable, together with the appropriate U.S. regulations and definitions are presented below.

3.1 U.S. COAST GUARD REGULATIONS

The U.S. marine safety regulations for DPPFs are based on the Code of Federal Regulations, Title 46, Chapter 1 (October 1986 Edition), Subpart 162.016 - "Flame Arresters for Tank Vessels". Additionally, flame screens are defined in Subpart 30.10-25 of the CFR. The "authority having jurisdiction" is the United States Coast Guard. Please see Appendix A.

3.2 UNDERWRITERS LABORATORIES, INC. (UL) STANDARDS FOR SAFETY

The appropriate testing procedures are laid down in ANSI/UL 525, "Standard for Flame Arresters for Use on Vents of Storage Tanks for Petroleum Oil and Gasoline" (Fifth Edition 1984), Underwriters Laboratories, Inc. (Appendix B). Test criteria requires resistance to flashback in a one-hour interrupted endurance burn, continuous burn for one hour with fuel mixture flow interruptions every 10 minutes for 15 seconds. For the flashback tests, UL does not require a specific type of enclosure to contain the explosive fuel/air mixture. The UL procedure specifies a fuel/air ratio to be used for all endurance burn tests and a specific fuel mixture flow rate for each size flame arrester. According to UL personnel, the flow rates were derived empirically years ago. The authority having jurisdiction is UL who provides a "follow-up service" to ensure that "UL listed" products are manufactured to the same standards as the tested samples.

3.3 FACTORY MUTUAL (FM) RESEARCH STANDARDS

Applications data is contained in Factory Mutual Loss Prevention Data Sheets, Section 7-88, "Storage Tanks for Flammable and Combustible Liquids" (reference 17). This document applies only to shore-based installation practices and procedures. Testing procedures are covered in Factory Mutual Document TIC 6061 (Appendix C) which calls for an endurance burn requiring resistance to flashback for 1/2 hour with uninterrupted fuel/air mixture flow. These are considered finite life endurance burn tests. For the flashback tests FM does not specify the type of enclosure to contain the explosive fuel/air mixture.

3.4 INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA (SOLAS)

The International Convention for the Safety of Life at Sea, 1974 (1974 SOLAS), together with the 1978 Protocol and consequent SOLAS Amendments of 1981 and 1983, have been adopted by the Maritime Safety Committee of the International Maritime Organization (IMO). Specifically, the requirements for DPPFs are laid down in SOLAS Regulation 59, "Venting, Purging, Gas Freeing and Ventilation", Chapter II-2 (1982 Amendments), para. 1.5. (Appendix D).

Flashback and Endurance Burning Tests procedures for DPPFs are described in Section 3.2, paragraphs 3.2.1 through 3.2.3.2, of IMO document MSC/Circ.373/Rev.1, "Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks, in Tankers," (Appendix E). The IMO standard calls for separate flashback and endurance burn tests utilizing the separate test apparatus described in Section 5 of this report. The test is considered by IMO to be the most stringent of the endurance burn tests because it requires the maximum heat transfer rate obtainable from the flame to the arrester element. The UL and FM tests do not ensure maximum heat transfer rate, they specify a finite time requirement for flame passage resistance.

4.0 PREVIOUS TESTING OF DPPFs

4.1 TESTING IN THE UNITED STATES

Considerable experimental research and testing of DPPFs has been conducted over the past 20 years into both the phenomena of flashback and to determine performance of DPPFs during endurance burn tests. This research has shown that in the case of flame passage, commercially available flame screens and flame arresters perform consistently well for a variety of common fuels.

Additionally, endurance burn tests (reference 4) to establish evaluation for the design of flame arresters to the exposure of prolonged methane/air and gasoline/air flames have been conducted by the USCG. This research was followed by further verification research (reference 5) related to endurance burning tests using butane/air fuel mixtures. These tests, performed for the Coast Guard, indicated that whereas some arresters resisted flame passage for greater than one hour, they did not reach thermal equilibrium. Therefore, there is concern that the newly developed IMO test criteria may be too stringent. The objectives of this test program are designed to determine if the IMO test criteria can be applied in an objective manner, independent of the testing facility, its location and, to ascertain if DPPFs currently approved to USCG (ANSI/UL 525) standards would pass the IMO tests.

The intent of presently accepted test methods by the Coast Guard and the IMO standards is for maximum heat transfer to occur between the flames and the device undergoing testing. The IMO standard attempts to achieve this through the requirement of the highest attainable temperature, implemented by fuel/air ratio and fuel flow rate adjustments. However, as mentioned in 4.3 of this report, such fuel/air adjustments also have cumulative effects on flame luminosity, flame speed and consequent heat transfer. All of these factors could influence the severity and integrity of the tests.

4.2 TESTING IN OTHER COUNTRIES

Tests conducted by a Danish manufacturer show that of several sizes[1] of flame arresters, up to 12 inches (31cm) in diameter, tested to the IMO standard, only sizes up to and including 6 inches (15.5cm) passed the endurance burn portion of the test. In a written communication (reference 6) with the German independent test facility, Physikalisch-Technische Bundestanstalt (PTB), it was noted that during the testing used to develop the IMO standard, the 6 inch (15.5cm) flame arrester was the largest size to pass the IMO endurance burn test. Their communication also included a formula to calculate fuel/air flow rate and adjustment for crimped-ribbon type flame arresters.

Experimental evaluation of DPPFs using n-hexane have been conducted in Japan (reference 7) and suggest that the cross-sectional configuration of the flame arrester has an effect on the flame arresting performance which may explain the poor performance of arresters in excess of 6 inch (15.5cm) diameter. The

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[1] Flame arrester sizes referred to in this report are those specifically designed for use in nominal pipe sizes.

Japanese study also confirmed that the quenching characteristics of the flame arrester are influenced by the flame propagation velocity of the fuel/air mixture, which in turn is influenced by the composition of the fuel/air ratio. These factors are also taken into consideration in current U.S. and IMO tests.

The British Fire Research Station (BRE) has conducted tests on flame arresters at their Cardington facilities. These tests utilized hydrogen/air fuel mixtures, and related performance of flame arresters against flashback from unconfined hydrogen gas cloud explosions. Results are not currently available and it is not known if other fuel/air mixtures were tested.

4.3 HEAT TRANSFER TO THE DPPFs

The IMO standard endurance burn test induces a condition for heat transfer through the DPPF, contributory factors being flame temperature, materials of construction, mass, ambient temperature, weather conditions an the design of the device. As mentioned earlier in this report, variation of the fuel/air ratio of a flammable mixture does result in different maximum flame temperatures (references 8 and 9), which would affect the temperature to which the DPPF was heated as it acted as a flame arrester. For flammable hexane/air mixtures, the maximum flame temperature increases from about 2200°F (1204°C) at the lower (fuel-lean) and upper (fuel-rich) flammability limits to about 3600°F (1982°C) at the stoichiometric limit. However, accompanying this change in temperature are concomitant changes in luminosity and flame speed (reference 10). The luminosity of the flame would affect the rate of heat transfer from the flame to the device, thereby influencing the heat transfer processes by which the device was heated. The higher the luminosity, the greater the heat transfer to the device. The highest flame luminosity occurs at the rich limit (yellow flame mode), which also has the lowest maximum flame temperature. Additionally, differences in flame speed would alter the severity of the flashback test (reference 8).

The tests indicated that the highest temperature obtainable on the tank side of the DPPF was higher when the flame was at the upper (fuel-rich) flammability limit than when it was at the stoichiometric limit. This observation indicated that flame luminosity was more important than maximum flame temperature in governing heat transfer processes to the device. This result would suggest that device heating and endurance testing should be done with an upper limit of flammable hexane/air mixtures. However, the flame speed at the upper limit of flammable hexane/air mixtures is approximately one-tenth less than that at the stoichiometric limit (reference 9). Therefore, endurance burn testing at the upper, rather than stoichiometric,

limit of flammable hexane/air mixtures would be less severe in terms of flashback probability, where flashback tendency is directly proportional to flame speed.

Other factors which are a part of the heat transfer phenomenon include the mass associated with the device and its attached ancillary equipment. Variations occur between model design and manufacturer even when constructed from the same materials. Heat transfer retention, or soak times, were noticeably longer for the DPPFs having greater mass. This heat retention could present a potential latent ignition source.

4.4 OTHER CONSIDERATIONS

The IMO test, and in most instances other official U.S. test procedures, is conducted using only one sample of each DPPF model. It can be claimed that testing a single article device does not represent a statistical sample. Furthermore, MSC/Circ.373/Rev.1 does not address whether all sizes of DPPFs should be tested. In addition, minor imperfections or deviations from the original manufacturing design standards could influence performance test results.

Clogging of flame screen and flame arrester elements may lead to the development of hot spots resulting in passage of flame to the tank side of the DPPF. However, reviewing test requirements for multiple test sampling and the potential for DPPF element clogging, and its effects, were not in the scope of this research.

5.0 TEST PROCEDURE

The scope of this project included verification of the MSC/Circ.373 protocol for flashback and endurance burn testing. It did not include other tests required by MSC/Circ.373 such as mechanical design standards (part 2.2), flow rate, fouling, extreme temperature operation, etc. (part 2.3), or corrosion and hydraulic pressure (part 3.5). MSC/Circ.373 does not provide the detailed test protocol necessary to conduct the flashback and endurance burn tests. Therefore, detailed test procedures were developed by the Coast Guard with contracted support from Underwriters Laboratories. These procedures, the required apparatus, the fuel used and the necessary instrumentation are discussed in the following subsections.

5.1 TEST APPARATUS

The test apparatus was designed in accordance with the description provided in the figure marked "Test Rig for Flashback Test" in Appendix 1 of the IMO standard. A basic schematic of the apparatus used for this test series is shown in figure 1.

The plastic bag for the flashback test was approximately 1m (3.28ft) in diameter, 2.5m (8.2ft) in length, and .05mm (0.02in) thick. In practice it was found that the plastic bag fell back onto the surface of the DPPFs after ignition. Therefore, a large aperture, coarse wire, cylindrical cage was constructed to support the plastic bag and to prevent melted plastic from contaminating the flame screen material. It is emphasized that the large aperture, coarse mesh of the wire cage did not in any way interfere with the test performance of the DPPFs. Figure 2 illustrates a typical plastic bag condition after ignition without the coarse wire cage.

The IMO test apparatus requires a tank as the conduit for the fuel/air mixture to reach the DPPF. A 12 inch (31cm) pipe was used as a tank. Tank size is not specified and a 12 inch (31cm) pipe was used as the conduit for the fuel/air mixture.

A sparkplug provided ignition for both the flashback tests and the endurance burn tests. The IMO Standard suggested a pilot flame for the endurance burn tests. However, a sparkplug system was safer in that it precluded accidental extinguishment of the pilot flame. Extinguishment would require personnel to enter an explosive atmosphere to relight the pilot flame.

A 3/4 inch (19mm) pipe was used as a support for the plastic bag and the sparkplug ignition system. It also served as an exhaust for the air in the bag. The fuel/air mixture flowed for 10 minutes. This allowed the fuel/air mixture to displace the air in the bag and give a homogeneous explosive mixture in the bag.

5.2 TEST FUEL

Section 3.1.3 of the IMO standard specifies the gasoline fuel for the endurance burn to have a boiling range approximating 150°F-167°F (65°C-75°C). Gasoline with that specific boiling range was not available in the United States. Gasoline is a generic term for various blends of aliphatic hydrocarbons and additives (e.g., tetra ethyl lead as an anti-knock additive). Gasoline blends vary greatly in the United States according to seasonal climate and regional air density. They will also deteriorate with aging. Each manufacturer adjusts the blend ratios of the hydrocarbons and additives according to their own formula and region. Commercially available gasolines have a much larger boiling range than the range required by IMO. Extensive research (presented in Subsection 5.2.1 of this report) for a suitable substitute was undertaken. n-Hexane, an isomorphic compound with a boiling range within the IMO specified limits, was determined to be the acceptable fuel. Its use by several independent testing facilities further corroborated n-hexane as the ideal choice.

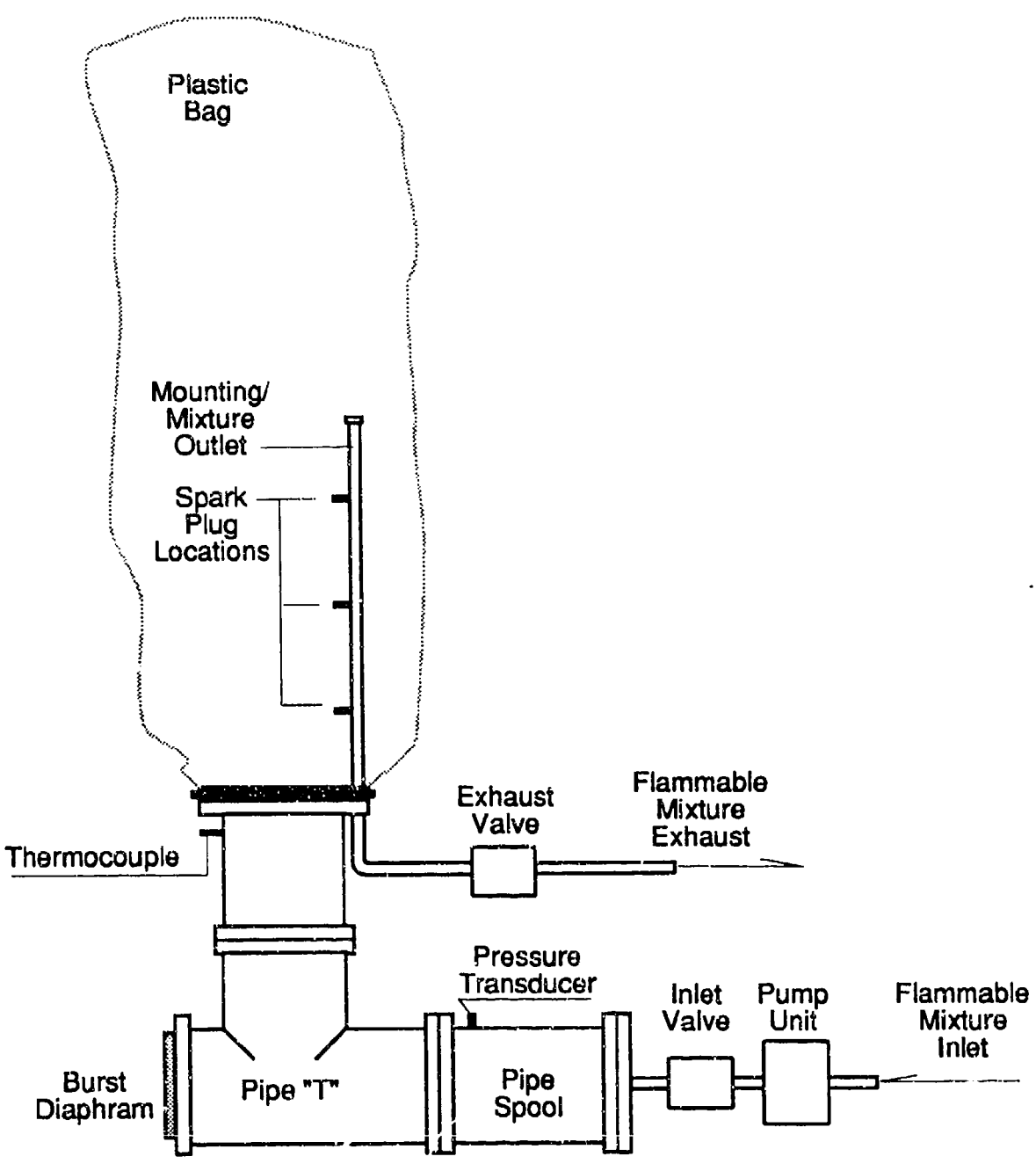

Figure 1. Test Rig for Flash Back Test

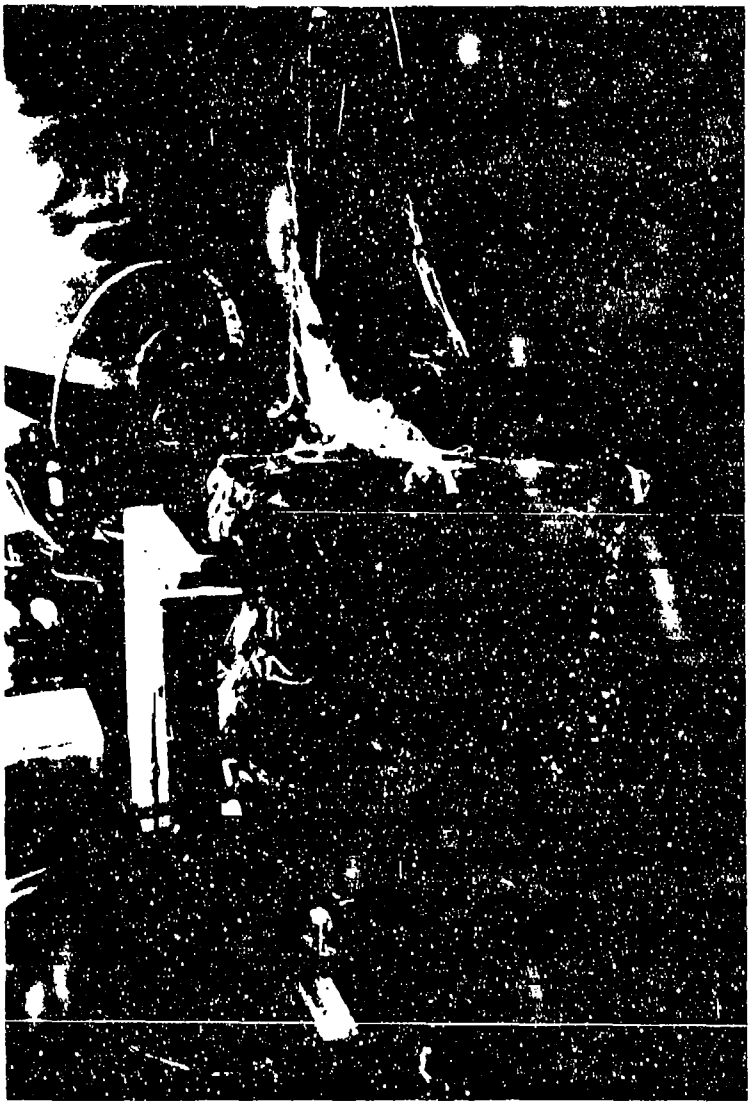

FIGURE 2. MELTED PLASTIC ADHERING TO TEST SPECIMEN

5.2.1 FUEL SELECTION

The rationale for selection of the fuels that are specified in current Underwriters Laboratories (UL) and International Maritime Organization (IMO) Standards for flame arrester tests is not stated in those documents. When testing in accordance with recognized standards, it is desirable to make conditions as uniform as possible, so as to ensure repeatability of test results. However, the types of test fuels specified in these UL and IMO Standards are commercial products consisting of mixtures of hydrocarbon compounds whose individual proportions are not directly controlled during processing. In addition, they may contain a variety of additives and other substances. It is possible that normal variations in fuel composition could have significant effects on the performance of the flame arresting devices. The description of the test fuel given in the IMO Standard is somewhat confusing in that the type of fuel mentioned does not normally possess the narrow range of properties indicated in the standard.

The following observations were prepared in order to summarize available information on some possible test fuels, and to present recommendations regarding the fuel that should be used in the flashback and endurance burn tests.

Summary of Available Information

1. IMO MSC/Circ.373, Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers, includes the following information:

a. "These standards cover flame arresters for the protection of cargo tanks containing flammable liquids of the aliphatic and aromatic groups of hydrocarbons having flashpoints of 60°C (140°F) (closed cup) or less, and Reid vapor pressures below atmospheric pressure" (paras. 1.2.1 and 1.2.3).

b. "These devices are intended for use on tanks containing crude oil and petroleum products; they are not generally suitable for tanks carrying chemical products in groups such as alcohols, amines, ethers and esters" (para. 1.2.3).

c. For testing of flame arresters intended for installation at openings to the atmosphere, the following test mixtures are to be used:

(1) Flashback tests: "The most easily ignitable propane/air or gasoline/air mixture" (para. 3.2.2.1).

(2) Endurance burn tests: "The most easily ignitable gasoline vapor/air mixture (para. 3.2.3.2) or the most easily ignitable technical hexane vapor/air mixture."

d. The gasoline test fuel is described as follows: "...gasoline vapors (a nonleaded petroleum distillate consisting essentially of aliphatic hydrocarbon compounds with a boiling range approximating 65°C/75°C..." (para. 3.1.3).

2. The Underwriters Laboratories Standard UL525; "Flame Arresters for Use on Vents of Storage Tanks for Petroleum Oil and Gasoline", includes the following information:

a. "These requirements cover flame arresters for use in open vent pipes, flame arresters for use with vent valves, and flame arrester-vent valves, all intended for use on vents of storage tanks for petroleum oil and gasoline." (para. 1.1)

b. Test mixtures are specified as follows:

(1) Explosion tests: "gasoline vapor-air mixture at a concentration of 1.90 ± 0.05 percent by volume, at an initial pressure of one atmosphere" (paras. 8.1, 8.9 and 9.1).

(2) Continuous burn tests: ..."Same mixture and concentration as for explosion tests; flow rate of the gasoline vapor-air mixture is specified as a function of the pipe size of the arrester; e.g., 1030 CFH for a 12 inch nominal pipe size" (paras. 9.1 and 9.3).

c. The test fuel is described as follows:

"The gasoline used in the tests is to be Naphtha 'R', a nonleaded petroleum distillate consisting essentially of aliphatic hydrocarbon compounds and having a specific gravity of 60-70 degrees API at 15.6°C (60°F)." (para. 8.8) (This range corresponds to 9.74-0.70 specific gravity.)

3. National Bureau of Standards Report 10 362; An Evaluation of Plastic Gasoline Containers, includes a description of a "gasoline simulant" which was used for pressure testing and permeation testing of small containers. (No fire tests were involved; consequently the flammability and burning characteristics of the gasoline simulant were presumably of no great concern for these particular tests.) A 70/30 mixture of "iso-octane" (2,2,4-trimethyl pentane) and toluene was used as the simulant. The report states, "The 70/30 mixture is a recognized gasoline simulant. It was used rather than commercially available gasoline to avoid variations in composition that might be found among gasolines produced by different manufacturers."

4. Naval Research Laboratories Report 5423; "Ignition of Hydrocarbon Vapors by Continuous DC Arcs", states that blends of normal heptane and normal octane were used to

obtain hydrocarbon vapor/air mixtures that could be ignited with low spark energies as follows:

Blend (% n-heptane/% n-octane)	Useful Temperature Range
100/0	55-68°F (13-20°C)
66.7/33.3	65-77°F (18-25°C)
33.3/66.7	74-86°F (23-30°C)
0/100	84-95°F (29-35°C)

5. Table 1 provides a comparison of physical properties for various materials. While preparing this table, it was noted that there is sometimes a considerable difference in temperature values (e.g., boiling point) given by different reference sources for the same pure hydrocarbon compound. Also, some sources do not differentiate between different forms (e.g., iso-octane and n-octane), which may have different properties.

General Comments

1. In IMO MSC/Circ.373, use of the word "gasoline" implies that a regular commercial product is to be used. However, the IMO definition of gasoline goes on to include "a boiling range approximating 65°/75°C", whereas gasoline typically has a boiling range from 30°C to 210°C (86° to 410°F). The IMO definition does not include requirements for other properties such as specific gravity, flammability, explosive limits, etc.

2. UL 525 specifies that the gasoline used in the tests is to be Naptha 'R', having a specific gravity of 60-70 degrees API (i.e., 0.70 to 0.74 times as dense as water). No other properties are specified. No mention of a substance called Naphtha 'R' can be found in any available publication, however, UL indicates that rubber solvent is a synonym for Naphtha 'R'. A limited amount of data on rubber solvent is available (reference 13). Additional information was also obtained from UL (reference 14). These sources indicate that rubber solvent's boiling point ranges between 40° and 135°C (104° and 275°F).

3. IMO and UL use identical words to describe the gasoline test fuel: "a nonleaded petroleum distillate consisting essentially of aliphatic hydrocarbon compounds..."

4. Aliphatic hydrocarbons are those in which carbon atoms are in open chains, as opposed to the ring structures of aromatics and naphthenic compounds (references 15 and 16).

Aliphatic hydrocarbons include pentane, hexane, heptane, octane, ethane, butane and acetylene.

Aromatic hydrocarbons include benzene, toluene, and xylene.

TABLE 1 - FUEL PROPERTIES

FUEL	DENSITIES		REID VAPOR PRESSURE	TEMPERATURES			FLAMMABLE LIMITS IN AIR (% By Volume)		MAXIMUM EXPERIMENTAL SAFE GAP	HEAT OF COMBUSTION
	Specific Gravity (Water=1.0)	Vapor Density (Air=1.0)	(PSIA)	Boiling Points	Flash Point	Ignition	Lower	Upper	(mm)	(BTU/LB)
n-heptane $CH_3(CH_2)_5CH_3$ — C_7H_{16} dipropylmethane 2-methyl hexane ref. 16 & 18	0.69	3.5	1.8	Initial: 201°F (94°C) End: 209°F (98°C)	25°F (-4°C)	419° to 536° F (215° to 280°C)	1.0	7.0	0.91	19,170 to 20,657
n-octane $CH_3(CH_2)_6CH_3$ — C_8H_{18} octyl hydride ref. 16,18, & 19	0.70	3.9		258°F (126°C)	56°F (13°C)	428°F (220°C)	1.0	6.5	0.94	19,110 to 20,530
iso-octane $(CH_3)_3CCH_2CH(CH_3)_2$ C_8H_{18} 2,2,4-trimethylpentane ref. 16 & 17	0.70	3.9		190° to 250°F (88° to 121°C)	10°F (-12°C)	779° to 784°F (415° to 418°C)	1.0	6.0		
toluene $C_6H_5CH_3$ — C_7H_8 toluol methylbenzene phenylmethane ref. 16,17 & 18	0.87	3.1	1.1	231°F (110°C)	40° to 48°F (4° to 9°C)	896° to 997°F (480° to 536°C)	1.2	7.1		17,430 to 18,250
gasoline, regular C_5H_{12} — C_8H_{20} ref. 16,17, & 18	0.70 to 0.75	3.0 to 4.0	7.4	Initial: 91°F (33°C) End: 403°F (206°C)	-36° to -50°F (-28° to -46°C)	700° to 853°F (371° to 456°C)	1.4	7.6		18,720 to 20,520
gasoline, unleaded ref. 12				Initial: 83°F (28°C) 50% 217°F (103°C) End: 413°F (212°C)						
rubber solvent (chiefly aliphatic hydrocarbons) ref. 11,14 & 15	0.70			Initial: 107°F (42°C) End: 275°F (135°C)	-40°F (-40°C)	450° to 601°F (232° to 316°C)	1.0	7.5		
n-pentane $CH_3(CH_2)_3CH_3$ — C_5H_{12} amyl hydride ref. 13,15,16,17 & 18	0.63	2.5		Initial: 95°F (35°C) End: 102°F (39°C)	-40° to -57°F (-40° to -49°C)	500° to 588°F (260° to 309°C)	1.4	8.3		19,350 to 19,745
n-hexane $CH_3(CH_2)_4CH_3$ — C_6H_{14} hexyl hydride ref. 15,16 & 18	0.66	3.0	5.0	Initial: 151°F (66°C) End: 160°F (71°C)	-7°F (-22°C)	437° to 453°F (225° to 234°C)	1.1	7.5	0.93	19,250 to 20,676
propane $CH_3CH_2CH_3$ — C_3H_8 dimethylmethane propl hydride ref. 11,14,16,17 & 20	0.51 to 0.59	1.56	1.90	-44°F (-42°C)	-155°F (-104°C)	842° to 871°F (450° to 466°C)	2.2	9.5	0.97	20,015 to 21,490 2518 (gross) 2316 (net) BTU/FT³

Naphthenic hydrocarbons include cyclopentane, cyclohexane and cyclopropane.

5. Distillation curve data (references 13, 15 and 16) are plotted in figure 3 for several materials that are classified as aliphatic hydrocarbons and considered to be common industrial solvents.

Observations

1. Commercially available gasoline is not available with the limited range of boiling points required by IMO MSC/Circ.373.

2. A wide variation is to be expected in the composition of gasoline, which is a mixture of hydrocarbon compounds generally ranging from C_5H_{12} to $C_{10}H_{22}$. Commercial manufacturers provide the proper volatility characteristics. The blending is adjusted on a seasonal basis to compensate for changing climatic conditions. Gasoline may also contain varying amounts of additives, depending on the manufacturer. In addition to the hydrocarbon compounds, unleaded gasoline may contain considerable amounts of alcohols and ethers (up to 7 percent each).

3. The composition of Naphtha 'R'/rubber solvent may also be expected to vary widely from manufacturer to manufacturer, if not from batch to batch.

4. Normal variations in the composition of gasoline and Naphtha 'R'/rubber solvent may have a significant effect on the flammability characteristics of these fuels. The magnitude of any such effects cannot be predicted.

5. Based solely on the requirements of IMO Standard MSC/Circ.373 (aliphatic hydrocarbon with 65° to 70°C (149° to 158°F boiling range), normal n-hexane appears to be the best choice from among the fuels shown in Table 1. It should be recognized, however, that when other properties (such as ignition temperature) are considered, there are appreciable differences between n-hexane and both gasoline and rubber solvent.

5.2.2 Fuel Ratio

The fuel/air mixture for all the flashback tests and initially for the endurance burn tests was 2.5% n-hexane in air. Previous experience with fuel/air mixtures has shown this ratio to yield the hottest flame. During the endurance burn tests the fuel ratio was adjusted to determine if it had a significant effect on the temperature downstream of the arrester. The adjustment increments were 0.1% in either direction.

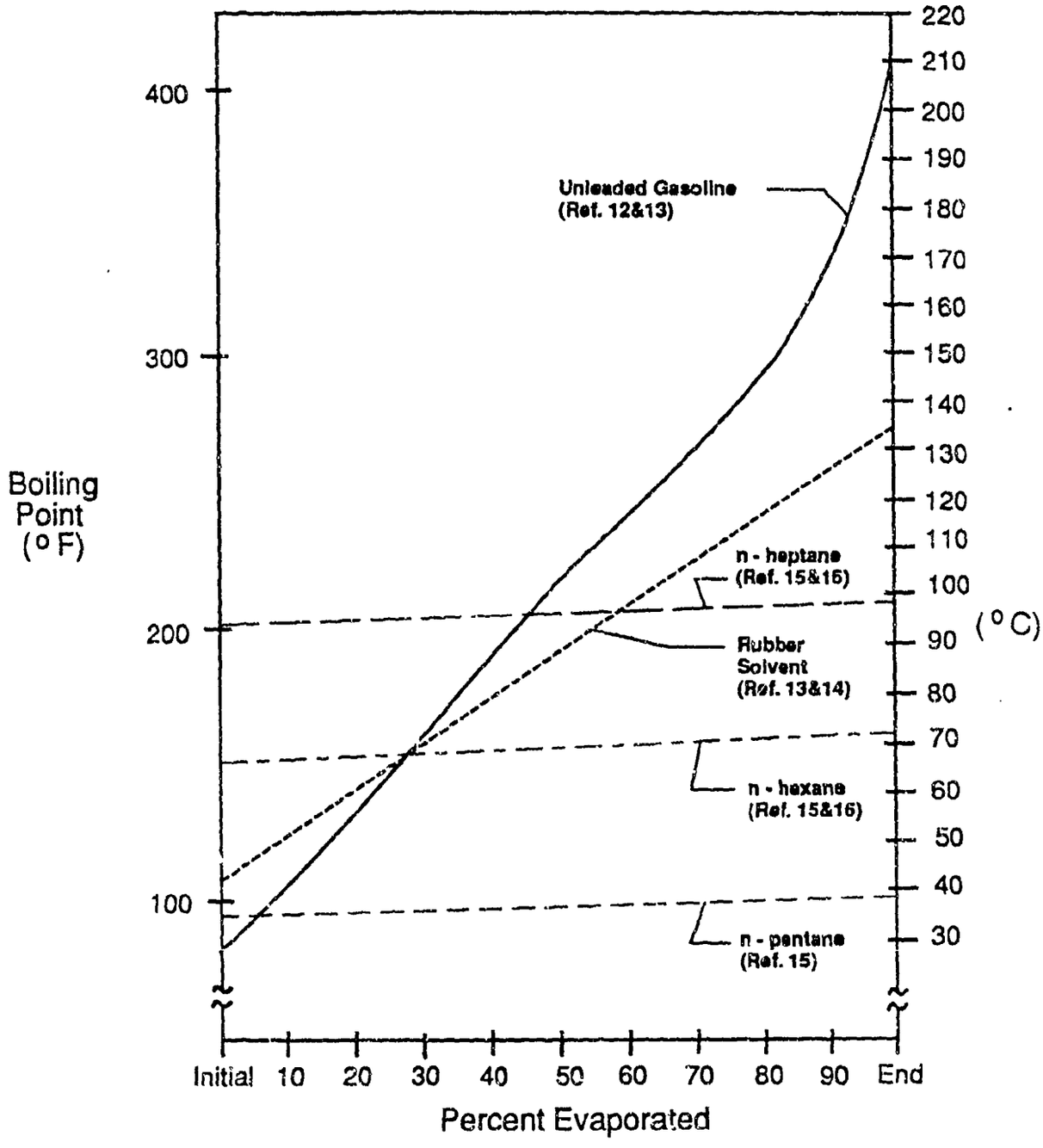

FIGURE 3. Temperature vs Evaporation

5.2.3 Fuel Mixture Flow Rate

The initial fuel mixture flow rate was 1139 standard cubic feet per hour (scfh) for the 12 inch (31cm) devices and 232 scfh for the 6 inch (15.5cm) devices. These flow rates were prescribed in UL Procedure 525 for endurance burn tests and were the most logical point of initial flow. Adjustments to the flow rates were made by means of adjustments to the static pressure head. Adjustments to the pressure head were made in one centimeter increments. The flow was then calculated using an algorithm which considered flow temperature, fuel/air ratio, and orifice/pipe coefficients. Flow rates and maximum temperature achieved from these calculations are shown in Table 2. The metering apparatus of the flow required the flow adjustments to be made in pressure head inches of mercury. The most practical adjustment for the apparatus was 1 inch (2.54cm) of mercury. With this adjustment, flow rates of 1018, 882, 674, and 510 scfh were attained for the 12 inch (31cm) devices. If the adjustment increments were too large, the flame would extinguish and a smaller increment, 0.5 inch of mercury, would be selected.

TABLE 2
FUEL MIXTURE FLOW RATES

ENDURANCE BURN TEST (MSC/CIRC.373)

TEST NUMBER	HEXANE IN AIR (%)	FLOW RATE @ FB (scfh)	DPPF MAX TEMP (deg C)	TOTAL TEST TIME (min)
A2-1	2.6	1139	243	13
A2-2	2.6	1139	n/m**	12
B2-1	2.4	510	n/m**	58
B2-2	2.4	1052	n/m**	70
C-1	2.5	1175	297	26
D-1	2.5	1189	870	88
D-2*	1.9*	1186	488	60
E1-1	2.5	233	364	113
E2-1	2.5	109	348	240
F1-1	2.5	235.9	432	220
F2-1	2.5	233	218	28
G-1	2.5	234.9	712	95
H-1	2.5	1106	933	40
K-1	2.5	395	843	508
L-1	2.5	233	22	3
M-1	2.6	234	783	150

* Continuous flame test (UL 525) using Naphtha-R in air
** Not Measured

Written communication with the German laboratory PTB (reference 8) indicates flow adjustments were made in 20% increments to an initial flow rate derived empirically. It appears that flow adjustments to obtain flow rates for maximum temperatures were made prior to actual testing at that flow rate, possibly with another DPPF. The actual flow data the German laboratory used could not be calculated because the dimensions of the crimpt-ribbon element were not available. Neither could flow rates prescribed by the German equation be calculated for the devices manufactured in the United States because the crimpt-ribbon dimensions were not available.

In order to ensure that an homogenous fuel/air mixture was achieved at the time of the test, a small diameter pipe was installed at the closed end of the plastic bag. This feature guaranteed that as the flammable mixture was introduced, it expelled the residual air from the tank and bag out through the small diameter pipe to evacuate the system. This procedure is not included in MSC/Circ.373/Rev.1. Omission of the practice could result in weak fuel/air mixtures at commencement of the test.

5.3 INSTRUMENTATION AND MATERIALS

Full details and specifications of the data recording instrumentation and materials are provided in Table 3. This equipment was utilized for both Flashback and Endurance Burn Tests.

Type J thermocouples were cemented to the upstream side (underside) of the flame screens for the endurance burn tests. One was located at the center of the device and three were located on radii 120° apart halfway along the radii. Poor adhesion of the thermocouples to the limited surface of the flame screens precluded all but three measurements, and even these are questionable. Figure 4 illustrates the location of the thermocouples on the screen.

Type K thermocouples were cemented to the flame arrester elements in the same locations as for the flame screens. Adhesion of the thermocouple to the flame arrester element was aided by the crimping action of the crimpt-ribbon itself. Temperature measurements for the flame arrester devices appear in the Test Results Section (7.0) of this report.

Underwriters Laboratories conducted all tests in a room having a blow-out panel. The room was designed to vent an explosion in such a manner that it did not harm operations personnel. It is recommended that other laboratories conducting similar DPPF tests, use a similar arrangement.

TABLE 3
APPARATUS AND MATERIALS

Name	Specification	Remarks
Carburetion System	Capable of generating mixtures of n-hexane in air over the flammable range, nominal flow capacity 30 to 1200ft^3/hr (0.85 to 34.0m^3/hr)	UL vapor air systems A and B or the equivalent.
Flammable Mixture Analyzer	n-hexane in air, 1.1 to 7.5 percent by volume	MSA, Lira 303 or equivalent
Thermocouple Potentiometer	Type J or K	Fluke, model 2100A or equivalent
Thermocouples	Type J or K	--
Flashback Tank	Heavy metal tank with burst diaphragm at one end, flammable mixture inlet with valve at other end and flame arrester mount at top.	Fabricate from pipe "T" fitting. May use size 10 in. (25.4cm) with adapter fittings for arrester sizes 6 through 12in. (15.5 - 31 cm) or the equivalant. See figure 1.
Ignition System	Sparkplug, high voltage cable, and high voltage transformer.	UL Spark Ignition transformers and cable.
Remote Monitoring System	Closed circuit television camera and monitor.	--
Flow Meter	Relative flow, 0-100 percent	Honeywell, Model NUF89X-H indicator, 738NISI pressure transmitter; orifice plate and manometer or equivalent.

TABLE 3 (cont'd)

Name	Specification	Remarks
n-Hexane	Technical grade, 95 percent min. purity.	Phillips 66 Co. or equivalent.
Plastic Bags	Nominally 2m (6ft, 8in.) circumference, 2.5m (8ft, 4in.) long, 0.05mm (0.002in.) thick or 68in. (1.73m) circumference, 98in. (2.49m)	AR-BEE Transparent Product, Inc., poly bags, 34x98in, standard weight or equivalent.
Burst Diaphragm	0.0015 to 0.010in. (0.038 to 0.254mm) thick, cellulose acetate film, polyester film, polyethylene terephthalate film, or equivalent.	--

Mention of a particular manufacturer or product does not infer U.S.C.G. sanction of that manufacturer or product.

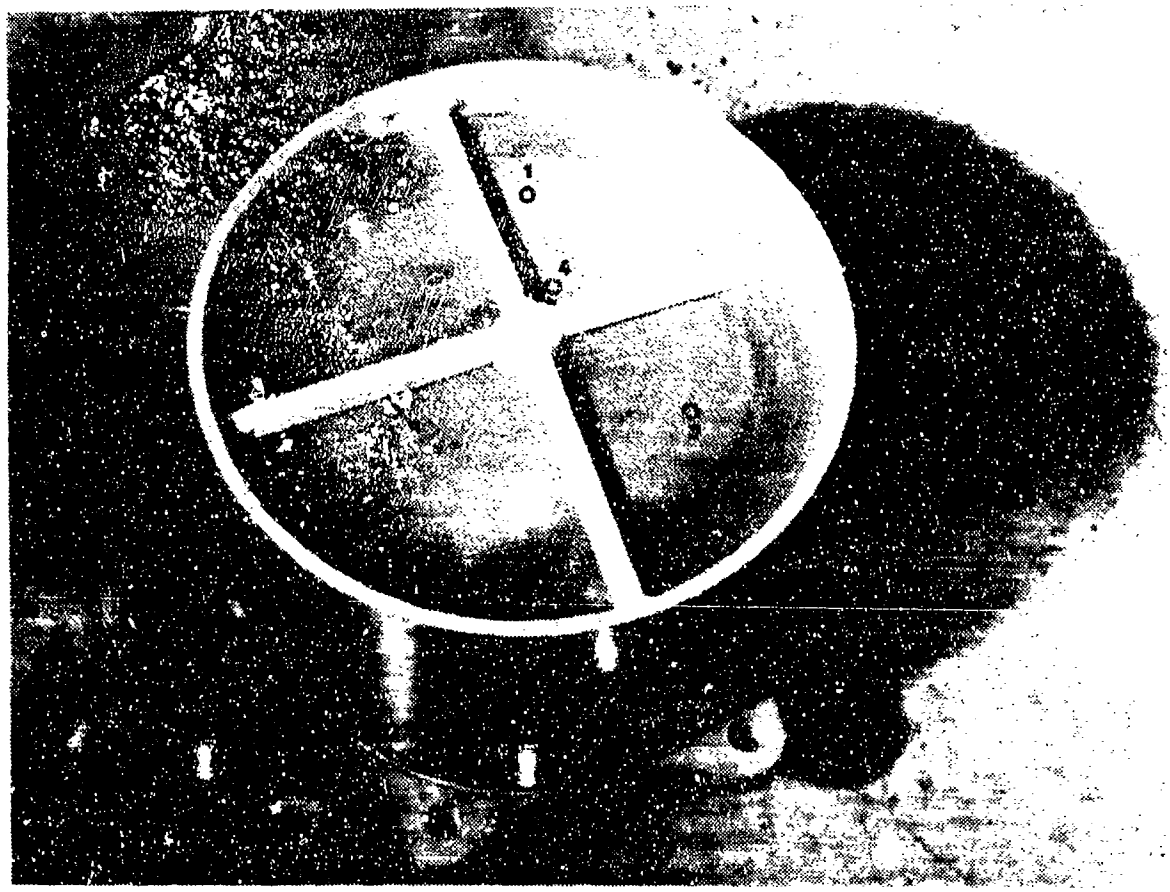

FIGURE 4. Locations of Thermocouples on Flame Screen

5.4 TEST CONDUCT

5.4.1 Flashback Tests

1. Install flashback (pipe) tank in test area. A 12 inch (31cm) pipe was used in lieu of a tank.

2. Mount flame arrester to top of tank using bolts and a gasket.

3. Mount coarse wire cage (plastic bag support).

4. Attach mounting/mixture outlet to flame arrester to provide for:

   a. Mounting sparkplugs

   b. Supporting plastic bag prior to filling with flammable mixture.

   c. Exhaust for explosive mixture during filling.

5. Locate sparkplug on mounting mixture outlet approximately 1 foot (0.3m) from the face of the arrester element but not closer than the edge of the flame arrester case. Connect the sparkplug to the ignition system.

6. Drape a plastic bag outside the wire cage, over the mounting/mixture outlet and top of the flame arrester and secure it to the sides of the flame arrester.

7. Install a burst diaphragm at the end of the flashback tank.

8. Connect flashback tank to carburetion system through inlet valve.

9. Connect mounting/mixture outlet to external exhaust system through exhaust valve.

10. Open the inlet and exhaust valves.

11. Adjust the carburetion system to provide a 2.5% mixture by volume of n-hexane in air as indicated by the flammable gas analyzer.

12. Adjust the mixture flow to cause the plastic bag to inflate.

13. Maintain mixture flow for at least ten minutes so that all air originally in the test rig and sample has been displaced and a homogenous flammable mixture achieved.

14. Close inlet and exhaust valves.

15. Ignite the flammable mixture in the plastic bag by use of the sparkplug.

16. Observe for propagation of flame through flame arrester. Observation shall be visual and be supplemented by heat and pressure transducers.

17. Purge test rig with air for at least five minutes.

18. Repeat steps 5 through 16 with the sparkplug located approximately at the mid-point and highest point in the plastic bag.

19. For each of the three ignitions, record the following:

    a. Start time for filling of flammable mixture.

    b. Stop time for filling of flammable mixture.

    c. Reading of flammable gas analyzer.

    d. Indicate if flame propagation occurred through the flame arrester.

The IMO standard requires three ignition positions for attempted flashback: 1) near the surface of the device, 2) midway to the top of the plastic bag, and 3) near the top of the plastic bag. It is implied that the same screen may be used for all three positions. However, since the screens are inexpensive, in some cases a new screen was used. Use of the new screen is denoted in the test matrix in the Results section. A single 30-mesh and a double 20-mesh screen, of 304 and 316 stainless steel, were tested. The double 20-mesh screen consisted of two, 20-mesh screens separated by a 1/2 inch (12.7 mm) thick fiber gasket. Coast Guard regulations require a double screen for 20-mesh with a gap between 1/2 inch to 1 inch (12.7 mm to 25.4mm).

Whenever screens showed signs of damage, (e.g., after flame passage), it was replaced with a new screen of simi-

lar specifications. Prior to the installation of the wire cage, screens were changed after each test when the plastic bag had melted onto the screen.

5.4.2 Endurance Burn Tests

1. The test setup used is as described for the flashback test except coarse wire cage, plastic bag and the mounting/mixture outlet are to be removed.

2. Affix a minimum of three thermocouples to the tank side of the flame arrester element, approximately 120 degrees apart, midway between the center and periphery, and one thermocouple at the center. Route the thermocouple wires out of the test rig through a seal. (Note: This may be done prior to performing the flashback test to obviate the need to remove the hot arrester after the flashback test and install the thermocouples.)

3. Mount a sparkplug near the face of the flame arrester element.

4. Open the inlet valve.

5. Adjust the carburetion system to provide a 2.5% mixture by volume of n-hexane in air as indicated by the flammable gas analyzer.

6. Ignite the mixture at the face of the flame arrester element. Re-ignite the mixture as needed if the flame extinguishes during test.

7. Adjust the flow rate so the flame burns at the face of the element.

8. Maintain the flow until the temperatures measured by the thermocouples have stabilized for a period of at least 10 minutes. Record the percent mixture, flow rate, and temperature.

9. Adjust the mixture in increments and repeat steps 7 and 8.

10. Adjust the carburetion system to the mixture giving the highest stabilized temperature.

11. In a similar manner, vary the flow rate to see if temperature increases. If temperature increases, note flow rate giving highest temperature.

12. Adjust mixture and flow rate to conditions resulting in highest temperature on tank side of element and maintain for ten minutes.

13. Close the inlet valve.

14. Observe for propagation of flame through the arrester. Observation was visual and was supplemented by heat and pressure transducers.

15. For each step, record the following:

    a. Start time
    b. Stop time
    c. Percent mixture, n-hexane in air
    d. Flow rate
    e. Temperatures
    f. Indication if flame propagation occurred through the arrester

6.0 SELECTION OF DPPFs FOR TEST

The selection of DPPFs for this test series was based upon the desire to utilize a representative set of samples currently in use and which had previously been tested to the USCG/UL 525 Specifications. Selection rationale is provided in the following sections. Table 4 shows a selection of Flame Arresters approved by the U.S. Coast Guard and tested to UL 525 Specification. In addition, this table includes samples tested in this project.

6.1 FLAME SCREENS

Flame screens were selected according to their definition in the Code of Federal Regulations, Part 46, Subparts 30.10 - 25. The screens tested are described in Table 5. The 12 inch size was chosen to represent the larger size screens used on tankers. The double 30x30 mesh and single 40x40 mesh screens were tested after the other screens had failed the flashback test. Both 304 and 316 stainless steel wires were tested. The flame screens were fabricated by the Marine Fire and Safety Research Division of the Coast Guard. This was used in lieu of commercially available flame screens. The screen cloth was purchased and the housing fabricated according to 46 CFR 30.10-25*.

6.2 FLAME ARRESTERS

The 6 inch and 12 inch (15.5mm and 31mm) size flame arresters were selected as being representative of medium and large size arresters. Previous tests show temperature increase rates are influenced dependent on size and may affect equilibrium. Therefore, the two representative sizes were selected. The PRES-VAC arrester, manufactured by a Danish company, was selected because it had passed the IMO test, and testing would determine repeatability and objectivity of the test.

6.3 TEST SPECIMENS

Specifications and descriptions of Flame Screens and Flame Arresters used in this test program are described in Table 5. Photographs of each test specimen are provided in figures 5 through 24 and cross-referenced into Table 5.

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* Code of Federal Regulations 46. 1986.

TABLE 4
FLAME ARRESTERS APPROVED BY THE U.S. COAST GUARD

Flame Arresters	Pipe Size (in inches) 2.5	3	4	6	8	10	12
GPE		CG	CG	CG*	CG	CG	CG*
Groth				CG*	CG	CG	CG*
Johnson & Jennings			CG	CG	CG	CG	
Pettibone Oceco Type			CG	CG	CG	CG	CG
Protectoseal			CG	CG	CG	CG	
Varec	CG	CG	CG	CG*	CG	CG	CG
NAO (Prototype)							N*
PRES-VAC (Danish Mfgr)		F	F	F*			

CG - approved by U.S. Coast Guard
F - approved by foreign country
N - not approved
* - tested for this project

TABLE 5
TEST SPECIMENS OF DEVICES TO PREVENT THE PASSAGE OF FLAMES (DPPFs)

Sample No.	NOM. SIZE (in.)	PRINCIPAL FEATURES	MATERIALS Body	MATERIALS Element	ELEMENT HEIGHT (in.)
		FLAME SCREENS			
A1	12	20-mesh double screen	Steel	304SS	0.65
A2	12	20-mesh double screen	Steel	316SS	0.65
B1	12	30-mesh single screen	Steel	304SS	0.10
B2	12	30-mesh single screen	Steel	316SS	0.10
I	12	30-mesh single screen	Steel	316SS	0.10
J	12	20-mesh double screen	Steel	316SS	0.65
N	12	40-mesh single screen	Steel	316SS	0.10
O	12	30-mesh double screen	Steel	316SS	0.65

Sample No.	NOM. SIZE (in.)	PRINCIPAL FEATURES	MATERIALS Body	MATERIALS Element	ELEMENT HEIGHT (in.)
		FLAME ARRESTERS			
C	12	Crimpt ribbon	1011 Al.	SS	
D	12	Crimpt ribbon	SS	SS	6.00
E1	6	Crimpt ribbon - split element	Bronze	316SS	0.79
E2	6	Same as E1 with new element	Bronze	316SS	0.79
F1	6	Crimpt ribbon	Cast Iron	304SS	
F2	6	Same as F1 with new element	Cast Iron	304SS	
G	6	Crimpt ribbon			4.00
H	12	Crimpt ribbon - no cover	316SS	316SS	2.00
K	6	Spiral-wrapped Sheet	Carb Steel	316SS	6.00
L	6	Parallel Sheet	356-T6 Al.	316SS	5.86
M	6	Crimpt ribbon split element		316SS	4.00

TABLE 5 (cont'd.)
TEST SPECIMENS (DPPFs)

Designation	Description
A1	Flame screen (figure 5) supplied by U.S. Coast Guard. Made from two, 20-mesh stainless steel screens of (items 3 and 5) 0.015in. (0.38cm) diameter wire, approximately 15-5/8in. (39.7cm) diameter, separated by a fiber gasket (item 4) mounted with two fiber gaskets (items 2 and 6) and two steel rings (items 1 and 7). Fiber gaskets were approximately 16in. (41cm) OD, 12in. (31cm) ID, 0.325in. (0.8cm) thick. Steel rings each approximately 19-1/8in. (48.6cm) OD, 12-3/16in. (31 cm) ID, 1/4in. (0.6cm) thick.
A2	Same as sample A1, except 20-mesh stainless steel screens made of 316SS wire 0.015 - 0.016in. (0.38 - 0.41 cm).
B1	Flame screen supplied by U.S. Coast Guard. One, 30-mesh stainless steel screen (figure 6) 0.011 - 0.012in. (0.279 - 0.305mm) diameter wire, approximately 15-5/8 (39.7cm) diameter. Mounted between two fiber gaskets and two steel rings as described for sample A1.
B2	Same as sample B1, except 30-mesh stainless steel screens were made of 316SS wire.
C	12in. flame arrester (figures 7 and 8) aluminum body, stainless steel bank, GPE Controls, Inc., Model 94306-19-56-77.
D	12in. flame arrester (figures 9 and 10) stainless steel body, stainless steel bank, Groth Equipment Corp., Model 7618-12-555-F00.
E	6in. flame arrester (figure 11) PRES-VAC Model WBC Drawing A001101414045.
E2	6in. flame arrester, PRES-VAC, Model WBC Drawing A001101414045. Same as sample E except new arrester bank (see figure 12).
F1	6in. flame arrester, GPE Controls, Inc., Model 94306-36-66-77 (see figures 13 and 14).
F2	Same as sample F1, except new bank.
G	6in. flame arrester, Groth Equipment Corp., Model SN 76H 8771570-01-001 (see figures 15 and 16).
H	12in. flame arrester, NAO, prototype model (see figures 17 and 18).

TABLE 5 (cont'd)

Designation	Description
I	Flame screen supplied by U.S. Coast Guard. Made from one, 30-mesh stainless steel screen, (item 3) 0.011 - 0.012in (0.279 - 0.305mm) diameter wire, ap-proximately 15-5/8in (39.7cm) diameter. Mounted with two fiber gaskets (items 2 and 4) and two steel rings (items 1 and 5). Fiber gaskets were approximately 16in. (40.6cm) OD, 12in. (30.5cm) ID, 0.325in. (0.8cm) thick. Steel rings were approximately 19-1/8in. (48.6cm) OD, 12-3/16in. (31.0cm) ID, 1/4in. (0.6cm) thick.
J	Flame screen supplied by U.S. Coast Guard. Made from two, 20-mesh stainless steel screens of (items 3 and 5) 0.015in. (0.38mm) diameter wire, approximately 15-5/8in. (39.7cm) diameter, separated by a fiber gasket (item 4) mounted with two fiber gaskets (items 2 and 6) and two steel rings (items 1 and 7). Fiber gaskets were approximately 16in. (40.6cm) OD, 12in. (30.5cm) ID, 0.325in (0.8cm) thick. Steel rings each approximately 19-1/8in. (48.6cm) OD, 12-3/16in. (31.0cm) ID, 1/4in. (0.6cm) thick.
K	6in. flame arrester, Varec, Div. of Emerson Electric Co., Model 195400060336 (see figures 19 and 20).
L	6in. flame arrester, Varec, Div. of Emerson Electric Co., Model 135010060116 (see figures 21 and 22).
M	6in. flame arrester, Groth Equipment Corp., Model 7618-06-14-WO (see figures 23 and 24).
N	Same as sample I, except 40-mesh stainless steel screen.
O	Same as sample J, except 30-mesh stainless steel screens of 0.011 - 0.012in. (0.279 - 0.305mm) diameter wire.

FIGURE 5. Sample A Flame Screen Supplied by U.S. Coast Guard

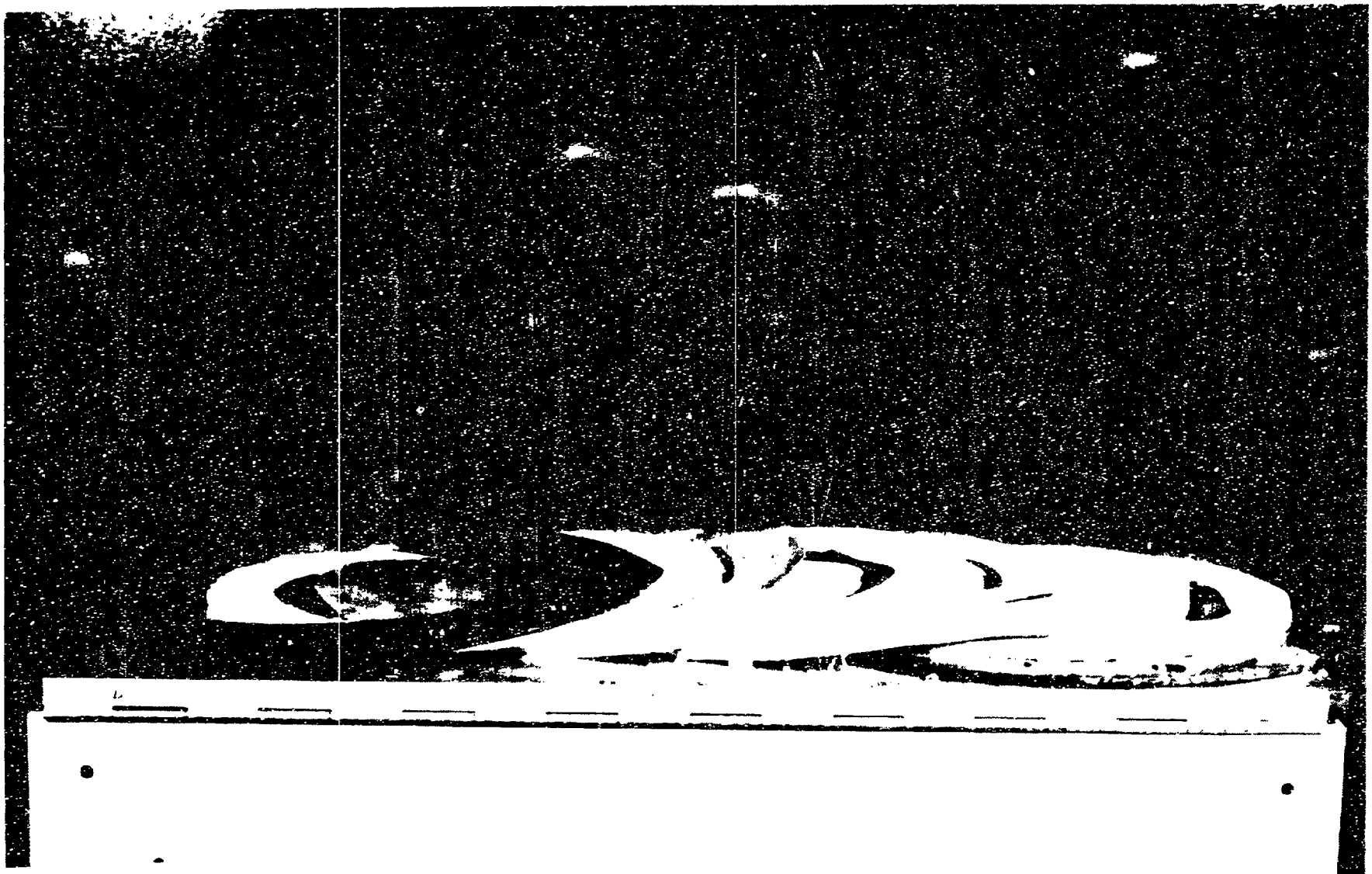

FIGURE 6. Sample B Flame Screen Supplied by U.S. Coast Guard

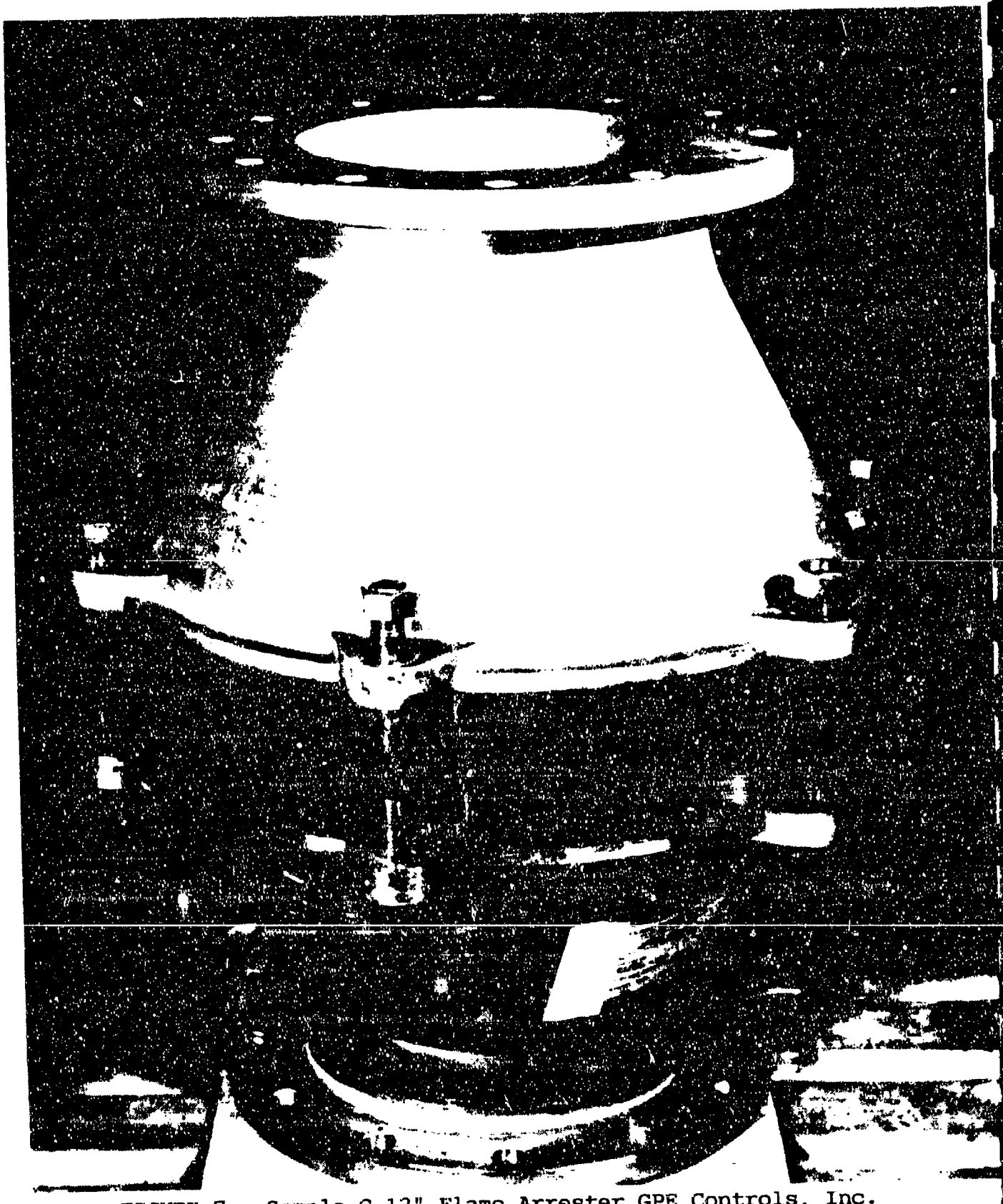

FIGURE 7. Sample C 12" Flame Arrester GPE Controls, Inc.

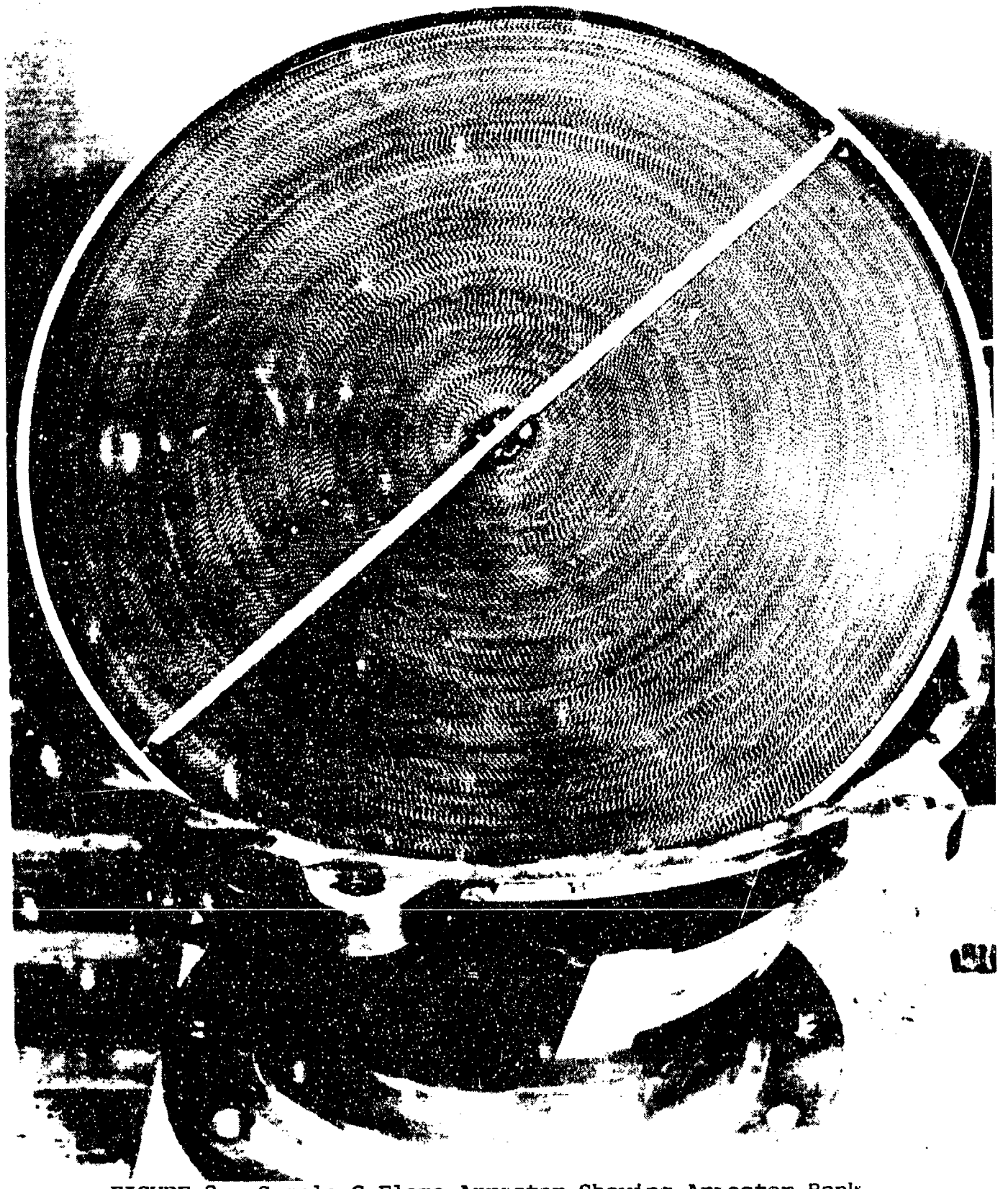

FIGURE 8. Sample C Flame Arrester Showing Arrester Bank

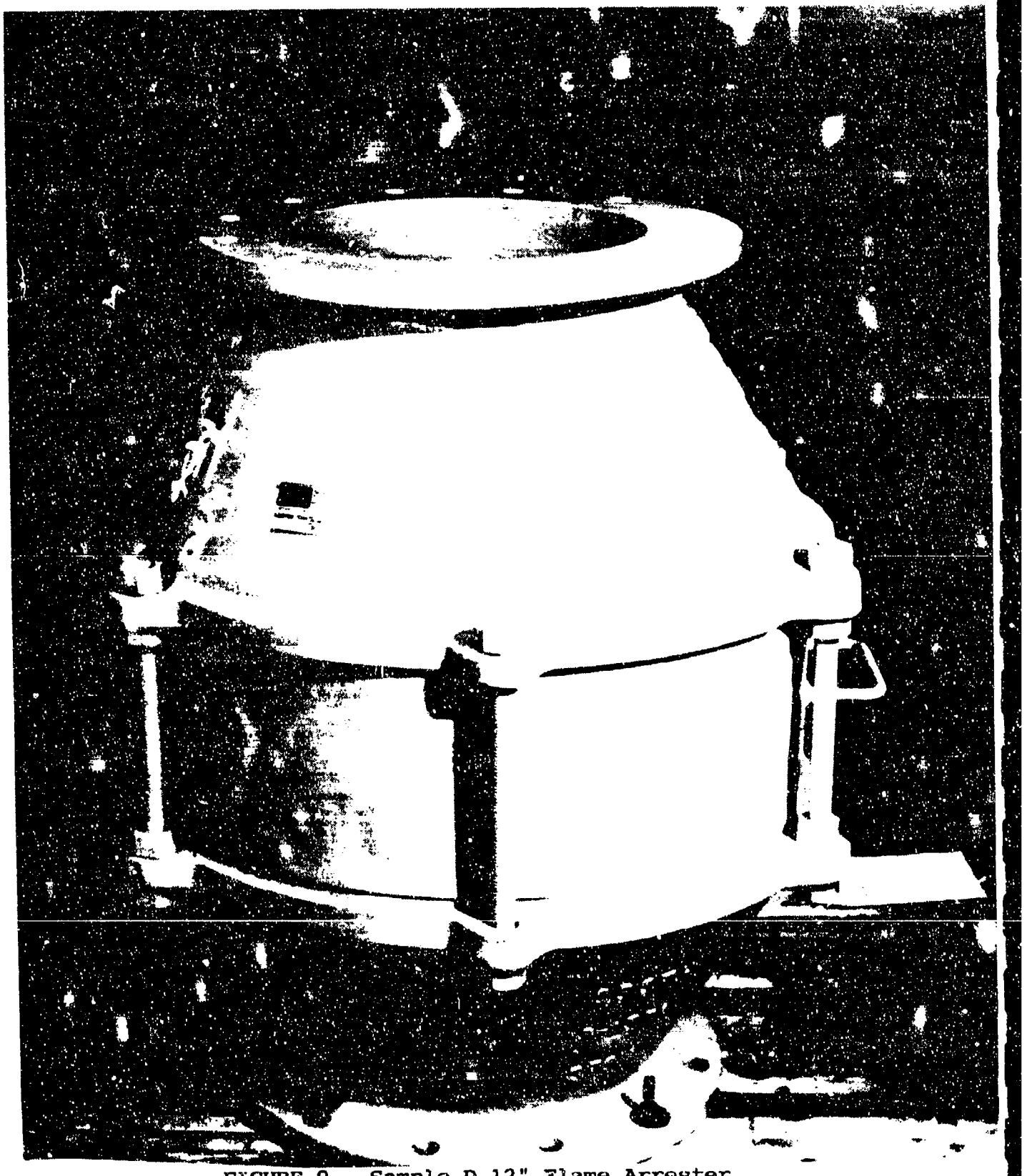

FIGURE 9. Sample D 12" Flame Arrester
Groth Equipment Corporation

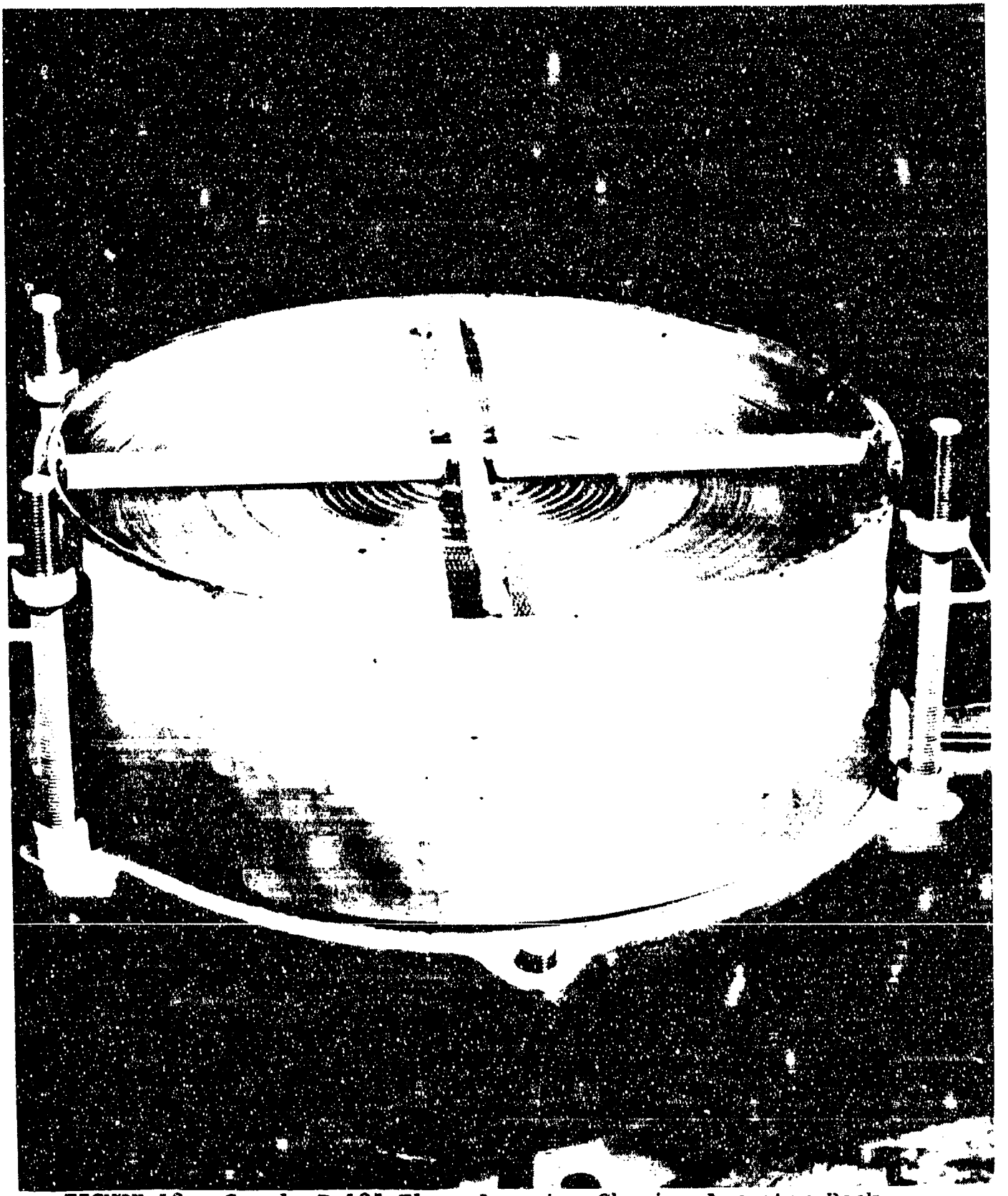

FIGURE 10. Sample D 12" Flame Arrester Showing Arrester Bank

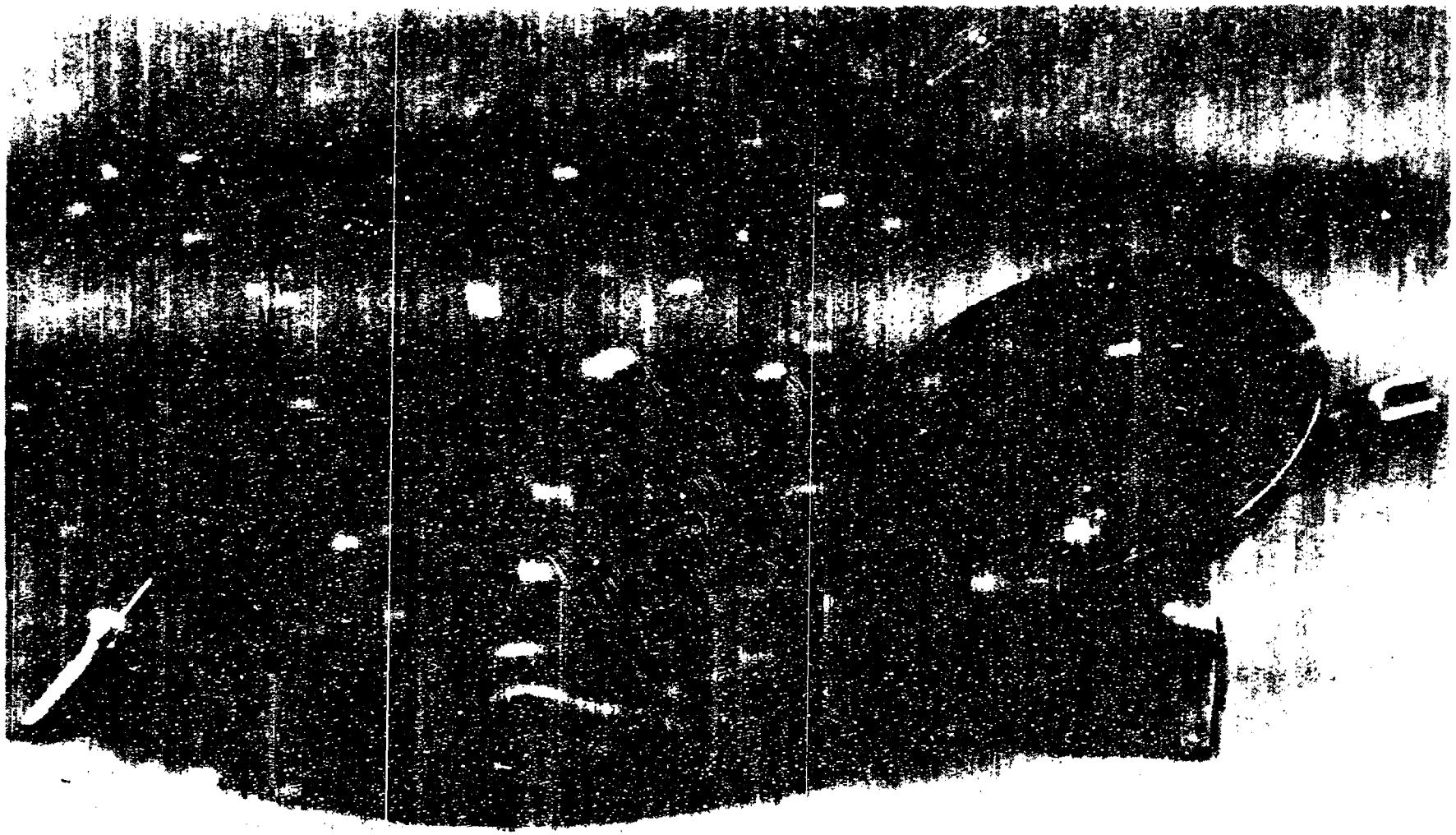

FIGURE 11. Sample E 6" Flame Arrester PRES-VAC Model WBC

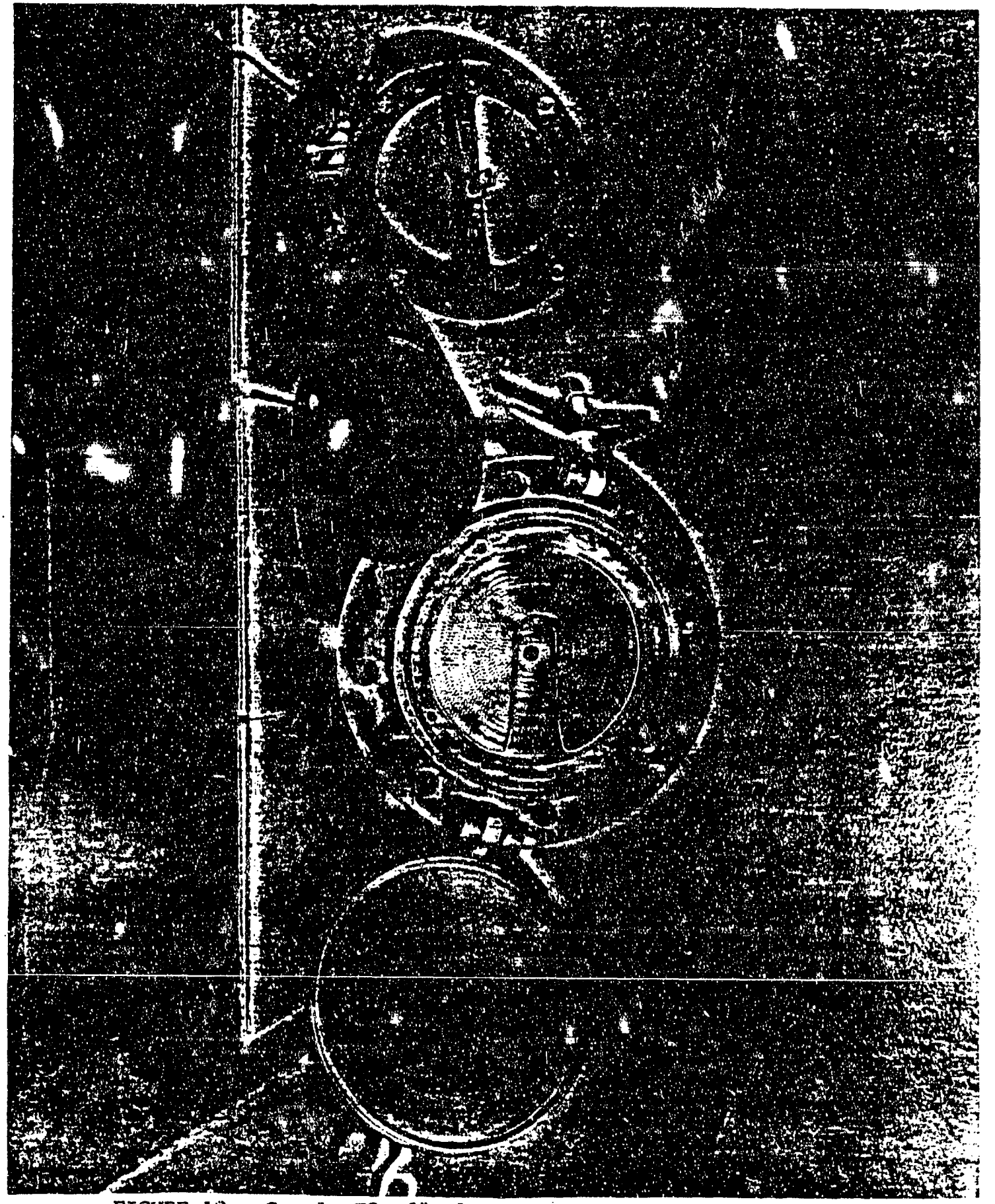

FIGURE 12. Sample E2 6" Flame Arrester PRES-VAC Model WBC Showing Replacement Flame Arrester Bank

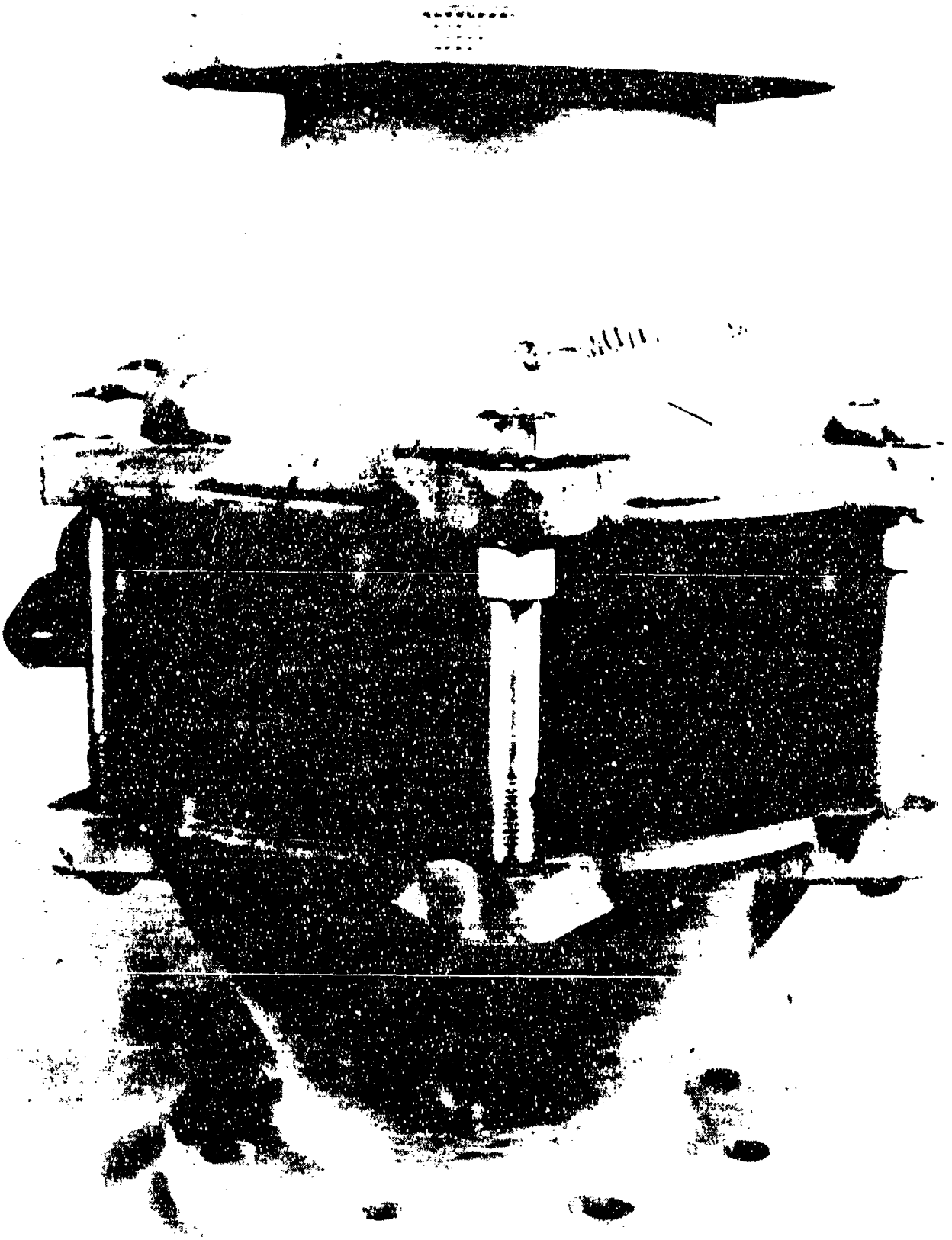

FIGURE 13. Sample F1 & F2 6" Flame Arrester GPE Controls, Inc.

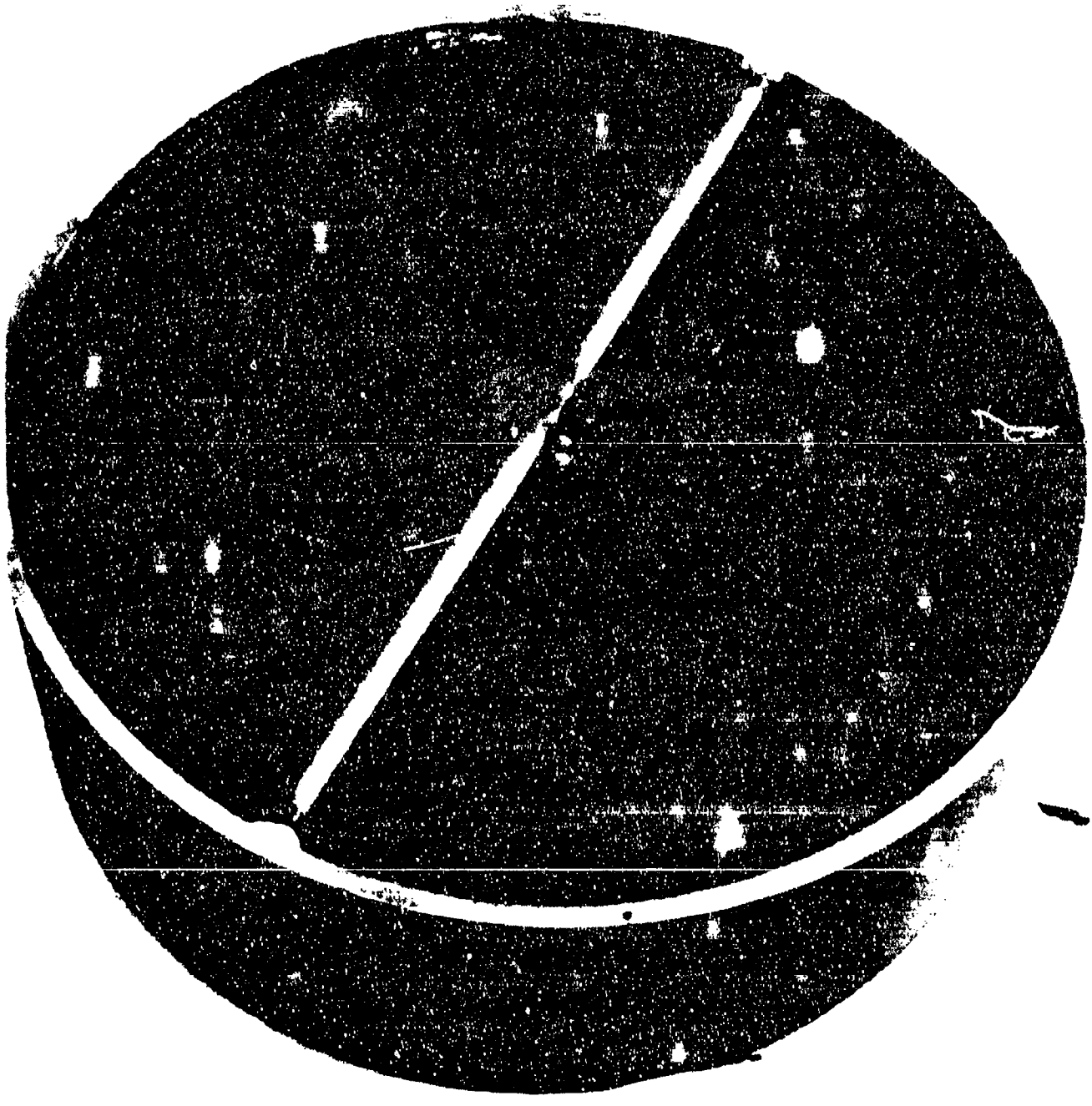

FIGURE 14. Sample F1 & F2 Flame Arrester Bank

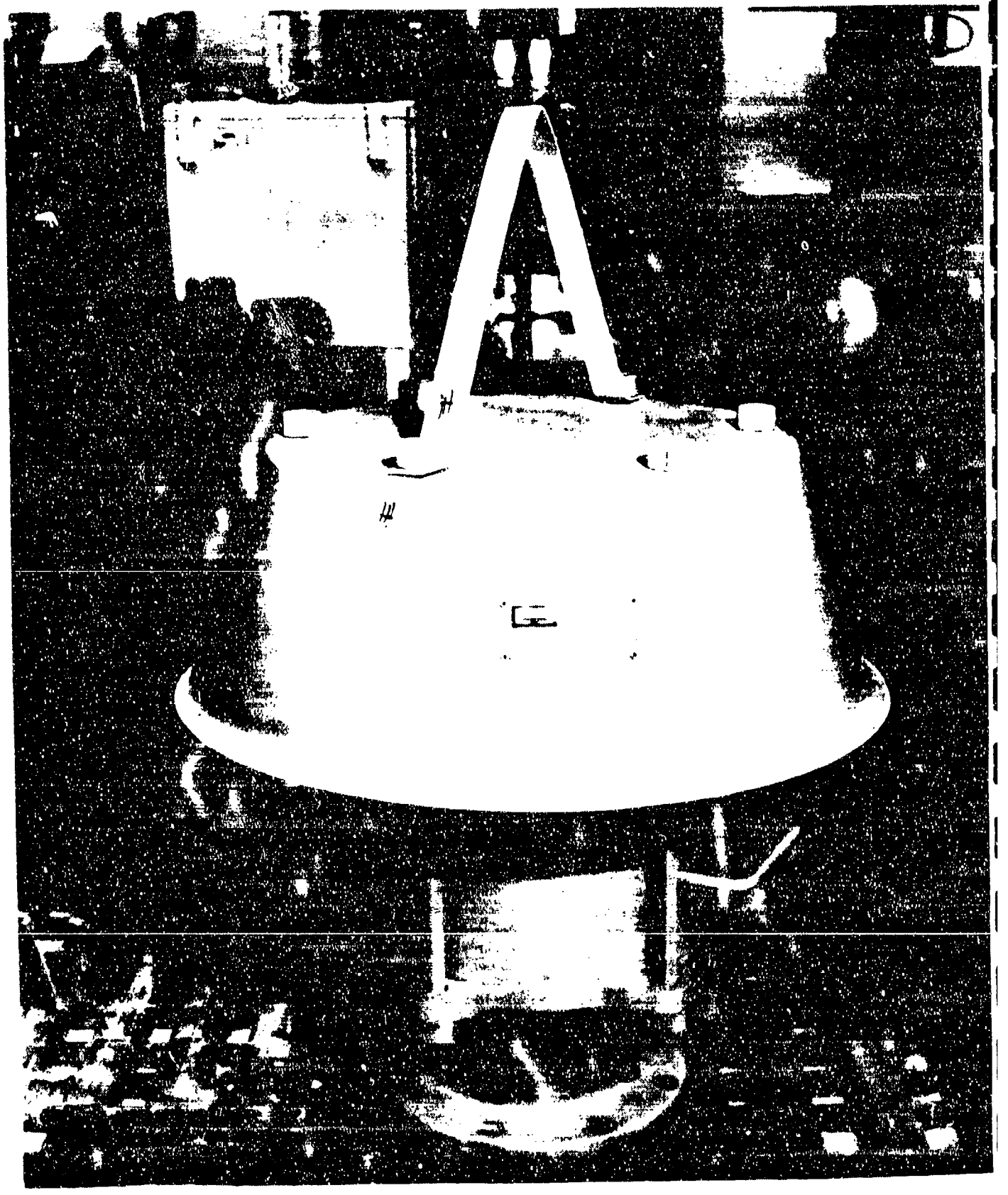

FIGURE 15. Sample G 6" Flame Arrester Groth Equipment Corporation

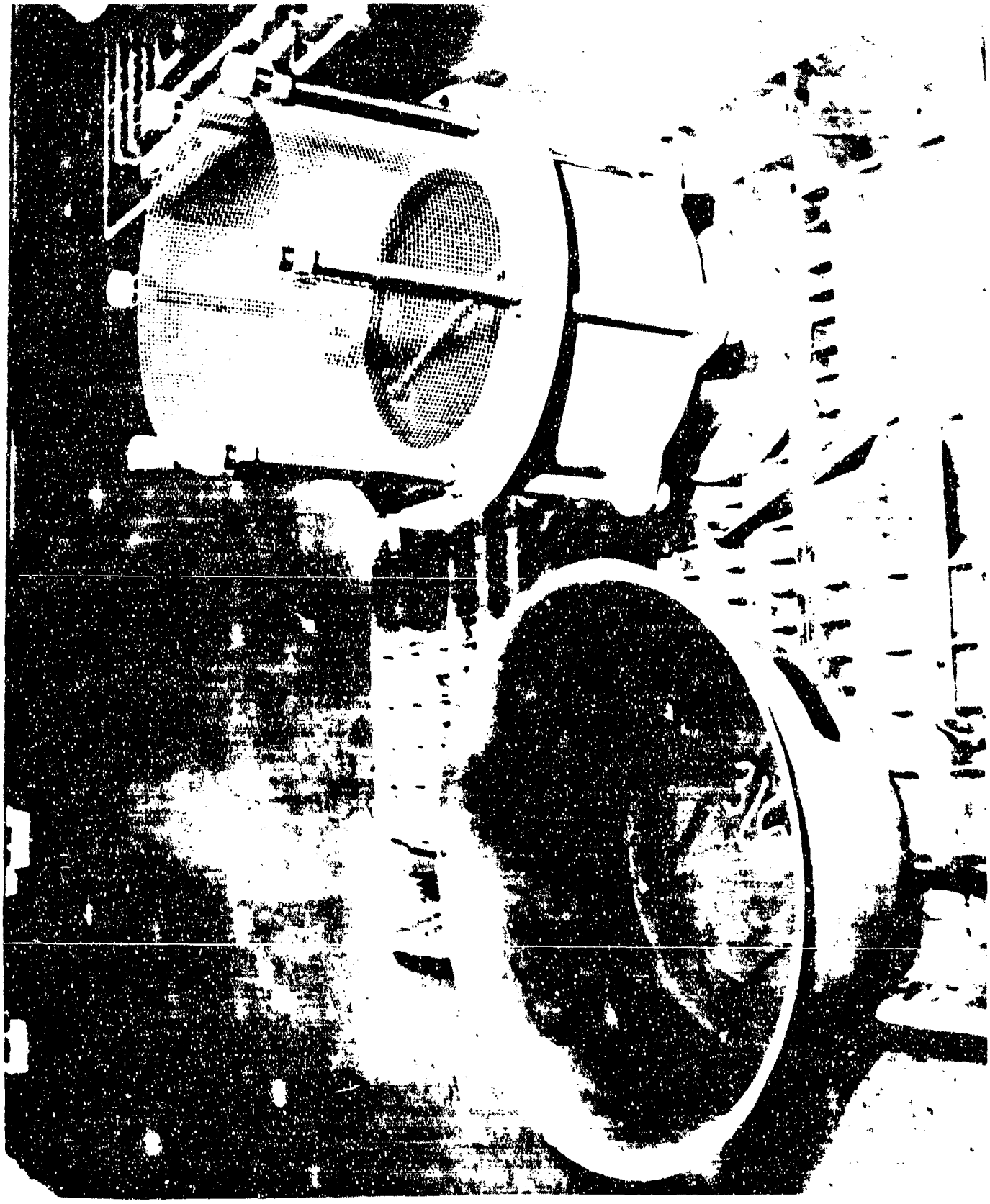

FIGURE 16. Sample C Showing Hood, Flame Guard, Mesh and Arrester Bank

FIGURE 17. Sample H 12" Flame Arrester NAO Prototype Model

FIGURE 18. Sample H Showing Damage to Flame Arrester Bank

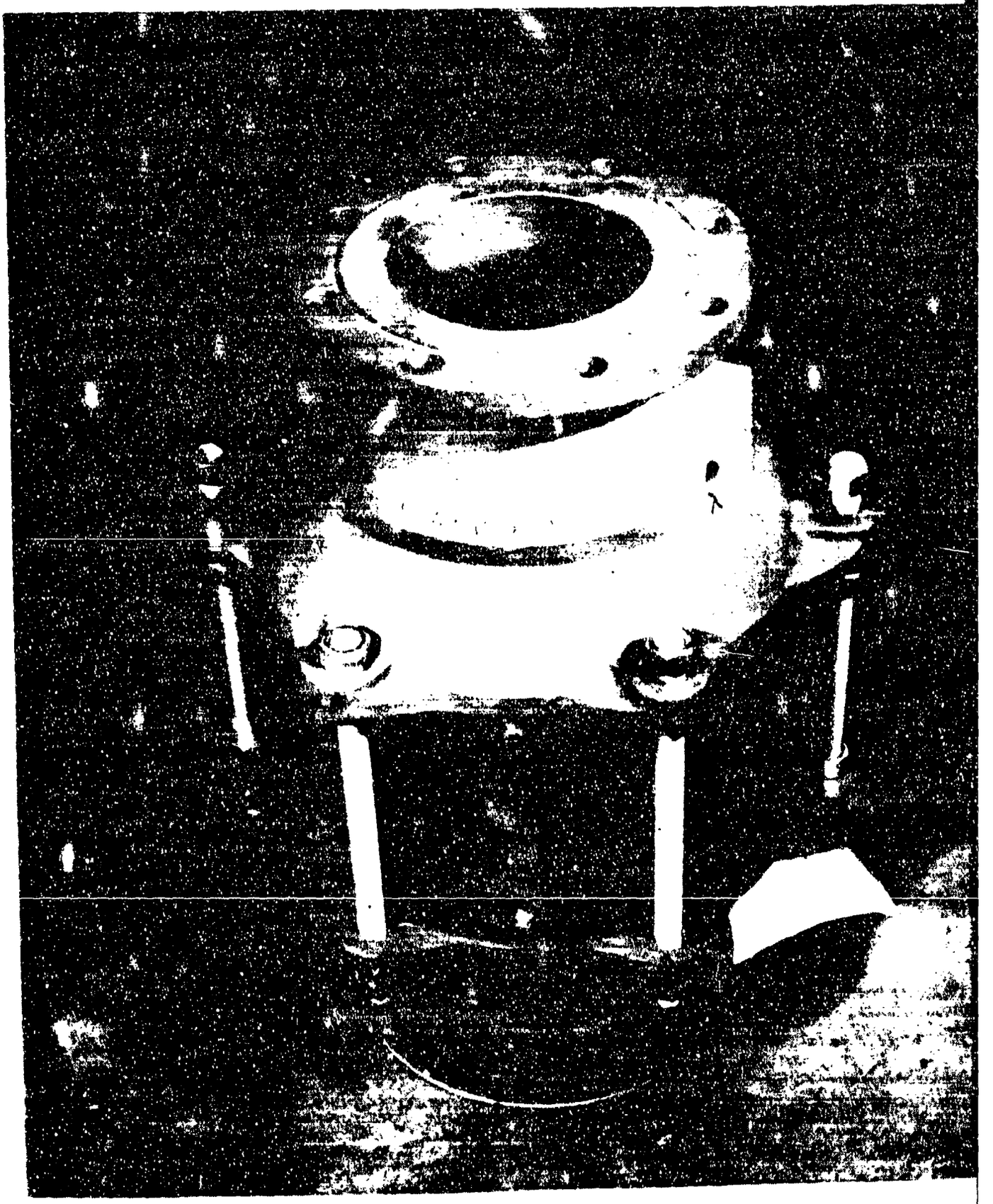

FIGURE 19. Sample K 6" Flame Arrester VAREC Division of Emerson Electric

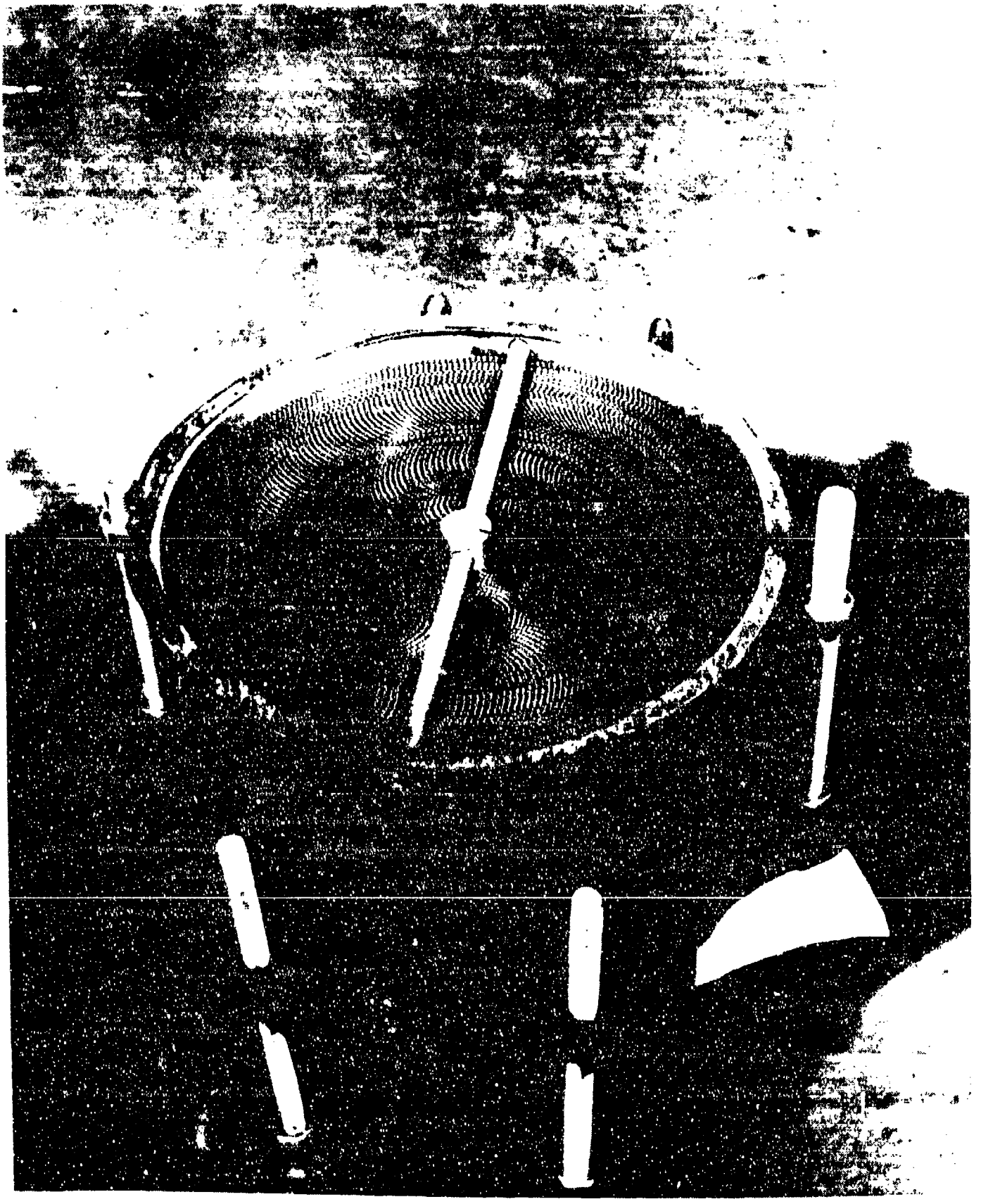

FIGURE 20. Sample K Showing Flame Arrester Bank

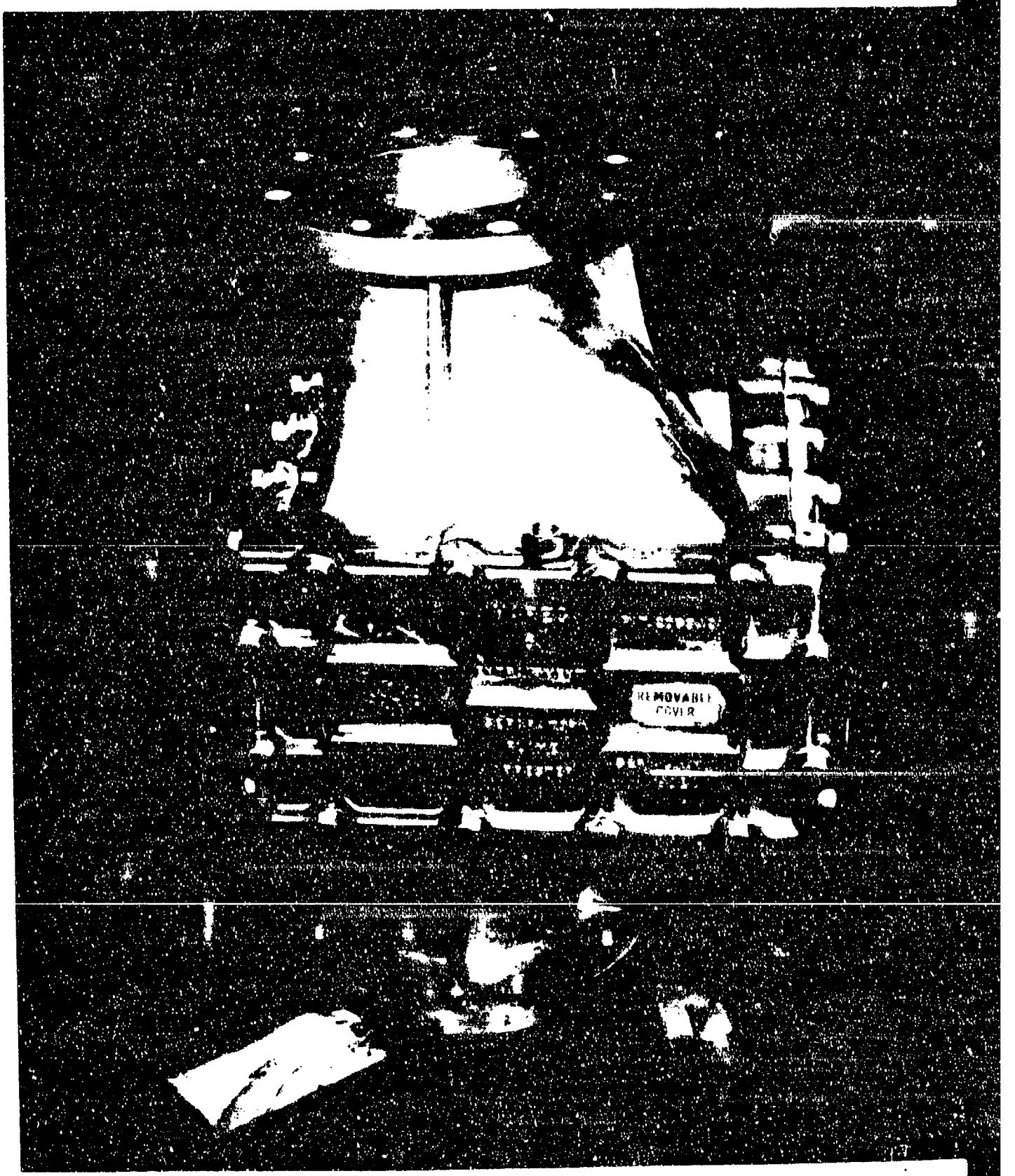

FIGURE 21. Sample L 6" Flame Arrester VAREC Division of Emerson Electric

FIGURE 22. Sample L Showing Flame Arrester Bank

FIGURE 23. Sample M 6" Flame Arrester Groth Equipment Corporation Showing Hood and Main Body

FIGURE 24. Sample M Showing Flame Arrester Bank

7.0 TEST RESULTS

7.1 FLAME SCREENS

7.1.1 Flashback Tests

Both the double 20-mesh and the single 30-mesh flame screens failed the flashback tests. These were 304 stainless steel screens. The 316 stainless steel screens were not tested for flashback. For the test with ignition in the mid position, the top screen in the double 20-mesh arrangement was torn by the flashback explosion. For results of tests, refer to Table 6.

TABLE 6
TEST RESULTS: FLAME SCREENS

Flashback Test

Sample No.	Material	Mesh	Igniter Location	Flashback
A1	304	20	Btm 1.0 ft	-
A2	S/S	double	Mid 2.5 ft	Fail
A2			Top 6.5 ft	-
A2			Mid 2.5 ft	-
B1	304	30	Btm 1.0 ft	Fail
B2	S/S	single	Mid 2.5 ft	-
B2			Top 6.5 ft	Fail

7.1.2 Endurance Burn Tests

The endurance burn test was conducted as described in Section 2 of this report. The following additional comments apply:

a. The IMO Standard does not require flame screens to be subjected to an endurance burn test. Subjecting the flame screens to the endurance burn test was done at the request of the U.S. Coast Guard.

b. For Sample A2, Test 2 was a repeat of Test 1, except no thermocouples were attached to the flame screen. This was done to study the effect of the thermocouples on the test results.

c. For Sample B2, in Test 1 the flammable mixture could not be re-ignited because the ignition system was damaged by heat of the flame.

d. For Sample B2, in Test 1 the flow rate of flammable mixture was varied to determine the flow rate resulting in maximum element temperatures. During Test 2, the mixture of n-hexane in air was varied.

Endurance burn tests are not required of flame screens, per the IMO standard. However, previous endurance burn tests (reference 4) showed flame screens to resist flashback for one hour (the presently accepted standard). Subjecting the screens to the endurance burn test would give a comparison for this type of device.

The fuel ratio and flow rate were set and adjusted as shown in Table 7. For the 12 inch (31mm) arresters manufactured by GPE, Groth and NAO, and the 6 inch (15.5mm) arrester manufactured by Groth, no adjustments were made. Stable temperatures were never reached, precluding adjustments in search of a higher stable temperature.

Endurance burn tests were conducted on single 30-mesh and double 20-mesh screens - 316 stainless steel (see Table 7). A single 30-mesh screen of 304 stainless steel was also tested. Initial fuel ratios and flow rates were set and adjusted, as described in the test section, until either the flame extinguished or flashback occurred. Adjustments were made first to the flow rate and then to the fuel ratio at the last flow rate. Determination of when to make adjustments was done visually. For the flame screens, since thermocouples would not adhere to the screens, the flow rate was lowered from the initial flow rate of 1138 scfh. If there was no visually observable change in the flame intensity after 10 minutes, the flow rate was further lowered by a rate equivalent to 1 inch of mercury pressure head. If the flame intensity diminished, the flow rate was returned to the previous rate and the fuel/air ratio was changed and flame intensity observed. The test was terminated when flashback occurred.

For the endurance burn test series, the double 20-mesh screens of 304 stainless steel (samples A1, A2) lasted approximately 12 minutes before flashback occurred. After 10 minutes, the fuel ratio was increased from 2.5 to 2.6%. The screens failed after 2-3 minutes. Two screen devices were tested, with and without thermocouples, as mentioned previously. The screens were tested without the thermocouples to determine if they had any effect on the flashback. Since both failed at approximately the same time, it was concluded that the thermocouples had no adverse effect.

The single 30-mesh, 316 stainless steel screen (sample B1) flame was extinguished after 58 minutes. The flame was relit and the screen lasted another 70 minutes. The test was terminated because of low fuel. At that point, flashback occurred when the fuel mixture was shut off. A further single 30-mesh, 316 stainless steel screen (sample B2) lasted only 10 seconds in the endurance burn test.

TABLE 7
TEST RESULTS: ENDURANCE BURN TEST

Flame Screens

Sample No.	Material	Mesh	Fuel Ratio	Flow Rate	Time	Elapsed Time	Flashback	Thermocouple
A2	316 S/S	20 double	2.5	1138	10	10	-	Y
			2.6	1138	3	13	Fail	Y
A2			2.5	1139	10	10	-	N
			2.6	1138	2	12	Fail	N
B1	304 S/S	30 single	2.5	1138	10 sec		Fail	N
B2	316 S/S	30 single	2.5	1138	13	13	-	N
			2.5	1038	10	23	-	N
			2.5	882	10	33	-	N
			2.5	674	10	43	-	N
			2.5	510	10	53	-	N
			2.4	510	3	56	-	N
			--------Opened valve to increase flow - flame extinguished --------					
			2.5	1139	10	66	-	N
			2.6	1139	10	76	-	N
			2.7	1165	10	86	-	N
			2.4	1168	10	96	-	N
			2.6	1167	10	106	-	N
			2.6	1050	5	111	-	N
			2.5	1051	5	117	-	N
			2.7	1049	5	122	-	N
			2.4	1052	5	127	Fail	N

7.2 FLAME ARRESTERS

7.2.1 Flashback Tests

Flashback tests for the flame arresters were conducted at the same three igniter positions as for the flame screens. All flame arresters passed the flashback tests.

7.2.2 Endurance Burn Tests

a. For Sample D, Test 2 was performed using a 1.9% mixture of Naphtha-R in air. The test was conducted per UL 525 except a flow rate of 1186 scfh, rather than 1030 scfh, was used to approximate that used in Test 1. Burning was for six, 10-minute periods, separated and followed by 15-second periods when the flow was turned off. This test was conducted to compare performance of the flame arrester when tested under both the IMO and the UL 525* test methods.

b. For Sample E, Test 1, both flow rate and mixture were varied to determine optimum combination. For the last combination in Table 8, the flow was maintained for only 7 minutes because the last combination was a repeat of the first. For the first combination, the element was maintained at stabilized temperatures for more than 10 minutes as required by the IMO Standards.

Samples C and D, both 12 inch (31cm) flame arresters, failed the endurance burn tests in 26 and 88 minutes, respectively. No adjustments were made to either the fuel ratios or the flow rates. As in both arrester tests, the temperature kept rising from the onset and never reached equilibrium.

Sample E, a 6 inch (15.5cm) flame arrester, passed the endurance burn test. The initial fuel ratio and flow rate were set at 2.5% and 232 scfh. After 20 minutes, the highest temperature reading, at the center, reached an equilibrium temperature of 350°C (662°F). Adjustments to the flow rate and then the fuel ratio were made. The temperature peaked at 364°C (687°F) then returned to 340°C (644°F) and remained stable. The test was terminated after 113 minutes with no flashback occurring. Thermal inertia carried the arrester element temperature to 407°C (765°F) after termination of the test.

As previously mentioned, the endurance burn test requires that the fuel/air mixture and flow rate be adjusted to produce the highest temperature, and that the temperature is to maintain stability for a period of at least ten minutes for each fuel/air mixture and flow rate. It is therefore possible for the

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* ANSI/UL 525 - 1984, Standard for Flame Arresters for Use on Vents of Storage Tanks for Petroleum Oil and Gasoline (Appendix B).

endurance burn test to last for less than one hour if temperature attains stability over a 10-minute period. Conversely, if temperature stability is not achieved within the specified limits, then the test can last for many hours (figure 25).

The flame arrester test specimen E1 passed the endurance burn test twice, once for almost two hours and once for four hours. In each case, the temperature never exceeded 207°C, (405°F) but because the temperature remained constant for ten minutes, the test was considered a success. Conversely, the flame arrester test specimen K failed only after longer than eight hours. The temperature maintained a slow rate of rise until at 843°C (1549°F) flashback occurred. Figure 25 expresses the endurance burn comparison as a function of time/temperature. It will be seen that other arresters failed at higher temperatures and longer endurance than sample E1 which passed the test (table 8).

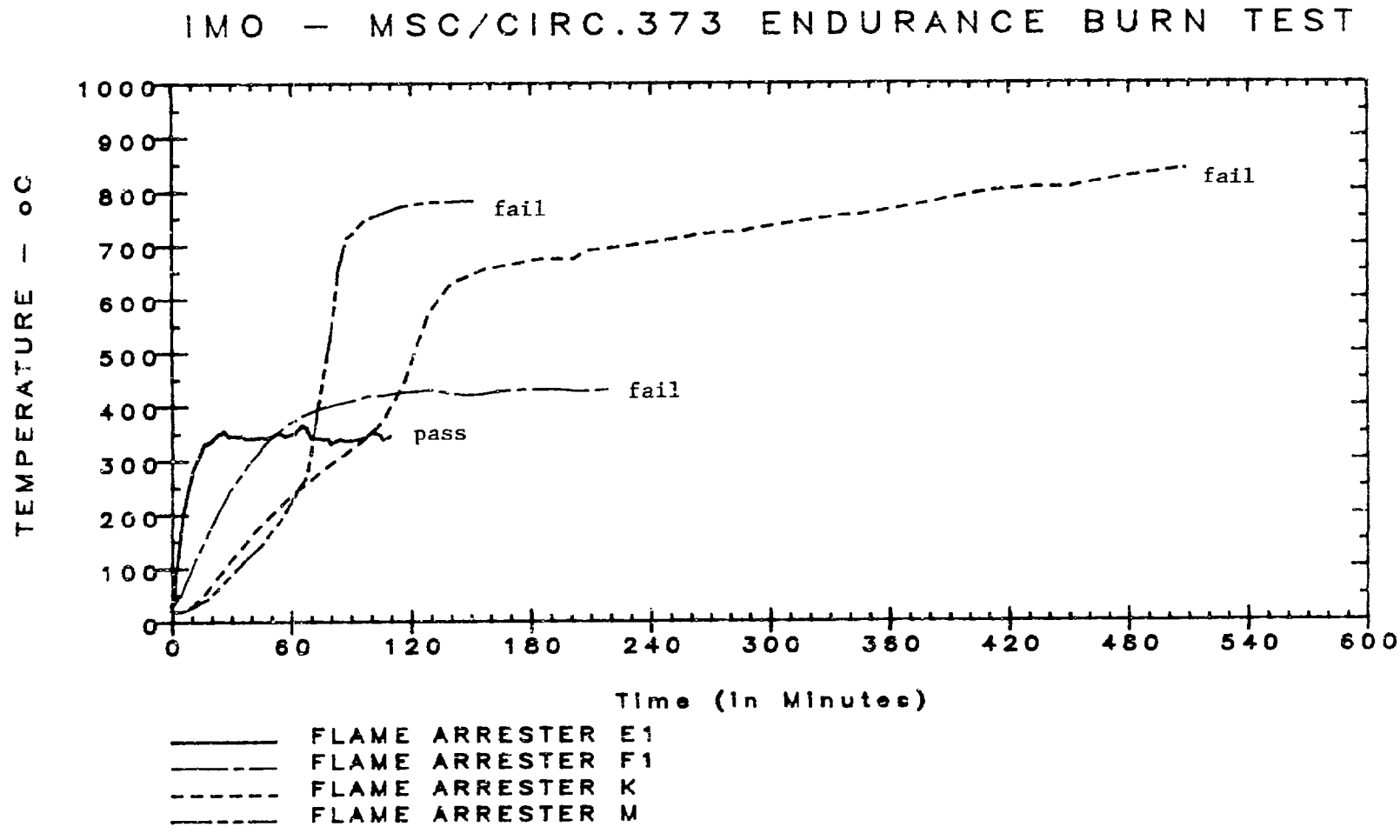

FIGURE 25

Time/Temperature Graph Showing Differences in Pass vs Fail Criteria

TABLE 8

TEST RESULTS: FLAME ARRESTERS

Endurance Burn

Sample	Size	Mfr	Element	Fuel Ratio	Flow Rate	Temp.	Time (min)	Elapsed Time (min)	Flashback
C	12"	GPE	4"	2.5	1167	297*	26	26	Fail
D	12"	Groth	8"	2.3	1174	>760	88	88	Fail
H	12"	NAO	2"	2.5	1106	933	40	40	Fail
G	6"	Groth		2.5	235	684	95	95	Fail
F1	6"	GPE		2.5	235	412			-
				2.5	238	425	18	18	-
				2.5	199	428	15	33	-
				2.5	183	430	16	49	-
				2.5	255	422	14	63	-
				2.5	235	429	19	82	-
				2.6	235	431	10	92	-
				2.7	235	432	13	105	-
				2.4	235	428	13	118	-
				2.3	235	431	7	125	Fail*
E	6"	PRES/VAC		2.5	234	353	40	40	-
				2.5	256	351	22	62	-
				2.5	215	364	8	70	-
				2.4	216	341	18	88	-
				2.6	215	341	9	97	-
				2.5	215	351	9	106	-
				2.5	233	348	7	113	-

*The flashback of this flame arrester during the endurance burn test occurred at a time well beyond the 10 minutes of stable temperature. The time was extended in search for higher stable temperatures. None were found; therefore, test termination at 10 minutes after the initial stable temperature may have precluded flashback.

8.0 CONCLUSIONS

This test program has identified several important factors which either (a) adversely influence the integrity of the IMO Test Standards, and/or (b) require further consideration with regard to the proper technical interpretation and application of the test protocols. We have identified these factors in the following subsections.

8.1 TECHNICAL IMPROVEMENTS TO IMO MSC/Circ.373 PROTOCOL

Clarification is needed to establish whether the same flame screen is to be used for all three ignition source locations (see section 7.1.1).

During the development of the test apparatus and the calibration of equipment for the Endurance Burn Tests, the greatest concern was over the following wording, which attempts to define the representative temperature of the Endurance Burn Test:

> "...the arrester shall be heated until the highest obtainable temperature on the cargo side of the arrester is reached" (IMO MSC/Circ.373, para. 3.2.3.2).

This passage could be interpreted two different ways, as follows:

- The gas temperature of the flammable hexane/air mixture entering the test specimen from the tank, or
- The internal surface temperature of the test specimen on the tank side.

The gas temperature of the flammable hexane/air mixture on the tank side was used as the representative endurance burn test temperature for the following reasons:

- The highest internal surface temperature of the specimen on the tank side could occur at any one of several locations, which could fluctuate in magnitude and change position during a test. Moreover, such location(s) would be test specimen specific, because each one is configured differently, giving rise to flames at different internal and external locations with different symmetries.
- The highest internal surface temperature of any specimen could only be identified by extensive temperature probing during the endurance burn test, which poses a safety risk. Such probing and eventual monitoring with a thermocouple inside the

specimen would alter the normal fluid flow patterns in some fashion. Perturbations by a foreign agent could conceivably alter the results of the endurance burn test, with the most probable direction being towards failure. (The thermocouple would improve heat transfer from the valve to the flammable mixture.)

- Monitoring the gas temperature of the hexane/air mixture entering the specimen from the tank would provide a standardized means by which to acquire a representative test temperature that was common to all specimens and thereby avoid any influence of the test procedure on the performance of the DPPFs.

As mentioned in Section 4.3, Heat Transfer of the DPPFs, a second issue concerns the logic behind how "the highest possible temperature on the tank side of the element" is to be reached via IMO/MSC procedures, as follows:

"...by varying the proportions of the flammable mixture..."

Information from the technical literature is used to address this concern, which involves the role of flame temperature, luminosity, and speed, and how these parameters may influence the severity of the flashback test (references 9 and 10).

Variation of the fuel/air ratio of a flammable mixture does result in different maximum flame temperatures (reference 10), which would affect the temperature to which any specimen was heated as it acted as a flame arrester. For flammable hexane/air mixtures, the maximum flame temperature increases from about 2200°F (1204°C), at the lower (fuel-lean) and upper (fuel-rich) flammability limits, to about 3600°F (1982°C) at the stoichiometric limit. However, accompanying these changes in temperature are concomitant changes in luminosity. The luminosity of the flame would affect the rate of heat transfer from the flame to the DPPF, thereby influencing the extent to which the DPPF was heated. The higher the luminosity, the greater the radiative heat transfer to the DPPF. The highest flame luminosity occurs at the rich limit (yellow flame mode), which also has the lowest maximum flame temperature. Hence, a tradeoff exists between luminosity and maximum temperature in terms of the extent of DPPF heating.

Tests conducted indicated that the highest temperature on the tank side of the DPPF was obtainable when the flammable mixture was at the upper flammability limit, rather than when it was at the stoichiometric limit. This observation indicated that flame luminosity was more important than maximum flame temperature in governing heat transfer processes to the DPPF. This result would suggest that heating and endurance testing

should be done with a flammable mixture of n-hexane/air at the upper flammability limit.

However, flashback tendency is also a function of "...the proportions of the flammable mixture". Specifically, flashback tendency is directly proportional to flame speed. As flame speed increases, the likelihood for flashback increases (reference 10). As the fuel/air ratio of n-hexane/air is changed from the stoichiometric limit (2.16 percent n-hexane) to the upper flammability limit (7.4 percent n-hexane), the flame speed decreases by an order of magnitude from about 10 to about 1.5 feet/second (references 9 and 10). Therefore, while the DPPF may get the hottest at the upper limit, flashback is more probable at the stoichiometric limit. This applies equally to the endurance burn of the DPPFs.

Additionally, the permitted flammable fuel/air mixtures identified in the IMO document includes the term "gasoline" and, as detailed in Section 5.2.1, "Fuel Selection". Our research establishes that gasoline is a generic term with a wide range of analytical parameters unsuitable for the specifics of a test standard. We conclude that the term "gasoline" together with the current definition, be omitted from the document and that n-hexane be nominated as the preferred flammable fuel.

It is essential in all cases of fuel/air applications that the specific fuel/air flow rate be specified to cover the appropriate range of flammability (i.e., limits of flammability). The current IMO MSC/Circ.373 does not specify critical flow rates or critical fuel/air mixture limits.

8.2 SAFETY PROCEDURES DURING TESTING

For the flashback tests, an exhaust line was used at the top of the plastic bag. This permitted purging of the air from both the piping and the plastic bag, ensuring only test vapor/air mixture in the test system. Approximately 1/2 inch (12mm) pipe was utilized as the exhaust. The vapor was permitted to flow for 10 minutes.

Apart from a brief reference in paragraph 1.2.3 in IMO document MSC/Circ.373, no consideration is given with regard to definitions and interpretation of maximum explosive safe gap (MESG), minimum ignition current (MIC), and minimum ignition energy (MIE) required to ensure ignition of the fuel/air mixtures across the range of flammable limits. It is suggested that these factors be covered in the Standard to ensure uniformity of test protocols. With particular regard to ignition source location and its relationship to the safe gap, Redeker (reference 22) has shown that in experiments and tests designed for the determination of MESG, consistent ignitability of flammable fuel/air mixtures is a function of gas flow and location of the ignition source. Shifts in the location of the source and the gap dimensions affect flame propagation.

For the Flame Screen and Flame Arrester tests, the ignition source used was a sparkplug. To ensure safety of personnel and observers it is recommended that a sparkplug be used as the ignition source for all endurance burn tests. Section 3.2.3.2 for the IMO MSC/Circ.373 document mentions either a spark igniter or a pilot flame. We recommend the use of a sparkplug because, in the event of extinguishment of the pilot flame during the pre-burn period and before actual endurance burn commences, re-ignition of the pilot flame in an atmosphere of possible explosive fuel/air mixture is hazardous.

8.3 Flame Screen/Flame Arrester Performance

Due to the inconsistencies within the IMO test procedures, it is difficult to evaluate the actual performance of the flame screens and arresters. Without a specific set of test procedures and parameters, it is equally difficult to evaluate the "fairness" of the test itself.

Initial review of the data may tend to indicate that the flame screens are not providing adequate protection. And though the majority of flame arresters "failed", arguments can be made that the test requirements are unrealistic. Before a final determination can be made concerning the performance of the flame screens and arresters, the items mentioned in section 8.1 need to be addressed. With a final, standard set of guidelines available, a performance evaluation can be made. Whether this will require a retest of these specific units or not, depends upon what changes are made to the IMO/MSC Procedures.

9.0 LABORATORIES CAPABLE OF CONDUCTING APPROVAL TESTS

Underwriters Laboratories, Inc., and Battelle Columbus Division have demonstrated their ability to perform flashback and endurance burn tests in accordance with IMO MSC/Circ.373. Both laboratories demonstrated high levels of expertise and conducted all tests under strict safety procedures. Based upon the test procedures which have been generated and used by Factory Mutual Research (FMR) for flashback and endurance testing of DPPFs, which are similar to those used in this program, it is reasonable to assume that FMR could also conduct these tests.

All three identified laboratories meet the Coast Guard requirements (46 CFR 159.010) for independent laboratories acceptable for performing approval testing of DPPFs.

REFERENCES

1. International Convention for the Safety of Life at Sea (SOLAS) Amendments, 1983.

2. International Maritime Organization: Document MSC/Circ.373. "Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame Into Cargo Tanks in Tankers." 1988.

3. Underwriters Laboratories, Inc., Standard for Safety, UL 525, "Flame Arresters for Use on Vents of Storage Tanks for Petroleum Oil and Gasoline." Fifth Edition, 1984.

4. Wilson, R.P., Jr., and Crowley, D.P., "Flame Arrester Design Requirements for Prolonged Exposure to Methane/Air, and Gasoline/Air Flames." USCG, 1978.

5. Bjorklund, R.A., and Kushida, R.O., "Flashback Flame Arrester Devices for Fuel Cargo Tank Vapor Vents." USCG, 1981.

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7. Komamiya, K., "The Quenching Ability of Flame Arrestors for n-hexane." Research Report of the Japanese Research Institute of Industrial Safety, 1969.

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(b) *Grade B.* Any flammable liquid having a Reid[1] vapor pressure under 14 pounds and over 8½ pounds.

(c) *Grade C.* Any flammable liquid having a Reid[1] vapor pressure of 8½ pounds or less and a flashpoint of 80° F. or below.

[CGFR 65-50, 30 FR 16657, Dec. 30, 1965, as amended by CGD 73-96, 42 FR 49023, Sept. 26, 1977]

§ 30.10-23 Flame arrester—TB/ALL.

The term "flame arrester" means any device or assembly of a cellular, tubular, pressure, or other type used for preventing the passage of flames into enclosed spaces.

§ 30.10-25 Flame screen—TB/ALL.

The term "flame screen" means a fitted single screen of corrosion-resistant wire of at least 30 by 30 mesh, or two fitted screens, both of corrosion-resistant wire, of at least 20 by 20 mesh, spaced not less than ½ inch or more than 1½ inches apart.

§ 30.10-27 Flashpoint—TB/ALL.

The term "flashpoint" indicates the temperature in degrees Fahrenheit at which a liquid gives off a flammable vapor when heated in an open-cup tester. For the purpose of the regulations in this subchapter, flashpoints determined by other testing methods will be equivalent to those determined with an open-cup tester, as follows:

TABLE 30.10-27—EQUIVALENT FLASHPOINTS

[In degrees Farenheit]

Open-cup tester	Tag closed-cup tester (A.S.T.M.)	Pensky-Martens closed tester (A.S.T.M.)
80	75	
150		140

§ 30.10-29 Gas free—TB/ALL.

The term "gas free" means free from dangerous concentrations of flammable or toxic gases.

§ 30.10-31 General rules and regulations—TB/ALL.

The term "general rules and regulations" means the requirements contained in this chapter.

§ 30.10-33 Great Lakes—TB/L.

Under this designation shall be included all tank vessels navigating the Great Lakes.

§ 30.10-35 Headquarters—TB/ALL.

The term "Headquarters" means the Office of the Commandant, U.S. Coast Guard, Washington, D.C. 20591.

[CGFR 65-50, 30 FR 16657, Dec. 30, 1965, as amended by CGFR 68-32, 33 FR 5712, Apr. 12, 1968]

§ 30.10-37 Keel laying date—TB/ALL.

The term "keel laying date" means the date upon which progressive construction identifiable with a specific vessel begins, including construction of the first module or prefabricated section of the hull that is identifiable with that vessel.

[CGD 74-127, 41 FR 3843, Jan. 26, 1976]

§ 30.10-38 Lightweight—TB/ALL.

The term "lightweight" means the displacement of a vessel in metric tons without cargo, oil fuel, lubricating oil, ballast water, fresh water, feedwater in tanks, consumable stores, and persons and their effects.

[CGD 74-127, 41 FR 3843, Jan. 26, 1976]

§ 30.10-39 Liquefied flammable gas—TB/ALL.

The term "liquefied flammable gas" means any flammable gas having a Reid vapor pressure exceeding 40 pounds, which has been liquefied.

[CGFR 66-33, 31 FR 15267, Dec. 6, 1966]

§ 30.10-41 Lakes, bays, and sounds—TB/B.

Under this designation shall be included all tank vessels navigating the waters of any of the lakes, bays, or sounds other than the waters of the Great Lakes.

TP42), U. S. Coast Guard, Washington, D.C. 20591; and

(2) Retain records of the test results for at least 5 years, or as long as the light is manufactured and certified, whichever is longer.

§ 161.013-13 Manufacturer certification and labeling.

(a) Each electric light intended as a Night Visual Distress Signal required by 33 CFR part 175 must be certified by the manufacturer as complying with the requirements of this subpart.

(b) Each electric light must be legibly and indelibly marked with:

(1) Manufacturer's name;

(2) Replacement battery type;

(3) Lamp size; and

(4) The following words—

"Night Visual Distress Signal for Boats Complies with U. S. Coast Guard Requirements in 46 CFR 161.013. For Emergency Use Only."

(c) If an electric light is designed for use with dry cell batteries the label must advise the consumer on the battery replacement schedule which under normal conditions would maintain performance requirements of § 161.013-3.

§ 161.013-17 Manufacturer notification.

(a) Each manufacturer certifying lights in accordance with the specifications of this subpart must send written notice to the Commandant (G-BBT/TP42), U. S. Coast Guard, Washington, D.C. 20591 within 30 days after first certifying them, and send a new notice every five years thereafter as long as it certifies lights.

PART 162—ENGINEERING EQUIPMENT

Subpart 162.016—Flame Arresters for Tank Vessels

162.016-1 Applicable specifications.
162.016-2 Type.
162.016-3 Materials, construction, and workmanship.
162.016-4 Inspection and testing.
162.016-5 Marking.
162.016-6 Procedure for approval.

Subpart 162.017—Valves, Pressure-Vacuum Relief and Spill, for Tank Vessels

162.017-1 Applicable specifications.
162.017-2 Type.
162.017-3 Materials, construction, and workmanship.
162.017-4 Inspections and testing.
162.017-5 Marking.
162.017-6 Procedure for approval.

Subpart 162.018—Safety Relief Valves, Liquefied Compressed Gas

162.018-1 Applicable specifications, and referenced material.
162.018-2 Scope.
162.018-3 Materials.
162.018-4 Construction and workmanship.
162.018-5 Blow-down adjustment and popping tolerance.
162.018-6 Marking.
162.018-7 Flow rating tests.
162.0 8-8 Procedure for approval.

Subpart 162.027—Combination Solid Stream and Water Spray Firehose Nozzle and Low-Velocity Water Spray Applicator

162.027-1 Applicable specifications.
162.027-2 Type and size.
162.027-3 Materials, construction, workmanship, and performance requirements.
162.027-4 Inspections and tests.
162.027-5 Marking.
162.027-6 Procedure for approval.

Subpart 162.028—Extinguishers, Fire, Portable, Marine Type

162.028-1 Applicable specifications.
162.028-2 Classification.
162.028-3 Requirements.
162.028-4 Marine type label.
162.028-5 Independent laboratories: Listing.
162.028-6 Examinations, tests, and inspections.
162.028-7 Procedure for listing and labeling.
162.028-8 Termination of listing or labeling.

Subpart 162.034—International Shore Connections (Ship)

162.034-1 Applicable specifications.
162.034-2 Type.
162.034-3 Materials, workmanship, and construction.
162.034-4 Inspection and tests.
162.034-5 Marking.
162.034-6 Procedure for approval.

Subpart 162.039—Extinguishers, Fire, Semiportable, Marine Type

162.039-1 Applicable specifications.
162.039-2 Classification.
162.039-3 Requirements.
162.039-4 Marine type label.
162.039-5 Recognized laboratory.
162.039-6 Examinations, tests, and inspections.
162.039-7 Procedure for listing and labeling.
162.039-8 Termination of listing or labeling.

Subpart 162.041—Backfire, Flame Control, Gasoline Engines; Flame Arresters; for Merchant Vessels and Motorboats

162.041-1 Applicable specifications.
162.041-2 Scope.
162.041-3 Flame arresters.
162.041-4 Materials, construction and workmanship.
162.041-5 Inspection and tests.
162.041-6 Marking.
162.041-7 Procedure for approval.

Subpart 162.042—Backfire Flame Control, Gasoline Engines; Engine Air and Fuel Induction Systems; for Merchant Vessels and Motorboats

162.042-1 Applicable specifications.
162.042-2 Scope.
162.042-3 Engine air and fuel induction systems providing backfire flame control.
162.042-5 Inspection and tests.
162.042-6 Marking.
162.042-7 Procedure for approval.

Subpart 162.043—Backfire Flame Control, Gasoline Engines; Engine Air Induction System; for Merchant Vessels and Motorboats

162.043-1 Applicable specifications.
162.043-2 Scope.
162.043-3 Engine air induction systems providing backfire flame control.
162.043-4 Materials, construction, and workmanship.
162.043-5 Inspection and tests.
162.043-6 Marking.
162.043-7 Procedure for approval.

Subpart 162.050—Pollution Prevention Equipment

162.050-1 Scope.
162.050-3 Definitions.
162.050-4 Documents incorporated by reference.
162.050-5 Contents of application.
162.050-7 Approval procedures.
162.050-9 Test report.
162.050-11 Marking.
162.050-13 Factory production and inspection.
162.050-14 Sample collection and preservation.
162.050-15 Designation of facilities.
162.050-17 Separator test rig.
162.050-19 Monitor and bilge alarm test rig.
162.050-21 Separator: design specification.
162.050-23 Separator: approval tests.
162.050-25 Cargo monitor: Design specification.
162.050-27 Cargo monitor: Approval tests.
162.050-29 Bilge monitor: Design specification.
162.050-31 Bilge monitor: Approval tests.
162.050-33 Bilge alarm: Design specification.
162.050-35 Bilge alarm: Approval tests.
162.050-37 Vibration test.
162.050-39 Measurement of oil content.

Subpart 162.016—Flame Arresters for Tank Vessels

AUTHORITY: R.S. 4417a, as amended, 4491, as amended, sec. 3, 68 Stat. 675; 46 U.S.C. 391a, 489, 50 U.S.C. 198; E.O. 11239; Treasury Department Orders 120, July 31, 1950, 15 FR 6521; 167-14, Nov. 26, 1954, 19 FR 8028.

SOURCE: CGFR 50-9, 15 FR 1679, Mar. 25, 1950, unless otherwise noted.

§ 162.016–1 Applicable specifications.

(a) There are no other specifications applicable to this subpart.

(b) Copies of the approved plans, specifications and the certificate of approval shall be kept on file by the manufacturer. They shall be kept for a period consisting of the duration of the approval and 6 months after termination of approval.

[CGFR 50-9, 15 FR 1679, Mar. 25, 1950, as amended by CGFR 65-16, 30 FR 10900, Aug. 21, 1965]

§ 162.016–2 Type.

(a) This specification covers the design and construction of flame arresters of the type intended for use in venting systems on tank vessels transporting inflammable or combustible liquids.

(b) The term "flame arrester" means any device or assembly of a cellular, tubular, or baffle arrangement or such other type as may be approved by the Commandant which is suitable for ar-

resting the propagation of flame into enclosed spaces containing explosive vapors.

§ 162.016-3 Materials, construction, and workmanship.

(a) Flame arrester housing and grid shall be of a suitable corrosion resistant material as may be approved by the Commandant.

(b) Nonmetallic materials shall not b permitted in the construction of the flame arrester, except where gaskets are employed as required by paragraph (c) of this section.

(c) Flame arrester housing shall be gas tight to prevent the escape of vapors. When installed in venting systems subject to pressures above atmospheric, flame arresters shall be fitted with non-combustible gaskets resistant to the product to be carried.

(d) The flame arrester grid assembly shall be fitted in the arrester housi. g in a manner that will insure tightness of metal-to-metal surface contacts, so that flame propagation will not occur through the joints between the arrester element and the housing.

(e) The design and construction of the flame arresters shall permit easy inspection and cleaning of the flame arrester grid or "tube bank."

(f) Flame arrester grid shall be so designed as to allow minimum restriction to the flow of vapors. Efficient drainage of the arrester grid shall be provided.

(g) Flame arresters for use on cargo tanks shall be of not less than 2½ inches nominal pipe size.

(h) Housing of flame arresters shall be designed to withstand a hydrostatic pressure of at least 125 pounds per square inch without rupturing or showing permanent distortion.

(i) The net free area through the arrester grid shall in no case be less than 1½ times the cross-sectional area of the pipe inlet.

(j) The flame arrester housing may have screwed or flanged pipe connections, or such type of connections as may be approved by the Commandant. If flanged, the thickness and drilling shall comply with the standards for 125 pounds cast iron flanged fittings.

(k) Where the design of the flame arrester does not permit complete drainage of the condensate to the attached cargo tank or vent line, the housing shall be fitted with a plugged drain opening on the side of the atmospheric outlet of not less than ½ inch pipe size.

(l) The device shall be of first class workmanship and shall be free from imperfections which may affect its serviceability.

§ 162.016-4 Inspection and testing.

(a) Flame arresters may be subject to inspection and tests at the plant of the manufacturer. An inspector may conduct such tests and examinations as may be necessary to determine compliance with this specification.

§ 162.016-5 Marking.

(a) Each flame arrester shall be legibly marked with the style, type, or other designation of the manufacturer, the size, and name or registered trademark of the manufacturer.

§ 162.016-6 Procedure for approval.

(a) *General.* Flame arresters of the type intended for use on tank vessels shall be approved for such use by the Commandant, U. S. Coast Guard, Washington, D.C. 20226.

(b) *Drawings and specifications.* Manufacturers desiring approval of a new design or type of flame arrester shall submit drawings in quadruplicate showing the design of the flame arrester, the sizes for which approval is desired, the size and material specifications of component parts, and the detail construction of arrester grid.

(c) *Pre-approval tests.* Before approval is granted, the manufacturer shall have tests conducted, or submit evidence that such tests have been conducted, and that the flame arrester has been found acceptable by the Underwriters' Laboratories, the Factory Mutual Laboratories, or by a properly supervised and inspected test laboratory acceptable to the Commandant, relative to determining the air flow capacity and vapor-air explosion resistance of a representative sample of the flame arrester in each size for which approval is desired. The explosion resistance of the assembly grid shall be determined by the explosion tests and

the continuous flame tests. The results of these tests shall indicate the ability of the flame arrester assembly to withstand the vapor-air internal explosion pressures and its effectiveness in arresting the propagation of flame.

[CGFR 50-9, 15 FR 1679, Mar. 25, 1950, as amended by CGFR 65-16, 30 FR 10900, Aug. 21, 1965]

Subpart 162.017—Valves, Pressure-Vacuum Relief and Spill, for Tank Vessels

AUTHORITY: R.S. 4417a, as amended, 4491, as amended, sec. 3, 68 Stat. 675; 46 U.S.C. 391a, 489, 50 U.S.C. 198; E.O. 11239, July 31, 1965, 30 FR 9671, 3 CFR, 1965 Supp.

SOURCE: CGFR 50-9, 15 FR 1680, Mar. 25, 1950, unless otherwise noted.

§ 162.017-1 Applicable specifications.

(a) There are no other specifications applicable to this subpart.

§ 162.017-2 Type.

(a) This specification covers the design and construction of pressure-vacuum relief valves and spill valves intended for use in venting systems on all tank vessels transporting inflammable or combustible liquids.

§ 162.017-3 Materials, construction, and workmanship.

(a) The valves shall be of substantial construction and first class workmanship and shall be free from imperfections which may affect its serviceability.

(b) Bodies of pressure-vacuum relief valves and spill valves shall be made of bronze or such corrosion-resistant material as may be approved by the Commandant.

(c) Valve discs, spindles, and seats shall be made of bronze or such corrosion-resistant material as may be approved by the Commandant.

(d) Where springs are employed to actuate the valve discs, the springs shall be made of corrosion-resistant material. Springs plated with corrosion-resistant material are not acceptable.

(e) Flame screens shall be made of corrosion-resistant wire.

(f) Nonmetallic materials will not be permitted in the construction of the valves, except bushings used in way of moving parts and gaskets may be made of nonmetallic material resistant to attack by the product carried. Nonmetallic diaphragms will be allowed where diaphragm failure will not result in unrestricted flow of cargo vapors to the atmosphere nor in an increase in the pressure or vacuum at which the valve normally releases.

(g) The design and construction of the valves shall permit overhauling and repairs without removal from the line.

(h) Valve discs shall be guided by a ribbed cage or other suitable means to prevent binding, and to insure proper seating. Where valve stems are guided by bushings suitably designed to prevent binding and to insure proper seating, the valves need not be fitted with ribbed cages.

(i) The disc shall close tight against the valve seat by metal to metal contact, however, resilient seating seals may be provided if the design is such that the disc closes tight against the seat in case the seals are destroyed or in case they carry away.

(j) Pressure-vacuum relief valves for venting cargo tanks shall be of not less than 2½ inches nominal pipe size.

(k) Bodies of valves shall be designed to withstand a hydrostatic pressure of at least 125 pounds per square inch without rupturing or showing permanent distortion.

(l) The valve discs may be solid or made hollow so that weight material may be added to vary the lifting pressure. If hollow discs are employed, a watertight bolted cover shall be fitted to encase the weight material. The pressure at which the discs open shall not exceed 120 percent of the set pressure.

(m) The free area through the valve seats at maximum lift shall not be less than the cross-sectional area of the valve inlet connection.

(n) Double flame screens of 20 x 20 corrosion-resistant wire mesh with a ½-inch corrosion-resistant separator on a single screen of 30 x 30 corrosion-resistant wire mesh shall be fitted on all openings to atmosphere. The net free area through the flame screens shall not be less than 1½ times the

cross-sectional area of the vent inlet from the cargo tanks.

(o) Valve bodies may have screwed or flanged pipe connections, or such types of connections as may be approved by the Commandant. If flanged, the thickness and drilling shall comply with USA standards for 150-pound bronze flanged fittings.

(p) Where design of valve does not permit complete drainage of condensate to attached cargo tank or vent line, the valve body shall be fitted with a plugged drain opening on the side of the atmospheric outlet of not less than ½ inch pipe size.

(q) Relief pressure adjusting mechanisms shall be permanently secured by means of lockwires, locknuts, or other acceptable means.

[CGFR 50-9, 15 FR 1680, Mar. 25, 1950, as amended by CGFR 68-82, 33 FR 18907, Dec. 18, 1968]

§ 162.017-4 Inspections and testing.

(a) Pressure-vacuum relief valves and spill valves may be inspected and tested at the plant of the manufacturer. An inspector may conduct such tests and examinations as may be necessary to determine compliance with this specification.

§ 162.017-5 Marking.

(a) Each valve shall be legibly marked with the style, type or other designation of the manufacturer, the size, pressure and vacuum setting and name or registered trademark of the manufacturer and Coast Guard approval number. The minimum wording for showing the approval number shall be "USCG/162.017/* *" or "USCG 162.017-* *".

[CGFR 68-82, 33 FR 18908, Dec. 18, 1968]

§ 162.017-6 Procedure for approval.

(a) *General.* Pressure-vacuum relief and spill valves intended for use on tank vessels shall be approved for such use by the Commandant (G-MTH), U.S. Coast Guard, Washington, D.C. 20593.

(b) *Drawings and specifications.* Manufacturers desiring approval of a new design or type of pressure-vacuum relief valve and spill valve shall submit drawings in quadruplicate showing the design of the valve, the sizes for which approval is requested, method of operation, thickness and material specifications of component parts, diameter of seat opening and lift of discs, mesh and size of wire of flame screens.

(c) *Pre-approval tests.* Before approval is granted, the manufacturer shall have tests conducted, or submit evidence that such tests have been conducted, by the Underwriters' Laboratories, the Factory Mutual Laboratories, or by a properly supervised and inspected test laboratory acceptable to the Commandant, relative to determining the lift, relieving pressure and vacuum, and flow capacity of a representative sample of the pressure-vacuum relief valve and spill valve in each size for which approval is desired. Reports of conducted tests, including flow capacity curves, shall be submitted.

(14 U.S.C. 632; 46 U.S.C. 369, 375, and 416; 49 U.S.C. 1655(b); 49 CFR 1.46(b))

[CGFR 50-9, 15 FR 1680, Mar. 25, 1950, as amended by CGFR 68-82, 33 FR 18908, Dec. 18, 1968; CGD 82-063b, 48 FR 4782, Feb. 3, 1983]

Subpart 162.018—Safety Relief Valves, Liquefied Compressed Gas

AUTHORITY: R.S. 4417a, as amended, 4491, as amended, sec. 3, 68 Stat. 675; 46 U.S.C. 391a, 489, 50 U.S.C. 198; E.O. 11239, July 31, 1965, 30 FR 9671, 3 CFR, 1965 Supp.

§ 162.018-1 Applicable specifications, and referenced material.

(a) There are no other specifications applicable to this subpart except as noted in this subpart.

(b) The following referenced material from industry standards of the issue in effect on the date safety relief valves are manufactured shall form a part of the regulations of this subpart (see §§ 2.-75-17 through 2.75-19 of Subchapter A (Procedures Applicable to the Public) and Subpart 50.15 of Subchapter F (Marine Engineering) of this chapter):

(1) ASME (American Society of Mechanical Engineers) Code (see § 50.-15-

* *Number to be assigned by the Commandant.

SUBCHAPTER Q—EQUIPMENT, CONSTRUCTION, AND MATERIALS: SPECIFICATIONS AND APPROVAL

PART 159—APPROVAL OF EQUIPMENT AND MATERIALS

Subpart 159.001—General

Sec.
159.001-1 Purpose.
159.001-3 Definitions.
159.001-5 Correspondence and applications.
159.001-7 Substituted procedures.
159.001-9 OMB Control Numbers assigned pursuant to the Paperwork Reduction Act.

Subpart 159.005—Approval Procedures

159.005-1 Purpose.
159.005-3 Application for preapproval review.
159.005-5 Preapproval review: Contents of application.
159.005-7 Preapproval review: Coast Guard action.
159.005-9 Approval inspections and tests.
159.005-11 Approval inspection or test report: Contents.
159.005-12 Plans.
159.005-13 Equipment or material: Approval.
159.005-15 Approval of equipment or material: Suspensions, withdrawals, and terminations.

Subpart 159.007—Production Inspection and Tests of Approved Equipment and Materials

159.007-1 Purpose.
159.007-3 Production inspections and tests: Independent laboratory's procedures.
159.007-5 Production inspections and tests: Application for acceptance.
159.007-7 Application for acceptance for production inspections and tests: Coast Guard action.
159.007-9 Production inspections and tests.
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159.007-13 Production inspections and tests: Records.

Subpart 159.010—Independent Laboratory: Acceptance, Listing, and Termination

159.010-1 Purpose.
159.010-3 Independent laboratory: Standards for acceptance.
159.010-5 Independent laboratory: Application for acceptance.
159.010-7 Independent laboratory: Standards for listing.
159.010-9 Independent laboratory: Application for listing.
159.010-11 Independent laboratory: Listing in subpart.
159.010-15 Contracting inspections and tests or transferals to another laboratory or person.
159.010-17 Application and test plans: Changes.
159.010-19 Termination of acceptance or listing of an independent laboratory.
159.010-21 Termination of acceptance or listing: Procedure.

AUTHORITY: Sec. 1, 73 Stat. 475 (46 U.S.C. 481); sec. 201 86 Stat 427, as amended (46 U.S.C. 391a); sec. 6(b)(1), 80 Stat 937 (49 U.S.C. 1655(b)(1)); 49 CFR 1.46 (b) and (n)(4).

SOURCE: 44 FR 73043, Dec. 17, 1979, unless otherwise noted.

Subpart 159.001—General

§ 159.001–1 Purpose.

(a) This part contains the procedures for the approval of equipment and materials when that equipment or material is inspected or tested by an independent laboratory or by the manufacturer of the equipment or material.

§ 159.001–3 Definitions.

(a) As used in this part:

(1) "Applicable subpart" means a subpart under which equipment or material is approved, or under which an independent laboratory is listed.

(2) "Listed laboratory" means an independent laboratory that has been listed in an applicable subpart under the provisions of § 159.010–11.

(3) "Test plan" means a description of the procedures by which an independent laboratory meets or exceeds the inspection and test requirements of an applicable subpart.

§ 159.001–5 Correspondence and applications.

(a) Unless otherwise specified, all correspondence and applications in connection with the approval and testing of equipment and materials shall be addressed to: Commandant (G-

MVI), U.S. Coast Guard, Washington, D.C. 20593.

(14 U.S.C. 632; 46 U.S.C. 369, 375, and 416; 49 U.S.C. 1655(b); 49 CFR 1.46(b))

[44 FR 73043, Dec. 17, 1979, as amended by CGD 82-063b, 48 FR 4782, Feb. 3, 1983]

§ 159.001-7 Substituted procedures.

(a) The Commandant may substitute the procedures in this part for the procedures in any other part of this subchapter. Each person known to be affected by the substitution shall be informed that the procedures in this part apply.

§ 159.001-9 OMB Control Numbers assigned pursuant to the Paperwork Reduction Act.

(a) *Purpose.* This section collects and displays the control numbers assigned to information collection and recordkeeping requirements in this subchapter by the Office of Management and Budget (OMB) pursuant to the Paperwork Reduction Act of 1980, (44 U.S.C. 3501 et seq.). The Coast Guard intends that this section comply with the requirements of 44 U.S.C. 3507(f) which requires that agencies display a current control number assigned by the Director of the OMB for each approved agency information collection requirement.

(b) *Display.*

46 CFR part or section where identified or described	Current OMB control No.
§ 159.007-11.13	2115-0090
§ 160.002-5	2115-0090
§ 160.047-5	2115-0090
§ 160.048-5	2115-0090
§ 160.050-5	2115-0090
§ 160.052-7	2115-0090
§ 160.063-4	2115-0090
§ 160.065-4	2115-0090
§ 160.064-6	2115-0090
§§ 161.001 through 161.010	2115-0121
§§ 162.001 through 161.018	2115-0525
§ 162.041	2115-0525
§ 162.043	2115-0525
§ 164.012-13	2115-0121

(44 U.S.C. 3507; 49 CFR 1.45)

[49 FR 38121, Sept. 27, 1984]

Subpart 159.005—Approval Procedures

§ 159.005-1 Purpose.

(a) This subpart contains the procedures by which the Coast Guard approves equipment and materials under other subparts of this subchapter that require—

(1) Preapproval inspections and tests by an independent laboratory;

(2) Preapproval inspections and tests by the manufacturer; or

(3) No preapproval inspections or tests.

§ 159.005-3 Application for preapproval review.

(a) Each manufacturer of equipment or material who seeks Coast Guard approval under an applicable subpart must submit an application that meets § 159.005-5 to the Commandant unless—

(1) The subpart contains a list of independent laboratories;

(2) The subpart does not require Coast Guard review prior to testing; and

(3) The manufacturer meets the requirements of paragraph (b) of this section.

(b) If the applicable subpart contains a list of independent laboratories and does not specifically require preapproval review by the Coast Guard, the manufacturer may have the tests performed by a listed laboratory and submit the report required by § 159.005-11 to the Commandant.

§ 159.005-5 Preapproval review: Contents of application.

(a) Each application must contain the following:

(1) The name and address of the manufacturer and the factory where the finished equipment or material is produced.

(2) One or more of the following as required by the applicable subpart:

(i) Two sets of general plans of the equipment or material.

(ii) Two sets of specifications of the equipment or material.

(iii) A sample of the equipment or material accompanied by a written description of its components.

(3) A statement signed by the manufacturer or the manufacturer's representative, that an official representative of the Coast Guard is allowed access to the place of manufacture and to the place of test to verify the information submitted in the application or to witness tests.

(b) If the equipment or material is required by the subpart to be inspected and tested by an independent laboratory, the application must contain the following additional information:

(1) The name and address of a laboratory that meets § 159.010-3(a) and that is selected by the manufacturer to perform or supervise the inspections and tests.

(2) If the laboratory has not been accepted previously for inspecting and testing the manufacturer's equipment or material under the applicable subpart, the completed application under § 159.010-5(a).

§ 159.005-7 Preapproval review: Coast Guard action.

(a) If approval inspections and tests are required under the applicable subpart, the Commandant takes the following action:

(1) If the Commandant determines from the application that the equipment or material appears to meet the design requirements of an applicable subpart or appears to have equivalent performance characteristics, and that the laboratory meets § 159.010-3(a), the Commandant informs the manufacturer that the required approval inspections and tests may be conducted.

(2) If the Commandant determines from the application for approval that the equipment or material does not appear to meet the design requirements of an applicable subpart or does not appear to have equivalent performance characteristics, or that the laboratory does not meet § 159.010-3(a), the Commandant informs the manufacturer of the reason why the equipment or material is not acceptable for approval inspections and tests or why the laboratory is not accepted.

(b) If no approval inspections or tests are required under the applicable subpart, the Commandant—

(1) Takes action in accordance with § 159.005-13; or

(2) Informs the manufacturer of additional information required before action under § 159.005-13 can be taken.

§ 159.005-9 Approval inspections and tests.

(a) Each manufacturer of equipment or material that is required to be subjected to approval inspections and tests must—

(1) If the applicable subpart requires the equipment or material to be inspected or tested, have the approval inspections or tests performed;

(2) If the applicable subpart requires the equipment or material to be inspected or tested by an independent laboratory, insure that a laboratory accepted by the Commandant performs or supervises the approval inspections or tests;

(3) Bear all costs of the approval inspections and tests;

(4) If requested, advise the Commandant of the time, date, and place of each approval inspection or test, or both, before the inspection or test is performed; and

(5) After completion of the approval inspections and tests, submit to the Commandant—

(i) A test report that meets § 159.005-11;

(ii) At least two sets of specifications of the material as inspected or tested or at least two sets of plans of the equipment as inspected or tested that meet § 159.005-12; and

(iii) A description of the quality control procedures that will be in effect during the production of the equipment or material.

§ 159.005-11 Approval inspection or test report: Contents.

(a) Each approval inspection or test report must contain the following:

(1) The name of the manufacturer.

(2) If the inspections or tests are performed or supervised by an independent laboratory, the name and address of the laboratory.

(3) The trade name, product designation (such as model numbers), and a brief description of the equipment or material inspected or tested.

(4) The time, date, and place of each approval inspection and test.

(5) The name and title of each person performing, supervising, and witnessing the approval inspections or tests.

(6) The performance data for each test required in the applicable subpart, including a description of each failure.

(7) A description or photographs of the procedures and apparatus used in the inspections or tests, or a reference to another document that contains an appropriate description or photographs.

(8) At least one photograph that shows an overall view of the equipment or material submitted for approval and other photographs that show—

(i) Design details; and

(ii) Each occurrence of damage or deformation to the equipment or material that occurred during the approval tests.

(b) Each inspection or test report must bear an attestation that the inspections or tests were conducted as required by the applicable subpart and that the report contains no known errors, omissions, or false statements. The attestation must be signed by:

(1) The manufacturer or manufacturer's representative, if the inspection or tests are conducted by the manufacturer; or

(2) The chief officer of the laboratory, or the chief officer's representative, if the inspection or tests were conducted by an independent laboratory.

NOTE: A false representation on a report is a ground for suspension or withdrawal of approval of the equipment or material. A false representation is also punishable as a crime under 18 U.S.C. 1001.

§ 159.005-12 Plans.

(a) Each set of plans under § 159.005-9(a)(5)(ii) for equipment must include the following:

(1) An assembly drawing or general arrangement drawing.

(2) A description of each component of the equipment that includes the name, the manufacturer, and the part identification of each component in—

(i) A detail drawing;

(ii) A bill of material or parts list; or

(iii) A specification for that component.

(3) A list of the drawings and specifications in the set of plans, including each revision, and the date of that list.

(4) If a manufacturer's instructions or manual is required in the applicable subpart, a copy of the instructions or manual.

§ 159.005-13 Equipment or material: Approval.

(a) If from analysis of the material and data required to be submitted under this subpart, the Commandant determines that the equipment or material meets the applicable subpart, the Commandant—

(1) Approves the equipment or material;

(2) Issues a certificate of approval to the manufacturer under § 2.75-5 of this chapter;

(3) Retains one set of approved plans and returns all others to the manufacturer; and

(4) Publishes a notice of the approval in the FEDERAL REGISTER.

(b) If from analysis of the material and data submitted the Commandant determines that the equipment or material does not meet the applicable subpart, the Commandant informs the manufacturer of the reason why that equipment or material does not meet the subpart.

(c) If an independent laboratory performs the approval inspections or tests, the Commandant will notify the laboratory of the actions taken under paragraph (a) or (b) of this section, unless the manufacturer specifically requests that the laboratory not be notified.

§ 159.005-15 Approval of equipment or material: Suspensions, withdrawals, and terminations.

(a) The Commandant suspends an approval issued under this subchapter in accordance with § 2.75-40 of this chapter, withdraws an approval issued under this subchapter in accordance with § 2.75-50(a) of this chapter, and terminates an approval issued under this subchapter in accordance with § 2.75-50(b) of this chapter.

Subpart 159.007—Production Inspection and Tests of Approved Equipment and Materials

§ 159.007-1 Purpose.

(a) This subpart contains the procedures under which production inspections and tests of approved equipment or materials are to be performed under this subchapter.

§ 159.007-3 Production inspections and tests: Independent laboratory's procedures.

(a) The manufacturer may follow an independent laboratory's procedures for production inspections and tests if those procedures—

(1) Meet or exceed the production inspection and test requirements of the applicable subpart or are equivalent to those inspections and tests;

(2) Include labeling or marking the equipment or material when the equipment or material meets the inspection and test procedures of the laboratory; and

(3) Are accepted by the Commandant under § 159.007-7(b).

§ 159.007-5 Production inspections and tests: Application for acceptance.

(a) If the applicable subpart requires production inspections and tests by an independent laboratory, the manufacturer must select a laboratory and submit an application for acceptance that meets § 159.010-5(a) unless the laboratory—

(1) Is listed in the subpart; or

(2) Is accepted by the Commandant for approval inspections and tests of the equipment or material under § 159.005-7(a)(1).

(b) If the manufacturer wants to follow the laboratory's procedures for production inspections and tests instead of meeting the Coast Guard procedures under this subchapter, the application must contain a description of those procedures.

§ 159.007-7 Application for acceptance for production inspections and tests: Coast Guard action.

(a) From the information submitted with the application, the Commandant determines whether or not the laboratory is accepted for production inspections and tests. The Commandant informs the manufacturer of the results of this determination, if the Commandant does not accept a laboratory, the reason for the disapproval will be given.

(b) From the description of the laboratory's procedures for production inspections and tests, the Commandant determines whether or not those procedures are accepted. The Commandant informs the manufacturer of the results of this determination. If the Commandant does not accept the laboratory's procedures, the reasons why they are not accepted will be given.

§ 159.007-9 Production inspections and tests.

(a) If the applicable subpart requires the production inspections and tests to be performed or supervised by an independent laboratory, the manufacturer shall insure that all required production inspections and tests are performed or supervised by an independent laboratory accepted by the Commandant.

(b) If the applicable subpart does not require an independent laboratory to perform the production inspections and tests, the manufacturer shall have those inspections and tests performed.

(c) Unless alternative procedures have been accepted by the Commandant under § 159.007-3 each production inspection and test must be performed or supervised in accordance with the applicable subpart.

§ 159.007-11 Production inspections and tests: Yearly report.

(a) When the manufacturer uses the production inspection and test procedures in an applicable subpart he must submit a yearly report. The report is not required when inspection and test procedures approved under § 159.007-3 are used.

(b) The report must include the following:

(1) A list of all inspections and tests performed;

(2) A summary of the results of each group of inspections or tests;

(3) A detailed description of any test failures; and

(4) A statement whether or not all required tests were performed.

§ 159.007-13 Production inspections and tests: Records.

(a) The manufacturer must have a completed record with the following information for each production inspection and test:

(1) The time, date and place of each inspection and test.

(2) The name and title of each person performing, supervising and witnessing the inspections or tests.

(3) The performance data for each test required in the applicable subpart, including a description of each failure.

(4) A description or photographs of the procedures and apparatus used in the inspections or tests.

(b) The manufacturer must retain each record under this section for at least 60 months after the month in which the inspection or test was conducted.

(c) The records must be made available for examination by the Commandant upon request.

Subpart 159.010—Independent Laboratory: Acceptance, Listing, and Termination

§ 159.010-1 Purpose.

(a) This subpart contains the following:

(1) The standards under which the Coast Guard accepts an independent laboratory that a manufacturer proposes to use.

(2) The standards and procedures under which a laboratory is listed in applicable subparts for tests and inspections required by that subpart.

(3) The circumstances under which the acceptance or listing of a laboratory is terminated.

§ 159.010-3 Independent laboratory: Standards for acceptance.

(a) To be accepted by the Coast Guard as an independent laboratory, a laboratory must—

(1) Be engaged, as a regular part of its business, in performing inspections and tests that are the same as or similar to the inspections and tests required in the applicable subpart;

(2) Have or have access to the apparatus, facilities, personnel, and calibrated instruments that are necessary to inspect and test the equipment or material under the applicable subpart;

(3) Not be owned or controlled by—

(i) The manufacturer of the equipment or material to be inspected or tested under this subchapter or any manufacturer of similar equipment or material;

(ii) A vendor of the equipment or material to be inspected or tested under this subchapter or a vendor of similar equipment or material; or

(iii) A supplier of materials to the manufacturer;

(4) Not be dependent on Coast Guard acceptance under this subchapter to remain in business; and

(5) Not advertise or promote the manufacturer's equipment or material that the laboratory inspects and tests under this subchapter.

§ 159.010-5 Independent laboratory: Application for acceptance.

(a) Each application for acceptance of a laboratory must contain the following:

(1) The name and address of the laboratory, its subsidiaries, and its divisions.

(2) The name, title, address, and principal business activity of each of the laboratory's officers and directors, and the name, address, and principal business activity of each person, company, or corporation that owns at least 3-percent interest in the laboratory or in a company or corporation that controls the laboratory.

(3) A list of the equipment or material that the laboratory would inspect or test, or both, under this subchapter.

(4) A description of the laboratory's experience and its qualifications for conducting the inspections and tests required in the applicable subpart.

(5) A description of the apparatus and facilities available to the laboratory for conducting those inspections and tests.

(6) The qualifications of personnel who are to perform, supervise, or witness those inspections and tests.

(7) A description of the laboratory's instrument calibration program.

(8) A statement, signed by the chief officer of the laboratory or the chief officer's representative, that an official representative of the Coast Guard is allowed access to the facility to verify the information submitted in the application, or to witness tests.

§ 159.010–7 Independent laboratory: Standards for listing.

(a) To be listed as an independent laboratory under an applicable subpart, a laboratory must—

(1) Meet § 159.010–3;

(2) Have a test plan that is accepted by the Commandant under § 159.010–11(a); and

(3) Agree to perform or supervise approval or production inspections or tests under that subpart upon request from a manufacturer, however a laboratory may limit the area it serves.

§ 159.010–9 Independent laboratory: Application for listing.

(a) A laboratory that wants to be listed in one or more applicable subparts must submit to the Commandant an application that contains the information required by § 159.010–5, and that includes—

(1) The subparts under which it wants to be listed;

(2) Its test plans; and

(3) A statement of any limitations on the availability of the laboratory's service.

§ 159.010–11 Independent laboratory: Listing in subpart.

(a) From the application, the Commandant determines whether or not the laboratory meets § 159.010–7. If it meets these standards, the laboratory is added to the list in the applicable subpart. If it does not meet these standards the Commandant informs the laboratory of the reasons why it is not added to the list.

§ 159.010–15 Contracting inspection and tests or transferrals to another laboratory or person.

(a) No independent laboratory may contract or transfer to another person or laboratory the performance or supervision of inspections or tests, or both, required under an applicable subpart for which it is accepted or listed unless—

(1) A request in writing regarding the contract or transfer is submitted to the Commandant before the contract is executed or the transfer is completed; and

(2) The Commandant notifies the laboratory in writing that the contract or the transfer is allowed.

§ 159.010–17 Application and test plans: Changes.

(a) If any of the information submitted under § 159.010–5(a) or § 159.010–9(a) changes, a notification in writing of each change must be submitted to the Commandant within 30 days after the change has occurred.

(b) If an independent laboratory wants to change its test plan, the proposed changes must be submitted to the Commandant. The Commandant notifies the laboratory if the changed test plan is accepted. If the changed test plan is not accepted, the Commandant informs the laboratory of the reasons why the changed test plan is not accepted.

§ 159.010–19 Termination of acceptance or listing of an independent laboratory.

(a) The acceptance or listing of a laboratory terminates if the laboratory—

(1) Requests termination; or

(2) Is no longer in business.

(b) The acceptance of a laboratory may be terminated by the Commandant if the laboratory—

(1) Fails to perform or supervise an inspection or test, or both, as required in an applicable subpart;

(2) Changes its test plan without Coast Guard acceptance;

(3) Attests to the lack of errors, omissions, or false statement of an approval test report that contains errors, omissions, or false statements;

(4) Does not meet § 159.010–3(a);

(5) Does not comply with § 159.010–17(a); or

(6) Unless allowed by the Commandant, contracts or transfers the performance or supervision of required inspections or tests, or both, to another laboratory or person.

(c) A laboratory is removed from the list published in an applicable subpart if the laboratory—

(1) Is no longer accepted by the Commandant; or

(2) Unreasonably refuses a request from a manufacturer to perform or supervise an approval or production inspection or test.

§ 159.010-21 Termination of acceptance or listing: Procedure.

(a) Whenever evidence is received that there exists a basis for termination of acceptance or listing of an independent laboratory under § 159.010-19 (b) or (c), the Commandant notifies the laboratory of the specific reasons for considering termination. If the deficiency could materially affect the validity of the approval issued under an applicable subpart, the Commandant may immediately suspend the acceptance of the laboratory and may direct the holder of the certificate of approval to cease claiming that the items tested or inspected by the laboratory are Coast Guard approved, pending a final decision in the matter. The Commandant may direct an investigation into the matter.

(b) Within 30 days after receipt of notice of the basis for considering termination, the laboratory may provide the Commandant evidence or arguments why acceptance or listing should continue. After consideration of all available material on the matter, the Commandant informs the laboratory, in writing, of this decision. Any person holding a certificate of approval affected by the decision is also notified of the decision.

PART 160—LIFESAVING EQUIPMENT

Subpart 160.001—Life Preservers, General

Sec.

160.001-1 Incorporation by reference.
160.001-2 General characteristics of life preservers.
160.001-3 General provisions for approval of life preservers.

Subpart 160.002—Life Preservers, Kapok, Adult and Child (Jacket Type), Models 3 and 5

160.002-1 Incorporation by reference.
160.002-2 Size and models.
160.002-3 Materials.
160.002-4 Construction.
160.002-5 Sampling, tests, and inspections.
160.002-6 Marking.
160.002-7 Procedure for approval.

Subpart 160.005—Life Preservers, Fibrous Glass, Adult and Child (Jacket Type), Models 52 and 56

160.005-1 Incorporation by reference.
160.005-2 Size and model.
160.005-3 Materials.
160.005-4 Construction.
160.005-5 Sampling, tests, and inspections.
160.005-6 Marking.
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Subpart 160.006—Life Preservers; Repairing and Cleaning

160.006-1 Applicable specifications.
160.006-2 Repairing.
160.006-4 Cleaning life preserver envelopes or covers.
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Subpart 160.010—Buoyant Apparatus for Merchant Vessels

160.010-1 Incorporations by reference.
160.010-2 Definitions.
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160.010-4 Buoyant apparatus with plastic foam buoyancy.
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Subpart 160.011—Gas Masks, Self-Contained Breathing Apparatus, and Supplied-Air Respirators, for Merchant Vessels

160.011-1 Applicable schedules.
160.011-2 Types.
160.011-3 Requirements.
160.011-4 Inspections and tests.
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Subpart 160.012—[Reserved]

Subpart 160.013—Hatchets (Lifeboat and Lifecraft) for Merchant Vessels

160.013-1 Applicable specification and plan.

UL 525

STANDARD for SAFETY

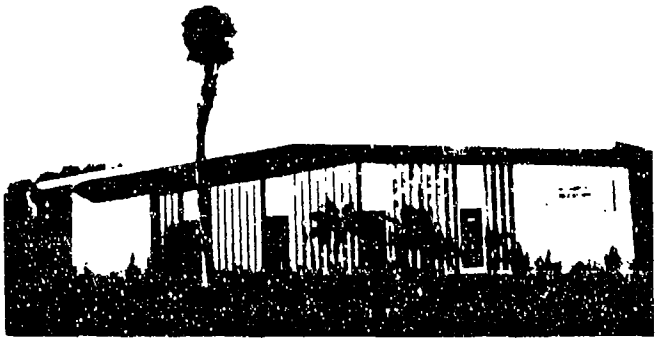
FLAME ARRESTERS
FOR USE ON VENTS OF STORAGE TANKS FOR PETROLEUM OIL AND GASOLINE

UNDERWRITERS LABORATORIES INC.

Northbrook, Illinois

Melville, New York

Santa Clara, California



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December 26, 1984

STANDARD FOR
FLAME ARRESTERS FOR USE ON VENTS OF STORAGE TANKS
FOR PETROLEUM OIL AND GASOLINE

UL 525, FIFTH EDITION

Accompanying this transmittal notice is a copy of the fifth edition of UL 525.

THIS EDITION OF THE STANDARD IS NOW IN EFFECT.

As indicated on the title page, this standard is an American National Standard.

Revised and/or additional pages may be issued from time-to-time.

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UL 525

STANDARD FOR FLAME ARRESTERS FOR USE ON VENTS OF STORAGE TANKS FOR PETROLEUM OIL AND GASOLINE

First Edition — December, 1936
Second Edition — July, 1946
Third Edition — September, 1973
Fourth Edition — June, 1979

FIFTH EDITION

December 26, 1984

Approval as an American National Standard covers the numbered paragraphs on pages dated December 26, 1984. These pages should not be discarded when revised or additional pages are issued if it is desired to retain the approved text. Revisions of this standard will be made by issuing revised or additional pages bearing their dates of issue.

Approved as ANSI Z22.1—1973, September 24, 1973
Approved as ANSI/UL 525—1984, October 1, 1984

(1-12/26/84)

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FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

GENERAL

1. Scope

1.1 These requirements cover flame arresters for use in open vent pipes, flame arresters for use with vent valves, and combination flame arrester-vent valves, all intended for use on vents of storage tanks for petroleum oil and gasoline.

1.2 The flame arresters covered by these requirements are intended to prevent the propagation of flame through the flame arrester into the storage tank.

1.3 A flame arrester is investigated for the installation for which it is designed, with respect to any of the following that is intended:

A. Connection in a vent line at a specified maximum distance from the open end of the pipe, or

B. Opening directly to the atmosphere through a specific weatherhood, or

C. Use with a specific vent valve.

2. Units of Measurement

2.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

3. Instructions

3.1 Printed instructions shall be provided with each flame arrester. The instructions shall include the following:

A. The intended method of installation.

B. The designation of the vent valve to be used if (1) the flame arrester is intended to be used with a specific vent valve, and (2) the vent valve is not part of the flame arrester.

CONSTRUCTION

4. Materials

4.1 A device shall be of metal resistant to corrosion under conditions of use.

4.2 The casing or housing shall be of cast iron, cast aluminum, or the equivalent.

4.3 Gaskets such as those made of animal or vegetable fibers shall not be used in the construction or assembly of the device.

5. Casings

5.1 The casing or housing shall withstand the internal pressure resulting from explosions without damage. See paragraphs 8.1—8.12.

5.2 Flat joints in a device and a flat surface to be mounted to the intended tank shall be machined to provide an arithmetical average roughness of not more than 250 microinches in accordance with the Standard for Surface Texture, ANSI B46.1—1978, and shall provide for a joint having a metal-to-metal width of not less than 1/4 inch (6.4 mm).

6. Provisions for Connection

6.1 A device shall have provision for flanged or threaded connection to standard pipe.

6.2 Pipe threads shall be in accordance with the Standard for General Purpose Pipe Threads (Inch) ANSI/ASME B1.20.1—1983.

6.3 Flanges shall conform to the appropriate American National Standard for Pipe Flanges and Flanged Fittings covering the material from which they are made.

PERFORMANCE

7. Hydrostatic Tests

7.1 Except as noted in paragraph 7.2, a casing or housing shall withstand a hydrostatic pressure of 250 pounds per square inch gauge (psig) (1725 kPa) for 1 minute without rupture or permanent distortion.

7.2 The casing or housing of a device intended to open and vent directly to the atmosphere or through not more than 7 feet (2.1 m) of open pipe shall withstand a hydrostatic pressure of 125 psig (860 kPa) for 1 minute without rupture or permanent distortion.

7.3 The hydrostatic pressure is to be applied at a rate of approximately 100 psig (690 kPa) per minute until the required internal pressure is reached. Gaskets or other means may be employed if necessary to prevent leakage of water during application of pressure.

8. Explosion Tests

8.1 A device shall not permit the passage of sparks or flame that will ignite the explosive mixture from the outlet (vent) end to the inlet (tank) end of the flame arrester when subjected to a series of explosion tests using gasoline vapor-air mixtures at an initial pressure of one atmosphere. The series of tests shall be sufficient to determine the effect of the most severe conditions of:

A. Pressure, and

B. Flame propagation.

8.2 As gasoline vapor-air mixtures that produce the maximum explosion pressure may not necessarily produce the maximum flame propagation effects, depending upon such factors as the construction of the specific device, a series of at least 13 tests over the flammable range are required to cover items A and B of paragraph 8.1.

8.3 The device is to be installed in a pipe line of the diameter for which it is designed. The pipe connected to the inlet (tank end) is to be at least 5 feet (1.5 m) long. The outlet of the device or test chamber (see paragraph 8.4), depending upon the intended use, is to be connected to:

A. A vent line at the maximum intended distance from the open end of the pipe; or

B. A 5-foot length of pipe, if it is intended to open directly to the atmosphere; or

C. The intended vent valve.

8.4 A flame arrester having multiple outlets intended to vent directly to the atmosphere is to be installed in a test chamber of the smallest practical size that will contain the device under test and permit the explosive mixture to surround completely all outlets. The outlet of the chamber is to be connected to a 5-foot (1.5-m) length of pipe of the same diameter as the inlet pipe.

8.5 The test installation, including the axes of the inlet and outlet pipes, is to be inclined 3/4 inch per foot (60 mm/m) from the horizontal with the inlet end higher than the outlet end unless the flame arrester is specifically designed for vertical use only, in which case the flame arrester is to be tested in that position.

8.6 The open ends of the inlet and outlet pipes are to be plugged with loosely fitting light weight material, each plug having an opening for inlet or outlet of the gasoline vapor-air mixture. Each end is to be closed by a pipe flange with reduced opening for inlet and outlet to the lines carrying the explosive mixture.

8.7 A device for recording peak explosion pressure is to be connected in the inlet end and another in the outlet end of the test installation. A spark plug is to be provided in the outlet end for ignition of the gasoline vapor-air mixture. In the test of a flame arrester intended for installation between a vent valve and the tank, the spark plug is to be located between the valve and the flame arrester.

GENERAL

1. Scope

1.1 These requirements cover flame arresters for use in open vent pipes, flame arresters for use with vent valves, and combination flame arrester-vent valves, all intended for use on vents of storage tanks for petroleum oil and gasoline.

1.2 The flame arresters covered by these requirements are intended to prevent the propagation of flame through the flame arrester into the storage tank.

1.3 A flame arrester is investigated for the installation for which it is designed, with respect to any of the following that is intended:

A. Connection in a vent line at a specified maximum distance from the open end of the pipe, or

B. Opening directly to the atmosphere through a specific weatherhood, or

C. Use with a specific vent valve.

2. Units of Measurement

2.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

3. Instructions

3.1 Printed instructions shall be provided with each flame arrester. The instructions shall include the following:

A. The intended method of installation.

B. The designation of the vent valve to be used if (1) the flame arrester is intended to be used with a specific vent valve, and (2) the vent valve is not part of the flame arrester.

CONSTRUCTION

4. Materials

4.1 A device shall be of metal resistant to corrosion under conditions of use.

4.2 The casing or housing shall be of cast iron, cast aluminum, or the equivalent.

4.3 Gaskets such as those made of animal or vegetable fibers shall not be used in the construction or assembly of the device.

5. Casings

5.1 The casing or housing shall withstand the internal pressure resulting from explosions without damage. See paragraphs 8.1—8.12.

5.2 Flat joints in a device and a flat surface to be mounted to the intended tank shall be machined to provide an arithmetical average roughness of not more than 250 microinches in accordance with the Standard for Surface Texture, ANSI B46.1—1978, and shall provide for a joint having a metal-to-metal width of not less than 1/4 inch (6.4 mm).

6. Provisions for Connection

6.1 A device shall have provision for flanged or threaded connection to standard pipe.

6.2 Pipe threads shall be in accordance with the Standard for General Purpose Pipe Threads (Inch) ANSI/ASME B1.20.1—1983.

6.3 Flanges shall conform to the appropriate American National Standard for Pipe Flanges and Flanged Fittings covering the material from which they are made.

PERFORMANCE

7. Hydrostatic Tests

7.1 Except as noted in paragraph 7.2, a casing or housing shall withstand a hydrostatic pressure of 250 pounds per square inch gauge (psig) (1725 kPa) for 1 minute without rupture or permanent distortion.

7.2 The casing or housing of a device intended to open and vent directly to the atmosphere or through not more than 7 feet (2.1 m) of open pipe shall withstand a hydrostatic pressure of 125 psig (860 kPa) for 1 minute without rupture or permanent distortion.

7.3 The hydrostatic pressure is to be applied at a rate of approximately 100 psig (690 kPa) per minute until the required internal pressure is reached. Gaskets or other means may be employed if necessary to prevent leakage of water during application of pressure.

8. Explosion Tests

8.1 A device shall not permit the passage of sparks or flame that will ignite the explosive mixture from the outlet (vent) end to the inlet (tank) end of the flame arrester when subjected to a series of explosion tests using gasoline vapor-air mixtures at an initial pressure of one atmosphere. The series of tests shall be sufficient to determine the effect of the most severe conditions of:

A. Pressure, and

B. Flame propagation.

8.2 As gasoline vapor-air mixtures that produce the maximum explosion pressure may not necessarily produce the maximum flame propagation effects, depending upon such factors as the construction of the specific device, a series of at least 13 tests over the flammable range are required to cover items A and B of paragraph 8.1.

8.3 The device is to be installed in a pipe line of the diameter for which it is designed. The pipe connected to the inlet (tank end) is to be at least 5 feet (1.5 m) long. The outlet of the device or test chamber (see paragraph 8.4), depending upon the intended use, is to be connected to:

A. A vent line at the maximum intended distance from the open end of the pipe; or

B. A 5-foot length of pipe, if it is intended to open directly to the atmosphere; or

C. The intended vent valve.

8.4 A flame arrester having multiple outlets intended to vent directly to the atmosphere is to be installed in a test chamber of the smallest practical size that will contain the device under test and permit the explosive mixture to surround completely all outlets. The outlet of the chamber is to be connected to a 5-foot (1.5-m) length of pipe of the same diameter as the inlet pipe.

8.5 The test installation, including the axes of the inlet and outlet pipes, is to be inclined 3/4 inch per foot (60 mm/m) from the horizontal with the inlet end higher than the outlet end unless the flame arrester is specifically designed for vertical use only, in which case the flame arrester is to be tested in that position.

8.6 The open ends of the inlet and outlet pipes are to be plugged with loosely fitting light weight material, each plug having an opening for inlet or outlet of the gasoline vapor-air mixture. Each end is to be closed by a pipe flange with reduced opening for inlet and outlet to the lines carrying the explosive mixture.

8.7 A device for recording peak explosion pressure is to be connected in the inlet end and another in the outlet end of the test installation. A spark plug is to be provided in the outlet end for ignition of the gasoline vapor-air mixture. In the test of a flame arrester intended for installation between a vent valve and the tank, the spark plug is to be located between the valve and the flame arrester.

8.8 The gasoline used in the tests is to be Naptha 'R,' a nonleaded petroleum distillate consisting essentially of aliphatic hydrocarbon compounds and having a specific gravity of 60—70 degrees API at 15.6°C (60°F).

8.9 The expolsive gasoline vapor-air mixture is to be prepared by auxiliary equipment capable of preparing and maintaining predetermined concentrations within the limits specified in paragraph 9.1.

8.10 The explosive mixture is to be introduced into the test installation until the original air is entirely displaced. Samples for determination of the concentration of gasoline vapor in air are to be withdrawn from the line supplying the vapor-air mixture and from the outlet line or test chamber.

8.11 The pipe flanges are to be removed from both inlet and outlet pipes and the vapor-air mixture is to be ignited in the outlet side of the test installation.

8.12 At the conclusion of each test, the installation is to be purged of residual gases with a stream of air.

9. Continuous Flame Tests

9.1 A device shall resist for 1 hour without flashback the flame of a continuously burning mixture of gasoline vapor and air at a concentration of 1.90 ± 0.05 percent by volume.

9.2 The flame arrester is to be connected for the installation that it is intended:

A. Using the maximum length of pipe intended, but not less than 5 feet (1.5 m);

B. Discharging directly to the atmosphere if intended for such use. A weatherhood, if provided, is to be in place; or

C. Connected to the specific vent-valve intended.

9.3 The gasoline vapor-air mixture mentioned in paragraph 9.1 is to be introduced into the inlet (tank) end of the test installation at the rate given in Table 9.1 and is to be burned at the outlet face of the arrester.

TABLE 9.1
RATE OF FLOW OF GASOLINE VAPOR-AIR MIXTURE

Pipe Size ANSI B36.10 Nominal Inches	Rate of Flow	
	Cubic Feet per hour	Cubic Meter per hour
1	9	0.26
2	35	0.99
2-1/2	55	1.56
3	80	2.27
4	120	3.40
6	235	6.66
8	408	11.56
10	716	20.28
12	1030	29.17

9.4 Samples of the vapor-air mixture are to be withdrawn from the inlet side of the test installation at intervals during the test and the concentration of the mixture is to be determined.

9.5 The temperature of the casing of the flame arrester is to be measured at intervals during the test.

9.6 The flow of explosive mixture into the inlet is to be stopped for 15 seconds every 10 minutes after initiation of the test. There shall be no flashback, as determined visually, at any time during the test including the 15 seconds following the sixth 10-minute burning interval.

10. Flow Capacities

10.1 The flow capacity of a device shall be determined at the operating pressures (both positive and negative) specified for it by the manufacturer.

MARKING

11. Details

11.1 Each flame arrester shall be marked with the following:

A. The manufacturer's or private labeler's name or trademark.

B. The catalog designation, or equivalent.

C. The U.S A. pipe size in inches.

D. One or more of the following, as applicable:

1. The maximum length of pipe to be connected to the vent end;

2. A statement that the flame arrester may open directly to atmosphere;

3. The specific type of vent valve with which the flame arrester has been tested.

11.2 The marking specified in paragraph 11.1 shall be (1) on a permanently-attached metal nameplate, or (2) embossed, stamped or molded in the casing.

11.3 If a manufacturer produces or assembles flame arresters at more than one factory, each finished flame arrester shall have a distinctive marking — which may be in code — by means of which it may be identified as the product of a pa icular factory.

APPENDIX C
FACTORY MUTUAL RESEARCH
Sample FM Approval Test Procedures for Flame Arresters
(TIC 6061)

IV. EXAMINATION AND TESTS

4.1 Applicable assembly and detail drawings with material specifications were submitted for the flame arrester unit and these are on file at Factory Mutual.

4.2 A series of flame arrester tests were made at the manufacturer's plant to determine that the construction would not permit flame propagation from the upper flame arrester screen surface through the flame arrester bank assembly during a continuous 30 min. burning period: and, except for the short interruption to try for flashback, the flow of gas/air mixture was continuous for the duration of the 30 min. burn test. Immediately after the interruption for the flashback test, the flow of gas/air mixture was restored and the combustion established at the upper flame resistor bank surface.

4.2.1 The flame arrester assembly was installed at the end of a 4 ft length of 6 in. diameter pipe arranged vertically and with a natural gas/air mixer installed at the bottom of the closure plate. Sight glasses were installed in the vertical pipe, as well as in the arrester lower body section so that visual evidence of any flashback through the flame arrester bank could be confirmed immediately.

4.2.2 Two fine wire gauge thermocouples were placed on the metal surface of both the upper and lower arrester bank so that these temperatures could be measured continuously by the use of a Leeds & Northrup strip chart recorder having a temperature range of 0 to 2000°F (-18 to 1093°C).

4.2.3 Flowmeters were used along with appropriate pressure gages in the air and natural gas supply lines to the burner assembly. This allowed continuous reading of gas/air mixtures by volume and pressure and enabled adjustments to be made as desired in the fuel/air mixture supplied to the burner assembly. The test was run indoors and the ambient temperature was approximately 68°F (20°C).

4.3 The following test results show that these various flame arrester assemblies withstood 30 min. continuous burning test with flashback occurring to the 4 in. thick bank when the fuel/air mixture was momentarily interrupted. After each of these tests for flashback, the flame was immediately re-established at the upper grid surface. Various flow rates from 700 cfh to 1,200 cfh total mixture flow were used during these tests. Fuel gas/air mixtures were at or near stoichiometric (10/1). At the end of the 30 min.

continuous burn test, the maximum temperature was recorded and flashback attempted. Results are as follows:

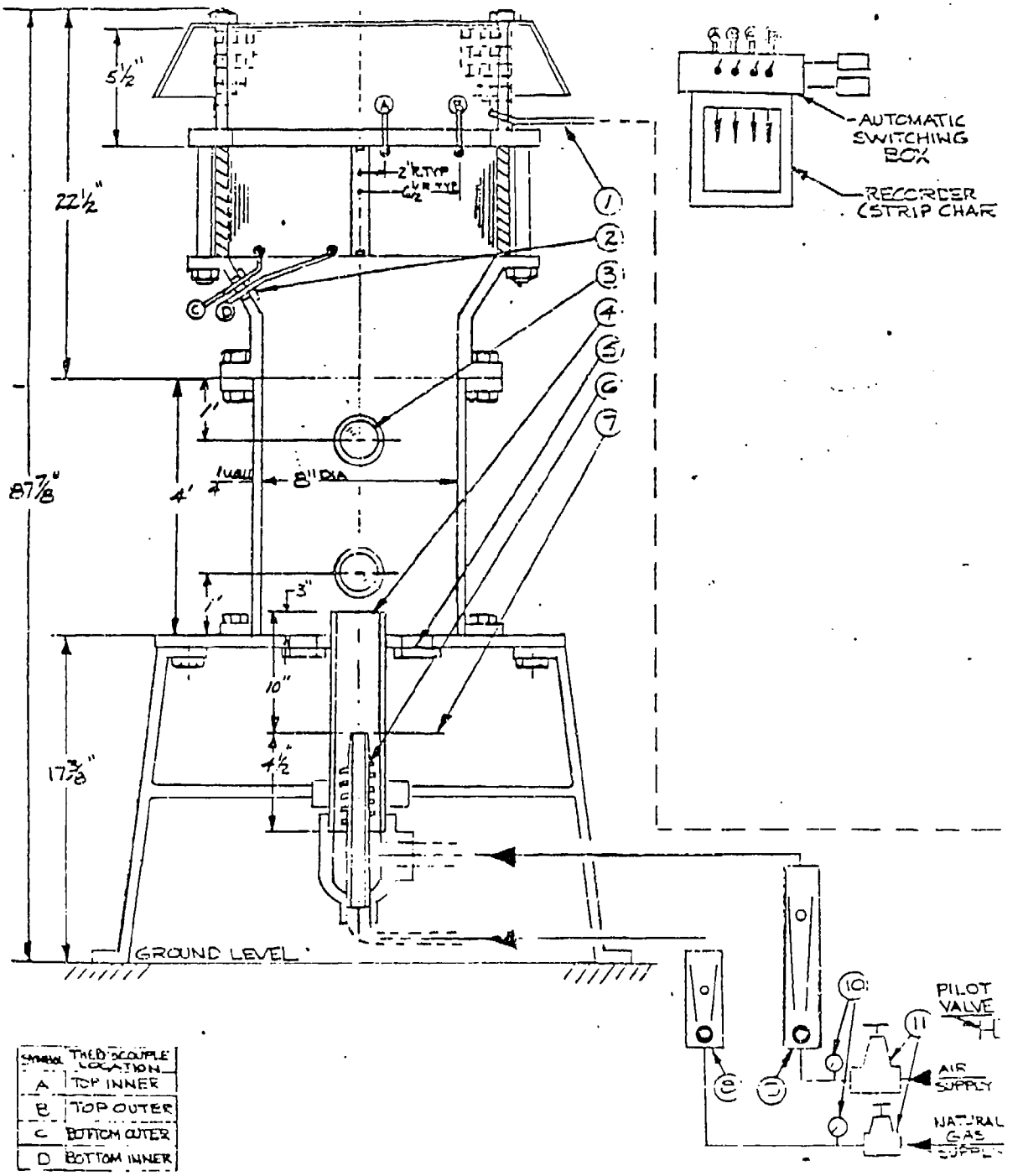
4.4 Examination of each of the flame arrester assemblies after the 30 min. continuous burn test indicated that each flame arrester bank was intact with no bulging or seam openings observed; discoloration of the bank material was noted and was expected. The pin which secured the bank in the shell remained secure.

4.5 Since no flashback has been observed in any of these tests, a 1/4 in. diameter hole was intentionally drilled through the 6 in. diameter bank and then plugged with a length of rod of the same diameter arranged such that it could easily be removed during a fire exposure on the grid. This bank was then fire tested and the temperatures in Test No. 5 were duplicated in approximately 32 min. The lights in the room were extinguished and the rod removed from the bank. Flashback occurred immediately, being seen through the viewports and heard as a muffled explosion. This proves the flame arrester bank was functioning properly when intact; and when damaged, as was intentionally done for this test, it is no longer safe as flashback was readily obtained.

4.6 The same 6 in. diameter aluminum flame bank was then subjected to a duration fire test to see if it would melt out and self-destruct. After 66 min. into the test the top of the flame bank was observed to have deformed and was tending to plug the bank. The gas/air mixture was cut off in an attempt to produce flashback, however, none occurred. These data are shown as Test No. 6 in paragraph 4.3.

4.7 The results of these tests and examination are satisfactory.

◀FM▶



SYMBOL	THERMOCOUPLE LOCATION
A	TOP INNER
B	TOP OUTER
C	BOTTOM OUTER
D	BOTTOM INNER

SYMBOL	DESCRIPTION
1	PILOT TUBE BURNER
2	THERMOCOUPLE MANIFOLD PLUG
3	SIGHT GLASS(2) CLEAR - 2½ DIA
4	1½" SCH 40 PIPE AREA I.D. = 2.036 IN²
5	ASBESTOS SHEET DISC 1/32 THK OVER(4) 2" DIA PORTS
6	⅞ SCH 40 PIPE W/VANES F/MIXING AREA I.D. = .1910 IN²
7	EFFECTIVE ANNULAR AREA AT AIR & GAS EXIT = 1.91 IN²
8	GAS FLOW METER RANGE 13 TO 130 SCFH (2" SCALE)
9	AIR FLOW METER RANGE 180 TO 1800 SCFH (10" SCALE)
10	PRESSURE GAUGE(S)
11	LINE REGULATOR(S)

TEST SET-UP SCHEMATIC
FOR
FLAME ARRESTOR & FREE VENT
BURN TEST

APPENDIX D
INTERNATIONAL CONFERENCE ON SAFETY OF LIFE AT SEA (SOLAS)
CHAPTER II-2 - REGULATION 59

Venting, purging, gas-freeing and ventilation

1 *Cargo tank venting*

1.1 The venting systems of cargo tanks are to be entirely distinct from the air pipes of the other compartments of the ship. The arrangements and position of openings in the cargo tank deck from which emission of flammable vapours can occur shall be such as to minimize the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard. In accordance with this general principle the criteria in paragraphs 1.2 to 1.10 will apply.

1.2 The venting arrangements shall be so designed and operated as to ensure that neither pressure nor vacuum in cargo tanks shall exceed design parameters and be such as to provide for:

.1 the flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a cargo tank in all cases through pressure/vacuum valves; and

.2 the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.

1.3.1 The venting arrangements in each cargo tank may be independent or combined with other cargo tanks and may be incorporated into the inert gas piping.

1.3.2 Where the arrangements are combined with other cargo tanks either stop valves or other acceptable means shall be provided to isolate each cargo tank. Where stop valves are fitted, they shall be provided with locking arrangements which shall be under the control of the responsible ship's officer. Any isolation must continue to permit the flow caused by thermal variations in a cargo tank in accordance with paragraph 1.2.1.

1.4 The venting arrangements shall be connected to the top of each cargo tank and shall be self-draining to the cargo tanks under all normal conditions of trim and list of the ship. Where it may not be possible to provide self-draining lines permanent arrangements shall be provided to drain the vent lines to a cargo tank.

1.5 The venting system shall be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of these devices shall comply with the requirements established by the Administration which shall contain at least the standards adopted by the Organization.*

---

* Reference is made to Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Oil Tankers adopted by the Maritime Safety Committee at its forty-ninth session in April 1984 (MSC/Circ.373).

1.6 Provision shall be made to guard against liquid rising in the venting system to a height which would exceed the design head of cargo tanks. This shall be accomplished by high-level alarms or overflow control systems or other equivalent means, together with gauging devices and cargo tank filling procedures.

1.7 Openings for pressure release required by paragraph 1.2.1 shall:

.1 have as great a height as is practicable above the cargo tank deck to obtain maximum dispersal of flammable vapours but in no case less than 2 m above the cargo tank deck;

.2 be arranged at the furthest distance practicable but not less than 5 m from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.

1.8 Pressure/vacuum valves required by paragraph 1.2.1 may be provided with a by-pass arrangement when they are located in a vent main or masthead riser. Where such an arrangement is provided there shall be suitable indicators to show whether the by-pass is open or closed.

1.9 Vent outlets for cargo loading, discharging and ballasting required by paragraph 1.2.2 shall:

.1.1 permit the free flow of vapour mixtures; or

.1.2 permit the throttling of the discharge of the vapour mixtures to achieve a velocity of not less than 30 m/sec;

.2 be so arranged that the vapour mixture is discharged vertically upwards;

.3 where the method is by free flow of vapour mixtures, be such that the outlet shall be not less than 6 m above the cargo tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard;

.4 where the method is by high velocity discharge, be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard. These outlets shall be provided with high velocity devices of an approved type;

.5 be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1.25 to take account of gas evolution, in order to prevent the pressure in any cargo tank from exceeding the design pressure. The master shall be provided with information

regarding the maximum permissible loading rate for each cargo tank and in the case of combined venting systems, for each group of cargo tanks.

1.10 In combination carriers, the arrangement to isolate slop tanks containing oil or oil residues from other cargo tanks shall consist of blank flanges which will remain in position at all times when cargoes other than liquid cargoes referred to in regulation 55.1 are carried.

2 *Cargo tank purging and/or gas-freeing*

Arrangements for purging and/or gas-freeing shall be such as to minimize the hazards due to the dispersal of flammable vapours in the atmosphere and to flammable mixtures in a cargo tank. Accordingly:

.1 When the ship is provided with an inert gas system the cargo tanks shall first be purged in accordance with the provisions of regulation 62.13 until the concentration of hydrocarbon vapours in the cargo tanks has been reduced to less than 2 per cent by volume. Thereafter, venting may be at the cargo tank deck level.

.2 When the ship is not provided with an inert gas system, the operation shall be such that the flammable vapour is initially discharged:

.2.1 through the vent outlets as specified in paragraph 1.9; or

.2.2 with a vertical exit velocity of at least 20 m/sec through outlets at least 2 m above the cargo tank deck level and which are protected by suitable devices to prevent the passage of flame.

When the flammable vapour concentration in the outlet has been reduced to 30 per cent of the lower flammable limit the discharge of the vapour mixture may be at the cargo tank deck level.

3 *Ventilation*

3.1 Cargo pump-rooms shall be mechanically ventilated and discharges from the exhaust fans shall be led to a safe place on the open deck. The ventilation of these rooms shall have sufficient capacity to minimize the possibility of accumulation of flammable vapours. The number of changes of air shall be at least 20 per hour, based upon the gross volume of the space. The air ducts shall be arranged so that all of the space is effectively ventilated. The ventilation shall be of the suction type using fans of the non-sparking type.

3.2 The arrangement of ventilation inlets and outlets and other deckhouse and superstructure boundary space openings shall be such as to complement the provisions of paragraph 1. Such vents especially for machinery spaces shall be situated as far aft as practicable. Due consideration in this regard should be given when the ship is equipped to load or discharge at the stern. Sources of ignition such as electrical equipment shall be so arranged as to avoid an explosion hazard.

APPENDIX E

IMO REVISED STANDARDS FOR THE DESIGN, TESTING AND LOCATING OF DEVICES TO PREVENT THE PASSAGE OF FLAME INTO CARGO TANKS IN TANKERS

[BLANK]

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REVISED STANDARDS FOR THE DESIGN, TESTING AND LOCATING OF DEVICES TO PREVENT THE PASSAGE OF FLAME INTO CARGO TANKS IN TANKERS

1 It is recalled that the Assembly, at its thirteenth session, by resolution A.519(13) requested the Maritime Safety Committee to finalize and adopt the Standards for devices to prevent the passage of flame into cargo tanks prior to the coming into force of the 1981 SOLAS amendments.

2 The Maritime Safety Committee, at its forty-ninth session, adopted the standards which were attached to MSC/Circ.373.

3 The Maritime Safety Committee also agreed that the inert gas system is to be considered as an equivalent to devices to prevent the passage of flame into cargo tanks only if vent outlets on ships fitted with inert gas systems are at least fitted with devices to prevent the passage of flame into cargo tanks, but that these devices need not comply with the test requirment for endurance burning. It was noted that in the Standards, emphasis is laid on compliance with test specifications rather than on construction. It is understood that, in the case of a tanker fitted with an inert gas system, the provision of flashback would suffice and a well-designed and fitted flame screen could meet this criterion. In summary, if a flame screen met the Standards, it would be accepted.

4 The Maritime Safety Committee, at its fifty-fifth session, adopted amendments to MSC/Circ.373 which are incorporated in the revised Standards, as set out in the annex.

5 Member Governments are invited to give effect to these Standards in conjunction with the application of regulation II-1/59.1.5 of the 1974 SOLAS Convention, as amended.

***

ANNEX

REVISED STANDARDS FOR THE DESIGN, TESTING AND LOCATING OF DEVICES TO PREVENT THE PASSAGE OF FLAME INTO CARGO TANKS IN TANKERS

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1 INTRODUCTION

1.1 Purpose

The 1981 and the 1983 amendments to the International Convention for the Safety of Life at Sea, 1974 (SOLAS) include revised requirements for fire safety measures for tankers. Regulation II-2/59 of these amendments contains provisions concerning venting, purging, gas-freeing and ventilation. regulation II-2/59.1.5 states:

> "The venting system shall be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of these devices shall comply with the requirements established by the Administration which shall contain at least the Standa is adopted by the Organization."

1.2 Application

1.2.1 These Standards are intended to cover the design, testing, locating and maintenance of "devices to prevent the passage of flame into cargo tanks" (hereafter called "devices") of tankers and combination carriers carrying crude oil and petroleum products having a flashpoint of 60°C (closed cup) or less, and a Reid vapour pressure below atmospheric pressure and other products having a similar fire hazard.

1.2.2 Oil tankers and combination carriers fitted with an inert gas system in accordance with regulation 62 shall be fitted with devices which comply with these Standards, except that the tests specified in 3.2.3 and 3.3.3.2 are not required. Such devices are only to be fitted at openings unless they are tested in accordance with 3.4.

1.2.3 These Standards are intended for devices protecting cargo tanks containing crude oil, petroleum products and flammable chemicals. In the case of the carriage of chemicals, the test media referred to in section 3 can be used. However, devices for chemical tankers dedicated to the carriage of products with MESG* less than 0.9 mm should be tested with appropriate media.

* Reference is made to IEC - Publication 79-1.

1.2.4 Devices shall be tested and located in accordance with these Standards.

1.2.5 Devices are installed to protect:

.1 openings designed to relieve pressure or vacuum caused by thermal variations (regulation II-2/59.1.2.1);

.2 openings designed to relieve pressure or vacuum during cargo loading, ballasting or during discharging (regulation II-2/59.1.2.2);

.3 outlets designed for gas-freeing as described in the proposed regulation II-2/59.2.2.3 (see appendix 1).

1.2.6 Devices shall not be capable of being bypassed or blocked open unless they are tested in the bypassed or blocked open position in accordance with section 3.

1.2.7 These Standards do not include consideration of sources of ignition such as lightning discharges since insufficient information is available to formulate equipment recommendations. All cargo handling, tank cleaning and ballasting operations shall be suspended on the approach of an electrical storm.

1.2.8 These Standards are not intended to deal with the possibility of the passage of flame from one cargo tank to another on tankers with common venting systems.

1.2.9 When outlet openings of gas-freeing systems on tankers not fitted with inert gas systems are required to be protected with devices, they shall comply with these Standards except that the tests specified in 3.2.3 and 3.3.3.2 are not required.

1.2.10 Certain of the tests prescribed in section 3 of these Standards are potentially hazardous, but no attempt is made in this circular to specify safety requirements for these tests.

1.3 Definitions

For the purpose of these Standards, the following definitions are applicable.

1.3.1 "Flame arrester" is a device to prevent the passage of flame in accordance with a specified performance standa . Its flame-arresting element is based on the principle of quenching.

1.3.2 "Flame screen" is a device utilizing wire mesh to prevent the passage of unconfined flames, in accordance with a specified performance standard.

1.3.3 "Flame speed" is the speed at which a flame propagates along a pipe or other system.

1.3.4 "Flashback" is the transmission of a flame through a device.

1.3.5 "High velocity vent" is a device to prevent the passage of flame, consisting of a mechanical valve which adjusts the opening available for flow in accordance with the pressure at the inlet of the valve in such a way that the efflux velocity cannot be less than 30 m/s.

1.3.6 "Pressure/vacuum valve" * is a device designed to maintain pressure and vacuum in a closed container within preset limits.

2 STANDARDS

2.1 Principles

2.1.1 Depending on their service and location, devices are required to protect against the propagation of:

.1 moving flames; and/or

.2 stationary flames from pre-mixed gases;

after ignition of gases resulting from any cause.

---

* Pressure/vacuum valves are devices to prevent the passage of flame when designed and tested in accordance with these Standards.

2.1.2 When flammable gases from outlets ignite, the following four situations may occur:

.1 At low gas velocities, the flame may:

.1 flashback; or

.2 stabilize itself as if the outlet were a burner.

.2 At high velocities, the flame may:

.1 burn at a distance above the outlet; or

.2 be blown out.

2.1.3 In order to prevent the passage of flame into a cargo tank, devices must be capable of performing one or more of the following functions:

.1 permitting the gas to pass through passages without flashback and without ignition of the gases on the protected side when the device is subjected to heating for a specified period;

.2 maintaining an efflux velocity in excess of the flame speed for the gas, irrespective of the geometric configuration of the device and without the ignition of gases on the protected side when the device is subjected to heating for a specified period; and

.3 preventing an influx of flame when conditions of vacuum occur within the cargo tanks.

2.2 Mechanical design standards

2.2.1 The casing or housing of devices shall meet similar standards of strength, heat resistance and corrosion resistance as the pipe to which they are attached.

2.2.2 The design of devices shall allow for ease of inspection and removal of internal elements for replacement, cleaning or repair.

2.2.3 All flat joints of the hosing shall be machined true and shall provide for a joint having an adequate metal-to-metal contact.

2.2.4 Flame arrester elements shall fit in the housing in such a way that flame cannot pass between the element and the housing.

2.2.5 The clear area through flame arresters shall be at least 1.5 times the cross-sectional area of the vent line.

2.2.6 Resilient seals may be installed only if their design is such that if the seals are partially or completely damaged or burned, the device is still capable of effectively preventing the passage of flame.

2.2.7 Devices shall allow for efficient drainage of moisture without impairing their efficiency to prevent the passage of flame.

2.2.8 The casing and element and gasket materials shall be capable of withstanding the highest pressure and temperature to which the device may be exposed under both normal and specified fire test conditions.

2.2.9 End-of-line devices shall be so constructed as to direct the efflux vertically upwards.

2.2.10 Fastenings essential to the operation of the device, i.e. screws, etc., shall be protected against loosening.

2.2.11 Means shall be provided to check that any valve lifts easily without remaining in the open position.

2.2.12 Devices in which the flame arresting effect is achieved by the valve function and which are not equipped with the flame arrester elements (e.g. high velocity valves) must have a width of the contact area of the valve seat of at least 5 mm.

2.2.13 Devices shall be resistant to corrosion in accordance with 3.5.1.

2.2.14 Elements, gaskets and seals shall be of material resistant to both seawater and the cargoes carried.

2.2.15 The casing or housing shall be capable of passing a hydrostatic pressure test, as required in 3.5.2.

2.2.16 In-line devices shall be able to withstand, without damage or permanent deformation, the internal pressure resulting from detonation when tested in accordance with section 3.4.

2.2.17 A flame arrester element shall be designed to ensure quality control of manufacture to meet the characteristics of the prototype tested, in accordance with these Standards.

2.3 Performance Standards

2.3.1 Devices shall be tested in accordance with 3.5 and thereafter shown to meet the test requirements of 3.2 to 3.4, as appropriate.

2.3.2 Performance characteristics, such as the flow rates under both positive and negative pressure, operating sensitivity, flow resistance and velocity shall be demonstrated by appropriate tests.

2.3.3 Devices shall be designed and constructed to minimize the effect of fouling under normal operating conditions. Instructions on how to determine when cleaning is required and the method of cleaning shall be provided for each device in the manufacturers' instruction manual.

2.3.4 Devices shall be capable of operating in freezing conditions and if any device is provided with heating arrangements so that its surface temperature exceeds 85°C, then it shall be tested at the highest operating temperature.

2.3.5 Devices based upon maintaining a minimum velocity shall be capable of opening in such a way that a velocity of 30 m/s is immediately initiated, maintaining an efflux velocity of at least 30 m/s at all flow rates and, when the gas flow is interrupted, be capable of closing in such a way that this minimum velocity is maintained until the valve is fully closed.

2.4 Flame screens

2.4.1 Flame screens shall be:

.1 designed in such a manner that they cannot be inserted improperly in the opening;

.2 securely fitted in openings so that flames cannot circumvent the screen; and

.3 able to meet the requirements of these Standards, except that the test specified in 3.2.3 need not be complied with.

2.5 Sizing, location and installation of devices

2.5.1 For determining the size of devices to avoid inadmissible pressure or vacuum in cargo tanks during loading or discharging, calculations of pressure losses shall be carried out. The following parameters shall be taken into account:

.1 loading/discharge rates;

.2 gas evolution;

.3 pressure loss across devices, taking into account the resistance coefficient;

.4 pressure loss in the vent piping system;

.5 pressure at which the vent opens if a high velocity valve is used; and

.6 density of the saturated vapour/air mixture.

2.5.2 Devices shall be located at the outlets to atmosphere unless tested and approved for in-line installation. Devices for in-line installation may not be fitted at the outlets to atmosphere unless they have also been tested and approved for that position.

2.5.3 Except as may be permitted in 1.2.2, flame screens referred to in 2.4 shall be fitted only at vacuum inlets through which vapours cannot be vented to atmosphere. Flame screens shall be protected against mechanical damage.

2.5.4 Where end-of-line devices are fitted with cowls, weather hoods and deflectors, etc., these attachments shall be fitted for the tests described in 3.2.

2.5.5 Where detonation flame arresters are installed, as in-line devices venting to atmosphere, they should be located at a sufficient distance from the open end of the pipeline so as to preclude the possibility of a stationary flame resting on the arrester.

2.5.6 When venting to atmosphere is not performed through an end-of-line device according to 2.5.4, or a detonation flame arrester according to 2.5.5, the in-line device has to be specifically tested with the inclusion of all pipes, tees, bends, cowls, weather hoods, etc., which may be fitted between the device and atmosphere. The testing shall consist of the flashback test of 3.2.2 and, if for the given installation it is possible for a stationary flame to rest on the device, the testing shall also include the endurance burning test of 3.2.3.

2.5.7 Means shall be provided to enable personnel to reach devices situated more than 2 m above deck to facilitate maintenance, repair and inspection.

3 TYPE TEST PROCEDURES

3.1 Principles

3.1.1 Tests shall be conducted by a laboratory acceptable to the Administration.

3.1.2 Only one device shall be submitted for each type test programme. Such a device shall have the same dimensions and most unfavourable clearances expected in the production model.

3.1.3 Tests described in this section using gasoline vapours (a non-leaded petroleum distillate consisting essentially of aliphatic hydrocarbon compounds with a boiling range approximating 65°C/75°C), technical hexane vapours, or technical propane, as appropriate, and referred to in this section, are suitable for all devices protecting tanks containing a flammable atmosphere

of the cargoes referred to in 1.2.1. This does not preclude the use of gasoline vapours or technical hexane vapours for all tests referred to in this section.

3.2 Test procedures for flame arresters located at openings to the atmosphere

3.2.1 The test rig shall consist of an apparatus producing an explosive mixture, a small tank with a diaphragm, a flanged prototype of the flame arrester, a plastic bag[1/] and a firing source in three positions (see appendix 2).[2/] Other test rigs may be used, provided the tests referred to in this section are achieved to the satisfaction of the Administration.

3.2.2 A flashback test shall be carried out as follows:

.1 The tank, flame arrester assembly and the plastic bag[1/] enveloping the prototype flame arrester shall be filled so that this volume contains the most easily ignitable propane/air mixture.[3/] The concentration of the mixture should be verified by appropriate testing of the gas composition in the plastic bag. Where devices referred to in 2.5.6 are tested, the plastic bag shall be fitted at the outlet to atmosphere. Three ignition sources shall be installed along the axis of the bag, one close to the flame arrester, another as far away as possible therefrom, and the third at the midpoint between these two. These three sources shall be fired in succession, one during each of the three tests.

1/ The dimensions of the plastic bag are dependent on those of the flame arrester, but for the flame arresters normally used on tankers, the plastic bag may have a circumference of 2 m, a length of 2.5 m and a wall thickness of 0.05 m.

2/ In order to avoid remnants of the plastic bag from falling back on to the device being tested after ignition of the fuel/air mixture, it may be useful to mount a coarse wire frame across the device within the plastic bag. The frame should be so constructed as not to interfere with the test result.

3/ Reference is made to IEC Publication 79-1.

.2 If a flashback occurs, the tank diaphragm will burst and this will be audible and visible to the operator by the emission of a flame. Flame, heat and pressure sensors may be used as an alternative to a bursting diaphragm.

3.2.3 An endurance burning test shall be carried out, in addition to the flashback test, for flame arresters at outlets where flows of explosive vapour are foreseeable:

.1 The test rig as referred to in 3.2.1 may be used, without the plastic bag. The flame arrester shall be so installed that the mixture emission is vertical. In this position the mixture shall be ignited. Where devices referred to in 2.5.6 are tested, the flame arrester shall be so installed as to reflect its final orientation.

.2 Endurance burning shall be achieved by using the most easily ignitable gasoline vapour/air mixture or the most easily ignitable technical hexane vapour/air mixture with the aid of a pilot flame or a spark igniter at the outlet. By varying the proportions of the flammable mixture and the flow rate, the arrester shall be heated until the highest obtainable temperature on the cargo tank side of the arrester is reached. The highest obtainable temperature may be considered to have been reached when the rate of rise of temperature does not exceed 0.5°C per minute over a ten minute period. This temperature shall be maintained for a period of ten minutes, after which the flow shall be stopped and the conditions observed. If difficulty arises in establishing thermal stability, the following criteria shall apply. When the temperature has reached the apparent maximum, using the most severe conditions of flammable mixtures and flow rate, but increases at a rate in excess of 0.5°C per minute over a ten minute period, endurance burning shall be continued for a period of two hours from the time the most severe apparent conditions have been established, after which the flow shall be stopped and the conditions observed. Flashback shall not occur during this test.

3.3 Test procedures for high velocity vents

3.3.1 The test rig shall be capable of producing the required volume flow rate. In appendices 3 and 4, drawings of suitable test rigs are shown. Other test rigs may be used, provided the tests are achieved to the satisfaction of the Administration.

3.3.2 A flow condition test shall be carried out with high velocity vents using compressed air or gas at agreed flow rates. The following shall be recorded:

.1 The flow rate. Where air or a gas other than vapours of cargoes with which the vent is to be used is employed in the test, the flow rates achieved shall be corrected to reflect the vapour density of such cargoes.

.2 The pressure before the vent opens. The pressure in the test tank on which the device is located shall not rise at a rate greater than 0.01 $N/mm^2/min$.

.3 The pressure at which the vent opens.

.4 The pressure at which the vent closes.

.5 The efflux velocity at the outlet which shall not be less than 30 m/s at any time when the valve is open.

3.3.3 The following fire safety tests shall be conducted using a mixture of gasoline vapour and air or technical hexane vapour and air, which produces the most easily ignitable mixture at the point of ignition. This mixture shall be ignited with the aid of a permanent pilot flame or a spark igniter at the outlet:

.1 Flashback tests in which propane may be used instead of gasoline or hexane shall be carried out with the vent in the upright position and then inclined at 10° from the vertical. For some vent designs further tests with the vent inclined in more than one direction may

be necessary. In each of these tests the flow shall be reduced until the vent closes and the flame is extinguished, and each shall be carried out at least 50 times. The vacuum side of combined valves shall be tested in accordance with 3.2.2 with the vacuum valve maintained in the open position for the duration of this test, in order to test the efficiency of the device which must be fitted.

.2 An endurance burning test, as described in 3.2.3, shall be carried out. Following this test, the main flame shall be extinguished and then, with the pilot flame burning or the spark igniter discharging, small quantities of the most easily ignitable mixture shall be allowed to escape for a period of ten minutes, during which time flashback shall not occur. For the purposes of this test the soft seals or seats shall be removed.

3.4 Test rig and test procedures for detonation flame arresters located in-line

3.4.1 A flame arrester shall be installed at one end of a pipe of suitable length and of the same diameter as the flange of the flame arrester. On the exposed flange, a plastic bag[1/] shall be affixed. The pipe shall be filled with the most easily ignitable mixture of propane and air, which shall then be ignited. The velocity of the flame near the flame arrester shall be measured and shall have a value of that for stable detonations.

3.4.2 Three detonation tests shall be conducted and no flashback shall occur through the device and no part of the flame arrester shall be damaged or show permanent deformation.

3.4.3 Other test rigs may be used provided the tests are achieved to the satisfaction of the Administration. A drawing of the test rig is shown in appendix 5.

1/ The dimensions shall be at least 4 m circumference, 4 m length and a material wall thickness of 0.05 mm.

3.5 Operational test procedures

3.5.1 A corrosion test shall be carried out. In this test a complete device, including a section of the pipe to which it is fitted, shall be exposed to a 20% sodium chloride solution spray at a temperature of 25°C for a period of 240 hours, and allowed to dry for 48 hours. An equivalent test may be used to the satisfaction of the Administration. Following this test, all movable parts shall operate properly and there shall be no corrosion deposits which cannot be washed off.

3.5.2 A hydraulic pressure test shall be carried out in the casing or housing of a simple device, in accordance with 2.2.1.

4 MISCELLANEOUS

4.1 Marking of device

Each device shall be permanently marked, or have a permanently fixed tag made of stainless steel or other corrosion-resistant material, to indicate:

.1 manufacturer's name or trade mark;

.2 style, type, model or other manufacturer's designation for the device;

.3 size of the outlet for which the device is approved;

.4 approved location for installation, including maximum or minimum length of pipe, if any, between the device and the atmosphere;

.5 direction of flow through the device;

.6 indication of the test laboratory and report number; and

.7 compliance with the requirements of MSC/Circ.373/Rev.1.

4.2 Laboratory report

4.2.1 The laboratory report shall include:

.1 detailed drawings of the device;

.2 types of tests conducted. Where in-line devices are tested, this information should include the maximum pressures and velocities observed in the test;

.3 specific advice on approved attachments;

.4 types of cargo for which the device is approved;

.5 drawings of the test rig;

.6 in the case of high velocity vent, the pressures at which the device opens and closes in the efflux velocity; and

.7 all the information marked on the device in 4.1.

4.3 Manufacturer's instruction manual

4.3.1 The manufacturer shall supply a copy of the instruction manual, which shall be kept on board the tanker and which shall include:

.1 installation instructions;

.2 operating instructions;

.3 maintenance requirements, including cleaning (see 2.3.3);

.4 copy of the laboratory report referred to in 4.2; and

.5 flow test data, including flow rates under both positive and negative pressures, operating sensitivity, flow resistance and velocity, shall be provided.

Appendix 1

PROPOSED AMENDMENTS TO REGULATION II-2/59

2 Cargo tank purging and/or gas-freeing*

Arrangements for purging and/or gas-freeing shall be such as to minimize the hazards due to the dispersal of flammable vapours in the atmosphere and to flammable mixtures in a cargo tank. Accordingly:

.1 When the ship is provided with an inert gas system, the cargo tanks shall first be purged in accordance with the provisions of regulation 62.13 until the concentration of hydrocarbon vapours in the cargo tanks has been reduced to less than 2% by volume. Thereafter, gas-freeing may take place at the cargo tank deck level.

.2 When the ship is not provided with an inert gas system, the operation shall be such that the flammable vapour is discharged initially:

.2.1 through the vent outlets as specified in paragraph 1.9; or

.2.2 through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 30 m/sec maintained during the gas-freeing operation; or

.2.3 through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 20 m/sec and which are protected by suitable devices to prevent the passage of flame.

When the flammable vapour concentration at the outlet has been reduced to 30% of the lower flammable limit, gas-freeing may thereafter be continued at cargo tank deck level.

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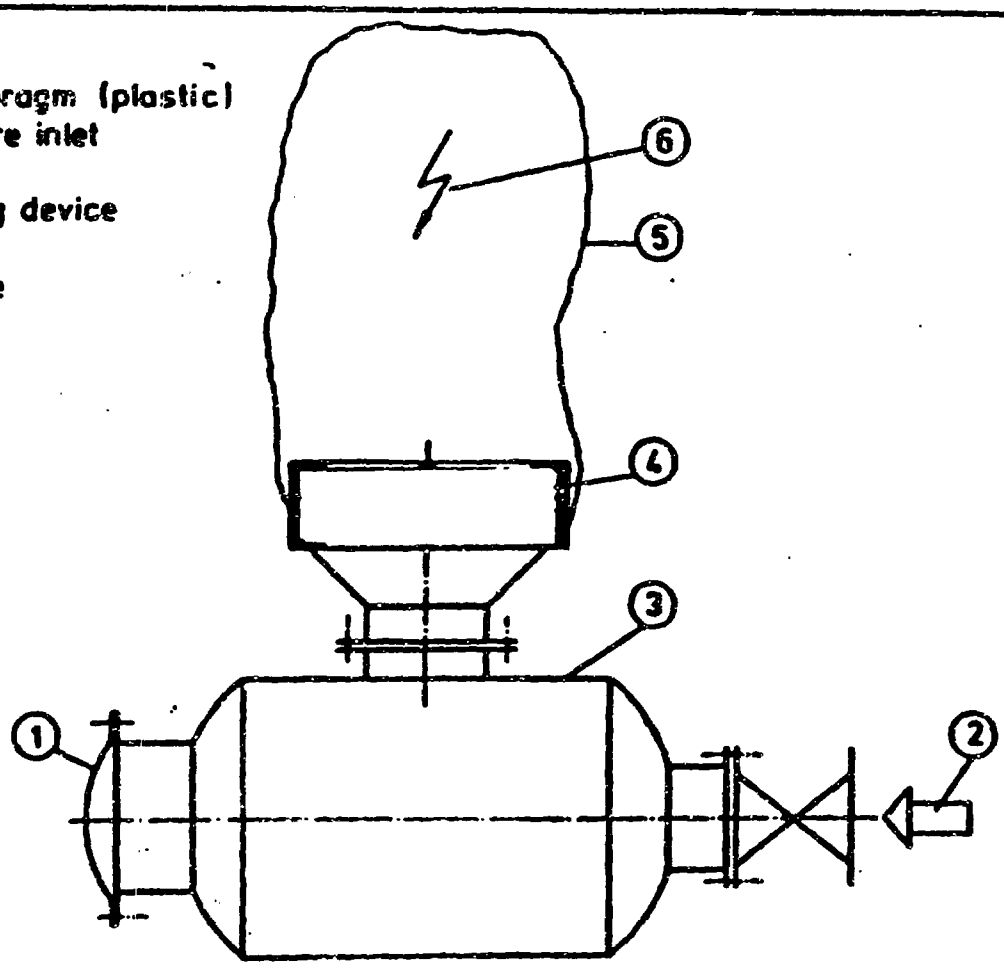
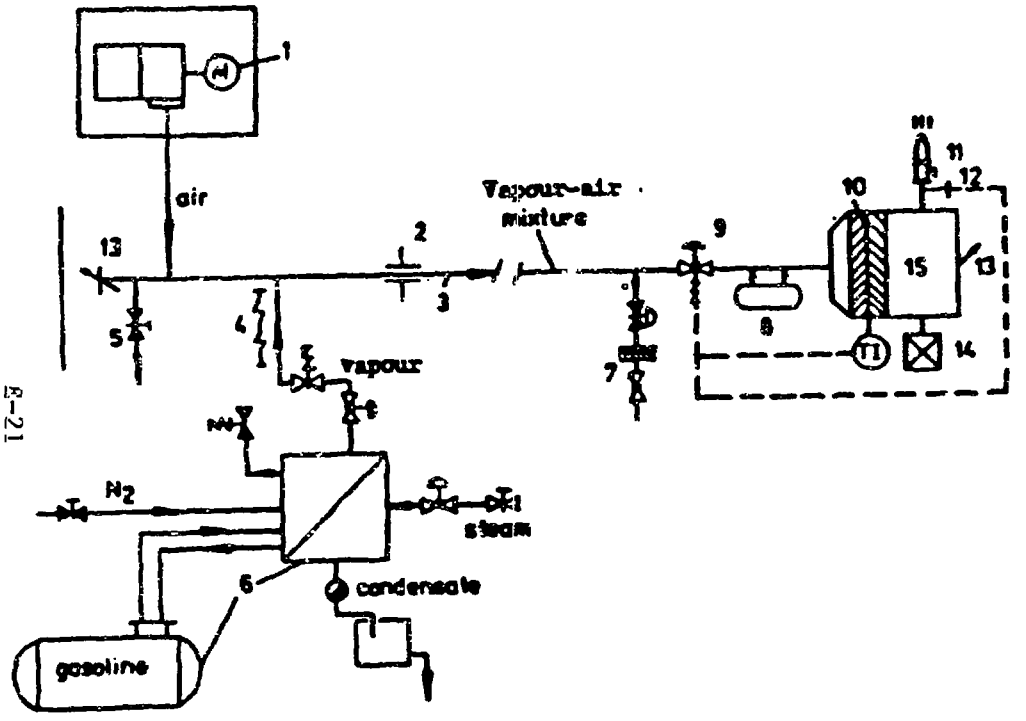
* Reference is made to the Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers (MSC/Circ.373/Rev.1) and to Revised Factors to be taken into Consideration when Designing Cargo Tank Venting and Gas-Freeing Arrangements (MSC/Circ.450/Rev 1).

1 -bursting diaphragm (plastic)
2 -explosivemixture inlet
3 -tank
4 -flame arresting device
5 -plastic bag
6 -ignition source



TEST RIG FOR FLASH BACK TEST

Appendix 3

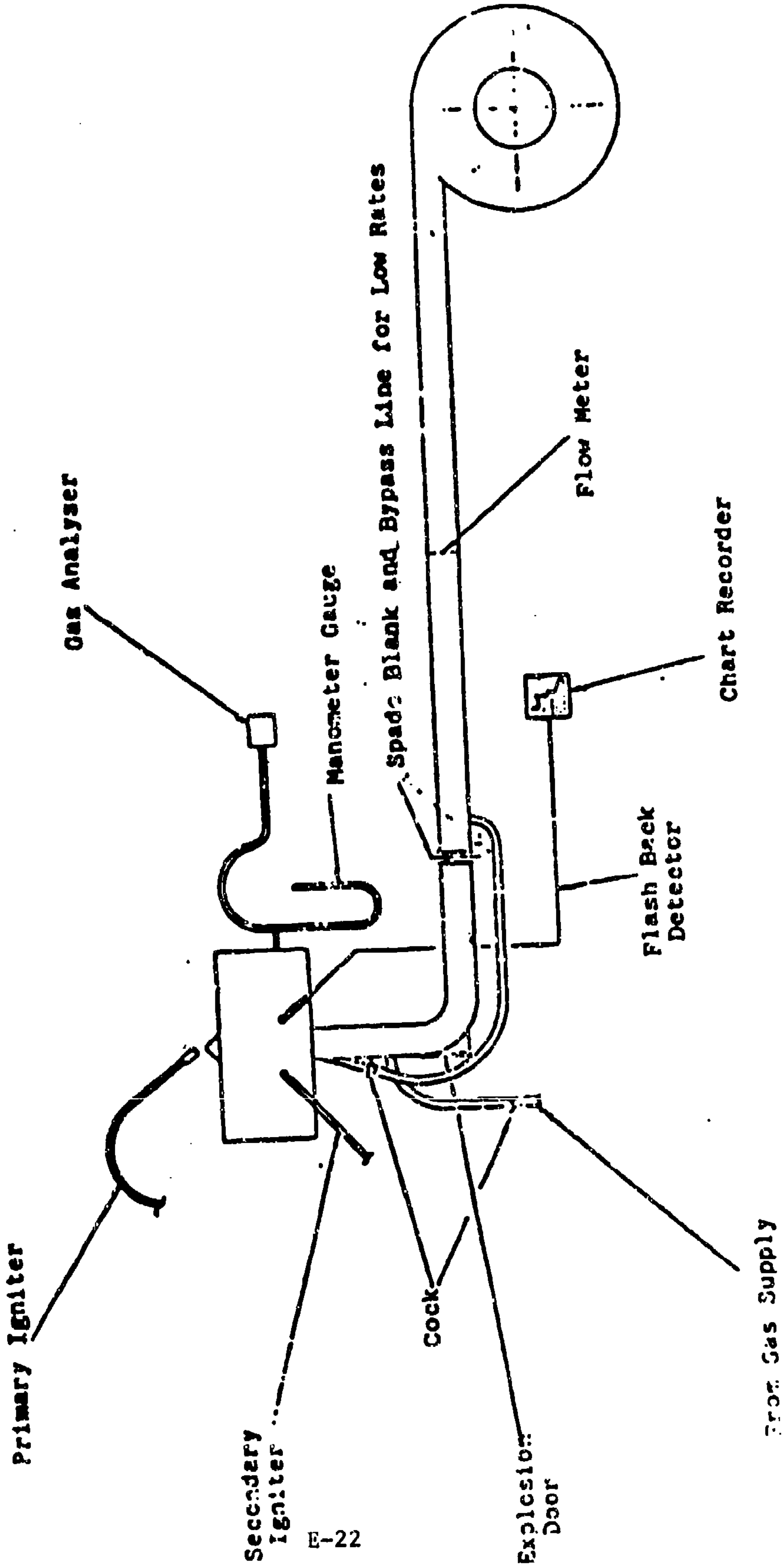


1 fan with variable speed
2 volume rate indicator
3 pipe (500 mm diameter), length ~ 30 m
4 heated vapour pipe
5 air bypass
6 evaporator and liquid storage tank
7 vapour/air-mixture bypass
8 extinguishing agents
9 control and quick action stop valve
10 explosion arresting crimped ribbon with temperature control for the safety of the test plant
11 high velocity valve to be tested
12 flame detector
13 bursting diaphragm
14 concentration indicator
15 tank

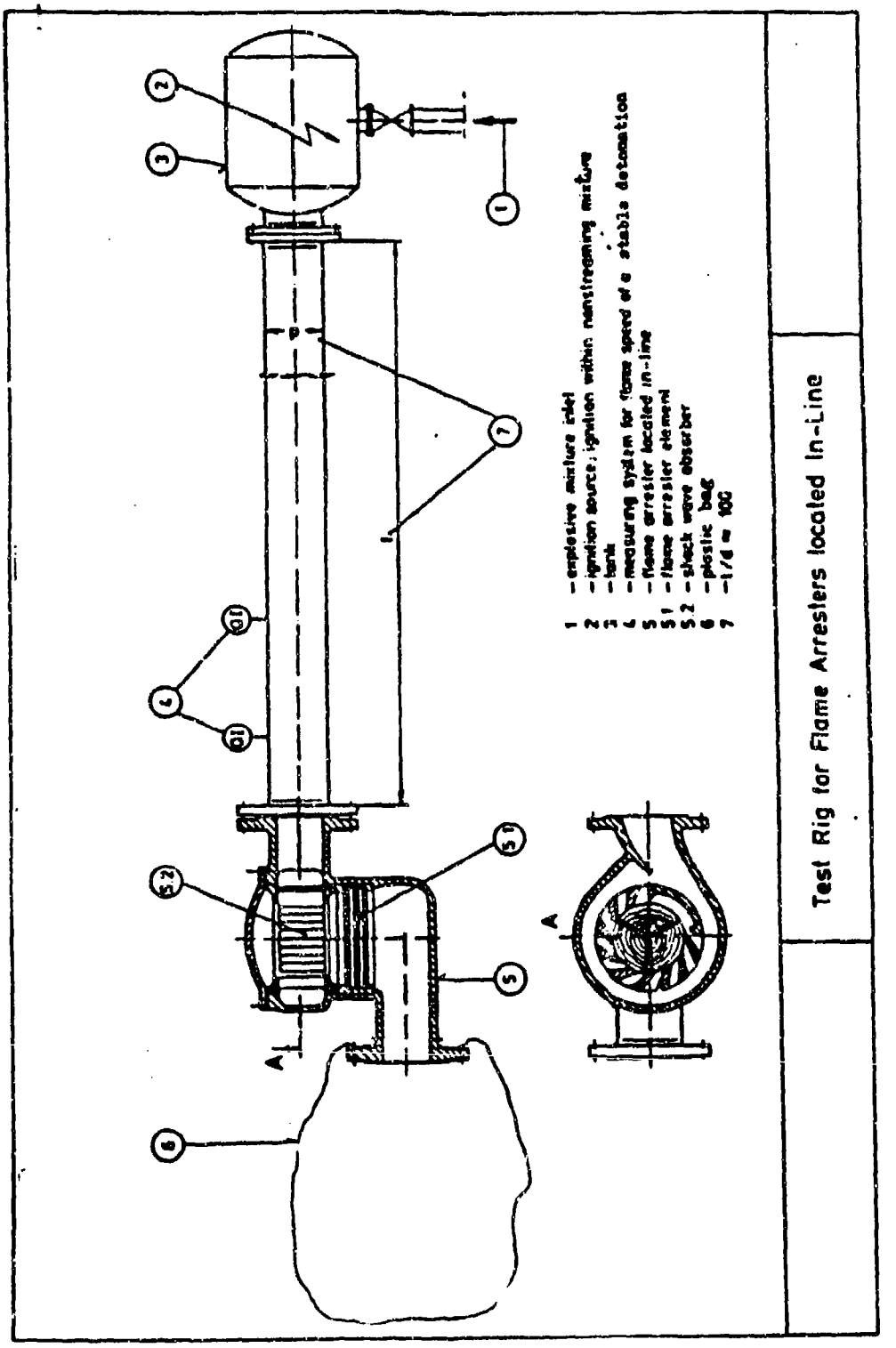
Schematic Plan of the Test Plant for High Velocity Valves
(endurance burning test only)

Appendix 4

TEST RIG FOR HIGH VELOCITY VENTS



Appendix 5


1 – explosive mixture inlet
2 – ignition source; ignition within nonstreaming mixture
3 – tank
4 – measuring system for flame speed of a stable detonation
5 – flame arrester located in-line
5.1 – flame arrester element
5.2 – shock wave absorber
6 – plastic bag
7 – l/d = 100
A
Test Rig for Flame Arresters located In-Line