

[54] FIRE SIMULATION FACILITY

[72] Inventors: E. Bruce Belason, Wilmington; George K. Castle, Chelmsford; Donald P. Crowley, Lowell; Joseph V. Morgida, Billerica, all of Mass.

[73] Assignee: Avco Corporation, Cincinnati, Ohio

[22] Filed: Nov. 3, 1969

[21] Appl. No.: 873,281

[52] U.S. Cl. 263/1, 263/40

[51] Int. Cl. F27b 3/00

[58] Field of Search 73/15 R; 13/2; 263/1, 2, 9, 263/40

[56] References Cited

UNITED STATES PATENTS

991,929 5/1911 Baily 263/9

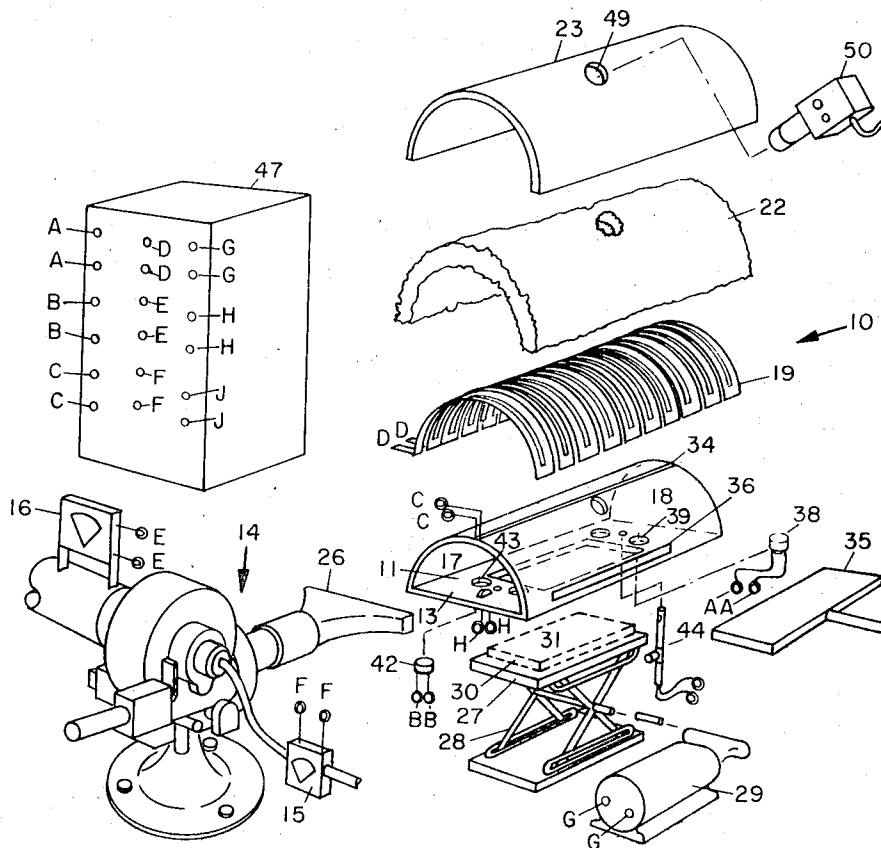
2,000,580 5/1935 Carruthers 263/1 X
 3,151,851 10/1964 Negley 263/40
 3,257,840 6/1966 Skinner 263/2 X

Primary Examiner—John J. Camby
 Attorney—Charles M. Hogan and Abraham Ogman

[57] ABSTRACT

The invention relates to a fire simulation facility which accurately reproduces the thermodynamic and thermochemical parameters of a fire under controllable conditions. The facility utilizes a combination of a radiative and a convective heat source. The radiative source utilizes electrical resistance heater heating and a radiating surface having an emissivity of 0.8 to 0.9 or greater. The convective source generates hot gases in the form of chemical combustion products. The fire simulator also includes instrumentation for controlling the heat flux emanating from the heat sources.

17 Claims, 2 Drawing Figures



FIRE SIMULATION FACILITY

As far as can be determined from the literature and interviews around the country, no facility exists which can economically simulate the important thermodynamic parameters of a real fire under controllable conditions. Existing fire test facilities either do not simulate a realistic fire as where an oxyacetylene torch or tungsten quartz lamps are used, or they are not suitable for materials development, as in the case of large liquid or gaseous fires, such as the 4,000-8,000 cubic feet Underwriters Testing Furnaces. In short, the only present way to realistically simulate a fire is to literally build a large bonfire. Large bonfires are expensive, require stringent safety measures and need large expensive samples. They are by their very nature somewhat uncontrollable; they do not lend themselves to produce reproducible environments; it is difficult or impossible to observe a specimen.

The fire simulation facility provides means for conducting meaningful research, development and evaluation of fire retardant materials and systems. The facility provides a capability of making reliable tests under controllable conditions on small samples of materials. These tests can be conducted quickly. The facility also provides means for selecting a desired fire environment by providing means for adjusting the rates of heat flux imposed upon the test materials.

OBJECTS

It is an object of the invention to provide a fire simulation facility which can economically, controllably and reproducibly simulate the thermodynamic parameters of real fire, particularly hydrocarbon fires.

It is yet another object of the invention to provide a fire simulation facility suitable for materials development.

Other objects of the invention are to provide a fire simulation facility which:

- a. simulates a wide spectra of fires;
- b. is capable of conducting tests of virtually any time duration (i.e., minutes to hours);
- c. creates an environment permitting the test specimen to undergo proper chemical reactions which, typically, take place in actual fires;
- d. permits the test specimen to be observed and easily retrieved;
- e. permits independent or coordinated control of radiative and convective heat fluxes; and
- f. which is capable of being constructed and operated at low cost.

In accordance with the invention, a fire simulation facility includes a combustion chamber having means for positioning and controlling the position of a test specimen therein. The combustion chamber includes a radiant heat source. The temperature of which and the emissivity of which may be easily controlled to provide a specified radiant heat flux history for accurate simulation of a particular fire environment. The fire simulation facility also includes means for generating a flow of hot gases to the test sample. Instrumentation is provided for adjusting the temperature and the composition of these hot gases for accurate fire simulation. Instrumentation including controllers is provided for maintaining the correct heat environmental conditions of both the radiant and convection heat sources. The fire simulation facility also includes means for adjusting and maintaining the position of a test sample within the combustion chamber and the exposure of the test sample in a controlled position in relation to the heat sources. As a result, the test specimen receives a known and uniform heat flux on its entire exposed surface.

The novel features that are considered characteristic of the invention are set forth in the appended claims; the invention itself, however, both as to its organization and method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in conjunction with the accompanying drawings, in which:

FIG. 1 is an exploded view of a fire simulation facility embodying the principles of the present invention; and

FIG. 2 is a partially cutaway view of the FIG. 1 fire simulation facility assembled.

Basically, a fully developed fire is a high temperature chemically reacting turbulent gas. The intensity of the fire depends on three prime variables: heat available, fuel supply and oxygen supply. In general, the great majority of nonplanned fires are high in soot concentration and reach temperatures of 1,800° to 2,000° F. in the flame zone. The heat flux felt by surrounding materials is primarily radiative in nature with intensity levels of up to 10-15 B.t.u./ft.²-sec. The character of the radiation will vary with the nature of the fire. In the fully developed fire the character of the radiation is essentially that of a gray gas with effective emittance of 0.8-1.0. Convection plays a secondary but nevertheless important role. It has been determined that under turbulent flow conditions the convective heat transfer to a cold wall area can reach levels of 3-4 B.t.u./ft.²-sec., although it is most often about 1 B.t.u./ft.²-sec.

It has also been determined that the interchange of radiation between two bodies is determined by equation 1:

EQUATION 1

$$q_{NET1-2} = \left[\frac{\epsilon_1 \epsilon_2 F_{2-1}}{1 - \rho_1 \rho_2 F_{2-1}^2} \right] \sigma T_1^4 - \sigma \epsilon_2 T_2^4$$

Where:

q_{NET1-2} = Net energy flux absorbed per unit area by body No. 2 (B.t.u./ft.²-sec.) in the presence of body No. 1 the flux source.

ϵ = Emissivity

σ = Boltzmann Constant

ρ = Reflectivity

F = Geometric View Factor

T = Temperature

Equation 1 shows that in order to properly simulate the net radiant interchange q_{NET} , the fire simulation facility must reproduce exactly T_1 , ϵ_1 and ρ_1 . The foregoing control the temperature and effective emission properties of the radiant flux. In addition, the facility must provide means for uniformly exposing the test sample to a known amount of T_1 . This is covered in Equation 1 by the geometric view factor F .

The fire simulation facility shown in FIGS. 1 and 2 which will be described in detail hereafter provides means for independently adjusting the radiant and convection heat fluxes as well as emissivities of radiating surfaces to provide a controllable and accurate simulation of numerable types of fire environments.

Referring to FIGS. 1 and 2 there is depicted a fire simulation facility 10. The fire simulation facility 10 includes a combustion chamber 11 defined by a 180° enclosure such as a semicylindrical arcuate hood 12 and a flat plate 13. The ends of the combustion chamber are open. Other shapes may be used providing they are substantially closed. In the event an opening is provided, a spatial relationship between the specimen and the opening is needed to obtain a geometric view factor approaching unity; this will be explained below.

The hood 12 includes an inner radiating surface 17 and an exterior surface 18. The hood is made of silicon carbide, a material having emissivity of 0.8-1.0, for those cases where it is desired to simulate a full blown and/or sooty fire having environmental temperatures of 1,800° to 2,000° F.

The hood 12 is electrically heated by means of an electrical resistance element 19 fixed to the exterior surface 18 either by means of a ceramic bond such as Alundum, by mechanical fastening or other suitable means. The electrical resistance element 19, in this case, is fabricated from sheet stock by machining or bending labyrinth paths into the resistance material. The electrical resistance element 19 is coupled through terminals "G-G" to a power supply 21 (not specifically shown). Suggested resistance materials are nickel chromium alloys, such as Nichrome V and Kanthal A-1, platinum, inconel, and 18-8 stainless steel. In cases where the heat source is not to exceed 1,000° F. graphite and

molybdenum may be used. These materials, however, oxidize at temperatures of 1,100° F. and are not suitable for simulating full blown fires.

The intimate contact between the electrical resistance element 19 and the hood exterior surface 18 enhances the heat transfer between these two components. Thermal insulation 22 composed of an inorganic blanket material such as an aluminum silicate sold under the trade name Fiberfrax overlies the electrical resistance element 19. A cover 23 is placed over the insulation 22 mainly for cosmetic purposes.

The flat plate 13 is a sheet of high temperature oxidation resistant material which is preferably, though not necessarily, the same material as the hood 12 material. Therefore, in the case of a full blown fire the plate 13 would be silicon carbide or other oxidation-resistant material with an emissivity of 0.8-1.0. A central opening 24 is defined in the plate 13 as indicated. It is into this opening that the specimen being evaluated is placed.

To approach closely a geometric view factor of one and consequently uniform heating, the ratio of the length of the combustion chamber to the length of the central opening is four, as a minimum.

The combination of hood 12 and electrical resistance heating element 19 makes up the radiation heat source. Note from Equation 1 that the net heat energy absorbed by a test specimen is a function of T_1 , the temperature of the radiating surface, and ϵ , the emissivity of this same surface. T_1 is easily controlled by the power supplied to the electrical resistance element 19. The emissivity is controlled by the material forming the radiating surface. The emissivity of material is a parameter found in handbooks, as is information concerning a materials capability of withstanding a specific temperature.

The fire simulation facility 10 also includes a convection heat source 14 which, in general, is a chemical fuel combustion subassembly. In the embodiment illustrated in FIG. 1 the convection heat source includes a conventional oil burner such as the Carlin Shell Heat Model 400 S2. It is an oil fired system and includes a flame shaper 26 which generates a uniform flow of hot gases over the area defined by the opening 24. Appropriate oil and air metering devices 15 and 16 respectively cooperate with the oil burner to provide controllable gas temperatures and heat fluxes. Dust particles or other additives may be mixed with the oil or air.

The composition of the convective gases can be varied by: (1) burning other fuels such as propane, (2) using oxygen or a mixture of an oxidizer and other gases, and (3) utilizing additives such as dust particles. The purpose clearly is to simulate the correct chemical composition and/or the correct convective heat flux.

The flame shaper 26 attaches to the oil burner and may be fabricated from machinable materials such as lava on stainless steel. The oil and airflow metering devices 15 and 16 are conventional in the industry and are used to set and control the convective gas parameters.

The flame simulation facility 10 also includes a specimen holder 25 for positioning a test specimen in the central opening 24.

The specimen holder 25 includes a metal or ceramic frame 27 fixed to a laboratory jack 28, or in the alternative, a rack and pinion. The jack 28 is modified to allow coupling to a motorized drive 29.

A test specimen 30, in dotted outline, is a frame 27. Generally, its top or exposed surface 31 is to be in the plane of flat plate 13. A position sensor 32 comprising an electromechanical device, such as microswitch and actuator, can control the height of the test specimen 30 in the central opening 24. An alternative method is hand positioning by the operator of the facility.

An insulating cover 35 is inserted through slot 36 to maintain the test specimen at ambient temperature while the heat sources are brought up to temperature. The insulating cover 35 is removed to initiate a test.

It is clear that such parameters as the temperature and pressure of the hot gases or the temperature of radiating surface as well as the placement of a test specimen are all subject to manual control.

However, the fire simulation system 10 includes provision for automatically controlling these parameters.

A central control console 47 is provided. No effort will be made to detail the structure of the console as means for controlling temperature, pressure, oil and air mixtures as well as positioning systems as well within the state of the art.

The central control console 47 includes input terminus A—A through H—H and J—J to receive signals from the several sensors now to be described.

The radiating surface 17 of the hood 11 contains thereon a thermocouple 34 which continuously monitors the temperature of the radiating surface. A total (radiative plus convective) heat flux sensor 38 is inserted in hole 39 in the plate 13. A radiation heat flux sensor 42 is provided in hole 43. Convective heat flux is computed at a central console 47 by arithmetic subtraction. Because of their proximity to the test specimen, this provides an accurate measurement of the total heat flux applied to the exposed surface 31 of a test specimen.

A radiation heat flux sensor 42 is provided in the aperture 43.

The pressure of the hot gases emanating from the convective heat source 20 is measured by a pressure sensor 44 positioned between the sensors 37 and 38. The temperature of the convective gases is measured by an appropriate sensor 46 positioned next to 32.

All of the sensors as well as the resistance heating element 19 and the fuel and air metering devices 15 and 16 are coupled to the central control console 47 through lettered terminals indicated.

The operation of the fire simulation system is quite straight forward. A test specimen 30 is inserted in the central opening 24 with its exposed surface 31 in the plane of the top surface of plate 13. The insulating cover 35 is inserted through slot 36 to cover the surface 31. Power is supplied to the electrical resistance element 19 to bring the radiating surface 17 to temperature. Fuel and air in measured amounts are fed to the convective heat source 14 and the pressure and temperature of the hot gases adjusted. At the desired equilibrium conditions the insulating cover is removed commencing the test.

It is clear that thermocouples may be attached to or inserted into the test specimen to obtain a true temperature history of the test. An optical pyrometer 50 looking through hole 49 is shown in FIG. 1 to measure the temperature of the exposed surface of 31 of the test specimen. The test duration is flexible from seconds to hours.

The various features and advantages of the invention are thought to be clear from the foregoing description. Various other features and advantages not specifically enumerated will undoubtedly occur to those versed in the art, as likewise will many variations and modifications of the preferred embodiment illustrated, all of which may be achieved without departing from the spirit and scope of the invention as defined by the following claims.

We claim:

1. A first simulation facility comprising:

a radiant heat source for directing radiant heat flux to a surface;

a convection heat source for generating a flow of hot gases to said surface; and

means for positioning and maintaining a test specimen on said surface, the heat flux delivered to the test specimen from the convective and radiant heat sources are independently variable and, in addition, the facility includes instrumentation for maintaining the radiant heat source and the convection heat source temperature the same.

2. A fire simulation facility as described in claim 1 which includes, in addition, instrumentation for adjusting and maintaining the test specimen in a predetermined position in said surface.

5

6

3. A first simulation facility as described in claim 1 in which the radiant heat source includes an electric heating means for heating a radiating surface having emissivity of 0.8-1.0 to a temperature of 2,000° F.

4. A fire simulation facility as described in claim 1 in which the convection heat source comprises a chemical fuel combustion means for forming a jet of hot gas.

5. A fire simulation facility as described in claim 1 in which the radiant heat source may be adjusted to a specific temperature and emissivity.

6. A fire simulation facility comprising a combustion chamber including means for positioning a test sample in said chamber, a radiant heat source for applying radiant heat to said test sample, means for generating the flow of hot gases to said test sample, and means for maintaining the radiant heat source and the hot gases at the same temperature.

7. A fire simulation facility as described in claim 6 in which said test sample is defined by a 180° enclosure portion and a plane portion with the radiant heat source in the 180° enclosure portion and the test sample positioned in said plane portion.

8. A fire simulation facility comprising a semicylindrical arcuate hood;

a plane surface covering said hood, the combination of semicylinder and plane surface defining a semicylindrical combustion sample with open ends;

a convection heat source for passing hot gases through one of said ends and across said plane surface;

means for positioning a test sample in said plane surface; and

instrumentation means for maintaining the temperature of

the radiant and convection heat sources the same.

9. A fire simulation facility as described in claim 8 in which the semicylindrical arcuate hood contains a radiant interior surface having an emissivity of 0.8-1.0.

10. A fire simulation facility as described in claim 9 in which said hood is made from silicon carbide.

11. A fire simulation facility as defined in claim 8 in which said radiant heat source is electrical heating means fixed to a silicon carbide hood.

12. A fire simulation facility as defined in claim 8 in which said plane surface includes a central opening.

13. A fire simulation facility as described in claim 12 in which the emissivity of the plane surface matches the emissivity of the hood.

14. A fire simulation facility as defined in claim 8 in which the convection heat source is a chemical fuel combustion means.

15. A fire simulation facility as defined in claim 14 in which said convection heat source includes means for shaping the combustion products for directing said combustion products uniformly over said plane surface.

16. A fire simulation facility as defined in claim 14 in which the convection heat source includes instrumentation having means for controlling the fuel to air ratio for controlling the temperature of the convection heat source.

17. A fire simulation facility as defined in claim 8 which includes, in addition, means for adjusting and maintaining the placement of a test sample in a predetermined relationship in the combustion chamber for controlling the heat flux received by the test sample.

* * * * *

35

40

45

50

55

60

65

70

75

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,647,193 Dated March 7, 1972

Inventor(s) E. Bruce Belason, George K. Castle, Donald P. Crowley,
and Joseph V. Morgida

It is certified that error appears in the above-identified patent
and that said Letters Patent are hereby corrected as shown below:

Column 1, line 36, for "wise", read---wide---; Column 1,
line 66, for "it", read---its---; Column 4, line 11, for "as", read
---are---; and Column 5, line 1, for "first", read---fire---

Signed and sealed this 6th day of March 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents