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(54) PROPANE FUELED FAST COOK-OFF BURNER

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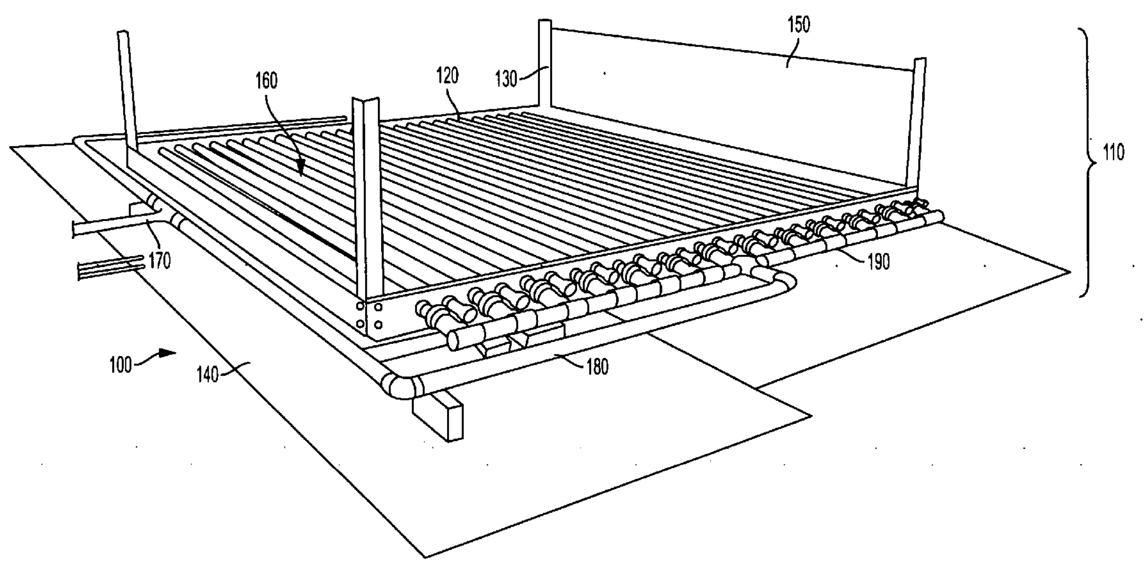
CPC *F23D 14/28* (2013.01); *F23D 14/04* (2013.01)

(57) ABSTRACT

A propane burner assembly is provided for producing a fast cook-off environment. The burner assembly includes a frame, parallel delivery pipes, a pair of manifolds with a corresponding pair of feed lines, a supply line, a fuel reservoir, a valve and an igniter pilot. The frame geometrically defines a platform region with a plurality of corners. The frame includes at least two opposite sides. The delivery pipes are supported by the frame. Each delivery pipe has a plurality of orifices. The manifold pair supplies propane to the delivery pipes. The manifolds are respectively disposed adjacent the two opposite sides. The feed lines transport propane to the manifolds. The fuel reservoir stores the propane. The supply line delivers propane from the fuel reservoir to the feed lines. The valve controls delivery of propane to the feed lines. The igniter pilot initiates combustion. Activating the valve enables propane to eject through the orifices to propagate combustion within the frame.



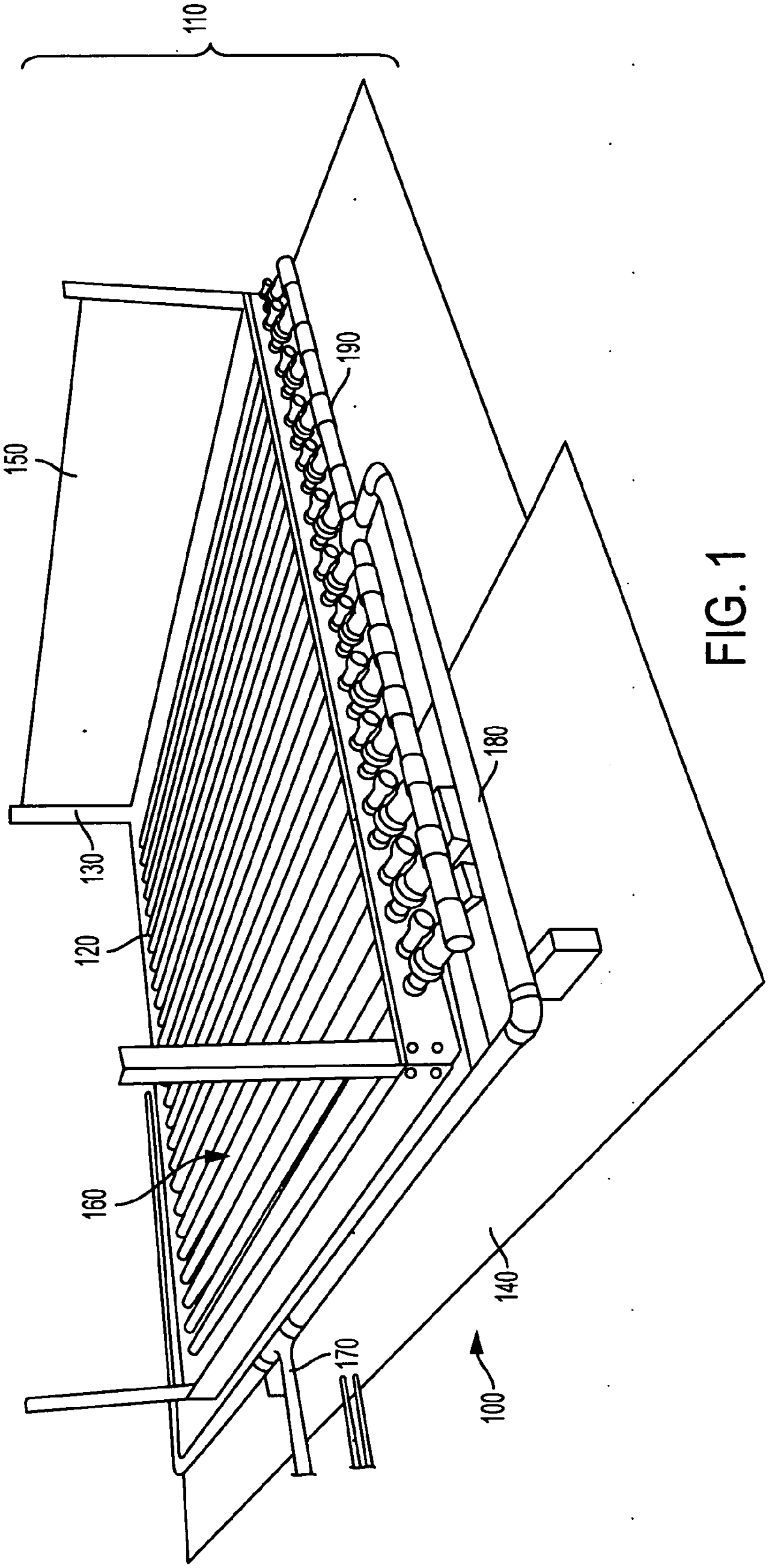


FIG. 1

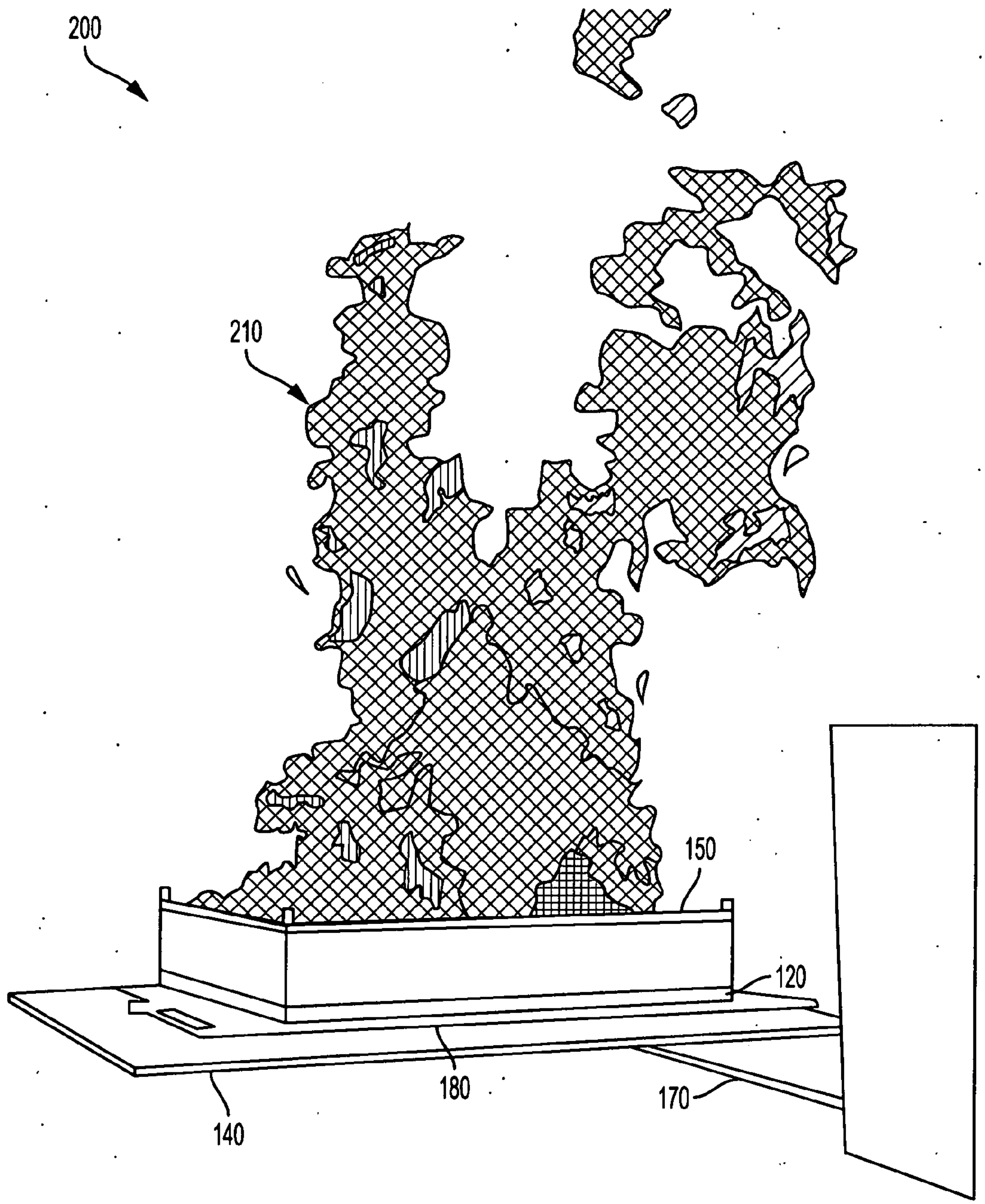


FIG. 2

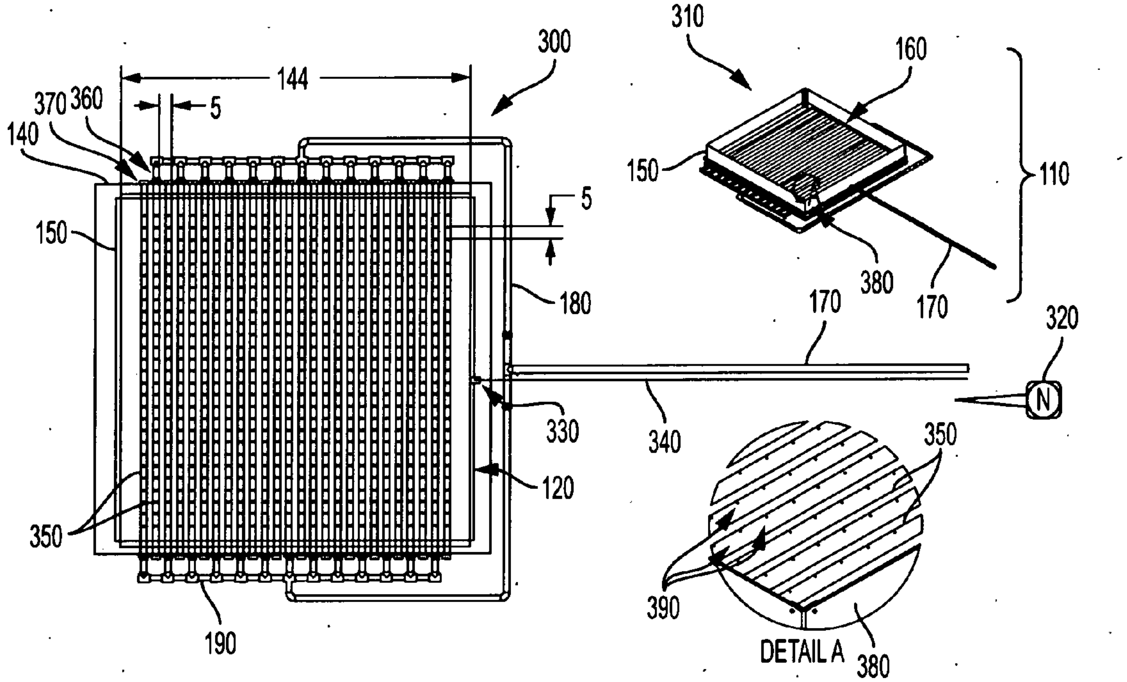

300
144
370
360
5
140
150
5
180
170
330
340
120
350
190
310
160
150
110
380
170
320
N
350
390
DETAIL A
380

FIG. 3

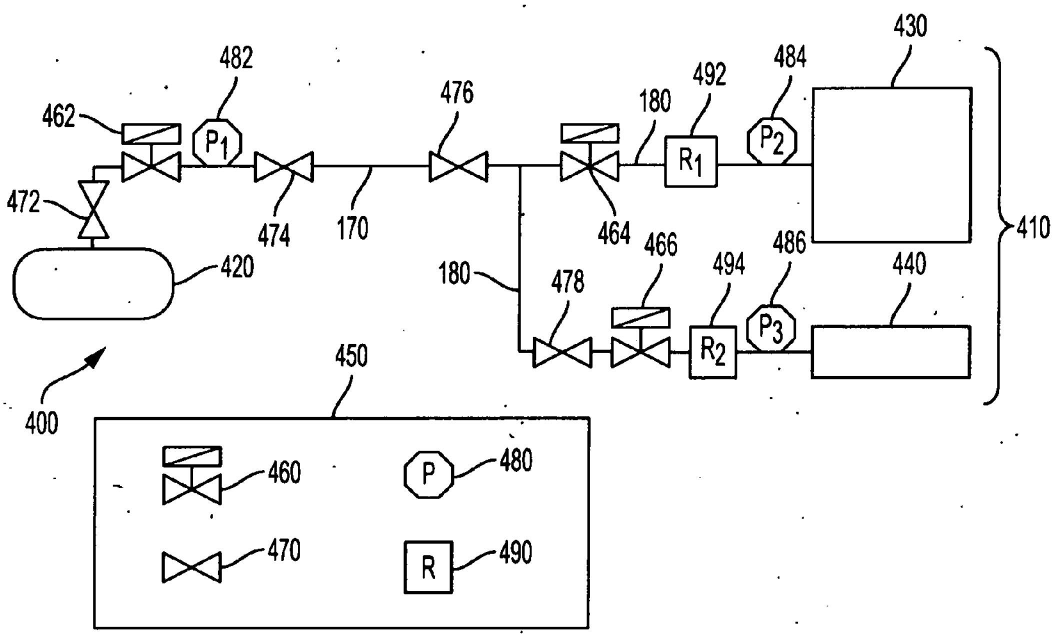

462
482
P_1
476
180
492
R_1
484
P_2
430
472
474
170
464
466
494
486
440
410
420
180
478
R_2
P_3
400
450
460
P
480
470
R
490

FIG. 4

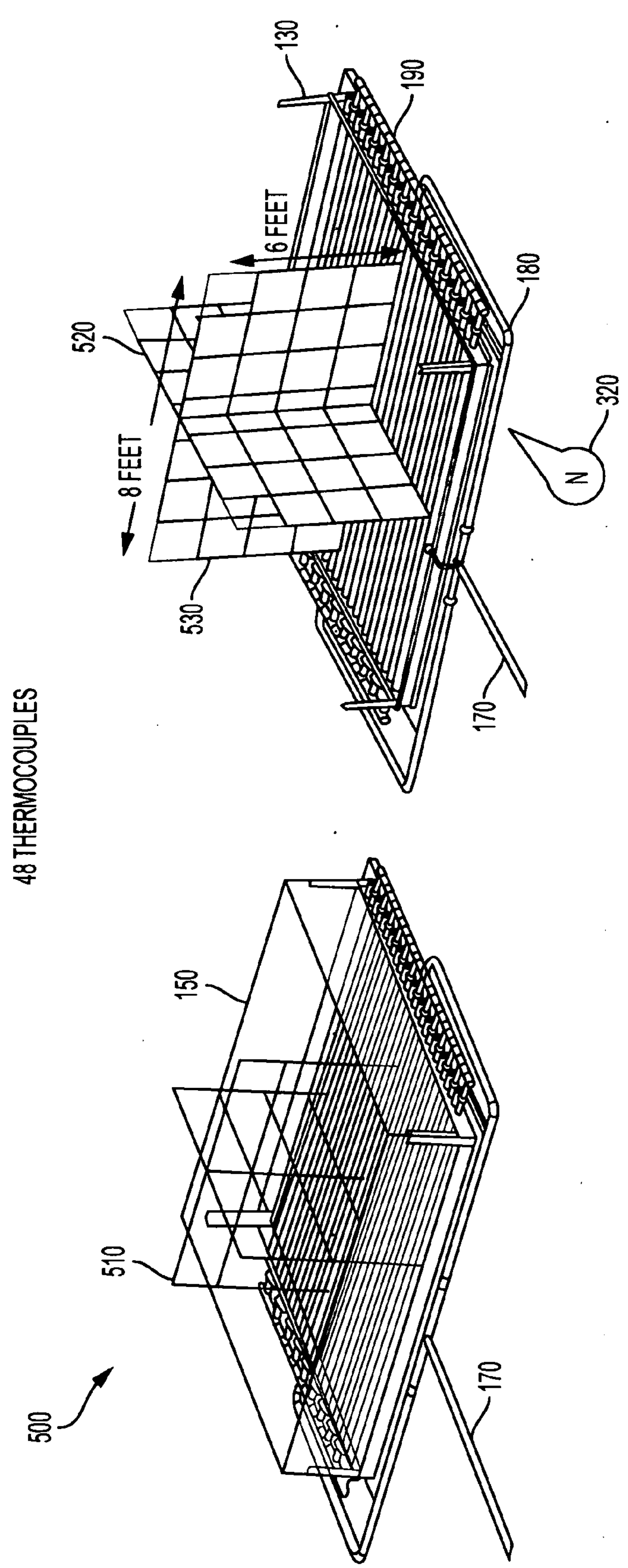

130
190
6 FEET
520
8 FEET
180
320
N
530
170
48 THERMOCOUPLES
150
510
500
170

FIG. 5

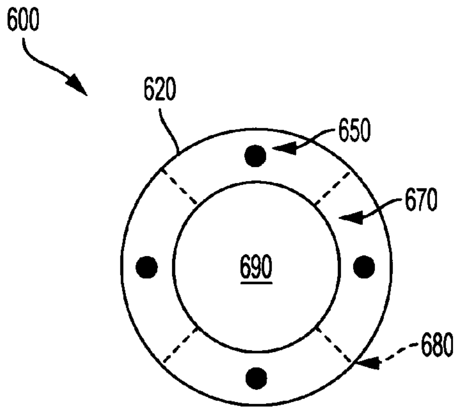


FIG. 6A

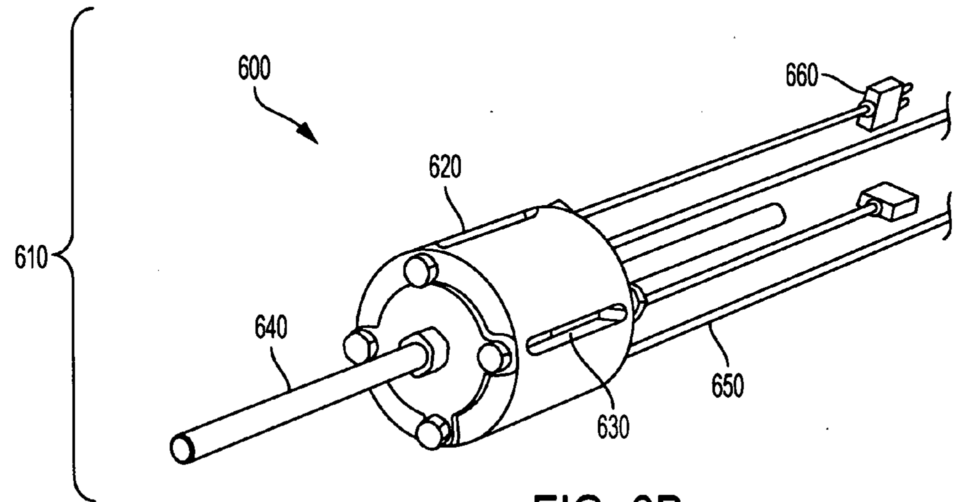


FIG. 6B

700

TABLE 1: PROPERTIES OF THE DSC

710 720

PARAMETER	UNITS
A_S	36.19 cm^2
ε	0.87 (MEASURED USING SURFACE OPTIC'S ET-100 REFLECTOMETER)
σ	5.67e-8 (W/m^2K^4)
m	0.2576 kg
C(T) (T IN KELVINS)	131.08·ln(T)-285.6 (J/kg K) CURVE FIT TO TABLE IN REFERENCE 6

FIG. 7

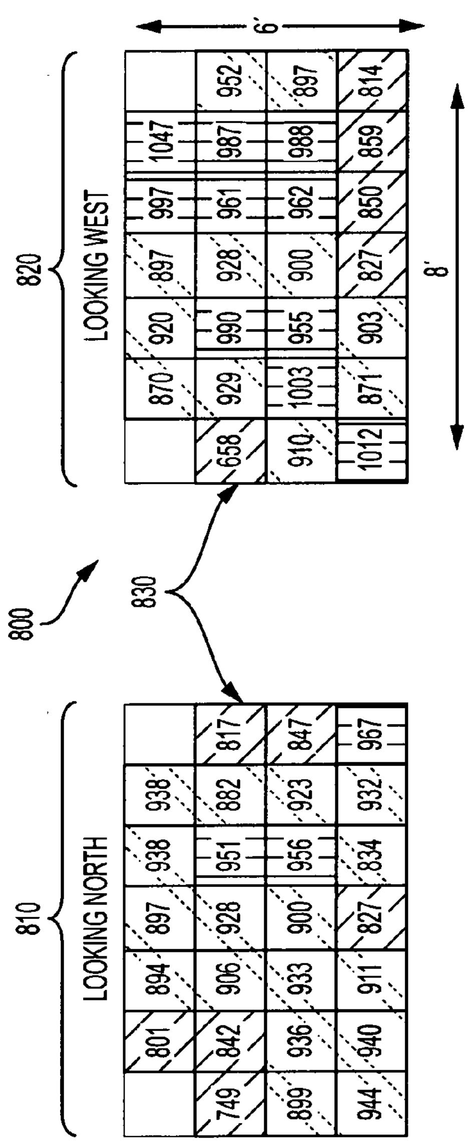

800
830
810
LOOKING NORTH
820
LOOKING WEST
6'
8'
749 801 894 897 938 938
817 882 951 928 906 842
847 923 956 900 933 936 899
967 932 834 827 911 940 944
870 920 897 997 1047
658 929 990 928 961 987 952
910 1003 955 900 962 988 897
1012 871 903 827 850 859 814

FIG. 8

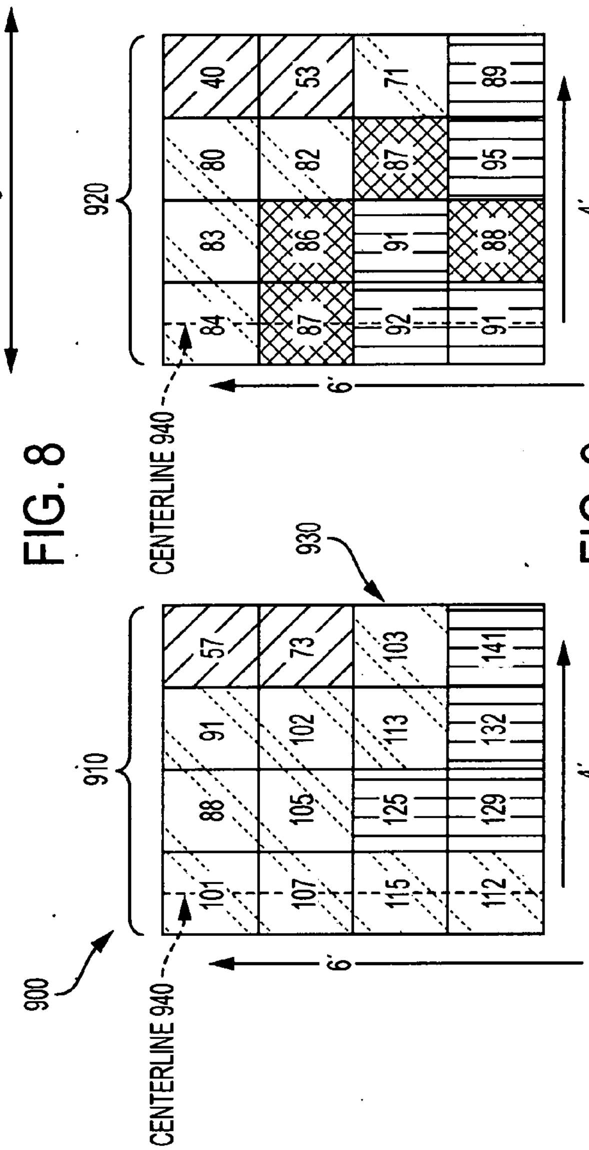

900
910
920
930
CENTERLINE 940
CENTERLINE 940
6'
6'
4'
4'
57 91 88 101
73 102 105 107
103 113 125 115
141 132 129 112
40 80 83 84
53 82 86 87
71 87 91 92
89 95 88 91

FIG. 9

PROPANE FUELED FAST COOK-OFF BURNER

CROSS REFERENCE TO RELATED APPLICATION

[0001] Pursuant to 35 U.S.C. §119, the benefit of priority from provisional application No. 62/194,778, with a filing date of Jul. 20, 2015, is claimed for this non-provisional application.

STATEMENT OF GOVERNMENT INTEREST

[0002] The invention described was made in the performance of official duties by one or more employees of the Department of the Navy, and thus, the invention herein may be manufactured, used or licensed by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND

[0003] The invention relates generally to producing an environmentally compliant fast cook-off test fixture. In particular, the invention relates to a propane burner with feed tubes for subjecting munitions to convective and radiative based fuel fire in thermal reaction testing.

[0004] The Department of the Navy has tested weapons that contain energetic material (e.g., explosives, pyrotechnics, solid propellants, etc.) to combustion environments so as to induce cook-off, such as supplied by a burning kerosene pool. These tests are necessitated in support of programs to reduce thermal vulnerability of munitions. As energetic materials rise in temperature, their chemical bonds decompose or rupture, causing exponential self-initiated thermal generation. This self-heating process can eventually lead to uncontrolled detonation, explosion, deflagration or burning.

SUMMARY

[0005] Conventional cook-off burners yield environmental disadvantages addressed by various exemplary embodiments of the present invention. In particular, exemplary embodiments provide a propane burner for producing fast cook-off environments. The exemplary burner includes The burner assembly includes a frame, parallel delivery pipes, a pair of manifolds with a corresponding pair of feed lines, a supply line, a fuel reservoir, a valve and an igniter pilot. The frame geometrically defines a platform region with a plurality of corners. The frame includes at least two opposite sides. The delivery pipes are supported by the frame. Each delivery pipe has a plurality of orifices. The manifold pair supplies propane to the delivery pipes. The manifolds are respectively disposed adjacent the two opposite sides.

[0006] In exemplary embodiments, the feed lines transport propane to the manifolds. The fuel reservoir stores the propane. The supply line delivers propane from the fuel reservoir to the feed lines. The valve controls delivery of propane to the feed lines. The igniter pilot initiates combustion. Activating the valve enables propane to eject through the orifices to propagate combustion within the frame. Other various embodiments additionally provide for thermocouples and directional slug calorimeter as instrumentation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and various other features and aspects of various exemplary embodiments will be readily understood with reference to the following detailed description taken in conjunction with the accompanying drawings, in which like or similar numbers are used throughout, and in which:

[0008] FIG. **1** is a perspective view of an exemplary burner configuration;

[0009] FIG. **2** is a perspective view of the burner in combustion operation;

[0010] FIG. **3** is a plan view of the exemplary burner configuration;

[0011] FIG. **4** is a schematic view of fuel control for the exemplary burner;

[0012] FIG. **5** is a perspective view of instrumentation arrangement for the exemplary burner;

[0013] FIG. **6**A is an elevation cross-section view of a directional slug calorimeter (DSC);

[0014] FIG. **6**B is a perspective view of the DSC;

[0015] FIG. **7** is a tabular view of quantitative characteristics for the DSC;

[0016] FIG. **8** is a diagram view of a temperature measurement array; and

[0017] FIG. **9** is a diagram view of a heat flux quantity array.

DETAILED DESCRIPTION

[0018] In the following detailed description of exemplary embodiments of the invention, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific exemplary embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized, and logical, mechanical, and other changes may be made without departing from the spirit or scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims.

[0019] Exemplary embodiments of a propane fast cook-off burner provide advantages over conventional pool fire burners, including reduced environmental pollution, cleaner and less expensive fuel, and improved safety from ignition control. Additional advantages include reductions in fuel consumption, post-test soot residue, post-test hazardous waste (from unburned jet fuel and combustive reaction residue) over conventional configurations.

[0020] FIG. **1** shows a perspective view **100** of an exemplary propane burner assembly **110**. A square horizontal frame **120** supports vertical posts **130** and is disposed on a ground base **140**. Panel shield walls **150** are disposed between the posts **130** to confine flames along the sides of a burner platform **160** for cook-off testing within the frame **120**. A fuel feed-line **170** forks into supply lines **180** that enter manifolds **190**. These lines **170**, **180** and **190** transport fuel for burning on the platform **160**.

[0021] FIG. **2** shows a perspective view **200** of the burner assembly **110** in combustion operation exhibiting a fire plume **210**. The burner assembly **110** is shown with the panels **150** obscuring the platform **160** from which the plume **210** originates. Due to the fuel-rich conditions, the flames from the exemplary burner **110** originate above the platform **160** to provide soot within the flames (rather than in the plume). The soot facilitates uniform radiation heating of a target munition for fast cook-off testing, rather than bottom heating as typical in conventional stoichiometric combustion.

[0022] FIG. **3** shows a plan view **300** of the exemplary burner assembly **110**. An insert view **310** shows a perspective view of the assembly **110**. A compass rose **320** shows the exemplary direction of north. The fuel feed-line **170** supplies fuel from a source from south of the frame **120** and divides at a T-joint into the supply lines **180** east (up) and west (down) in the view **300**. The supply lines **180** feed the manifolds **190** that flank the frame **120**. An ignition torch **330** on the frame **120** and controlled via a cable **340** initiates combustion of fuel ejected from parallel delivery pipes **350** supplied through the manifolds **190**. In the exemplary configuration, the frame **120** is twelve feet on each side, and separation between delivery pipes **350** is five inches. These exemplary dimensions are illustrative of a tested design, and are not limiting. Other propane burner configurations with alternate dimensions (for a variety of FCO test articles) can be considered for such purposes without departing from the scope of the claims. Alternate hydrocarbon fuels besides propane that are in gaseous phase at standard temperature and pressure can also be contemplated.

[0023] The manifolds **190** connect to interleaving pipes **350** by unions **360**, with adjacent pipes **350** sealed by caps **370**. The insert view **310** includes a corner detail **380**, which in its enlarged portion shows a portion of the delivery pipes **350** and the orifices **390** arranged therealong at spacing intervals of five inches. After cook-off of a tested munition, damaged pipes **350** can be disconnected from the manifold **190** at their corresponding unions **360** and replaced.

[0024] FIG. **4** shows a schematic view **400** of an exemplary fuel control configuration **410**. A fuel tank **420** supplies fuel for the feed-line **170**. A burner **430** and pilot **440** provide combustion initiators. A legend **450** identifies instrumentation and control devices. Remote solenoid valves **460** include the tank exit **462**, burner entrance **464** and pilot entrance **466**. Manual valves **470** include the first valve **472** at the tank exit, second valve **474**, third valve **476** before the fork, and fourth valve **478** leading to the pilot **440**. Pressure transducers **480** include positions at the tank exit **482**, burner entrance **484** and pilot entrance **486**. Regulators **490** include the burner entrance **492** and the pilot entrance **494**.

[0025] FIG. **5** shows perspective views **500** of thermal instrumentation arrays for the exemplary burner assembly **110**. An upright frame **510** contains the instrumentation shown as a north-south array **520** and an east-west array **530**. The arrays **520** and **530** are about eight feet across and six feet high. The instrumentation arrays were employed for evaluating performance of the burner assembly **110**, but are not used for cook-off tests with munitions.

[0026] FIGS. **6**A and **6**B show detail views **600** of a directional slug calorimeter (DSC) assembly **610**. FIG. **6**B shows an isometric view, including a tubular housing **620** with longitudinal grooves **630**, while FIG. **6**A shows a cross-section elevation view of that housing **620**, which is subdivided into four symmetric quadrants. The assembly further includes a support tube **640**, a thermocouple **650**, and connectors **660**. The housing **620** is divided into four quadrants **670**, separated by isolation cut interfaces **680**. The thermocouple **650** is disposed in each groove **630** and internal insulation **690**. The DSC **610** is described in greater detail in application Ser. No. 14/293,078, published as publication 2015/0346042, being incorporated by reference in its entirety.

[0027] FIG. **7** shows a tabular view **700** of parameters for properties of the DSC **610**. The Table includes a left column **710** with Parameters and a right column **720** with exemplary values and their associated units. The parameters include surface area, emissivity, Stefan-Boltzmann constant, mass and curve-fit coefficient.

[0028] FIG. **8** shows an elevation view **800** of the thermocouple measurements array. The left array **810** shows the temperature values from instrumentation **530** looking to the north. The right array **820** shows the temperature values from instrumentation **520** looking to the west. Temperatures are shown in degrees Celsius (° C.). Both arrays **810** and **820** provide orthogonal planes discretized into grids.

[0029] FIG. **9** shows an elevation view **900** of the heat flux values array on a first side **910** and a second side **920** of the burner. Individual values **930** in particular cells show heat flux in kilowatts-per-square-meter derived from calorimetry measurements from view **800**. These values range from 40 kW/m^2 at the extremities to 115 kW/m^2 along the centerline. The sides are arranged along and adjacent to a centerline **940**.

[0030] Fast cook-off testing using liquid hydrocarbon fuel pits has been a standard test method for insensitive munition classification. Recently, environmental concerns over the pollution caused by these tests have pushed many nations to examine candidates for a cleaner alternative. This disclosure describes efforts within the Department of the Navy to develop and characterize an exemplary propane fueled burner assembly **110** that produces thermal stimuli similar to that produced by a liquid hydrocarbon pool fire. The burner transports liquid propane from a fuel tank **420** into a number of delivery pipes **350** within the hearth of the test area platform **160**.

[0031] Once ignited, radiative feedback from the fire plume **210** vaporizes the liquid propane within the tubes to produce propane gas that exits the delivery pipes **350** and combusts within the burner platform **160**. The resulting fire (as exhibited by plume **210**) is very fuel rich in the test region (bounded by the panels **150**) with sufficient soot to produce the thermal radiation levels seen in typical liquid hydrocarbon fueled combustion.

[0032] To verify the thermal characteristics of the propane fire in the exemplary burner **110**, both temperature and heat flux measurements were collected, with examples respectively shown in views **800** and **900**. Testing demonstrates that the propane burner produced temperatures that were comparable to those produced by a liquid hydrocarbon fueled fire and satisfied the temperature requirements of STANAG 4240. Additionally, and perhaps more importantly, total heat flux measurements were also similar between the two fires. Both temperature and heat flux measurements showed that the heating was also uniform within the burner **110**. The totality of these results indicates that the exemplary propane burner **110** produced by the Navy Department is an acceptable alternative to liquid hydrocarbon pool fires for fast cook-off testing.

[0033] Fast cook-off (FCO) testing is a standard insensitive munitions test that is used to determine how munitions react when subjected to rapid heating. These tests are used to simulate real-world scenarios such as carrier deck fires or transportation accidents where ordinance items have the potential to be exposed to a fire. Traditionally, these tests have been performed by positioning the item over large pools of liquid hydrocarbon fuels such as kerosene or jet fuel. During the test, the fuel is ignited and the item is completely engulfed in the flame. The response of the item to this fire exposure is then measured. This response can range from a severe detonation (type I) to more mild reactions such as burning (type V) or no reaction whatsoever (type VI). The goal of weapon development is to produce ordnance items that have the mildest possible reaction during FCO testing in order to mitigate hazards aboard combat vessels of ordnance on board. These conditions exhibited their deadly effect in the devastating fire and explosions that killed 134 sailors aboard the U.S.S. Forrestal in July 1967.

[0034] The fuel-fire test is required by both the Department of Defense Explosive Safety Board (DDESB) and the Insensitive Munitions (IM) office in the United States. The fuel-fire test is specified as the liquid fuel, external fire test as described in TB 700-2 for hazards classification relative to transportation and storage while operational scenarios are covered in MIL-STD-2105D. These tests are performed at a system level in accordance to STANAG 4240, "Liquid Fuel/External Fire, Munition Test Procedures" (2003) issued by NATO.

[0035] In recent years however, environmental pressure has forced nations to re-examine how they perform FCO testing. The large black clouds of soot produced by these tests attract unwanted attention from communities surrounding test sites. Additionally, the large open pools of fuel create the opportunity for spills leading to ground contamination. These environmental concerns prompted a debate on whether a cleaner alternative could be used for FCO testing.

1. A propane burner assembly for producing a fast cook-off testing environment, said burner assembly comprising:

a frame that geometrically defines a platform region with a plurality of corners, said frame having first and second sides opposite each other;

a parallel plurality of delivery pipes supported by said frame, each delivery pipe having a plurality of orifices;

first and second manifolds to supply propane to said delivery pipes, said manifolds being respectively disposed adjacent said first and second sides;

first and second feed lines to transport said propane to said manifolds;

a fuel reservoir for storing said propane;

a supply line for delivering said propane from said fuel reservoir to said feed lines;

a valve for controlling delivery of said propane to said feed lines; and

an igniter pilot for initiating combustion, wherein activating said valve enables said propane to eject through said orifices to propagate said combustion within said frame;

2. The burner assembly according to claim **1**, wherein said frame further includes a post at each corner of said plurality of corners, with a panel disposed between each pair of posts.

3. The burner assembly according to claim **1**, wherein same valve is a solenoid valve.

4. The burner assembly according to claim **1**, wherein said manifolds supply said propane to alternating delivery pipes.

5. The burner assembly according to claim **1**, further including an instrumentation structure for disposing a plurality of thermal measurement instruments, each instrument being arranged in a grid.

6. The burner assembly according to claim **5**, wherein said instrument is a thermocouple.

7. The burner assembly according to claim **5**, wherein said instrument is a directional slug calorimeter.

8. The burner assembly according to claim **1**, where in said platform region is rectangular.

9. The burner assembly according to claim **4**, wherein said adjacent delivery pipes are antiparallel.

10. The burner assembly according to claim **1**, wherein said fuel reservoir stores a fuel mixture of propane and at least one of methane, ethane and butane.

* * * * *