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(54) Title of the invention : A NOVEL TEST STAND AND METHOD TO MEASURE THE BURNING RATE OF FLAMMABLE LIQUIDS

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Filing Date :NA

(71)**Name of Applicant :**
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2)ANKIT SHARMA

(57) Abstract :
The present invention provides a system and method for measuring the burning rates of flammable liquids. A new test system and method for measuring the maximum burning rates of flammable liquids. The correct measurement of burning rate with proposed new test set-up ensures that all the realistic boundary conditions are imposed to measure the maximum burning rates that could occur in a real sized tanks storing flammable liquids. Such precise measurement of burning rate will help to develop proper safety distances from the fires to the people and infrastructure thereby saving the losses of all kinds.

No. of Pages : 12 No. of Claims : 7

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GOVERNMENT OF INDIA

Controller General of Patents,Designs and Trademarks
Department of Industrial Policy and Promotion
Ministry of Commerce and Industry

Application Details	
APPLICATION NUMBER	201811016328
APPLICATION TYPE	ORDINARY APPLICATION
DATE OF FILING	01/05/2018
APPLICANT NAME	INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE
TITLE OF INVENTION	"A NOVEL TEST STAND AND METHOD TO MEASURE THE BURNING RATE OF FLAMMABLE LIQUIDS"
FIELD OF INVENTION	PHYSICS
E-MAIL (As Per Record)	
ADDITIONAL-EMAIL (As Per Record)	iprcell.iitroorkee@gmail.com
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PRIORITY DATE	NA
REQUEST FOR EXAMINATION DATE	--
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Application Status	
APPLICATION STATUS	**Application Published**

View Documents

512557

FORM 5
THE PATENT ACT, 1970
(39 OF 1970)
&
The Patents Rules, 2003
DECLARATION AS TO INVENTORSHIP
[See section 10(6) and rule 13(6)]

1. NAME OF APPLICANT (S)	**Indian Institute of Technology, Roorkee**

hereby declare that the true and first inventor(s) of the invention disclosed in the complete specification filed in pursuance of our application title "**A Novel Test Stand and Method to Measure the Burning Rate of Flammable Liquids**" is/are

2. INVENTOR (S)

Name	Nationality	Address	Signature
Kirti Bhushan Mishra	Indian	Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand–247667, India.	
Ankit Sharma	Indian	Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand–247667, India.	Ankit Sharma

3. DECLARATION TO BE GIVEN WHEN THE APPLICATION IN INDIA IS FILED BY THE APPLICANT (S) IN THE CONVENTION COUNTRY:-

Dated this day of 2018

For **Indian Institute of Technology, Roorkee**
Dean
Sponsored Research & Industrial Consultancy
Indian Institute of Technology Roorkee
Rookree-247667 (INDIA)

Signature :-

To,
The Controller of Patent
The Patent Office, at Delhi

512556

FORM 3
THE PATENT ACT, 1970
(39 OF 1970)
&
The Patents Rules, 2003
STATEMENT AND UNDERTAKING UNDER SECTION 8
(See section 8, rule 12)

We **Indian Institute of Technology, Roorkee** having address, IIT-R, Roorkee, Uttarakhand – 247667, India, hereby declare

(i) that /We who have made this application **"A Novel Test Stand and Method to Measure the Burning Rate of Flammable Liquids"**, made for the same/substantially same invention, application(s) for patent in the other countries, the particulars of which are given below :

Name of the country	Date of Application	Application No.	Status of the application	Date of publication	Date of grant
Not Applicable					

(iii) that the rights in the application(s) have been assigned to us and that We undertake that upto the date of grant of the patent, by the Controller. We would keep him informed in writing the details regarding corresponding applications for patents filed outside India within three months from the date of filing of such application.

Dated this th day of 2018

✓
Indian Institute of Technology, Roorkee
Dean
Sponsored Research & Industrial Consultancy
Indian Institute of Technology Roorkee
Rookree-247667 (INDIA)

To,
The Controller of Patent
The Patent Office, Delhi

512555

COMPLETE SPECIFICATION

Page - 18
Claim - 07

"**FORM 1** THE PATENTS ACT 1970 (39 of 1970) and THE PATENTS RULES, 2003 **APPLICATION FOR GRANT OF PATENT** (See section 7, 54 and 135 and sub-rule (1) of rule 20)	(FOR OFFICE USE ONLY) Application No. Filing date: Amount of Fee paid: CBR No: Signature: Govt. of India, Patent Office, New Delhi Received Rs. 8000/- in Cash/ CHEQUE/ DD ON 01 MAY 2018 Vide Entry No. 1115 in the Register of Valuables Cashier DDO
1. APPLICANT'S REFERENCE / IDENTIFICATION NO. (AS ALLOTTED BY OFFICE)	201811016328

2. TYPE OF APPLICATION *Please tick (√) at the appropriate category+

Ordinary (√)		Convention ( )		PCT-NP ( )	
Divisional ( )	Patent of Addition ( )	Divisional ( )	Patent of Addition ( )	Divisional ( )	Patent of Addition ( )

3A. APPLICANT(S)

Name in Full	Nationality	Country of Residence	Address of the Applicant	
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			Street	
			City	Roorkee
			State	Uttarakhand
			Country	India
			Pin code	247667,

3B. CATEGORY OF APPLICANT [Please tick (√) at the appropriate category]

Natural Person ( )	Other than Natural Person		
	Small Entity ( )	Startup ( )	Others ()

4. INVENTOR(S) [Please tick (√) at the appropriate category]

Are all the inventor(s) same as the applicant(s) named above?	Yes ( )	No (√)

If "No", furnish the details of the inventor(s)

Kirti Bhushan Mishra	Nationality	Country of Residence	Address of the Inventor	
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			City	Roorkee
			State	Uttarakhand
			Country	India
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Ankit Sharma	Nationality	Country of Residence	Address of the Inventor	
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				Indian Institute of Technology Roorkee
			City	Roorkee
			State	Uttarakhand
			Country	India
			Pin code	247667,

5. TITLE OF THE INVENTION

"A Novel Test Stand and Method to Measure the Burning Rate of Flammable Liquids"

6. AUTHORISED REGISTERED PATENT AGENT(S)	IN/PA No.	N/A
	Name	N/A
	Mobile No.	N/A
7. ADDRESS FOR SERVICE OF APPLICANT IN INDIA	Name	
	Postal Address	**Indian Institute of Technology Roorkee**, Roorkee-247667, Uttarakhand
	Telephone No.	
	Mobile No.	
	Fax No.	-
	E-mail ID	Iprcell.iitroorkee@gmail.com ipr-cell@iitr.ac.in

8. IN CASE OF APPLICATION CLAIMING PRIORITY OF APPLICATION FILED IN CONVENTION COUNTRY, PARTICULARS OF CONVENTION APPLICATION

Country	Application Number	Filing date	Name of the applicant	Title of the invention	IPC (as classified in the convention country)
NA	NA	NA	NA	NA	NA

9. IN CASE OF PCT NATIONAL PHASE APPLICATION, PARTICULARS OF INTERNATIONAL APPLICATION FILED UNDER PATENT CO-OPERATION TREATY (PCT)

International application number	International filing date
NA	NA

10. IN CASE OF DIVISIONAL APPLICATION FILED UNDER SECTION 16, PARTICULARS OF ORIGINAL (FIRST) APPLICATION

Original (first) application No.	Date of filing of original (first) application
NA	NA

11. IN CASE OF PATENT OF ADDITION FILED UNDER SECTION 54, PARTICULARS OF MAIN APPLICATION OR PATENT

Main application/patent No. NA	Date of filing of main application

12. DECLARATIONS

(i) Declaration by the inventor(s)

(In case the applicant is an assignee: the inventor(s) may sign herein below or the applicant may upload the assignment or enclose the assignment with this application for patent or send the assignment by post/electronic transmission duly authenticated within the prescribed period).

I/We, the above named inventor(s) is/are the true & first inventor(s) for this Invention and

declare that the applicant(s) herein is/are my/our assignee or legal representative.

S. No.	Name	Signature	Date
1.	KIRTI BHUSHAN MISHRA		3|4|18
2.	ANKIT SHARMA	Ankit Sharma	03|04|2018

(ii) Declaration by the applicant(s) in the convention country

(In case the applicant in India is different than the applicant in the convention country: the applicant in the convention country may sign herein below or applicant in India may upload the assignment from the applicant in the convention country or enclose the said assignment with this application for patent or send the assignment by post/electronic transmission duly authenticated within the prescribed period)

I/We, the applicant(s) in the convention country declare that the applicant(s) herein is/are my/our assignee or legal representative.

(a) Date

(b) Signature(s)

(c) Name(s) of the signatory:

Dean
Sponsored Research & Industrial Consultancy
Indian Institute of Technology Roorkee
Roorkee-247667 (INDIA)

Indian Institute of Technology, Roorkee

(iii) Declaration by the applicant(s)

I/We the applicant(s) hereby declare(s) that: -

(√) I am/ We are in possession of the above-mentioned invention.

(√) The ~~provisional/~~complete specification relating to the invention is filed with this application.

(×) ~~The invention as disclosed in the specification uses the biological material from India and the necessary permission from the competent authority shall be submitted by me/us before the grant of patent to me/us.~~

(√) There is no lawful ground of objection(s) to the grant of the Patent to me/us.

(√) I am/we are the true & first inventor(s).

(√) I am/we are the assignee or legal representative of true & first inventor(s).

(√) The application or each of the applications, particulars of which are given in Paragraph-8, was the first application in convention country/countries in respect of my/our invention(s).

(×) ~~I/We claim the priority from the above mentioned application(s) filed in convention country/countries and state that no application for protection in respect of the invention had been made in a convention country before that date by me/us or by any person from which I/We derive the title.~~

(×)~~My/our application in India is based on international application under Patent Cooperation Treaty (PCT) as mentioned in Paragraph 9.~~

(×)~~The application is divided out of my /our application particulars of which is given in Paragraph 10 and pray that this application may be treated as deemed to have been filed on DD/MM/YYYY under section 16 of the Act.~~

(×) ~~The said invention is an improvement in or modification of the invention particulars of which are given in Paragraph 11.~~

13. FOLLOWING ARE THE ATTACHMENTS WITH THE APPLICATION

(a) Form 2

Item	Details	Fee	Remarks
Complete specification)#	No. of pages:	8800	For 12 pages and 07 claims

No. of Claim(s)	No. of claims: No. of pages.:	07 02	Claims 07 Pages 02
Abstract	No. of pages.:	01	01
No. of Drawing(s)	No. of drawings: No. of pages	05 03	Figure 05 Pages 03

In case of a complete specification, if the applicant desires to adopt the drawings filed with his provisional specification as the drawings or part of the drawings for the complete specification under rule 13(4), the number of such pages filed with the provisional specification are required to be mentioned here.

(b) Complete specification (in conformation with the international application)/as amended before the International Preliminary Examination Authority (IPEA), as applicable (2 copies).
~~(c) Sequence listing in electronic form~~
(d) Drawings (in conformation with the international application)/as amended before the International Preliminary Examination Authority (IPEA), as applicable (2 copies).
~~(e) Priority document(s) or a request to retrieve the priority document(s) from DAS (Digital Access Service) if the applicant had already requested the office of first filing to make the priority document(s) available to DAS.~~
~~(f) Translation of priority document/Specification/International Search Report/International Preliminary Report on Patentability.~~
(g) Statement and Undertaking on Form 3
(h) Declaration of Inventorship on Form 5
(i) ~~Power of Authority~~
(j).....

Total fee ☐...8800.in ~~Cash~~/ ~~Banker's Cheque~~ /Bank Draft bearing No.21240**Date**17.04.18**.on PNB..... Bank.**

I/We hereby declare that to the best of my/our knowledge, information and belief the fact and matters slated herein are correct and I/We request that a patent may be granted to me/us for the said invention.

Dated this rd day of , 2018

✓ Dean
Sponsored Research & Industrial Consultancy
Indian Institute of Technology Roorkee
Roorkee-247667 (INDIA)

Authorized Signature
Indian Institute of Technology, Roorkee

To,
The Controller of Patents
The Patent Office, at Delhi

Note: -
* Repeat boxes in case of more than one entry.
* To be signed by the applicant(s) or by authorized registered patent agent otherwise where mentioned.

* Tick (√)/cross (x) whichever is applicable/not applicable in declaration in paragraph-12.
* Name of the inventor and applicant should be given in full, family name in the beginning.
* Strike out the portion which is/are not applicable.
* For fee: See First Schedule";

~~COMPLETE~~ ~~SPECIFICATION~~
COMPLETE AFTER PROVISIONAL APPLICATION

App. No. 201811016328 dt 01/05/2018

Page 14
Claim 7

FORM-02

The Patent Act 1970

Complete Specification

Section 10

39260
E-2/828/2018-Del
11/05/18

TITLE

"A Novel Test Stand and Method to Measure the Burning Rate of Flammable Liquids"

APPLICANT

"INDIAN INSTITUTE OF TECHNOLOGY ROORKEE, Roorkee-247667, Uttarakhand"

The following specification describes the invention

FIELD OF INVENTION:

The present invention relates to the system and method for measuring the burning rates of flammable liquids. The present invention in particular relates to a test-stand for correct measurement of burning rate of flammable liquids.

DESCRIPTION OF THE RELATED ART:

In the prior art, the burning rates of flammable liquids e.g. petrol, diesel, crude oil, ethanol, biodiesel and peroxides were measured for a particular diameter (d) with a fixed amount of fuel inside the pan. The diameters (d) of such pans range from 1 cm to 25 m [1-5]. It was found for all the fuels that the burning rate becomes independent of the diameter for d > 1 m. Most of these experiments were performed for fixed mass of fuel kept in a tank or a pan. The fuel was allowed to burn under ambient conditions (1 bar and 293 K) till it was fully consumed. An example of the standard test-set-up for the measurement of burning rate has been shown below in Fig. 1. It was also established that the variation in wind speed also influence the burning rates. A number of data-sets are used to develop correlations for burning rates for different diameters and fuels. The developed correlations are included in several frequently used quantitative and qualitative risk assessment programs (PHAST, SAFETI, TNO Risk Curves) for process and plant safety which are widely used in industries [6-8].

Reference may be made to the following:

US Patent No. **6,464,391** provides a calorimeter that measures heat release rates of very small samples (on the order of one to 10 milligrams) without the need to separately and simultaneously measure the mass loss rate of the sample and the heat of combustion of the fuel gases produced during the fuel generation process. The sample is thermally decomposed in a small volume pyrolysis chamber. The resulting fuel gases are immediately swept by an inert gas stream from the pyrolysis chamber into a combustion furnace in a plug-like flow. This plug flow substantially synchronizes the emerging fuel gases with the mass loss rate of the sample. Oxygen is metered into the fuel gas stream just before it enters the combustion furnace where the fuel gases are completely oxidized. The effluent from the furnace is analyzed to determine the amount of oxygen consumed per

unit time and the heat release rate is computed without the need to separately measure the mass loss rate of the sample.

US Patent No. **5,869,343** provides a method and an apparatus for the automated testing of the flash point and can be used for determining the flash point of flammable liquids. In particular, the inventive method makes is possible to automate the phase of preparing and changing the samples. The apparatus described is characterized in that the whole of the test equipment (1) consists of a stationary simultaneous function head (2) and a mobile test insert (3), which can be separated completely from the simultaneous function head (2), the test insert (3), pre-installed, having the temperature sensor (4) and the flash point indicator (5) and contacting elements (6) for producing the electrical connection to the temperature sensor (4) and to the flash point indicator (5) and at least one coupling element (10) for producing the mechanical connection between a stirrer driving mechanism (7) and the stirrer (8) being disposed at the simultaneous function head (2). The arrangement of an additional flash point indicator (5a) outside of the test insert (3) is possible.

US Patent No. **US1779569** provides automatically regulating the proportions of air or oxygen and flammable gases in a chamber in such manner as to avoid with certainty the production of explosive mixtures therein.

US Patent No. **US2499105** provide apparatus for deter (cias-11) mining the initial boiling points of liquids and has particular reference to an' apparatus for accurately measuring the initial boiling' point of a desired low boiling point fraction of a mixture of liquids such as a mixture of hydrocarbons.

US Patent No. **5,981,290** provides a calorimeter for measuring flammability parameters of materials using only milligram sample quantities. The thermo chemical and thermo physical processes associated with the flaming combustion of solids are reproduced in the device through rapid anaerobic pyrolysis in a thermo gravimetric analyzer. Volatile anaerobic thermal decomposition products are swept from the pyrolysis chamber by an inert gas and combined with excess oxygen in a combustion chamber maintained at several hundred degrees Centigrade to simulate the combustion reactions which occur in a well ventilated diffusion flame. Mass loss is measured continuously during the process and heat release rate is calculated from the oxygen consumed from the gas stream.

US Patent No. **6,991,365**provides a flammability test apparatus comprises a chamber, an inlet, an ignition source, a heater, pressure and temperature sensors. In one embodiment, the chamber includes a horizontally-oriented, cylindrically-shaped section. The inlet allows a fluid to be introduced into the chamber. The ignition source ignites the fluid within the chamber, and the heater adjusts the temperature of the fluid within the chamber. The test apparatus includes a sparger for dispersing the fluid within the chamber, and the sparger disposed within the chamber and attached to the inlet. The test apparatus also includes a relief system for exhausting the chamber after the pressure of the fluid in the chamber exceeds a preset pressure.

Publication No. **WO2007001384** relates to a flammability tester for samples in the milligram range. A tube (40) with a lower pyrolyzing region, or pyrolyzer (42), contains a sample (10) that is heated to thermally degrade in the absence of oxygen, or pyrolyzed, to produce fuel gases. An inert gas carries the fuel gases to an upper combustion region, or combustor (46) , where oxygen is metered into the gas flow. Combustion occurs at a temperature where the reaction time of the fuel gases is = 10 seconds. Under these conditions, the combustor volume need for compete combustion is small, permitting the fuel gases to be oxidized as they are liberated and travel from the pyrolyzer into the combustor in what is essentially sequential flow. Complete combustion in such a small volume produces a large decrease in the oxygen content of the gases emerging from the combustor, allowing the use of a simple inexpensive oxygen analyzer (72) to measure the oxygen content of the gases emerging from the combustor.

Publication No. **US2017343210**relates to methods and systems for clean-up of hazardous spills are provided. In some aspects, there is provided a system for burning an water-oil emulsion that includes an enclosure configured to hold a water-oil emulsion; one or more conductive rods disposed throughout the enclosure, each rod of the one or more roads having a heater portion to be submerged in the water-oil emulsion and a collector portion to project above the water-oil emulsion, wherein the collector portion is longer than the heater portion; and a delivery system for supplying water-oil emulsion to the enclosure, the delivery system is configured to maintain a constant level of the water-oil emulsion in the enclosure as the water-oil emulsion is burned. The enclosure may further include one or more adjustable air inlets.

Publication No. **EP1516173** relates to a novel flame temperature analyzer (FTA) method and apparatus for measuring combustible gas concentration and oxygen content in a sample gas includes supplying a mixture of oxidant (93) and fuel (30) to a sensing flame (48) and measuring the temperature of the flame as sample (26) is added to the combustion chamber (16).

The erroneous measurements of burning rates cause underestimation of potential fire hazards in oil/petrochemical/refineries. Due to this underestimation of hazard significant number of lives i.e. employees of plant and nearby residents are at high risk along with that of infrastructure and environment. Therefore, a new test method was the need of hour where the maximum burning rate of a flammable liquid can be measured under realistic weather/boundary conditions. It was also necessary to develop a test method which can measure the maximum burning rates under steady-state conditions.

In order to overcome one or more shortcomings, present invention aims to provide a test-stand and its method for correct measurement of burning rate of flammable liquids.

OBJECTS OF THE INVENTION:

The principal object of the present invention is to provide a system and method for measuring the burning rates of flammable liquids

Another object of the present invention is toprovidea new and improved test set-up and method for flammable liquids.

Yet another object of the present invention is to providecorrect measurement of burning rates which are 8-40%.

Still another object of the present invention is to providecorrect and realistic measurement of burning rates of large tank fires in small-scale laboratory test set-up.

Another object of the present invention is toproviderealistic estimation of safety distances (8-40% higher) for oil/gas storage facilities and transportation of hazardous substances.

Yet another object of the present invention is toprovideoptimum estimation of foreseeable fire hazard for proper risk assessment.

BREIF DESCRIPTION OF THE INVENTION:

The present invention provides a system and methodfor measuring the burning rates of flammable liquids. A new test system and method for measuring the maximumburning rates of flammable liquids.The correct measurement of burning rate with proposed new test set-up ensures that all the realistic boundary conditions are imposed to measure the maximum burning rates that could occur in a real sized tanks storing flammable liquids. Such precise measurement of burning rate will help to develop proper safety distances from the fires to the people and infrastructure thereby saving the losses of all kinds.

The test-bench (Fig. 3a) is comprises reservoir 1 containing liquid fuel supply it to the fuel pan 13 through gate valve 2, motor 3, pump 4, valve 5, pressure relief valve 6, flowmeter/mass flow controller 7, valves 7, 8, piping 9, steel table 10, fuel collection cone 12. The pan 13 is 95% filled with a liquid fuel 13a. The pan 13 is connected to a load cell 15 via a shaft 14. The fuel was ignited by a lighter/hand torch (not shown) and flame 14a develops. Thermocouples 15a were also connected via a stand 16 to record the temperature of flame. The measurements of mass loss in load cell 15 and thermocouples were transferred via cables 17 to data acquisition system 18 and then to the computer 19. Each measurement was repeated for three times to ensure the reproducibility.

In an embodiment, the flammable fuel is diesel, gasoline, biodiesel, ethanol or any other such kind

BRIEF DESCRIPTION OF THE DRAWINGS:

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered for limiting of its scope, for the invention may admit to other equally effective embodiments.

Fig. 1 showstypical set-up for a small as well as large-scale burning rate test (d = 0.04 m to 4.28 m) where a fixed mass of fuel is filled in the pans and mass loss or burn rate was measured with time [6].

Fig. 2 shows maximum burning rates vs. fuel type for (d = 0.1 m) measured using prior-art under no, slight and moderate wind conditions. It can be seen that under no and slight and moderate wind conditions the rise in burning rates are by only factors of 1.6 to 3.3.

Fig. 3a showstest stand in present invention for correct measurement of burning rate (d = 0.1 m) where fuel layer is kept constant (95% of the pan volume) in the pan and mass loss is measured with time (Total burning time = 15 minutes).

Fig. 3b showscloser view of the test stand in present invention where the fuel is coming into the pan from a collecting cone and producing flame. The steel pan is connected to a shaft to a load cell under the table. The thermocouples are inside the flame to record the temperature.

Fig. 3c showscloser view of the pan filled liquid fuel up to 95% of the volume. The collecting cone supplies the fuel to the pan to maintain the 95% volume. Two thermocouples are inserted inside the pan to measure the temperature rise of liquid.

Fig. 3d showsarrangement for the measurement of maximum burning rate of fuel under different wind speed supplied by the fan located diagonally at the shaft of one of the leg of table.

Fig. 4showsmeasured maximum burning rates vs. fuel type in prior-art and present invention.

Fig. 5 (a) shows measured maximum burning rates vs. fuel type in prior-art and present invention for 5 m/s and (b) measured maximum burning rates vs. fuel type for three wind speed in present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

Accordingly the present invention provides a system and methodfor measuring the burning rates of flammable liquids. The correct measurement of burning rate

with proposed new test set-up ensures that all the realistic boundary conditions are imposed to measure the maximum burning rates that could occur in a real sized tanks storing flammable liquids. Such precise measurement of burning rate will help to develop proper safety distances from the fires to the people and infrastructure thereby saving the losses of all kinds.

The schematic of test-bench is shown in Figure 3 which comprises reservoir 1 contain liquid fuel supply it to the fuel pan 13 through gate valve 2, motor 3, pump 4, valve 5, pressure relief valve 6, flowmeter/mass flow controller 7, valves 7, 8, piping 9, steel table 10, fuel collection cone 12. The pan 13 is 95% filled with a liquid fuel 13a. The pan 13 is connected to a load cell 15 via a shaft 14.

The fuel was ignited by a lighter/hand torch (not shown) and flame 14a develops. Thermocouples 15a were also connected via a stand 16 to record the temperature of flame. The measurements of mass loss in load cell 15 and thermocouples were transferred via cables 17 to data acquisition system 18 and then to the computer 19.

In Fig. 3b pan receives the fuel from the collecting cone, ignites and flame develops. The thermocouples 15b measure the flame temperatures at different axial locations and 13b measure the temperature rise of the liquid fuel.

In Fig. 3c a closer view of the fuel pan shows the additional thermocouples inside the liquid fuel which measure the temperature rise with time.

In Fig. 3d the test arrangement for maximum burning rate is shown. A fan 21 is located diagonally via a shaft 20 to the flame which provides different wind speed and enhances the burning rate of liquid fuel.

Each measurement was repeated for three times to ensure the reproducibility.

The average values were taken with a standard deviation of ± 5%. The errors were within ± 1 gram for constant fuel level measurement.

The results obtained from the present test methods and differences between prior art are shown in Figs. 4, 5a, 5b and listed in Table 2. All the fuels when burned with the present test methods have shown 20-31% higher burning rates than that in prior-art. This is due to the development of a steady-state condition between unburned and burned fuel layers which was not there in the prior-art.

In an aspect, the influence of wind boundary conditions on burning rates are shown in Fig. 5a. Under 5 m/s wind speed the burning rates for burning rates for the considered fuels increased between 8% (ethanol) to 40%(diesel) when compared to prior-art. Similar results are obtained for a wind speed of 2 m/s too ranging 15% (diesel) to 34% (gasoline). In Fig.5b the maximum burning rates for different fuelsmeasured with different wind speed have been shown. The maximum burning rates are generally shown $d \geq 1$ m. The same maximum burning rates can be measured for $d = 0.1$ m provided the wind boundary conditions are increased to introduce same amount of entrainment/turbulence. So using the present test method the maximum burning rates for a fuel can be measured in the lab-scale set-up itself. This will save lot of cost and time and ensure accuracy.

Table 2: Mass burning rates in prior-art and present invention and corresponding increase in the same with different wind speed.

Diesel	0 m/s	2.6 m/s	5 m/s
Prior Art	3.57	9.43	10.06
Present	4.7	11.1	16.2
% increase	24	15	40

Gasoline	0 m/s	2.6 m/s	5 m/s
Prior Art	10.58	28.87	33.73
Present	14.6	43.5	49.1
% increase	27.5	33.6	31

Ethanol	0 m/s	2.6 m/s	5 m/s
Prior Art	5.71	9.35	12.87
Present	7.1	11.4	14.1
% increase	19.6	18	8

Biodiesel	0 m/s	2.6 m/s	5 m/s
Prior Art	2.23	5.62	7.38
Present	3.25	6.68	9.23
% increase	31	16	20

Depending on the plant conditions (strong wind, moderate wind, calm) different burning rates can be used to estimate the total fraction of heat that will be lost in form of radiation as written in eqs. below

$$Q_{max} = \dot{m}''_{max} \Delta H_C (kW/m^2) \ldots\ldots\ldots\ldots (1)$$

$$Q_{rad,max} = f_{rad}\, \dot{m}''_{max} \Delta H_C (kW/m^2) \ldots\ldots\ldots\ldots (2)$$

Where Q_{rad} = radiative output(kW/m^2)

f_{rad}= radiation fraction (-) (0.15 to 0.25)

$\dot{m}''_{max}$= Maximum mass burning rate ($kg/m^2.s$)

ΔH_C= Heat of combustion (kJ/kg)

Such maximum radiation emitted by a fire can be further used to develop safety distance by the equation below

$E(\Delta y)= \tau\phi\ Q_{rad,max}\ (kW/m^2)$.....(3)

Where E= irradiance at a distance (Δy)

τ = transmissivity of fire (-) usually 1.

Φ= view factor (-)

In eqs. (1), (2) and (3) it is shown that the safety distance from a single tank fire is directly related to the maximum mass burning rate of the fuel. In case the same is measured inappropriately as in prior-art the safety distance will also be much smaller than expected posing an increased risk to the public and property. In present method we have developed a test method and stand to measure the mass burning rate correctly in a scientifically justified way.

The fuel pan is filled with 95% of flammable liquid and then ignited with a hand torch. The motor/pump is switched on from the computer software and the supply of fuel begins at a low rate (1 ml/min). The supply rate is controlled by using the mass flow controller and gradually matched with the burning rate. This is verified by the load cell reading on the computer. When the mass fluctuation is about ±1 gram it is said that the supply rate equals the burning rate. This supply rate of fuel becomes the correct mass burning rate under steady-state conditions.

In the second part of the invention the maximum burning rate is measured in the similar way as above except the flame was subjected to different wind speeds by using swirling fans of different capacities and mounted diagonally on the steel shaft on one of the leg of the table. The different wind speeds generated different levels of turbulence. The maximum turbulence produced maximum burning rate of the fed duel. This way the maximum supply/feeding rate was termed as the maximum burning rate of any flammable liquid.

In another embodiment, the present invention provides correct measurement of burning rates which are 8-40% higher than in prior-art. It provides correct and realistic measurement of burning rates of large tank fires in small-scale laboratory test set-up, realistic estimation of safety distances (8-40% higher) for oil/gas

storage facilities and transportation of hazardous substances and optimum estimation of foreseeable fire hazard for proper risk assessment.

Numerous modifications and adaptations of the system of the present invention will be apparent to those skilled in the art and thus it is intended by the appended claims to cover all such modifications and adaptations which fall within the true spirit and scope of this invention.

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WE CLAIM:

1. A system and method for measuring the burning rates of flammable liquids comprises reservoir 1 containing liquid fuel supply it to the fuel pan 13 through gate valve 2, motor 3, pump 4, valve 5, pressure relief valve 6, flowmeter/mass flow controller 7, valves 7, 8, piping 9, steel table 10, fuel collection cone 12 wherein the pan 13 is connected to a load cell 15 via a shaft 14, thermocouples 15a were also connected via a stand 16 to record the temperature of flame.

2. The system and method for measuring the burning rates of flammable liquids, as claimed in any of the preceding claims, wherein the measurements of mass loss in load cell 15 and thermocouples were transferred via cables 17 to data acquisition system 18 and then to the computer 19.

3. The system and method for measuring the maximum burning rates of flammable liquids, as claimed in any of the preceding claims, wherein the maximum mass loss are achieved by subjecting the flame to different wind turbulence by fan.

4. The system and methodfor measuring the burning rates of flammable liquids, as claimed in any of the preceding claims, wherein the flammable liquid is diesel, gasoline, biodiesel, ethanol or any other such kind

5. The system and methodfor measuring the burning rates of flammable liquids, as claimed in any of the preceding claims, wherein the fuel pan is filled with 95% of flammable liquid and then ignited with a hand torch, the motor/pump is switched on and the supply of fuel begins at a low rate (1 ml/min) whereinthe supply rate is controlled by using the mass flow controller and gradually matched with the burning rate.

6. The system and methodfor measuring the burning rates of flammable liquids, as claimed in any of the preceding claims, wherein when the mass fluctuation is about ±1 gram it is said that the supply rate equals the burning rate,the supply rate of fuel becomes the correct mass burning rate under steady-state conditions.

7. The system and methodfor measuring the burning rates of flammable liquids, as claimed in any of the preceding claims, wherein the method provides correct and realistic measurement of burning rates of large tank fires in small-

scale laboratory test set-up, realistic estimation of safety distances for oil/gas storage facilities and transportation of hazardous substances and optimum estimation of foreseeable fire hazard for proper risk assessment.

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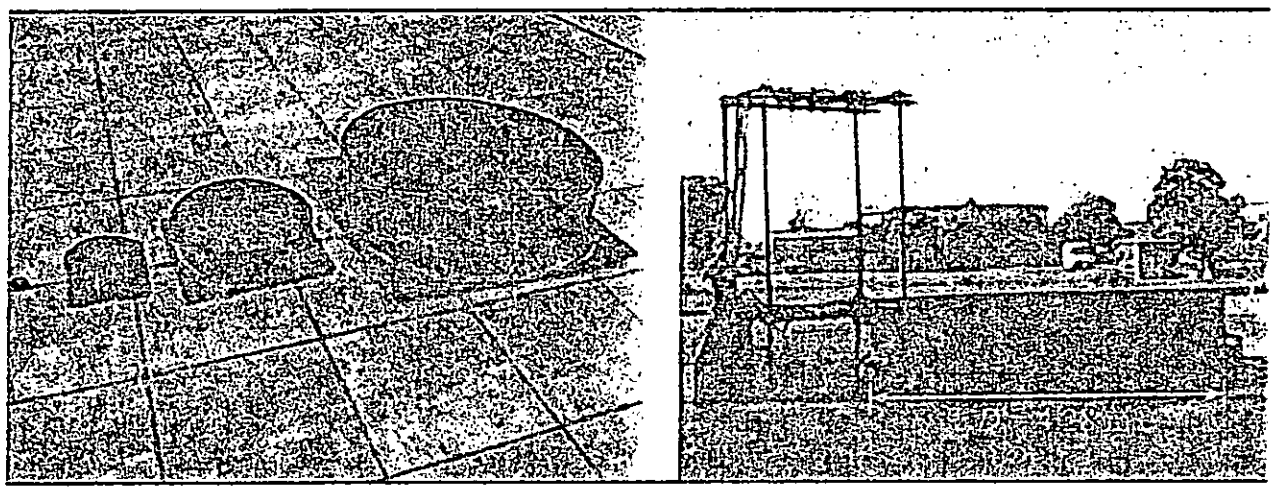

Fig 1 (Prior Art)

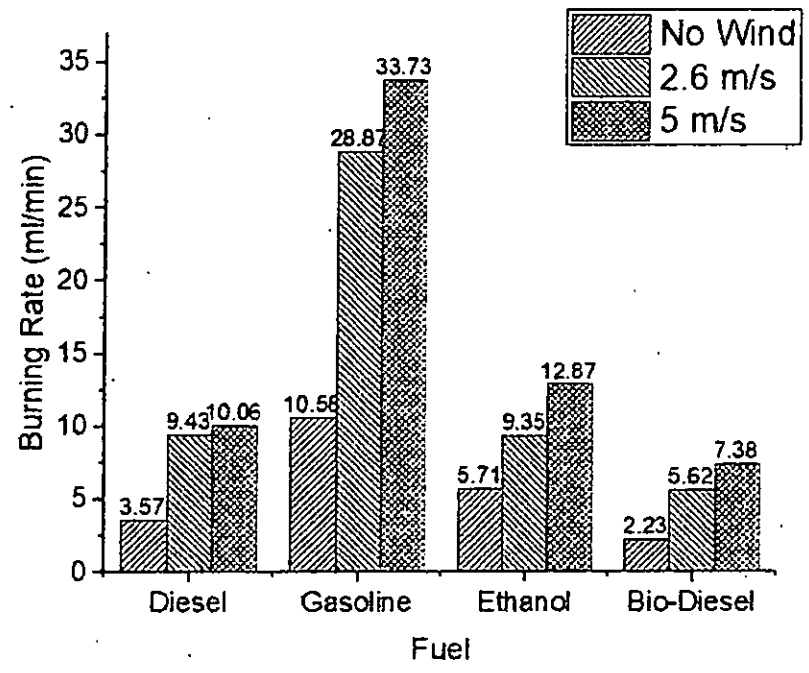

Fig 2 (Prior Art)

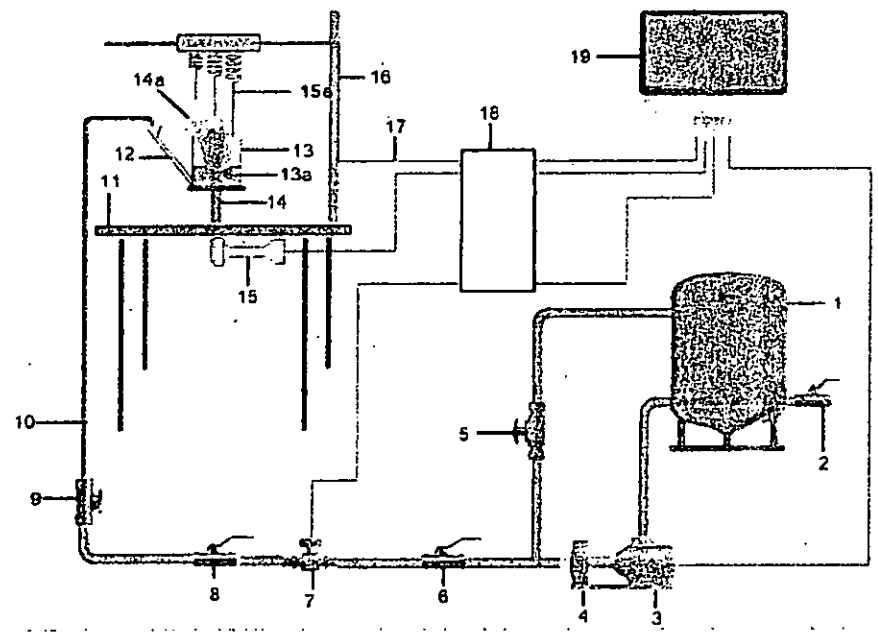

Fig 3a

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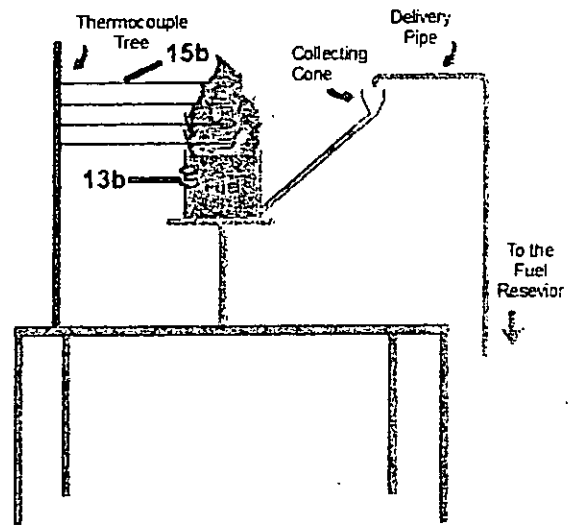

Fig. 3b

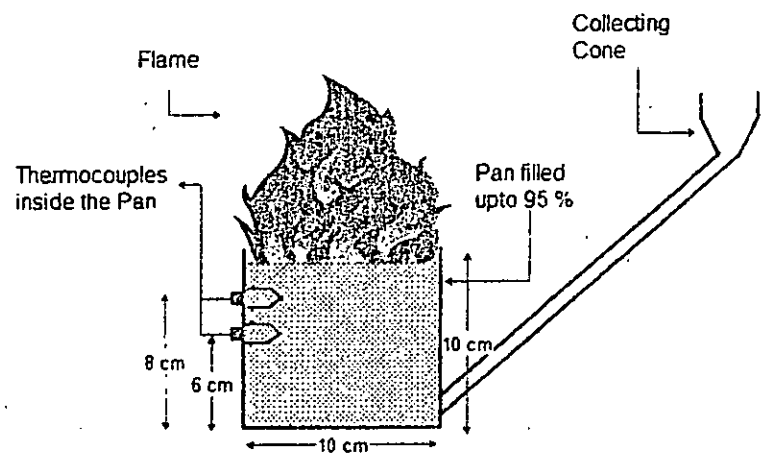

Fig. 3c

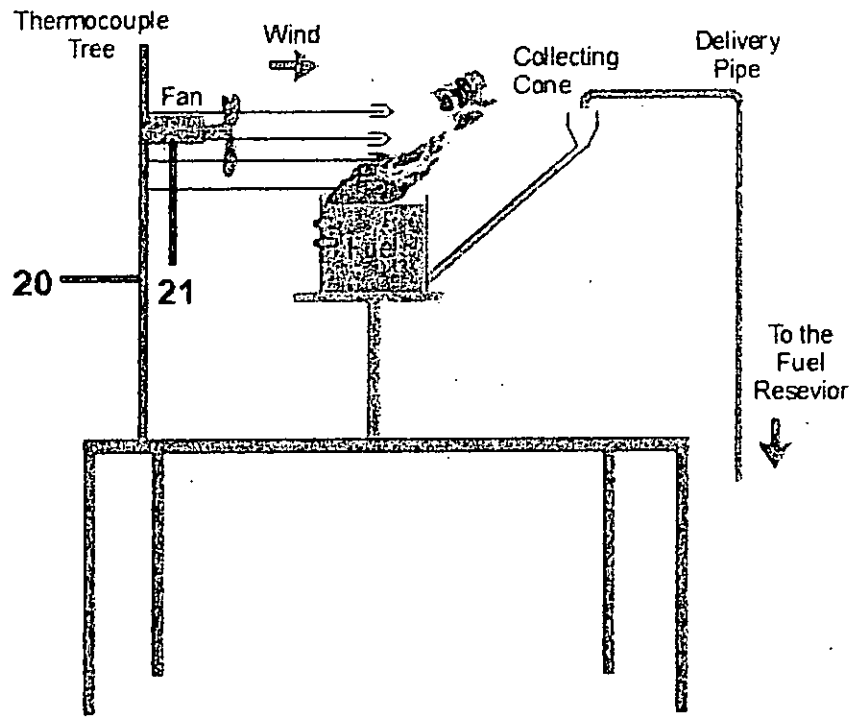

Fig. 3d

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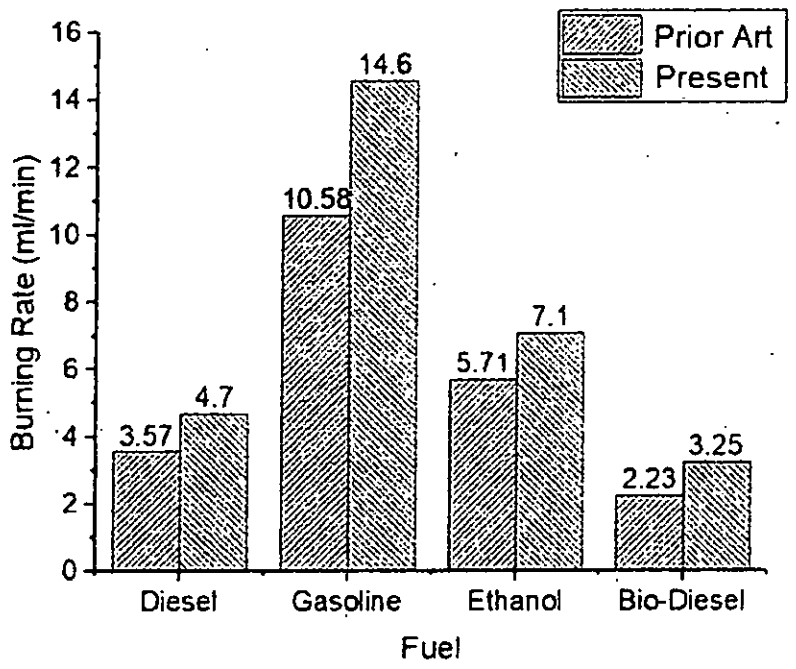

Fig.4

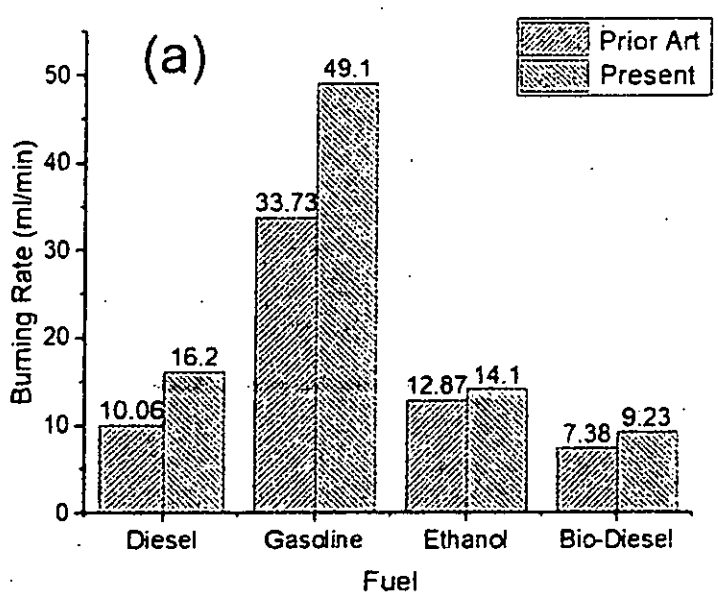

Figure 5(a)

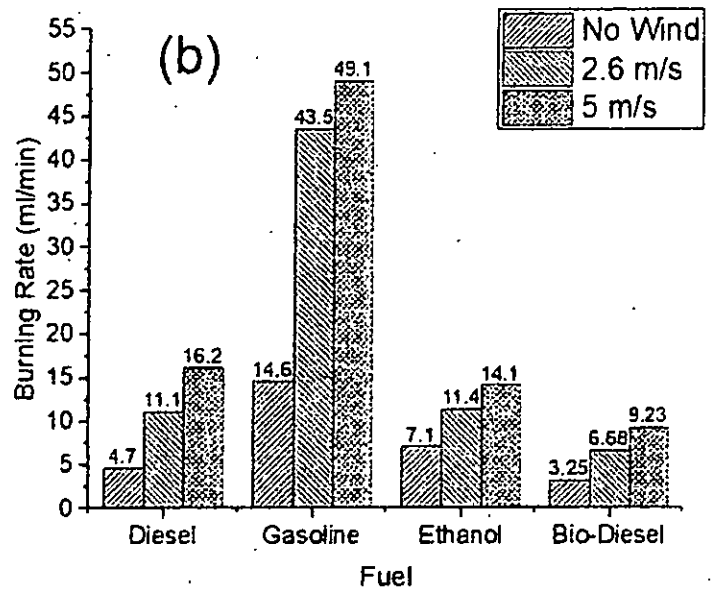

Figure 5(b)

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ABSTRACT

A Novel Test Stand and Method to Measure the Burning Rate of Flammable Liquids

The present invention provides a system and method for measuring the burning rates of flammable liquids. A new test system and method for measuring the maximum burning rates of flammable liquids. The correct measurement of burning rate with proposed new test set-up ensures that all the realistic boundary conditions are imposed to measure the maximum burning rates that could occur in a real sized tanks storing flammable liquids. Such precise measurement of burning rate will help to develop proper safety distances from the fires to the people and infrastructure thereby saving the losses of all kinds.

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