Korean Research Results

"Fire resistance test"

March 18, 2015

Hyuk JUNG, Chief Researcher

Korea Transportation Safty Authority (TS)
Korea Automobile Testing & Research Institute (KATRI)

Progress Report of KATRI Research

Research items for the fire resistance test

- CFD simulation about current test-equipment of KATRI
- Study on justification for the temperature and thermal energy of the fire resistance test(A) compared to those of test(B)
- Develop an optimized solution of current test equipment by CFD simulation
- Modify the current test equipment and performance test
  - Additional performance test of the modified test equipment (small mock-up)
  - Decision of the height of flame to the DUT and the horizontal areas of flame
- The equivalency of test condition between test(A) and test(B)
  - Perform the test as followed by test(A) and (B) with same type of REESS
  - Compare and analyze the inside temperature of DUT during the test
- Review the applicability of test(A) to vehicle based test
- Additional review related Part 2
  - Comment for the test time

Notice

1) Test(A) : Fire resistance test procedure which is proposed by Korea as an alternative

2) Test(B) : Fire resistance test procedure which is proposed by OICA according to UN R.100

Progress Report of KATRI Research

Study Process

CFD simulation about current test equipment of KATRI

Correlate CFD simulation result with test (A)
(Using the temp. data of KATRI's fire resistance test A)

Develop a optimized solution of current test equipment of KATRI by CFD simulation

Modify the current test-equipment according to total optimization solution

Verify performance of modified test-equipment
(Fire resistance test A with mockup, Temp. measuring)

CFD simulation about test A & B in same condition (with Mockup)

KATRI's indoor fire resistance test (B)

CFD simulation about fire resistance test (B) condition

Correlate CFD simulation result with test (B)
(Using the temp. data of KATRI's fire resistance test B)

CFD simulation about test A & B under the same condition (with Mockup)

1. Present the specification of optimized test equipment to test conditions of fire resistance test(A)
2. Temperature and thermal energy of the fire resistance test(A) compared to those of GTR draft(B)

3. Exposure area test -Test(A)
4. REESS case Internal temp. test -Test(A), (B)
5. Component based fire resistance test -Test(A), (B)
6. Vehicle based exposure temp. test -Test(A), (B)

Progress Report of KATRI Research

KATRI's indoor fire resistance test (B)

15th Apr. 2014

- Test Site : Korea Institute of Construction Technology (KICT) / Fire Research Center

✓ Size : 30m(W) × 38m(L) × 39m(H),
- Floor area : 1,140㎡

✓ Dust collection equipment : 150,000 m^3/hr

✓ Hood : Ø 10 m

- Test configurations

Descriptions

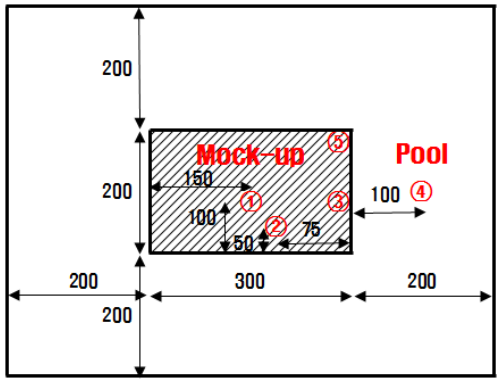
* Mock-up simulates real REESS size
  - Small : 300×200×300 mm, Bottom area : 0.06 ㎡
  - Large : 1,000×1,000×200 mm, Bottom area : 1 ㎡

* Pool size & Fuel quantity(25ℓ/m^2)
  - Small (0.42㎡) : 700 × 600 × 130 mm, 10.5ℓ
  - Large (2.25㎡) : 1,500 × 1,500 × 130 mm, 56.25ℓ
  - Water 25 mm, Fuel 25 mm

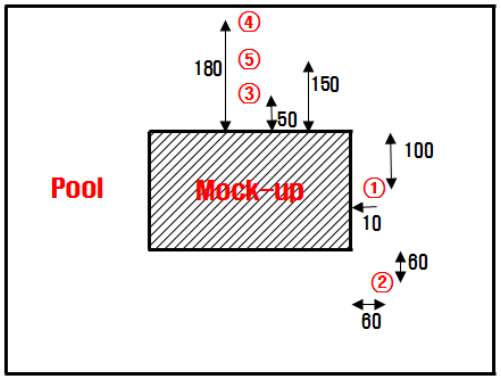
* DAQ : 25 temp. channel
  -10, 30, 50, 70, 100cm above the Fuel surface
  - Horizontally 5 points at each height
  - K-Type Thermocouple : ∅1.6mm, L: 1300mm

Progress Report of KATRI Research

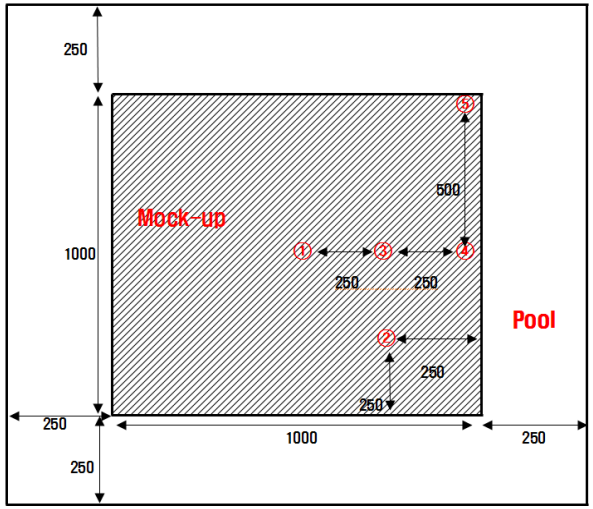
- Horizontally 5 points



< Small Size 5 points>

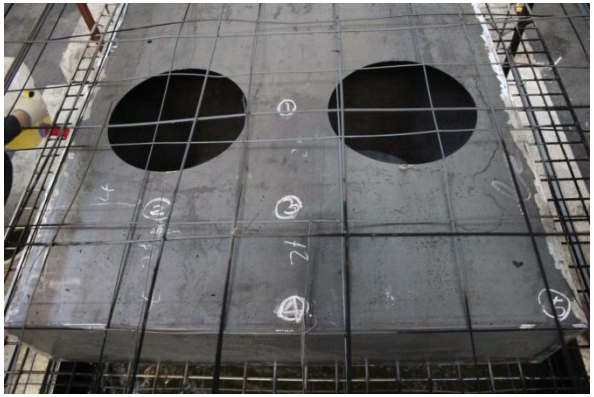


< Small Size – with Mockup(70cm) >



< Large Size 5 points>

< Small Size Mockup >



< Large Size Mockup >

Progress Report of KATRI Research

- Test condition
  - ✓ Small & Large pool / Free burning & with Mock-up condition: total 4 conditions
  - ✓ Flame temperature measuring continuously from ignition to natural extinguishing
  - ✓ Ambient Temperature : about 20 ℃

Air flow : 0.02~0.33 m/s

- Test scene

< Small pool-Free burning >

< Small pool-Burning with Mockup >

Hood height : 6m
Frame height : 2~3m

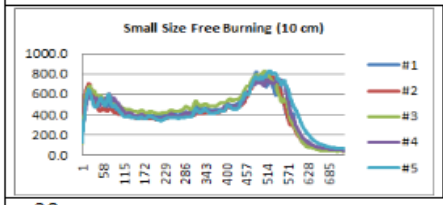
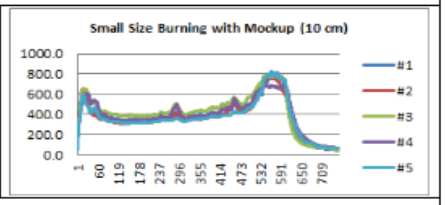
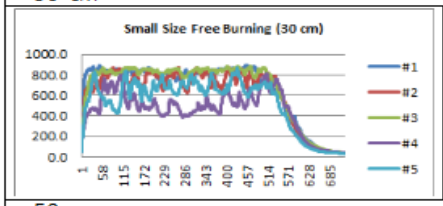
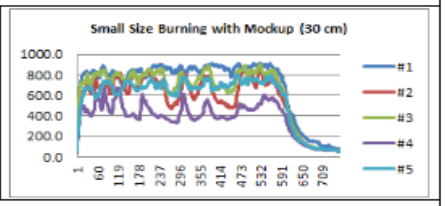
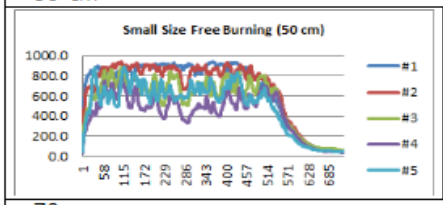
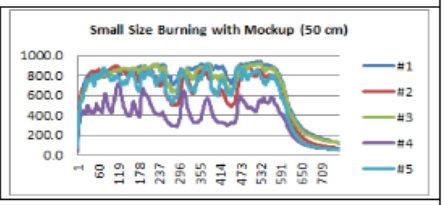
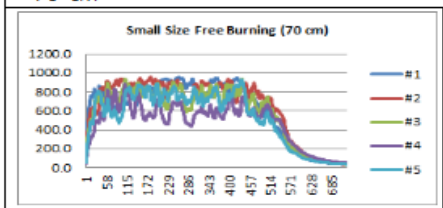
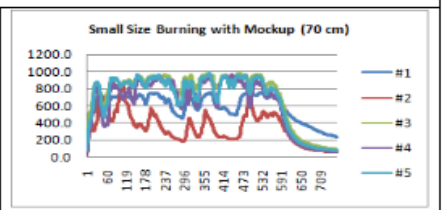
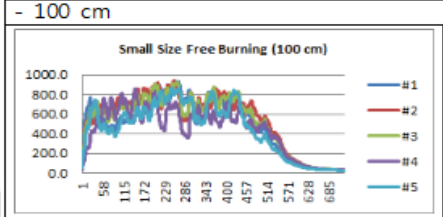
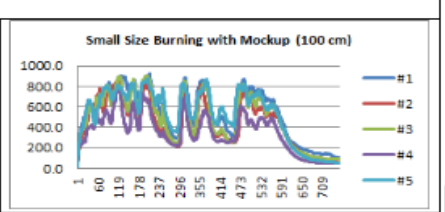
< Large pool-Free burning >

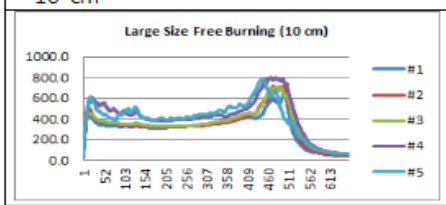
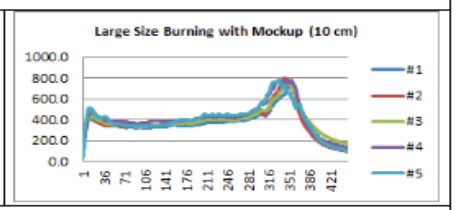
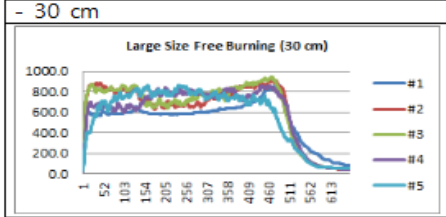
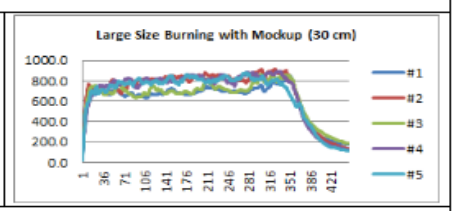
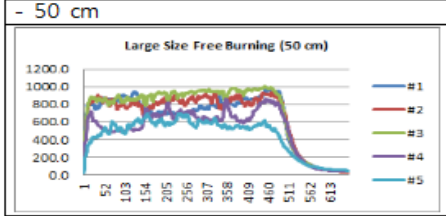
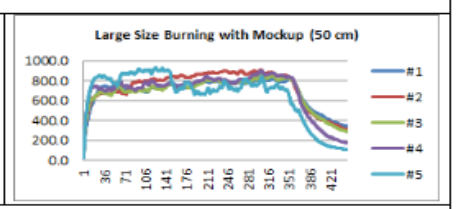
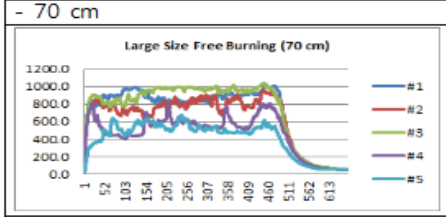
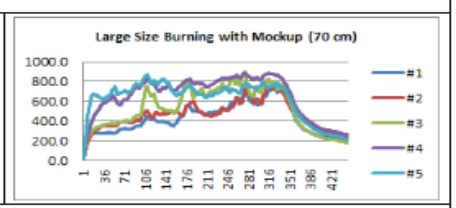
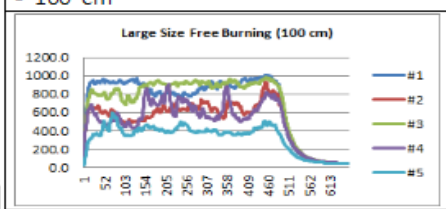
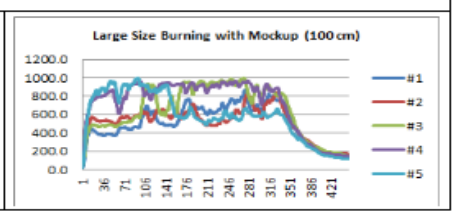
< Large pool-Burning with Mockup >

Hood height : 7m
Frame height : 4~6m

Progress Report of KATRI Research

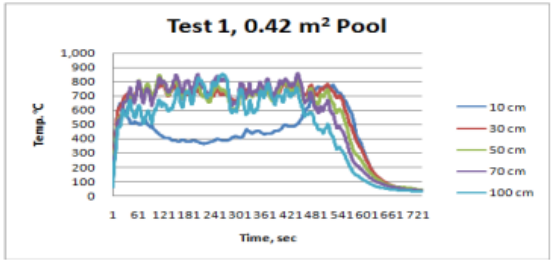
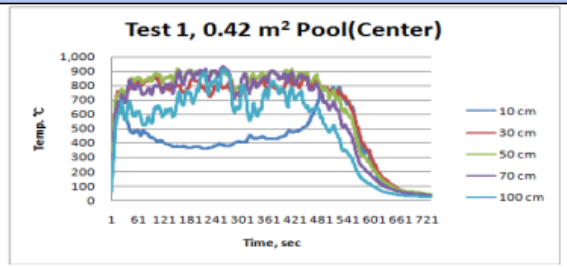
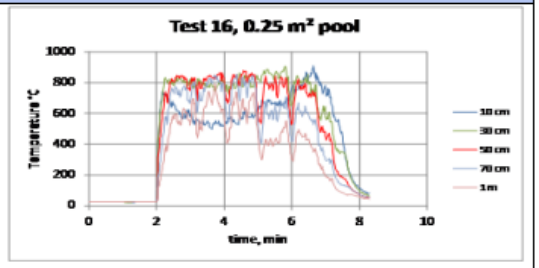
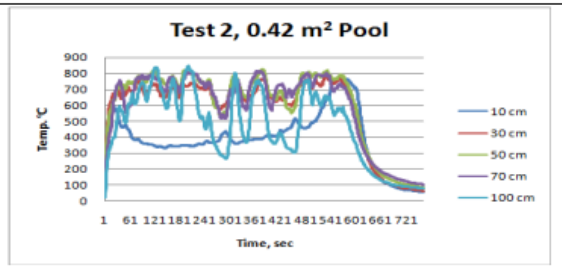
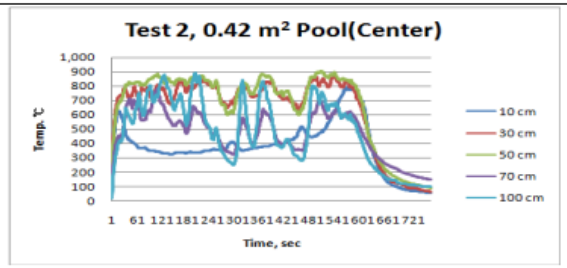
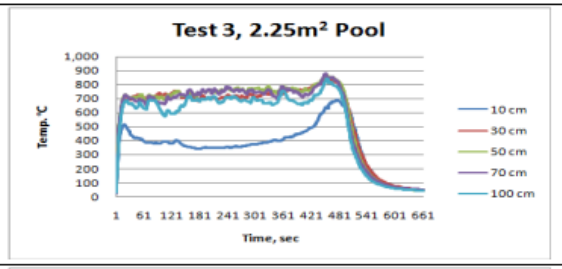
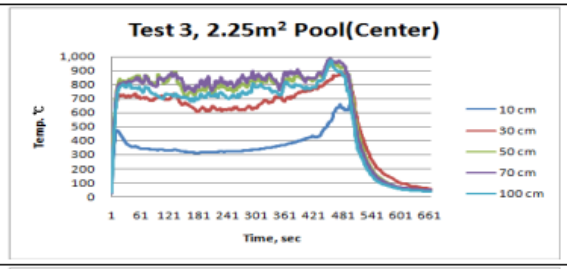
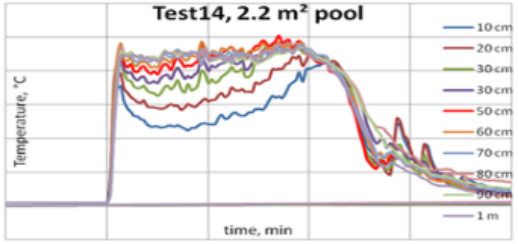
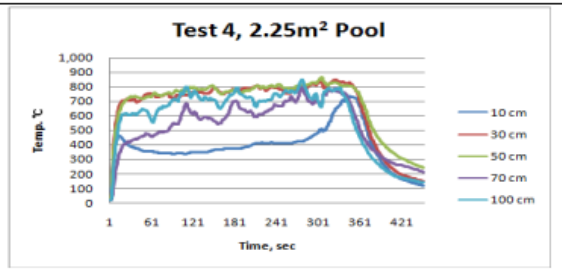
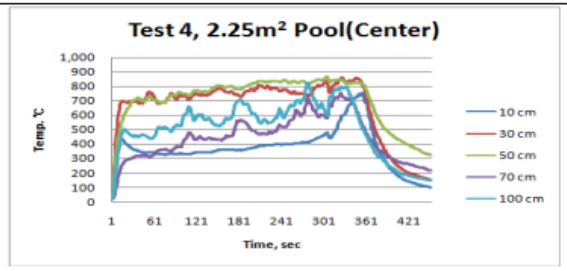
- Test result

Small Size Free Burning	Small Size Burning with Mockup
- 10 cm	
	
- 30 cm	
	
- 50 cm	
	
- 70 cm	
	
- 100 cm	
	

Large Size Free Burning	Large Size Burning with Mockup
- 10 cm	
	
- 30 cm	
	
- 50 cm	
	
- 70 cm	
	
- 100 cm	
	

Progress Report of KATRI Research

- Test result

Test	KATRI Result		EVS GTR Draft 4. TECHNICAL JUSTIFICATION N0. 45.
	Total Avg.	Center Avg.	
Small Pool (Free buring)			
Small Pool (with Mockup)			-
Large Pool (Free buring)			
Large Pool (with Mockup)			-

CFD simulation

- Introduction of CFD simulation tools

- FDS software:

The Fire Dynamics Simulator (FDS) and Smoke view are the products of an international collaborative effort led by the National Institute of Standards and Technology (NIST) and VTT Technical Research Centre of Finland.
Fire Dynamics Simulator is a computational fluid dynamics (CFD) model of fire-driven fluid flow. FDS solves numerically a form of the Navier-Stokes equations appropriate for low-speed (Ma < 0.3), thermally-driven flow with an emphasis on smoke and heat transport from fires. FDS has been aimed at solving practical fire problems in fire protection engineering, while at the same time providing a tool to study fundamental fire dynamics and combustion.
This software is used for simulating the gasoline pool-burning.

- ANSYS FLUENT software:

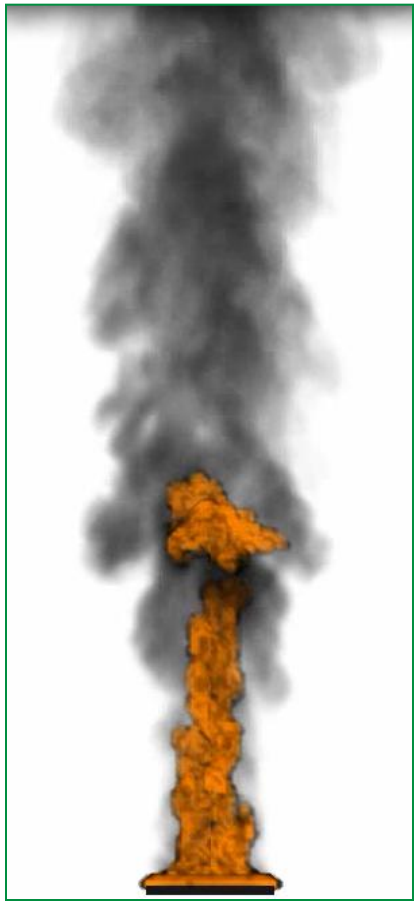
ANSYS Fluent software contains the broad physical modeling capabilities needed to model flow, turbulence, heat transfer, and reactions for industrial applications ranging from air flow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing, and from clean room design to wastewater treatment plants. ANSYS Fluent incorporates a comprehensive suite of reacting flow-modeling capabilities and simulate gaseous reactions using either reduced or complex chemistry. Pollutant models are built in to allow easy and accurate pollution emission predictions for NO, SO and soot.
This software is used for simulating the LPG burner-burning.

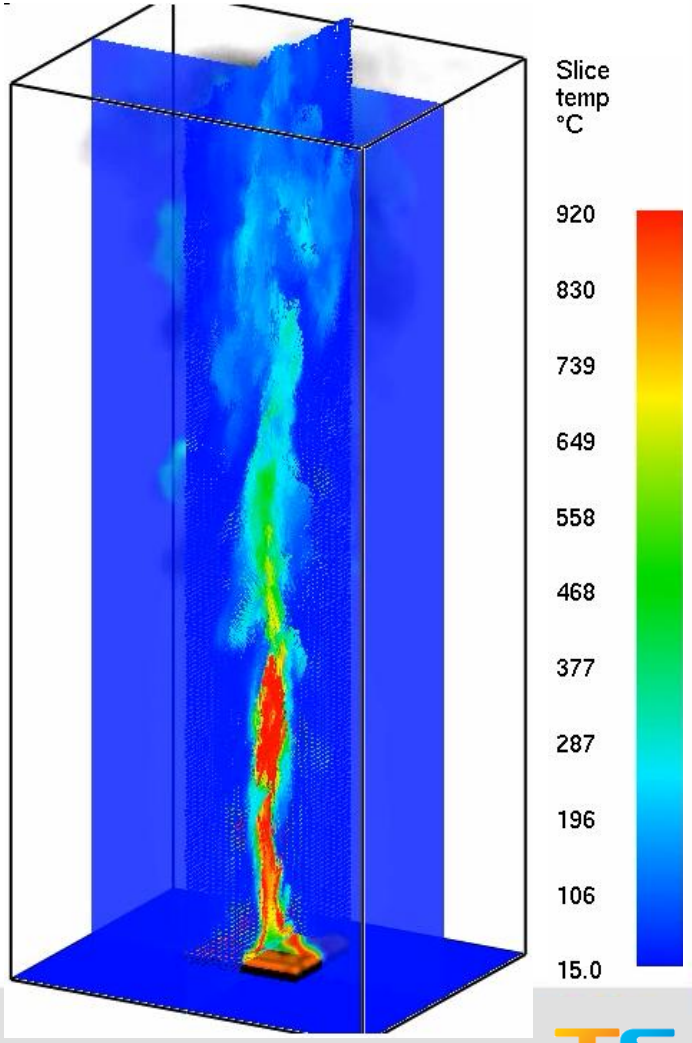
Progress Report of KATRI Research

Verify CFD simulation result of test (B)

[By FDS Software]

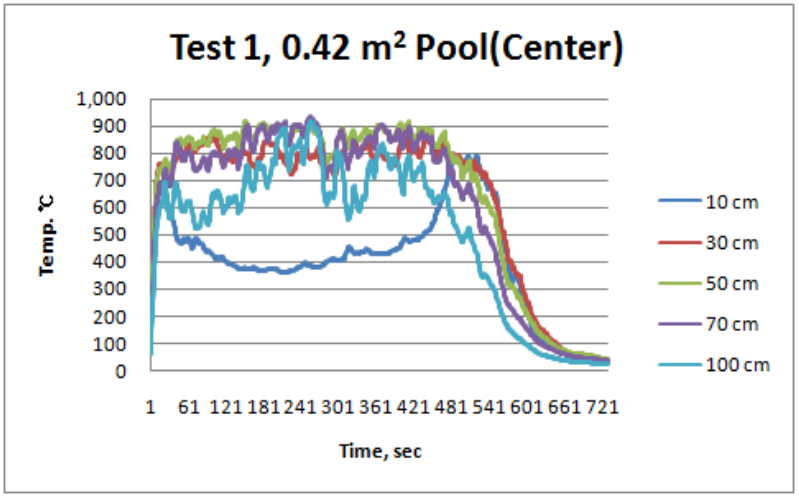
- Small pool-Free burning Simulation

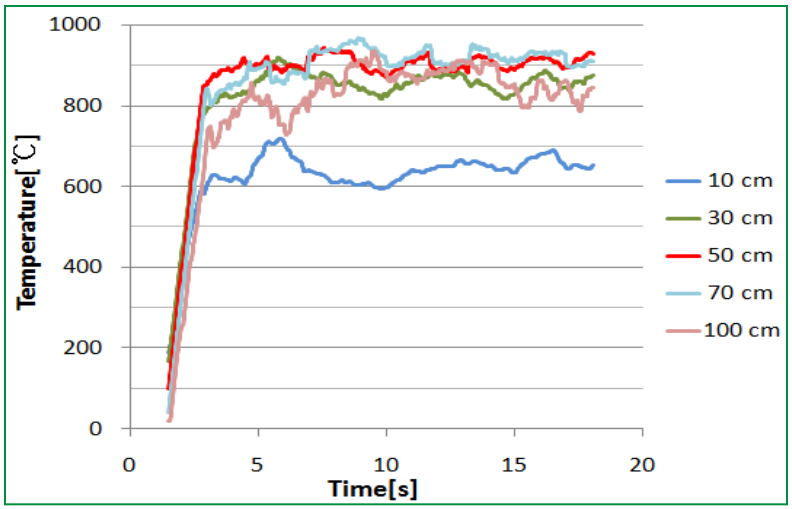




Progress Report of KATRI Research

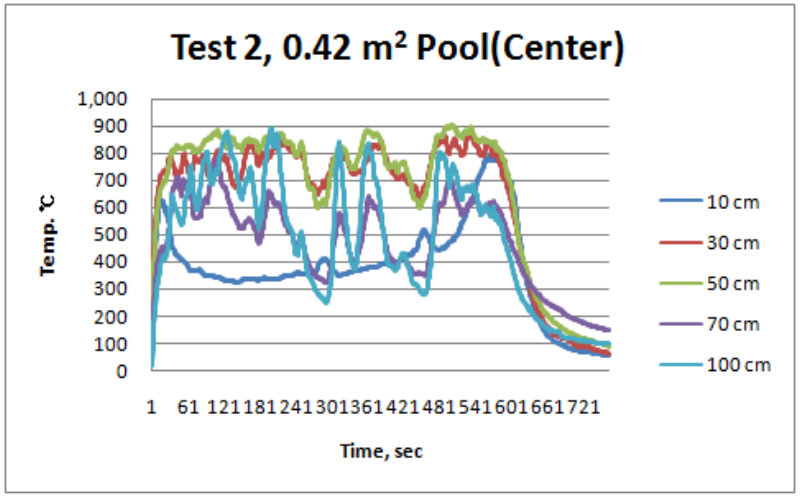
- Small pool-Free burning

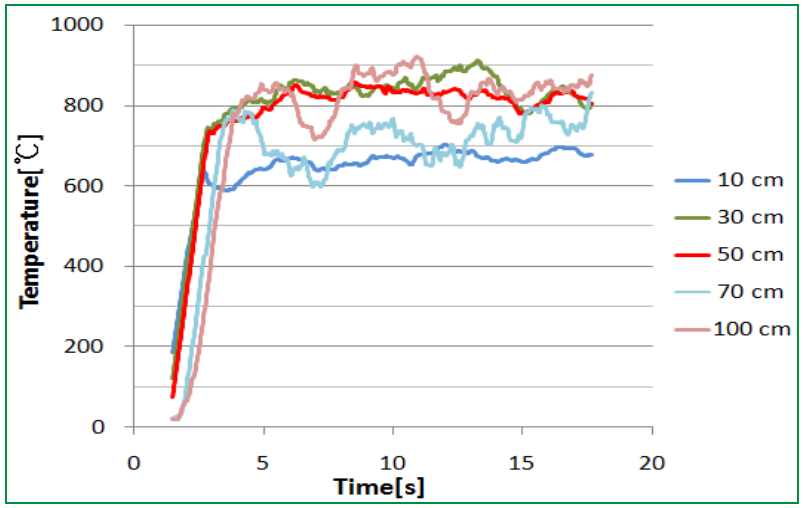




<Small pool-Free burning CFD simulation result>

- Small pool- Burning with Mockup

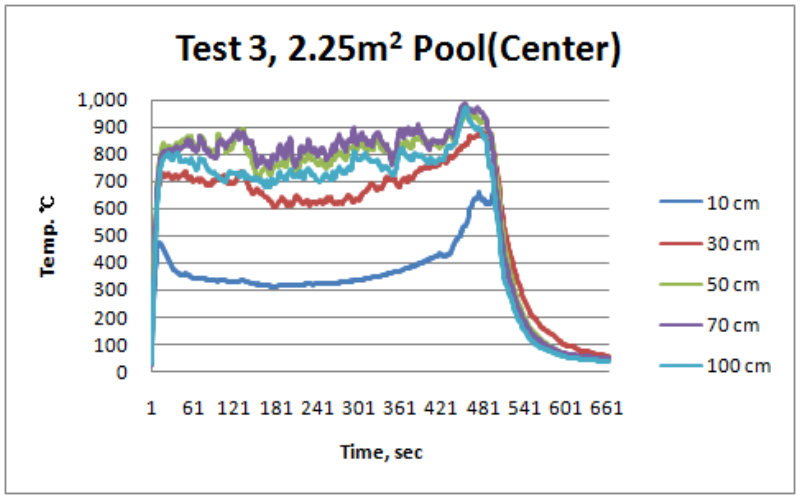


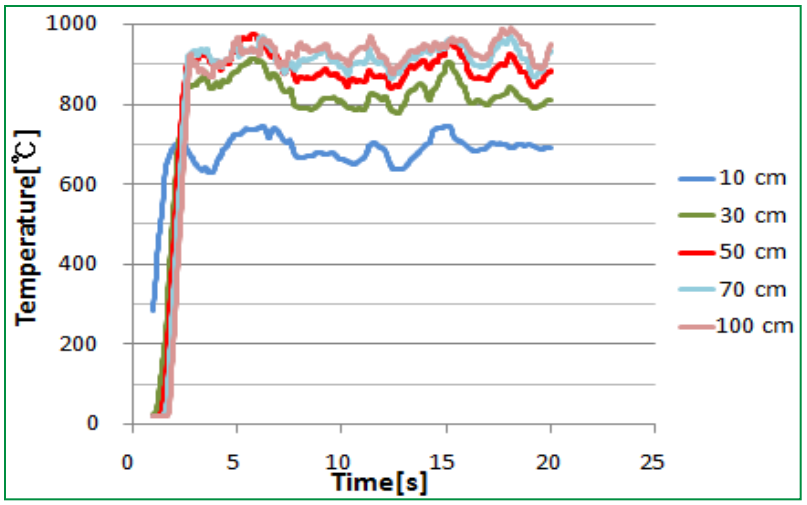


<Small pool-Burning with Mockup CFD simulation result>

Progress Report of KATRI Research

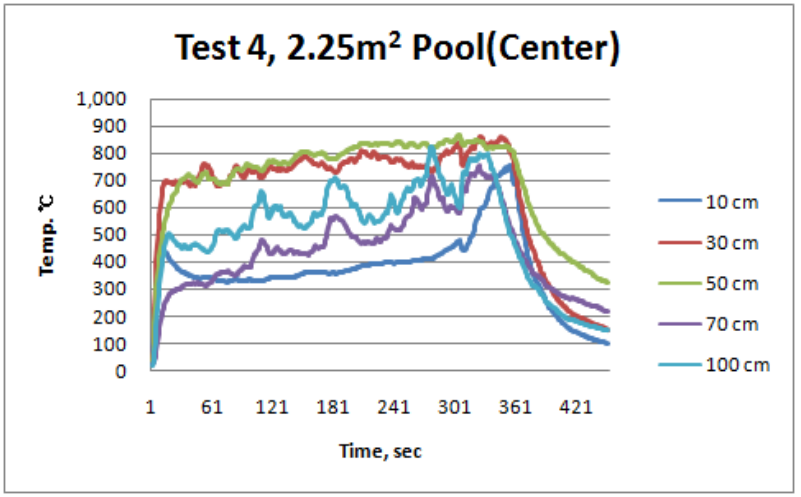
- Large pool-Free burning

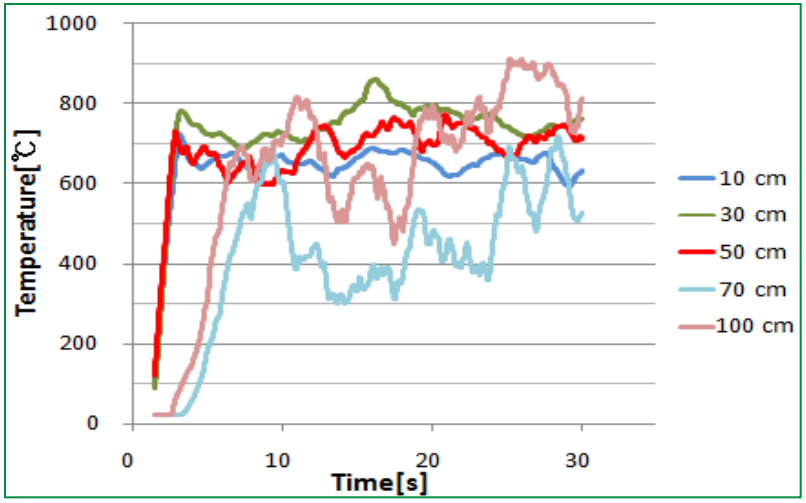




<Large pool-Free burning CFD simulation result>

- Large pool- Burning with Mockup





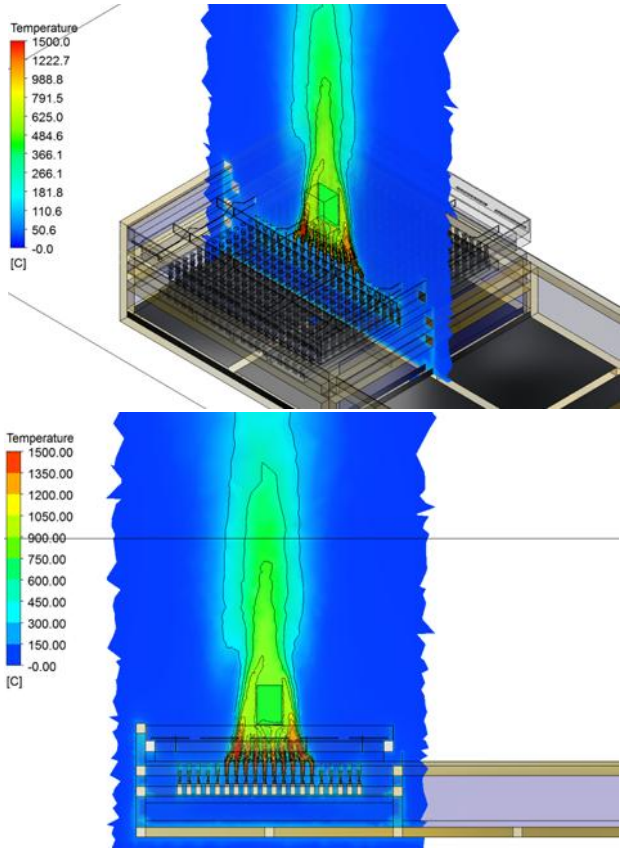
<Large pool-Burning with Mockup CFD simulation result>

Progress Report of KATRI Research

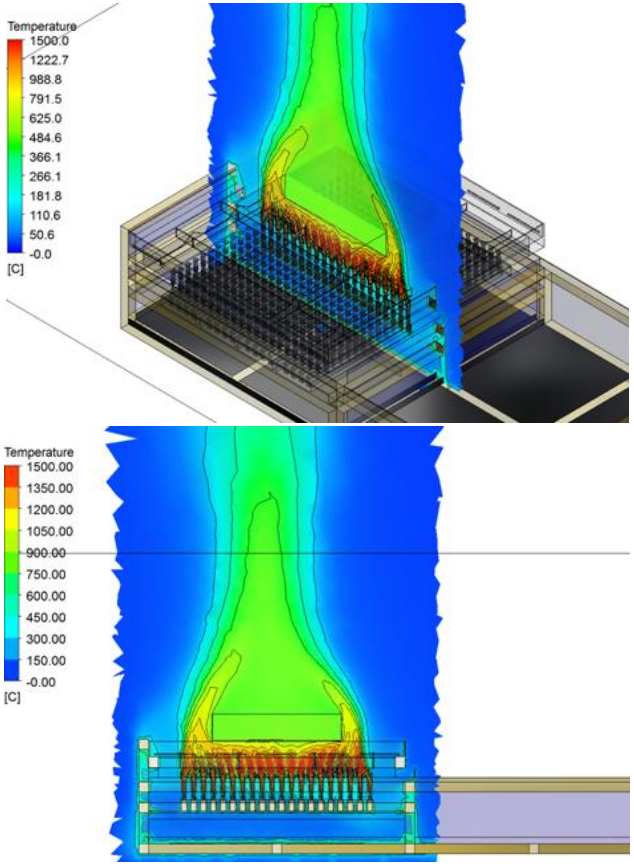
Develop an optimized solution of current test equipment by CFD simulation

- LPG Burner-Burning with Mockup Simulation

[By ANSYS FLUENT Software]



<LPG Burner-Burning with Small Mockup
CFD simulation result (Middle of Mockup)>

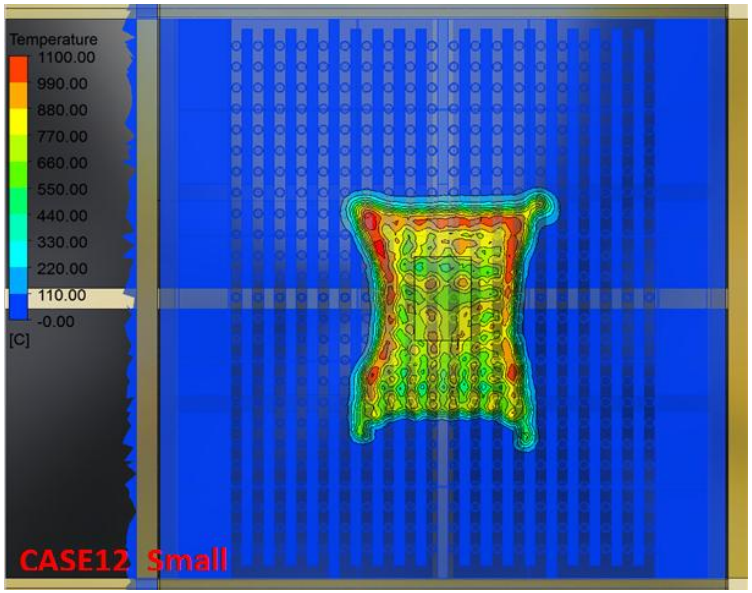


<LPG Burner-Burning with Large Mockup
CFD simulation result (Middle of Mockup)>

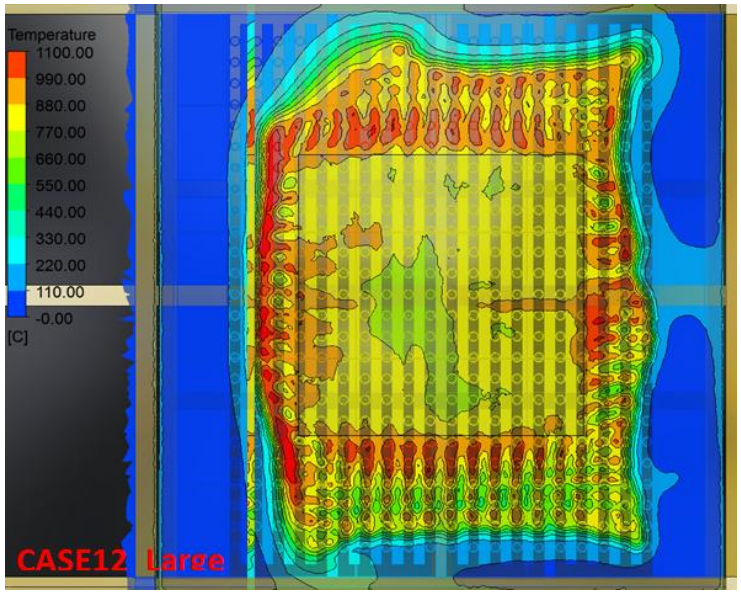
Progress Report of KATRI Research

Develop a totally optimized solution of current test equipment of KATRI by CFD simulation

- LPG Burner-Burning with Mockup Simulation



<LPG Burner-Burning with Small Mockup CFD simulation result>



<LPG Burner-Burning with Large Mockup CFD simulation result>

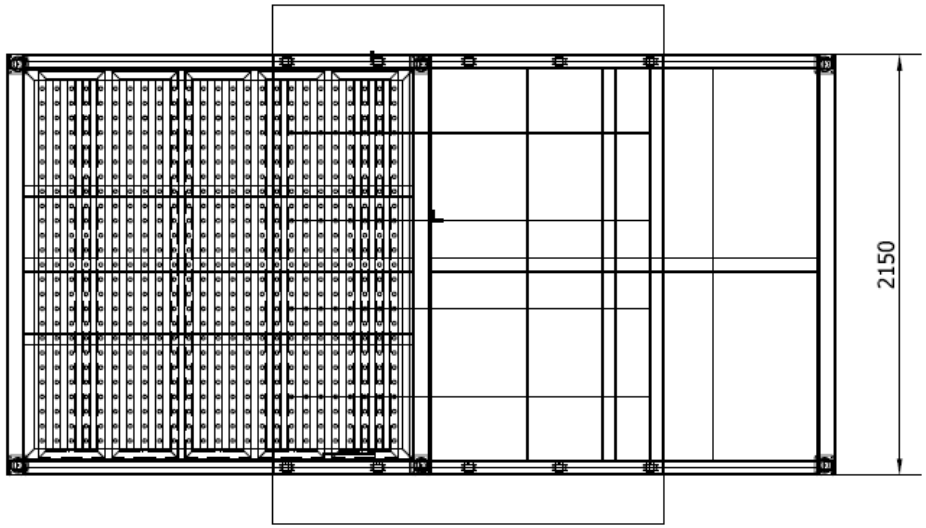
- Optimized conditions

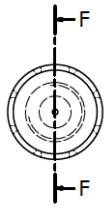
✓ Nozzle spacing : 75 mm ✓ Number of Nozzle : 500 EA ✓ Need to test on indoor

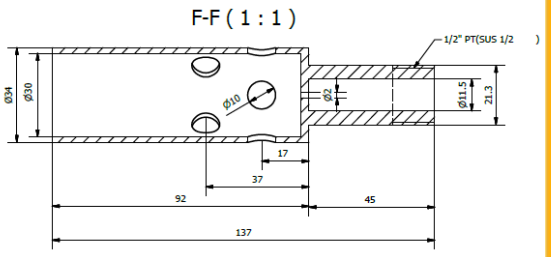
✓ LPG mass flow rate: 150 kg/h

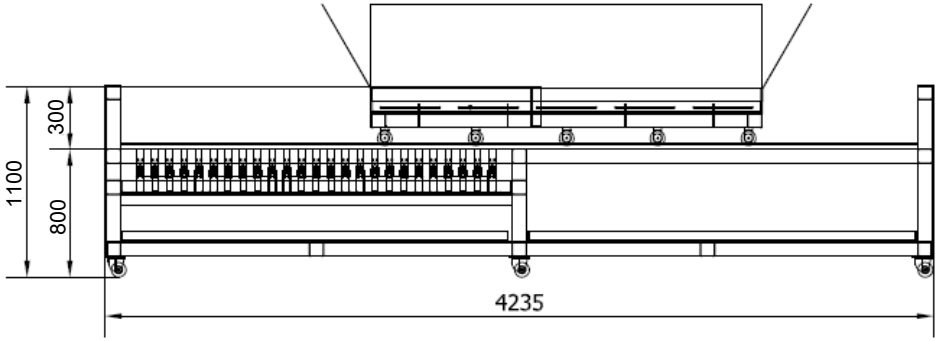
Progress Report of KATRI Research

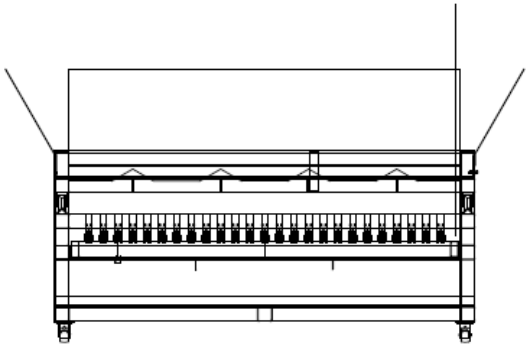
Specification of optimized test equipment



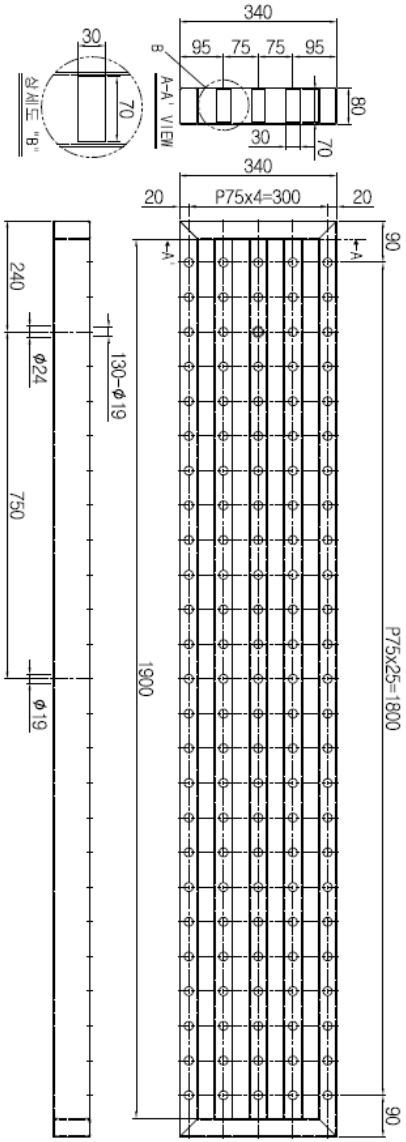


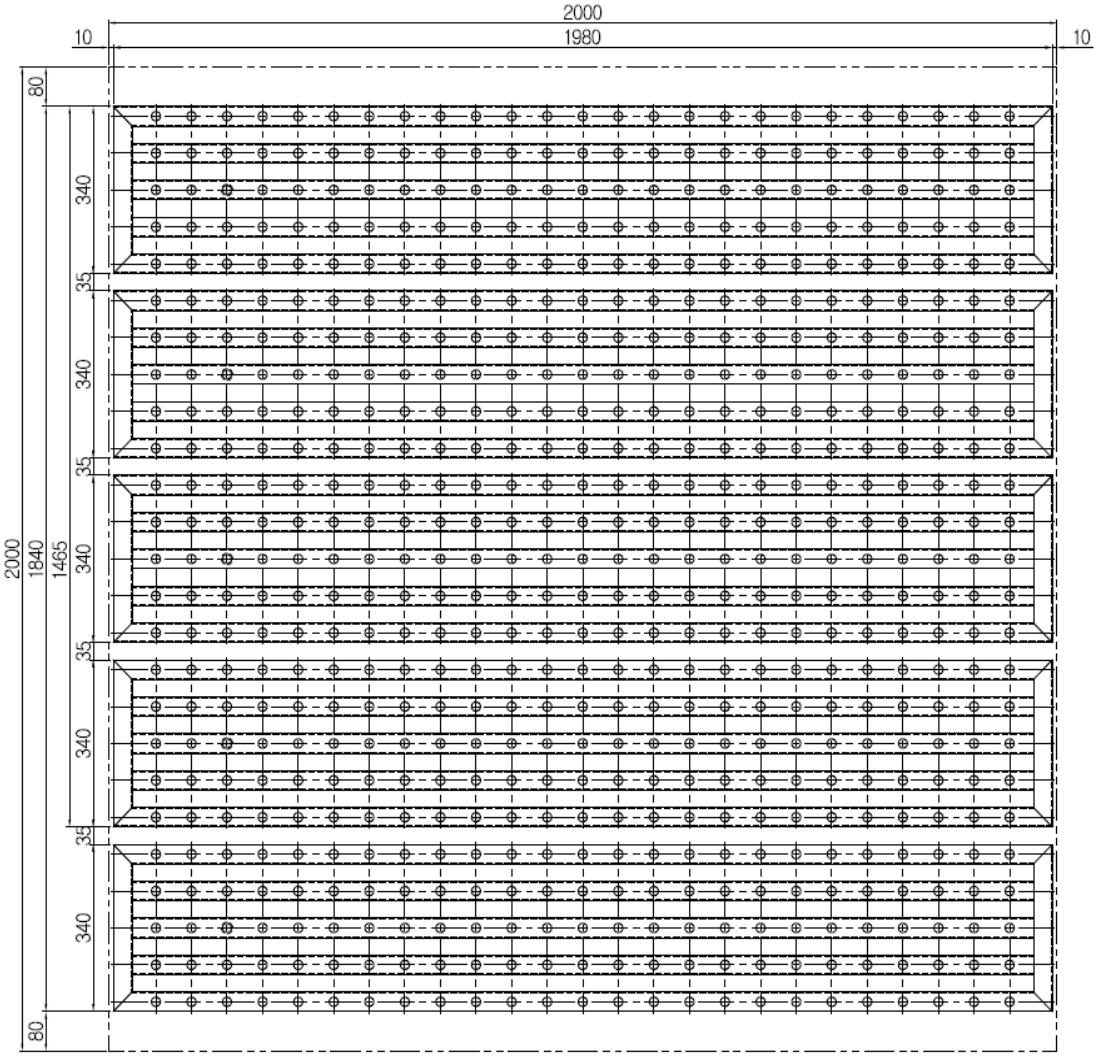






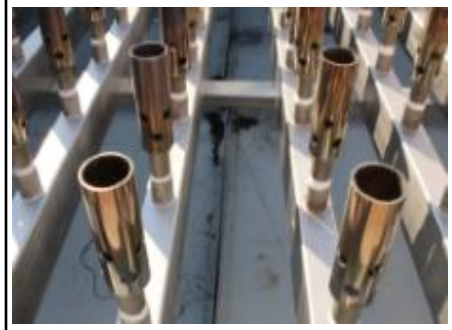
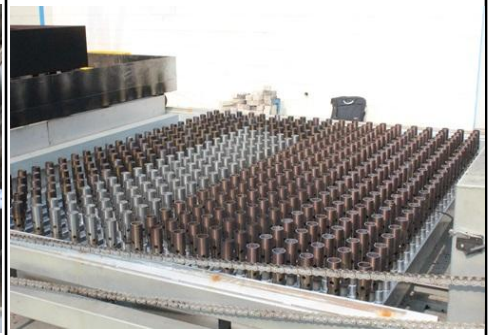
Progress Report of KATRI Research





Progress Report of KATRI Research

Modify the current test-equipment according to total optimization solution

BEFORE			?	
	✓ Nozzle spacing : 150 mm	✓Number of Nozzle : 156 EA	✓ LPG mass flow rate	✓ Test site : Out door test facility
AFTER				
	✓ Nozzle spacing : 75 mm	✓ Number of Nozzle : 625 EA ✓ Height of flame : about 50 cm	✓ LPG mass flow rate: Minimum 150 kg/h	✓ Test site : Temporary indoor test facility

Progress Report of KATRI Research

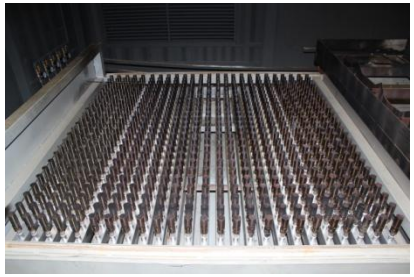
Verify performance of modified test-equipment

Mar. 2015

< KATRI's indoor fire resistance test (A) >

- Test Site :
  KATRI / Temporary fire resistance test facility
  - ✓ Size : 9m(W) × 9m(L) × 8.2m(H)
  - ✓ Hood : 16m^2

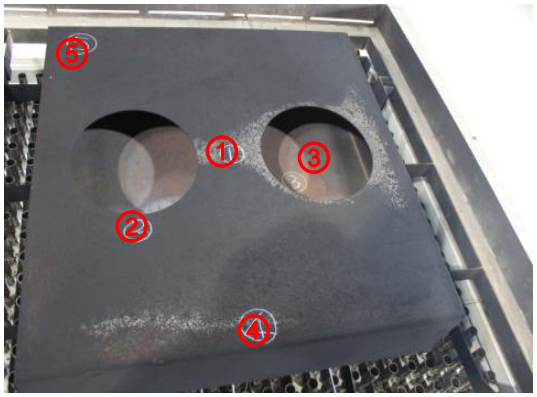
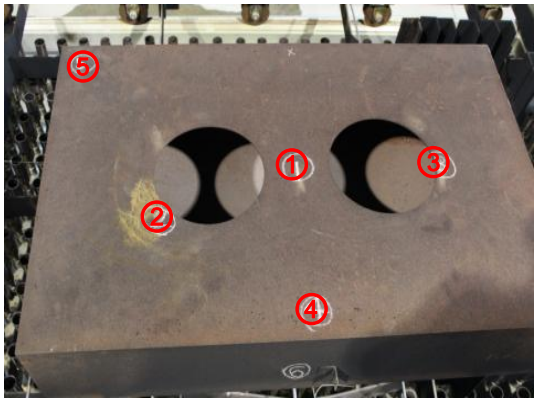
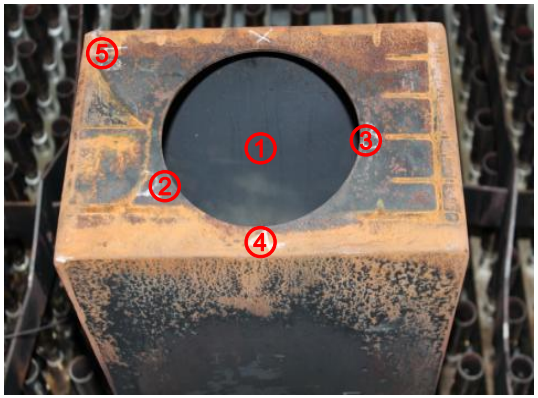
- Test configurations



Descriptions
* DUT(Mock-up) dimensions - Large : 1,000×1,000×200 mm, Floor area : 1 ㎡ - Medium : 920×605×206 mm, Floor area : 0.56 ㎡ - Small : 300×200×300 mm, Floor area : 0.06 ㎡
* DAQ get 5 temp. channel - Measuring point : 25±5mm from the bottom of DUT's outside surface by the vertical direction : 5 points - K-Type Thermocouple : ∅1.6mm

Progress Report of KATRI Research

- Horizontally 5 Temp. measuring points

		
1,000×1,000×200 mm, Floor area : 1 ㎡	920×605×206 mm, Floor area : 0.56 ㎡	300×200×300 mm, Floor area : 0.06 ㎡
< Large Size Mock-up >	< Medium Size Mock-up >	< Small Size Mock-up >

- Test condition
  - ✓ Measuring the flame temperature continuously for about 4 minutes from ignition
  - ✓ Ambient temperature : about 10 ℃

K-Type ∅1.6mm / 25±5mm from the bottom of DUT

< K-Type Thermocouple >

Progress Report of KATRI Research

● Test Result

● Procedure of test(A)

✓ Install the Tested-Device on the fire resistance test device by the horizontal to the ground.

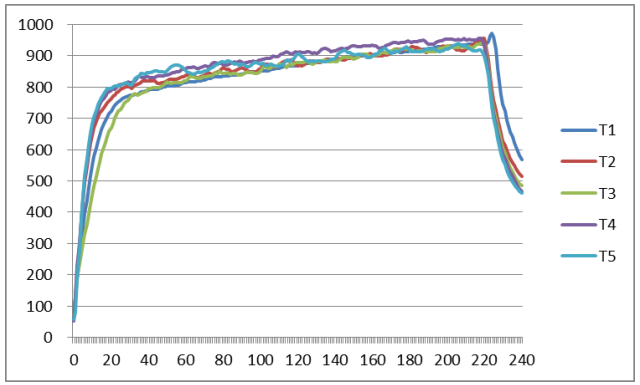
✓ Install 5 or more temperature sensors in the whole area of the Tested-Device can be represented with the height of 25mm±10mm from the bottom of the Tested-Device's external surface by the vertical direction.

✓ Heat the entire lower part of battery equally and directly through fuel combustion.

✓ Increase the temperature to 800°C within 30 seconds, cease the heating 2 minutes after reaching 800°C. Complete the test after 2 hours passes. However, the temperature shall not exceed 1100°C.

● Test scene and result

< Large Mock-up>

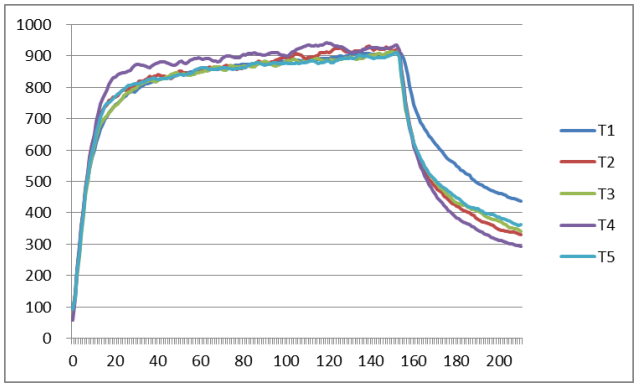


✓ Temp. distribution

- Avg. Temp. : 881 ℃
  (Ignition after 30 sec ~ Fuel cut)
- Max. Temp. : 955 ℃
- Height of flame : about 50 cm
- DUT setting Height : 31.5 cm
  (Nozzle to Bottom of DUT)

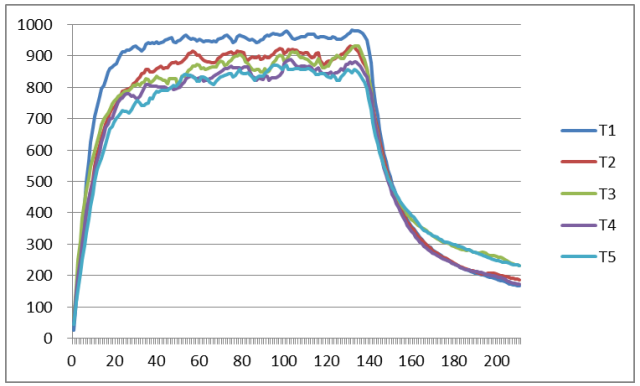
Progress Report of KATRI Research

< Medium Mock-up>



✓ Temp. distribution
- Avg. Temp. : 878 ℃
(Ignition after 30 sec ~ Fuel cut)
- Max. Temp. : 940 ℃
- Height of flame : about 50 cm
- DUT setting Height : 31.5 cm
(Nozzle to Bottom of DUT)

< Small Mock-up>



✓ Temp. distribution
- Avg. Temp. : 877 ℃
(Ignition after 30 sec ~ Fuel cut)
- Max. Temp. : 980 ℃
- Height of flame : about 50 cm
- DUT setting Height : 26 cm
(Nozzle to Bottom of DUT)

● Comment

- The modified test equipment satisfy temperature condition of Test(A) with all DUTs.
- The temperature distribution is regular with 5 points in case of large and medium mock-up tests.
- In case of small mock-up test, it is hard to satisfy test condition since too small exposure area.
  Lower the installation height of mock-up, it is possible to satisfy the temperature condition.

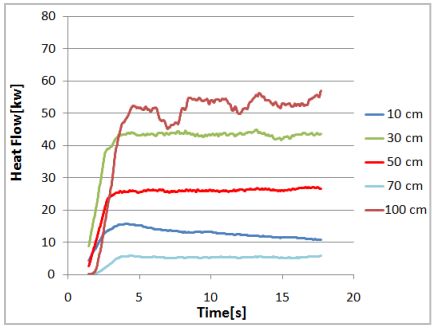
Progress Report of KATRI Research

Thermal energy comparison of test(A) with GTR draft(B)

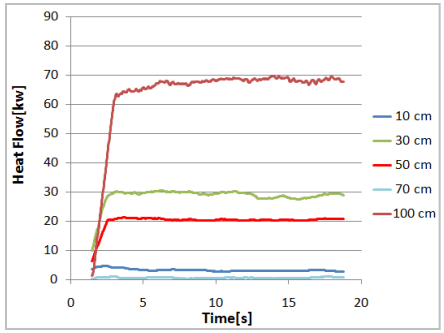
- Heat Flow by CFD simulation in the pool-burning and LPG Burner-Burning with Mockup

Test (A)	Heat Flow[kW]
Parameter	Direct exposure
Small Mockup	16.50
Large Mockup	117.99

Test (B)	Heat Flow[kW] at 50cm	
Parameter	Phase B	Phase C
Small Mockup	26	20
Large Mockup	160	105

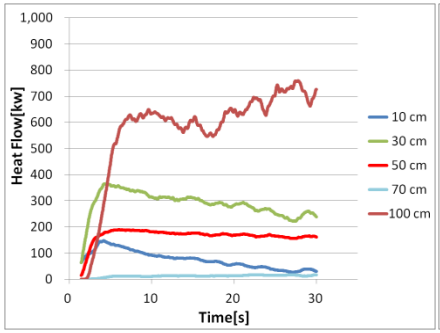


Phase B

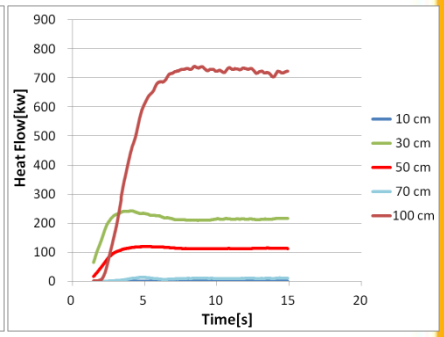


Phase C

<TEST(B) Small pool-burning CFD simulation result>



Phase B



Phase C

< TEST(B) Large pool-burning CFD simulation result>

<cf.> Heat flow is defined: $\dot{q} = \int c_p \rho (T - T_\infty)\mathbf{u} \cdot \mathrm{dS}$

where c_p is specific heat, T is temperature and pu•dS is mass flow rate.

Progress Report of KATRI Research

Thermal energy comparison of test(A) with GTR draft(B)

- Total Energy per unit area by CFD simulation

Test (A)	Direct exposure, 120[s]		Pre-heating30[s]	SUM
Parameter	Heat Flux [kW/m^2]	Thermal Energy [kJ/m^2]	Thermal Energy [kJ/m^2]	Total Energy [kJ/m^2]
Small Mockup	275	32,992	4,124	37,116
Large Mockup	118	14,158	1,770	15,928

☜ *800 ℃ Reaching Time*

Test (B)	Phase B, 70[s]		Phase C, 60[s]		SUM
Parameter	Heat Flux [kW/m^2]	Thermal Energy [kJ/m^2]	Heat Flux [kW/m^2]	Thermal Energy [kJ/m^2]	Total Energy [kJ/m^2]
Small Pool	433	30,333	333	23,333	53,667
Large Pool	160	11,200	105	7,350	18,550

- Comment

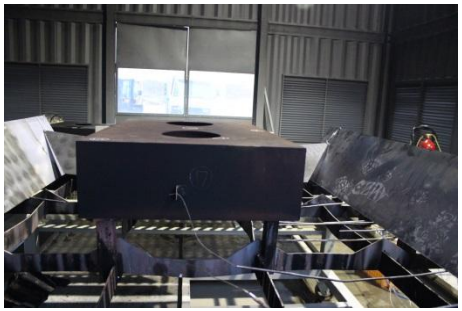
▪ The thermal energy per unit area of test (B) is 44% higher than test (A) for the small, and 16% higher than test (A) for the large

Progress Report of KATRI Research

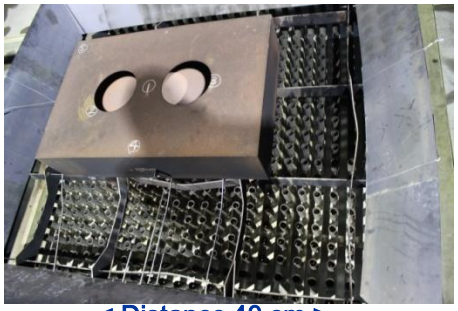
Mar. 2015

Exposure area test on test (A)

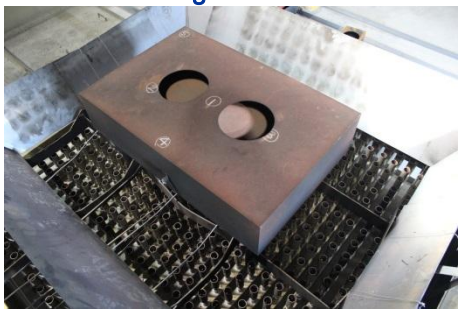
- Test configurations



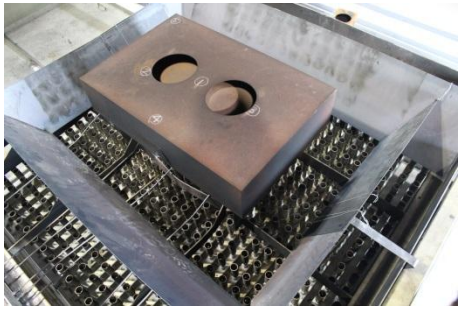
<Configuration>



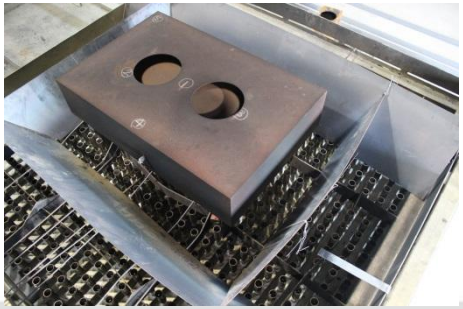
< Distance 40 cm >



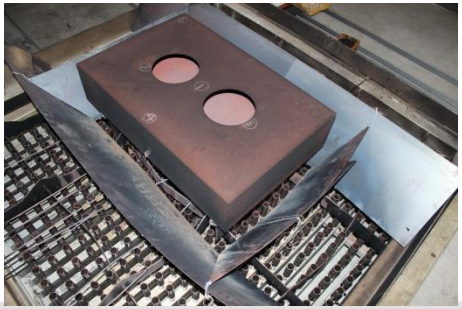
< Distance 30 cm >



< Distance 20 cm >



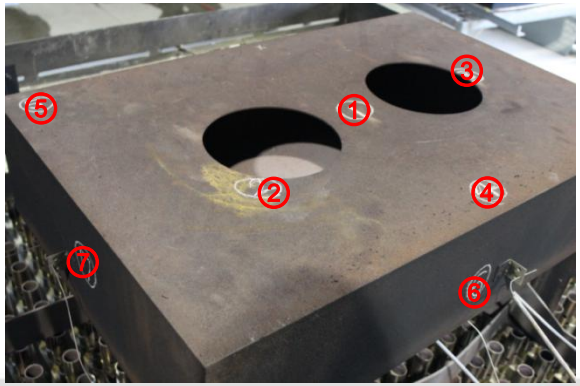
< Distance 10 cm >



< Distance 0 cm >

Descriptions
* DUT(Mock-up) - Medium : 920×605×206 mm, Floor area : 0.56 ㎡ - DUT setting Height : 31.5 cm *(Nozzle to Bottom of DUT)*
* DAQ get 7 temp. channels - Measuring point ・25±5mm from the bottom of DUT's outside surface by the vertical direction : 5 points ・25±5mm from the side of DUT's surface : 2 points - K-Type Thermocouple : ∅1.6mm
* Flame exposure area - 40, 30, 20, 10, 0 cm distance from DUT end

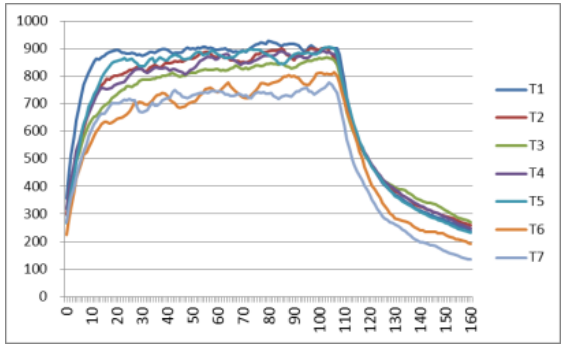
- Temp. measuring 7 points



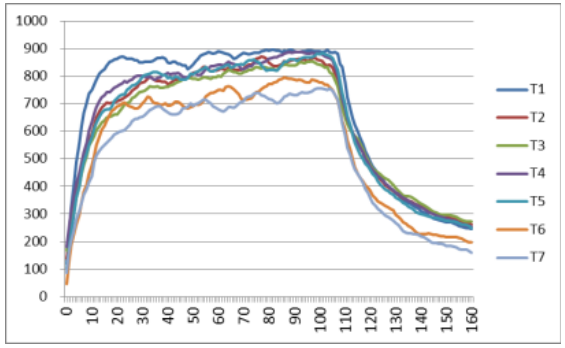
Progress Report of KATRI Research

● Test Result

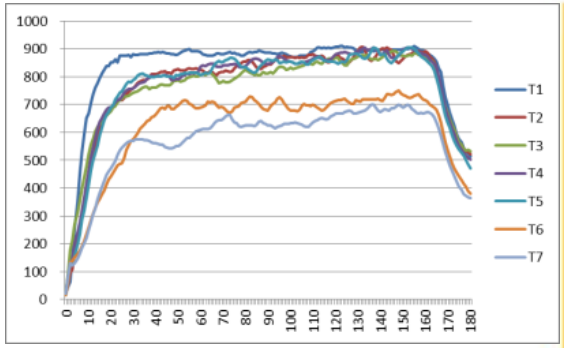
● Test Result



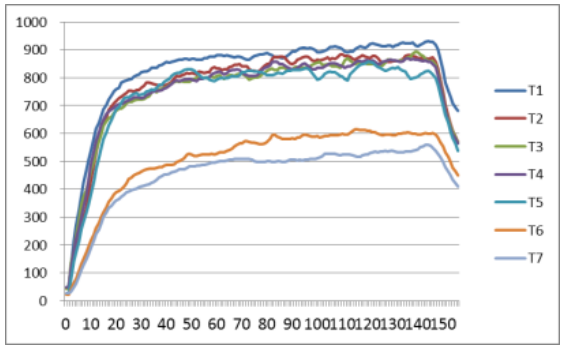
<Distance 40 cm>



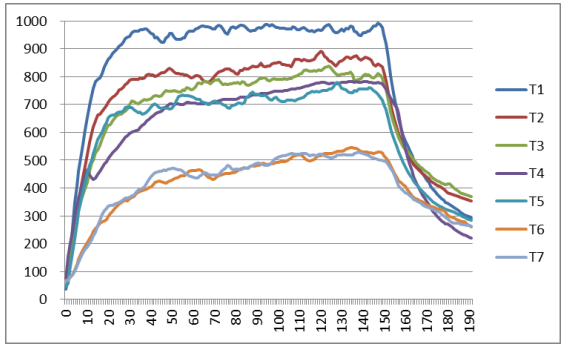
<Distance 30 cm>



<Distance 20 cm>



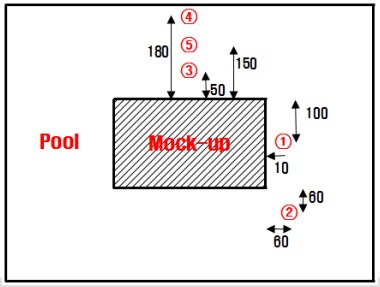
<Distance 10 cm>

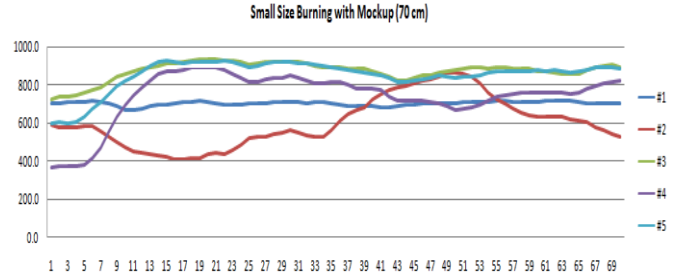


<Distance 0 cm>

Distance	Avg. Temp. (Bottom)	Avg. Temp. (Side)	Max. Temp.
40 cm	865 ℃	742 ℃	926 ℃
30 cm	836 ℃	724 ℃	895 ℃
20 cm	852 ℃	665 ℃	910 ℃
10 cm	839 ℃	533 ℃	932 ℃
0cm	804 ℃	476 ℃	992 ℃

✓ Result of KATRI's indoor fire resistance test (B)
<Apr. 2014>





✓ Temp. distribution(#1)
- Avg. Temp : 703 ℃
- Max. Temp : 717 ℃
- Min. Temp : 668 ℃

Progress Report of KATRI Research

- Comment

- The exposure area is smaller, the temperature is lower
- Especially, the temperature of side wall is highly influenced by the distance from DUT
- In case of Test(A) distance 40cm and 30cm, the average temp. of side wall(742 ℃, 724 ℃) are similar to the average temp. of side wall(703 ℃) of Test(B) which is performed last year.
- For stable test condition, recommended exposure area exceed at least 30cm from DUT end

Progress Report of KATRI Research

Component based internal temperature comparison test

Mar. 2015

- Test configurations

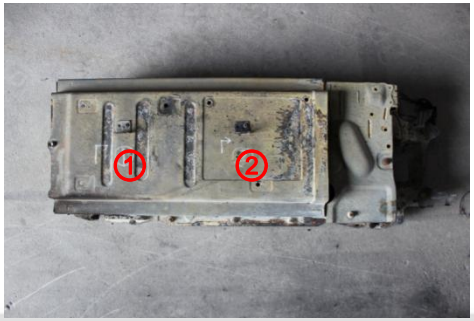
Test(A)-KMVSS	Test(B)-GTR Draft
	
	

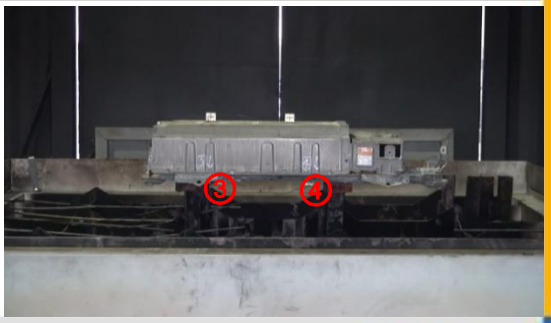
Descriptions

* DUT : PRIUS REESS Case
- Remove the battery cell and sub systems
- Size : 1011×387×225 mm
- DUT setting Height
  - TEST(A) : 31.5 cm *(Nozzle to bottom of DUT)*
  - TEST(B) : 50 cm *(Fuel surface to bottom of DUT)*

* DAQ get 4 temp. channels
- Measuring point
  - 25±5mm from the bottom of DUT's outside surface by the vertical direction : 2 points
  - Inside of DUT (Depth : 3cm) : 2 points
- K-Type Thermocouple : ∅1.6mm

- Temp. measuring 4 points
  - ①②: Inside
  - ③④: Outside (Bottom)

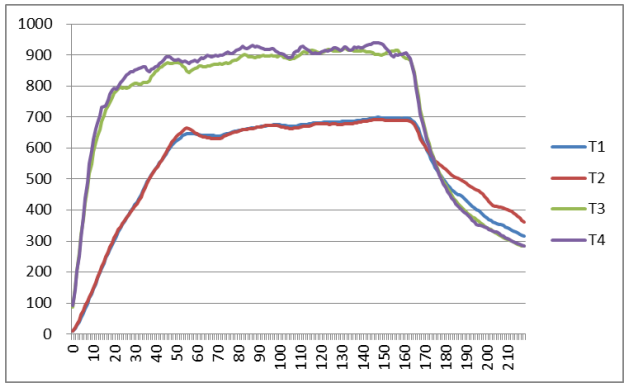




Progress Report of KATRI Research

● Test Result

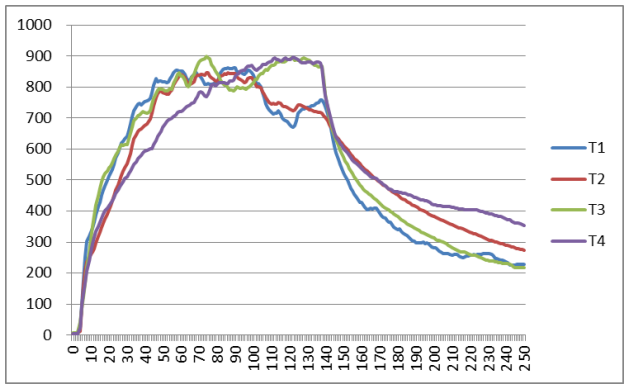
< TEST(A)>



✓ Temp. distribution

- Avg. Temp.*(150 sec from ignition)*
  - · Inside : 557 ℃
  - · Bottom : 838 ℃
- Max. Temp. : 938 ℃

< TEST(B)>



✓ Temp. distribution

- Avg. Temp.*(150 sec from ignition)*
  - · Inside : 678 ℃
  - · Bottom : 690 ℃
- Max. Temp. : 898 ℃

● Comment

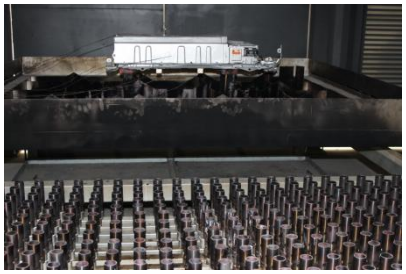
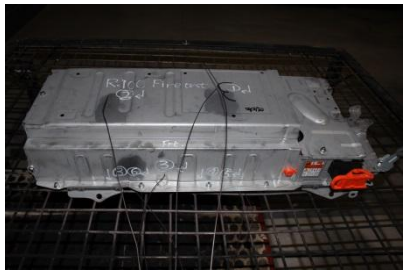
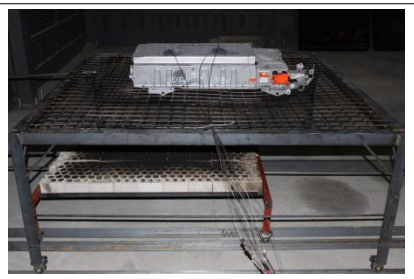
- These tests show the different temperature distribution of Test(A) and Test(B)
- Test(A)'s inside temperature remain about 670 ℃ while test(B) is 700-850 ℃
- This trend is caused by difference of thermal energy between Test(A) and Test(B)

Progress Report of KATRI Research

Component based fire resistance comparison test

- Test configurations

Mar. 2015

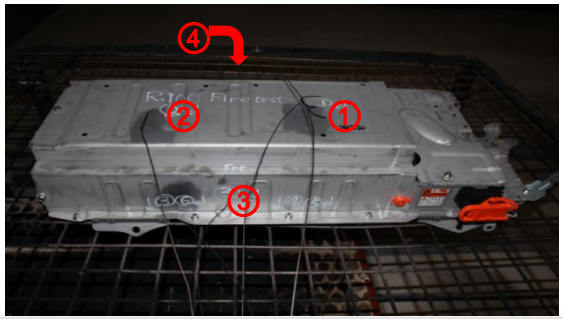
Test(A) - KMVSS	Test(B) - GTR Draft
	
	

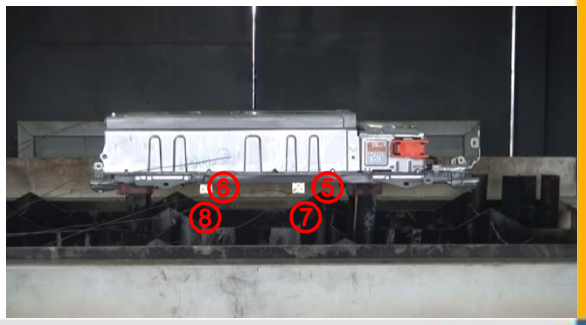
Descriptions

* DUT : PRIUS REESS
- Spec. : 201.6V, 6.5A, 6.5Ah / Weight : 41kg
- Usage SOC 88~18.4%, / Size : 1011×387×225 mm
- Setting SOC : 50%
- DUT setting height
  - TEST(A) : 31.5 cm *(Nozzle to bottom of DUT)*
  - TEST(B) : 50 cm *(Fuel surface to bottom of DUT)*

* DAQ get 8 temp. channels
- Measuring point
  - 25±5mm from the bottom of DUT's outside surface by the vertical direction : 2 points
  - Inside of DUT : 6 points
- K-Type Thermocouple : ∅1.6mm

- Temp. measuring 8 points
  - ①② : Inside (Top)
  - ③④ : Inside (Side)
  - ⑤⑥ : Inside (Bottom)
  - ⑦⑧ : Outside (Bottom)



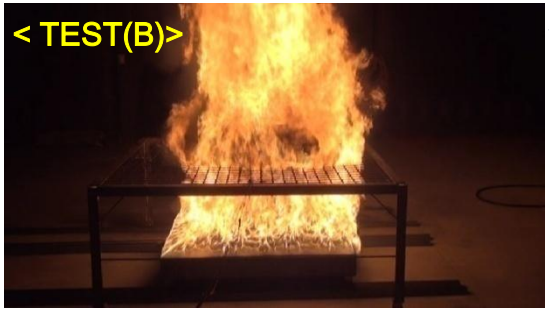


Progress Report of KATRI Research

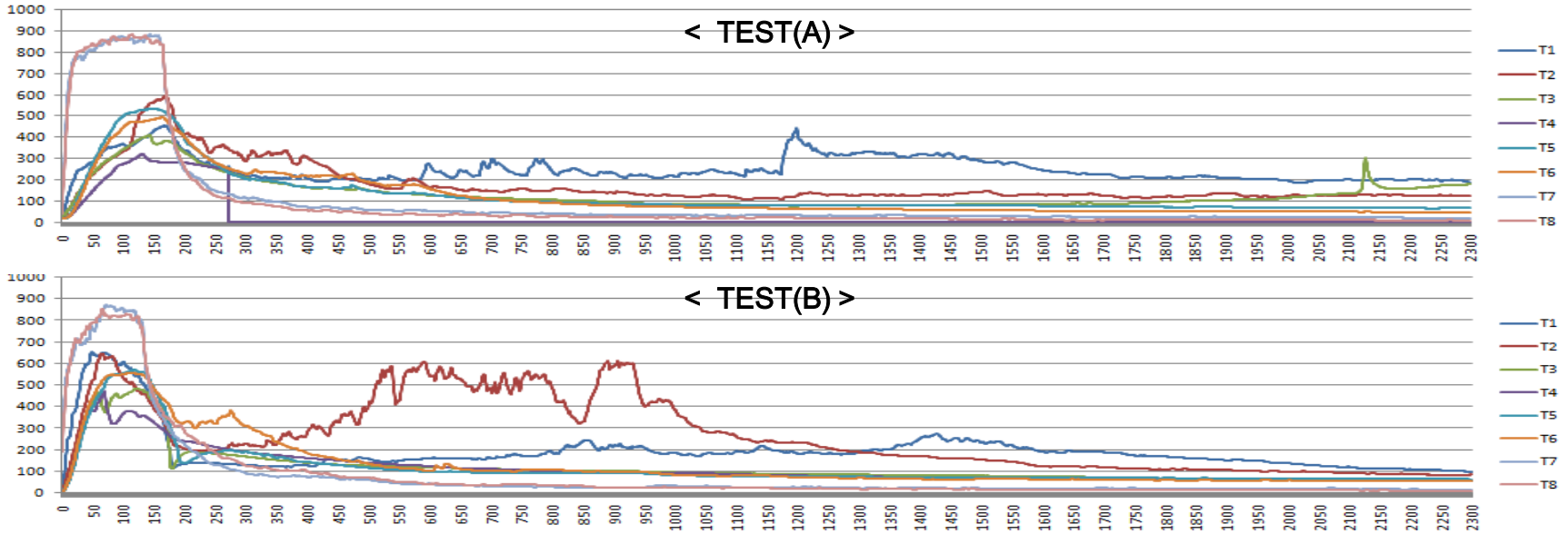
● Test Result

● Test Result

✓ Temp. distribution
- Avg. Temp. *(150 sec from ignition)*
  · Inside : 287 ℃
  · Bottom : 800 ℃
- Avg. Temp. *(40 min from ignition)*
  · Inside : 159 ℃
- Max. Temp. : 887 ℃



✓ Temp. distribution
- Avg. Temp. *(150 sec from ignition)*
  · Inside : 408 ℃
  · Bottom : 755 ℃
- Avg. Temp.*(40 min from ignition)*
  · Inside : 154 ℃
- Max. Temp. : 872 ℃



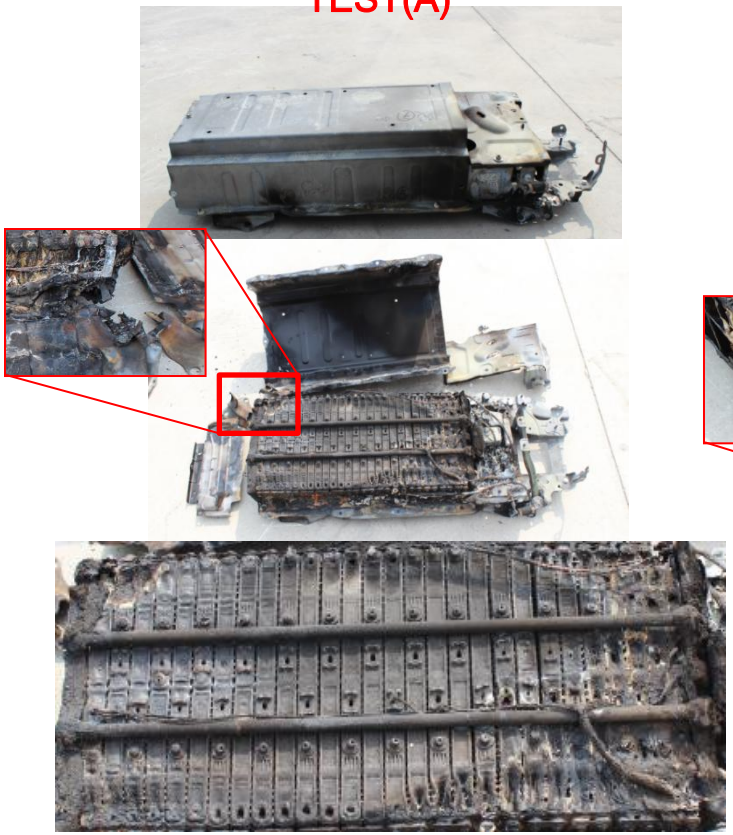
● Comment

- Test(B)'s inside temperature is 100-200 ℃ higher then Test(A) during fire exposure time
- After, both DUTs burn themselves until they burn out showing different temperature trend

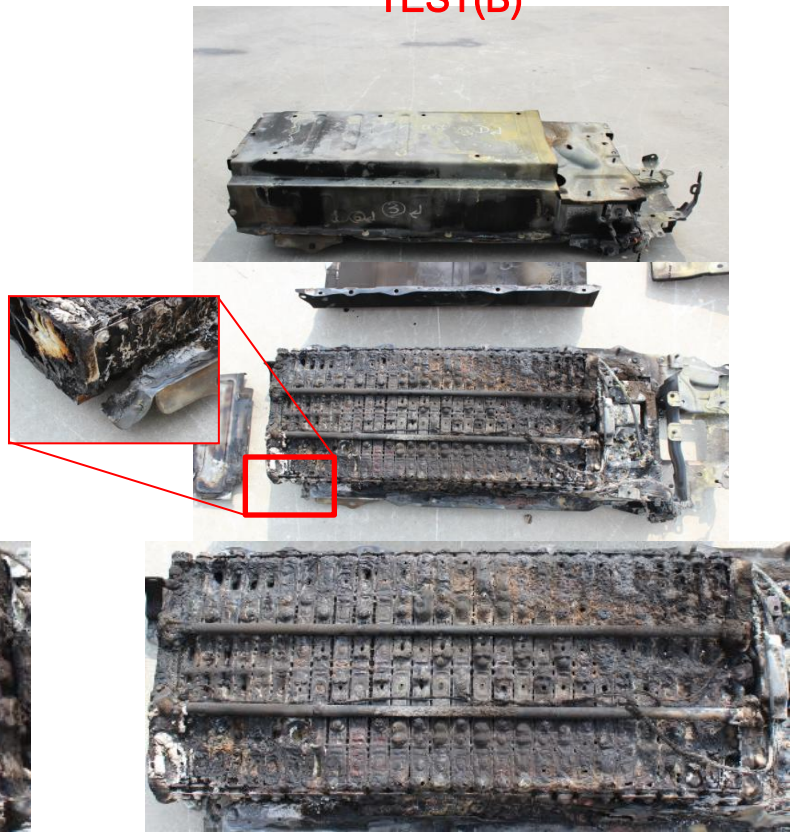
Progress Report of KATRI Research

- Inside appearance of DUT after test

TEST(A)



TEST(B)



- Comment

  - The DUT of Test(B) damaged more than Test(A) comparatively due to higher thermal energy
  - As seen in the video, the point where arcing happened is damaged more severely

Progress Report of KATRI Research

Vehicle based exposure temperature comparison test

Mar. 2015

- Test configurations

Test(A)-KMVSS	Test(B)-GTR Draft
	
	

Descriptions

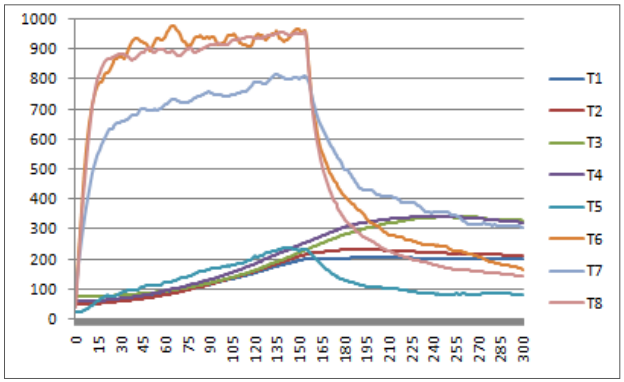
* DUT : PRIUS Body & REESS Case
- Body : Remove the combustible material in body
- REESS : Remove the battery cell and sub systems
- DUT setting Height
  - TEST(A) : 31.5 cm *(Nozzle to bottom of vehicle body)*
  - TEST(A') : Actual mounting condition
  - TEST(B) : Actual mounting condition

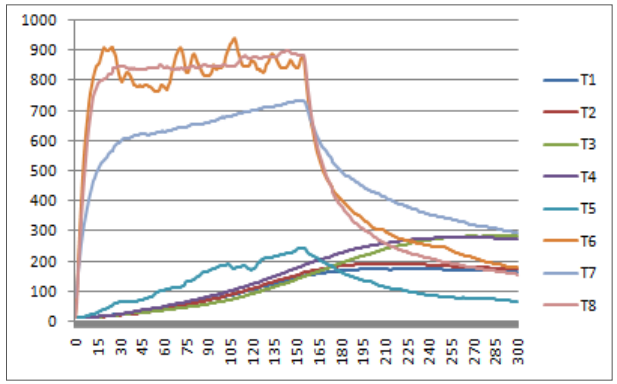
* DAQ get 8 temp. channel
- Measurement height : 25±5mm from the bottom of DUT's external surface by the vertical direction
- REESS Case : 4 points
- Vehicle body: 4 points
- K-Type Thermocouple : ∅1.6mm

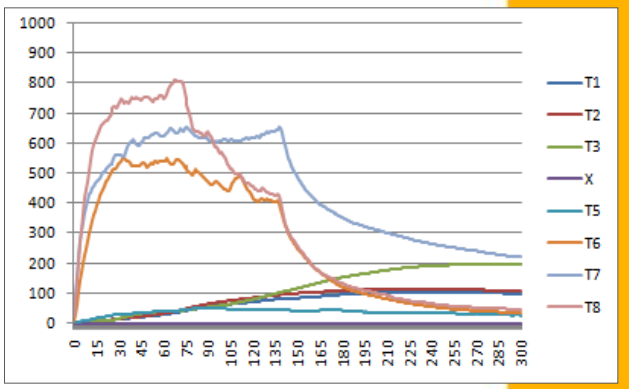
- Temp. measuring 8 points
  - ①② : Inside temp. (Case)
  - ③④ : Bottom temp. (Case)
  - ⑤ : Inside temp. (Body)
  - ⑥⑦⑧ : Bottom temp (Body)

Progress Report of KATRI Research

● Test Result







Measurement	TEST(A)	TEST(A')	TEST(B)
● Avg. Temp.	(For 150 sec)	(For 150 sec)	(For 130 sec)
- REESS Inside	109 ℃	64 ℃	37 ℃
- REESS Bottom	122 ℃	66 ℃	38 ℃
- Body inside	141 ℃	125 ℃	35 ℃
- Body Bottom(High)	693 ℃	617 ℃	570 ℃
- Body Bottom(Low)	872 ℃	813 ℃	537 ℃
● Max. Temp.	976 ℃	939 ℃	887 ℃

● Comment

- The temperature of Test(A) is about 100℃ higher than the Test(A')
- The temperature of Test(B) is lower than others due to its small exposure area
- The temperature of Test(A) around the bottom are irregular because the shape of vehicle's body frame is not flat at the bottom

Progress Report of KATRI Research

Comment for the test time - Enough time to evacuate

- **Golden Time**

From the fire started

- **Purpose of Fire resistance test**
  - ✓ To verify the resistance of the REESS, against exposure to fire from outside of the vehicle due to a fuel spill from a vehicle
  - ✓ Leave the driver and passengers with enough time to evacuate.
- **Vehicle fire test** : KATRI, Jun. 2010
  - ✓ Ignition point : Driver's seat

<BSI DD 180> Hazard of the major toxicity gas concentration (Unit : ppm)

Gas	2 min		5 min		30 min	
	Dyspnea	Die	Dyspnea	Die	Dyspnea	Die
$C0_2$	70,000 (7%)	150,000 (15%)	70,000 (7%)	100,000 (10%)	60,000 (6%)	100,000 (10%)
CO	12,500	40,000	5,000	16,000	1,000	3,000
HCl	1,000	40,000	1,000	16,000	200	3,000
HCN	200	400	150	300	50	100

- **Comment**
  - ✓ The initial condition of this test is somewhat less damaged which is ignited with small flame than fire test procedure in GTR draft
  - ✓ Wrapped in flame and smoke within 2 minutes
  - ✓ Toxic gases(CO_2, CO, HCl, HCN etc.) generated by burning the interior material
  - ✓ In case of vehicle fire, damaged severely by complex effect of heat, flame, gases than general fire condition
  - ✓ Hardly survived if a driver and passengers are in a coma or seriously injured so could not evacuate in 2 minutes.
  - ✓ Fire exposure time(USABC: 120sec, R34: 120sec R.100: 130sec) may be originated from these reason

Progress Report of KATRI Research

Comments for 'Fire resistance test'

- Result for KATRI indoor fire resistance Test(B)
  - ✓ This test shows a large deviation of flame temperature from 500℃ to 1000℃, according to measured positions at the same height.
  - ✓ The average temperature of center area at each height is a little bit higher then or similar to frame temperature of "Technical Justification No 45" on EVS GTR draft .
- Verify CFD analysis result of test(B)
  - ✓ The flame pattern and the temperature is similar to actual data of KATRI.
- CFD simulation result of test(A)
  - ✓ Develop an optimized solution of current test equipment of KATRI by CFD simulation.
- Modify the current test-equipment according to total optimization solution and performance test
  - ✓ Major specification of modified test equipment are nozzle spacing 75 mm, number of nozzle 625EA, LPG mass flow rate minimum 150 kg/h and height of flame about 50 cm.
  - ✓ The modified test equipment satisfy temperature requirement of Test(A) with 3 performance test conditions(Large, medium and small mock-up).

Progress Report of KATRI Research

- The thermal energy per unit area of test (B) is 44% higher than test (A) for the small mock-up condition, and 16% higher than test (A) for the large.
- For stable test condition of test(A), recommended exposure area exceed at least 30cm from DUT end.
- At the component based internal temperature and fire resistance comparison test, test(B)'s inside temperature is about 100~200 ℃ higher than test(A) caused by difference of thermal energy.
- At the vehicle based exposure temperature comparison test, the exposure temperature of test(B) is lower than test(A) because of small exposure area.
- It is possible to perform vehicle based test with equipment for test(A), but some area at the bottom doesn't satisfy the temperature condition(up to 800 ℃) because of shape of vehicle body. If the test(A) apply to vehicle based test, need to consider about flame temp. additionally.
- Vehicle based test is more suitable than component based test for simulating exposure to fire from outside of the vehicle due to a fuel spill from a vehicle which is purpose of GTR draft.
- But vehicle based test could not represent all real fire situation perfectly.
  For example, the test procedure requires to remove a combustible material in vehicle.

Progress Report of KATRI Research

- Both test condition of component based test are much more severe than vehicle based test condition.
- Actually according to the test result, there is huge difference in temperature condition between component and vehicle based test. If performing vehicle based test with REESS, it may not have damage as low temperature.

- Component based test(max. temp.	- Vehicle based test
◦Test(A) : DUT inside 699℃ , DUT bottom 920℃	◦Test(A) : DUT inside 154 ℃, DUT bottom 178 ℃
◦Test(B) : DUT inside 862℃ , DUT bottom 898℃	◦Test(B) : DUT inside 88 ℃, DUT bottom 89 ℃

(Maximum temperature during the period of exposure to the flame)

- It is more important to verify the equivalency between component and vehicle based test than the equivalency between Test(A) and Test(B).
- A repeatability is one of crucial factor for compliance test in Self-certification system.
- Therefore, Test(A) is suitable to apply to GTR as an alternative component based fire resistance test procedure which shows regular temperature distribution and good repeatability.

Thank you!