A STUDY ON FIRE RESISTANCE TEST PROCEDURE FOR TRACTION BATTERY

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ABSTRACT

Market share of electrically propelled vehicle are increasing due to high oil prices and environmental concerns. These electrically propelled vehicles demand to ensure high safety of electric energy storage system, high voltage system and mechanical structure which is equivalent to existing ICE vehicle.
Due to these social demands, global organizations like UN/ECE and ISO are under discussion to make the safety test specification of Lithium-battery, one of rechargeable energy storage systems. KATRI also have researched and developed KMVSS which is for electrically propelled vehicles since 2006, and seven traction battery safety tests have been issued and conducted since 2009. Fire resistance test is to confirm whether traction battery could withstand the intended fire for 2 minutes which is minimum time for evacuating driver and passengers from burning car. This test is considered one of important traction battery safety tests.
In this study, current KMVSS traction battery fire resistance test, draft of ECE R-100 RESS fire resistance test in outside and draft of GTR/SGS-test procedure for hydrogen storage fire test were comparatively analyzed. Subsequently, this study proposed new fire resistance test procedure for traction battery with verification.

INTRODUCTION

In this study, fire tests were conducted with commercialized traction battery or Mock-up.
To check how much of fire heat transferred, metal shielded K-type thermocouples were set up in various position. Position of thermocouples is considered to confirm fire heat profile in each X-Y-Z planes.
To check explosion as a test criteria, visible inspection were carried out with video recording. First test was the current KMVSS fire resistance test. It took more than 5 minutes until stable heat of 890 ~ 900 ℃ was maintained. Secondly, draft of ECE R-100 fire resistance test in outside used commercial fuel for positive-ignition engines (gasoline) and flame temperature was about 700 ℃ at the bottom of DUT. Thirdly, draft of GTR/SGS- hydrogen storage fire test was suitable to meet test flame temperature of 600 ~ 1100 ℃. Three fire tests had impressive characters which are wide temperature fluctuation window, control hardness belonging to gasoline as a fuel and suitability to meet test fire temperature.
This study proposes optimized traction battery fire resistance test as a results of comparative test analysis. This optimized test using LPG direct injecting method to attain test temperature easily heats whole bottom area of DUT. Also, this test procedure has another merit which is relatively short time to maintain test temperature condition. After verifying this optimized fire resistance test, KATRI plans on proposing the draft amendment of KMVSS test procedure to the government and UN/ECE GTR/EVS informal group.

KMVSS Article 18-3. Traction Battery

The necessity of the legislation for safety standards of traction battery came to the fore since HEV were propagated to public organizations and provincial governments in the capital region by Ministry of Environment, 2004.

Ministry of Land, Transport and Maritime Affairs consigned KATRI the government project and KATRI carried out research on the development of safety-Assessment Procedures for HEV from October, 2006 to September, 2008.

During this project, KATRI conducted research on not only traction battery, but also all aspects of Hybrid vehicles. Furthermore, we drew deficiencies of the then safety standards and submitted a complement to safety standard proposals. Consequently, Korean government revised the KMVSS 8 Articles in Jan 2009. At this time, revision articles were Definitions, Motor and Transmission System, Brake System, Fuel System, Motor Power and EMC. And newly inserted High voltage electric device and Traction Battery. And Revised the seven test Procedures according to revision of KMVSS in Feb. 2009.

Table1.
Summary of KMVSS related the traction battery

Article	Description
Article 2 Definition	"Traction Battery" means the storage of electrical energy to propel a vehicle
Article 18-3 Traction Battery (RESS)	General Structural Requirements Traction batteries in a vehicle shall meet each of the following requirements. 1. The batteries shall be isolated from the wall or guard plate. 2. They shall be equipped with functions to prevent an overcharge or over-current exceeding the range specified in the design. 3. Traction batteries shall be free of the possibility for fire or explosion that can take place in physical, chemical, electrical, and thermal shock conditions as notified by the Minister of Land, Transport and Maritime Affairs.

Table2.
Summary of KMVSS test procedure for traction battery safety(Annex 1 -Part 48)

Test	Procedure	Specimen	Criteria
Drop	Drop from 4.9 m high	package or system	Fire & Explosion
Immersion	Immerse completely in the sea water	package or system	Fire & Explosion
Over - charge	Charge up to 150% SOC	System	Fire & Explosion
Over - discharge	Discharge with 1C rate	System	Fire & Explosion
Short circuit	Closed circuit with total resistance of 50 mΩ or less for 1 hour	System	Fire & Explosion
Heat Exposure	Exposed to 80 ℃ heat for 4 hour	package or system	Fire & Explosion
Fire Resistance	Exposed to flame of 890 to 900℃ for 2 min.	package or system	Explosion

KMVSS Test Procedure Annex 1.48. Traction Battery Safety Test
48.6.7 Fire Resistance Test

1. Test purpose

The purpose of current KMVSS fire resistance test is to confirm the safety of traction battery to secure an evacuation time for driver and passengers when vehicle is on fire. Test procedures are as follows.

2. Test procedures

The following requirements and conditions shall apply to the test

(a) Discharge the traction battery completely at room temperature and then charge until target SOC with rated current.

(b) At the beginning of the test, the SOC shall be adjusted to a value in the maximum charged SOC among the vehicle normal operating range. however, if there is no standardized SOC, the SOC shall be adjusted to a value in the 80 percent.

(c) Measure the voltage of traction battery.

(d) The traction battery shall be placed on the test equipment and then bottom area of the traction battery shall be directly heated by flames.

(e) Set the flame temperature at 890℃ to 900℃ shall be maintained for 2 minutes.

(f) Check the explosion of traction battery during the test and then measure the voltage of traction battery after the test

3. Review

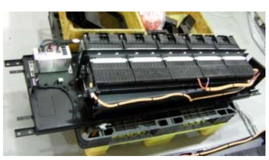
The component of fire resistance test equipment in KATRI is as shown Figure1. Combustion method of this equipment is a top open burner type which maintains a flame temperature of 890℃ to 900℃ by supply of LPG and air with PID control.

Figure1. Fire resistance test equipment and test scene according to current KMVSS test procedure

The current procedure of KMVSS fire resistance test is appropriate for a small scale of HEV traction battery when a flame temperature is adjusted and a test specimen is placed on the test equipment. However, a problem comes up when EV traction battery is tested, because it is so large and heavy that a test specimen is hard to be placed on the test equipment. Also, a flame temperature is difficult to adjust because top of the burner is open. Consequently, KATRI recognized the need of the revision on the current test procedure and examined the validity of the application of ECE R-100 fire resistance test draft and GTR/HFCV-SGS Hydrogen Storage Fire Test procedure.

Table3 shows traction batteries for EV which are currently under the mass production and development in Korea.

Table3.
Example of traction battery specification of electric vehicle in Korea

Appearance	specification
	RAY (M1) Li-ion 1.7×1.1×0.3m , 300kg 360v, 75Ah
	SM3 Z.E. (M1) Li-polymer 1.3×0.7×0.8m, 250kg 360v, 65Ah
	ELEC-CITY (M3) Li-polymer Sub Pack. 1.5×0.9×0.4m , 150kg, 380v, 250Ah
	E-PRIMUS (M3) Li-polymer Sub Pack. 1.65×0.7×0.5m, 320kg, 613v, 140Ah
	QTPE-BUS (M3) Li-ion 1.9×1.1×0.5m, 620kg 591V, 70Ah

Draft of ECE R-100 Fire Resistance Test

This test procedure, based on existing ECE R-34 ["Uniform provisions concerning the approval of vehicles with regard to the prevention of fire risks" / 5. Requirements for liquid fuel tanks / Annex 5. Testing of fuel tanks made of a plastic material / Appendix 1 Test of resistance to fire], was suggested by SP Technical Research Institute of Sweden. Test procedures are as follows.

1. Test purpose

The purpose of draft of ECE R-100 fire resistance test procedure is to verify the resistance of the REESS, against exposure to fire from outside of the vehicle due to e.g. a fuel spill from a vehicle (either the vehicle itself or a nearby vehicle). This situation should leave the driver and passengers with enough time to evacuate. Test procedures are as follows.

2. General test conditions

The following requirements and conditions shall apply to the test:

(a) the test shall be conducted at a temperature of at least 0 °C,

(b) at the beginning of the test, the SOC shall be adjusted to a value in the upper 50 percent of the normal operating SOC range,

(c) at the beginning of the test, all protection devices which effect the function of the Tested-Device and are relevant for the outcome of the test shall be operational.

3. Test procedures

A vehicle based test or a component based test shall be performed at the discretion of the manufacturer:

(a) Vehicle based test

The Tested-Device shall be mounted in a testing fixture simulating actual mounting conditions as far as possible; no combustible material should be used for this with the exception of material that is part of the REESS. The method whereby the Tested-Device is fixed in the fixture shall correspond to the relevant specifications for its installation in a vehicle. In the case of a REESS designed for a specific vehicle use, vehicle parts which affect the course of the fire in any way shall be taken into consideration.

(b) Component based test

The Tested-Device shall be placed on a grating table positioned above the pan, in an orientation according to the manufacturer's design intent.

The grating table shall be constructed by steel rods, diameter 6-10 mm, with 4-6 cm in between. If needed the steel rods could be supported by flat steel parts.

The flame to which the Tested-Device is exposed shall be obtained by burning commercial fuel for positive-ignition engines (hereafter called "fuel") in a pan. The quantity of fuel shall be sufficient to permit the flame, under free-burning conditions, to burn for the whole test procedure. The fuel temperature shall be ambient temperature.

The fire shall cover the whole area of the pan during whole fire exposure. The pan dimensions shall be chosen so as to ensure that the sides of the Tested-Device are exposed to the flame. The pan shall therefore exceed the horizontal projection of the Tested-Device by at least 20 cm, but not more than 50 cm. The sidewalls of the pan shall not project more than 8 cm above the level of the fuel at the start of the test.

The pan filled with fuel shall be placed under the Tested-Device in such a way that the distance between the level of the fuel in the pan and the bottom of the Tested-Device corresponds to the design height of the Tested-Device above the road surface at the unladen mass if paragraph (1) is applied or approximately 50 cm if Paragraph (2) is applied. Either the pan, or the testing fixture, or both, shall be freely movable.

During phase C of the test, the pan shall be covered by a screen. The screen shall be placed 3 cm +/- 1 cm above the fuel level measured prior to the ignition of the fuel. The screen shall be made of a refractory material, as prescribed in Annex. There shall be no gap between the bricks and they shall be supported over the fuel pan in such a manner that the holes in the bricks are not obstructed. The length and width of the flame shall be 2 cm to 4 cm smaller than the interior dimensions of the pan so that a gap of 1 cm to 2 cm exists between the flame and the wall of the pan to allow ventilation. Before the test the screen shall be at least at the ambient temperature. The firebricks may be wetted in order to guarantee repeatable test conditions.

If the tests are carried out in the open air, sufficient wind protection shall be provided and the wind velocity at pan level shall not exceed 2.5 km/h.

The test shall comprise of three phases B-D, if the fuel is at least at temperature of 20 °C. Otherwise the test shall comprise four phases A–D.

(a) Phase A: Pre-heating (Figure 2)

The fuel in the pan shall be ignited at a distance of at least 3 m from the Tested-Device. After 60 seconds pre-heating, the pan shall be placed under the Tested-Device. If the size of the pan is too large to be moved without risking liquid spills etc. then the Tested-Device and test rig can be moved over the pan instead.

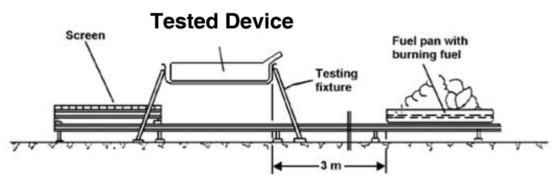


Figure 2. Phase A: Pre-heating

(b) Phase B: Direct exposure to flame (Figure 3)

The Tested-Device shall be exposed to the flame from the freely burning fuel for 70 seconds.

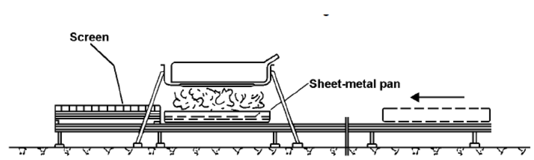


Figure 3. Phase B: Direct exposure to flame

(c) Phase C: Indirect exposure to flame (Figure 4)

As soon as phase B has been completed, the screen shall be placed between the burning pan and the Tested-Device. The Tested-Device shall be exposed to this reduced flame for a further 60 seconds.

Instead of conducting Phase C of the test, Phase B may at the manufacturer's discretion be continued for an additional 60 seconds.

However this shall only be permitted where it is demonstrable to the satisfaction of the Technical Service that it will not result in a reduction in the severity of the test.

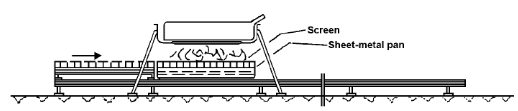


Figure 4. Phase C: Indirect exposure to flame

(d) Phase D: End of test (Figure 5)

The burning pan covered with the screen shall be moved back to the position described in phase A. No extinguishing of the Tested-Device shall be done. After removal of the pan the Tested-Device shall be observed until such time as the surface temperature of the Tested-Device has decreased to ambient temperature or has been decreasing for a minimum of 3 hours.

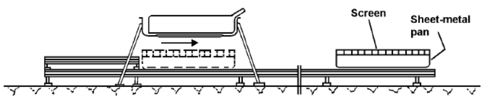


Figure 5. Phase D: End of test

4. Review

As examined previously, ECE R-100 fire resistance test procedure is very complicated compared to KMVSS.

KATRI participated in UN/ECE WP29 RESS informal meeting to amend ECE R-100 and suggested our opinions to make fire resistance test carried out outside because currently KATRI does not have an indoor facility for fire resistance test.

Figure 6 shows vehicle based fire resistance test scene according to the draft of ECE R-100 by SP Technical Research Institute of Sweden at 3rd RESS informal meeting in April, 2011.

Figure 6. Fire resistance test scene according to the draft of ECE R-100(vehicle based)

Draft of ECE R-100 Fire Resistance Test in Outside

1. Test purpose

KATRI verified whether Fire Resistance Test in outside was possible or not according to fire resistance test procedure specified in the draft of ECE R-100. For the test, Mock-up DUT fitted to the size of NEV traction battery was manufactured and the dimension of pan, type of fuel, quantity of fuel and wind velocity condition for outdoor test were set up to satisfy requirements of the draft of ECE R-100. Moreover, the test was carried out under the condition of only direct exposure to flame. Verification of the temperature distribution and problems in test procedure was achieved by measuring the temperature of eight points around DUT.

2. Test Configurations

Figure 7 and Table 4 shows the dimension of DUT and pan, temperature measuring point and wind speed measuring point for the test.

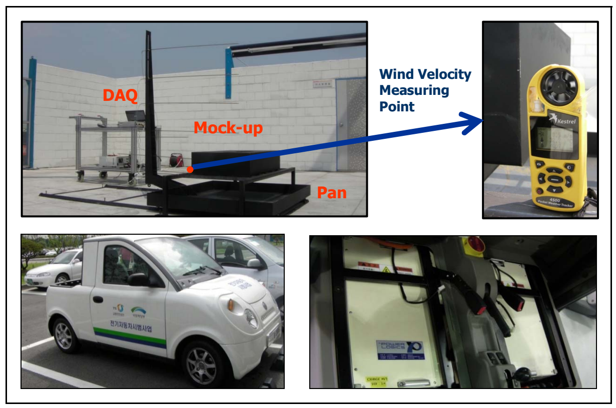


Figure 7. Test Configurations

Table4.
Test conditions of ECE R-100 Fire Resistance Test in Outside

Test conditions
• Mock-up simulates real DUT size : 920 x 605 x 206 mm
• DAQ get 8 temp. channels
- Under the DUT (center & side)
- Middle of DUT (external)
- 200, 500, 800, 1100 mm above the DUT
• Pan exceed the horizontal projection of the every DUT side by 25 cm (Draft : 20 ~ 50 cm)
• K-type sheath Thermocouple(3.2 mm)
• Initial ambient temp : 32.2 ℃
• Wind speed : about 0.5 m/sec (Draft : not exceed 2.5 km/h(= 0.69 m/sec))
• Fuel quantity : 25 lit./m^2

3. Test Result

This tests are carried out only direct exposure to flame condition according to draft of ECE R-100 fire resistance test procedure in outside. Test procedure and Temp. Data were acquired for 120 sec. Test scene and results of each points measuring flame temperature are as follows.

Figure 8. Fire resistance test scene according to draft of ECE R-100 in Outside

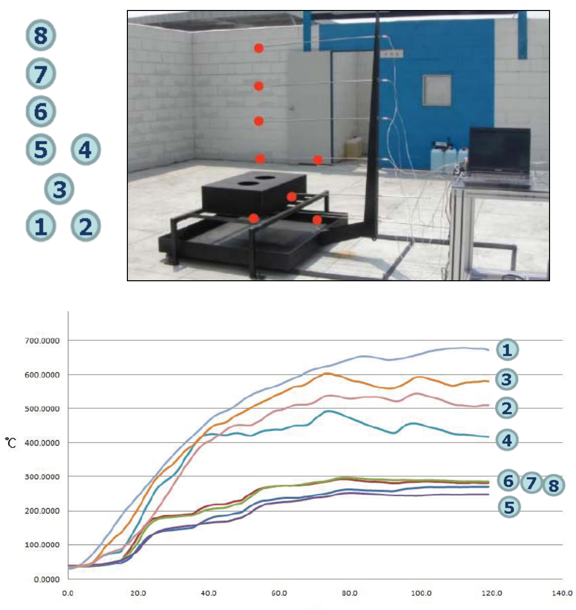


Figure 9. Flame temperature at each point

4. Review

Despite of the weak wind, temperature curve cannot be easily stabilized. Even if initial wind velocity is lower than draft limitation, heat generated by flame causes turbulence due to the evaporation rate and difference of thermal distribution. In this test, reasonable flame temperature data could not be acquired because of turbulence except just one point. It is #1 point (in Figure 9) that located at the bottom of DUT. Average temperature was about 700 ℃ during the test. This temperature is very important to decide the heating condition on the draft amendment of KMVSS fire resistance test procedure.

As a test result, KATRI recognized the difficulty of doing the test according to the draft of ECE R-100 fire resistance test procedure in outside. If we adopt the draft, then KATRI and vehicle or battery manufacturer have to construct an explosion proof facility for indoor test including a large ventilation and emission and waste water disposal facility with an enormous expense.

Draft of GTR/HFCV-SGS HYDROGEN FUELED VEHICLE "Test Procedures for Service Terminating Performance in Fire"

1. Test purpose

This regulation specifies safety-related performance requirements for hydrogen-fueled vehicles. The purpose of this regulation is to minimize human harm that may occur as a result of fire, burst or explosion related to the vehicle fuel system and/or from electric shock caused by the vehicle's high voltage system. Test procedures are as follows.

2. Definitions

The hydrogen container assembly consists of the compressed hydrogen storage system with additional relevant features, including the venting system (such as the vent line and vent line covering) and any shielding affixed directly to the container (such as thermal wraps of the container(s) and/or coverings/barriers over the TPRD(s)).

Either one of the following two methods are used to identify the position of the system over the initial (localized) fire source:

Method I: Qualification for a Generic (Non-Specific) Vehicle Installation

If a vehicle installation configuration is not specified (and the qualification of the system is not limited to a specific vehicle installation configuration) then the localized fire exposure area is the area on the test article farthest from the TPRD(s). The test article, as specified above, only includes thermal shielding or other mitigation devices affixed directly to the container that are used in all vehicle applications. Venting system(s) (such as the vent line and vent line covering) and/or coverings/barriers over the TPRD(s) are included in the container assembly if they are anticipated for use in any application. If a system is tested without representative components, then retesting of that system is required if a vehicle application specifies the use of these type of components.

Method 2: Qualification for a Specific Vehicle Installation

If a specific vehicle installation configuration is specified and the qualification of the system is limited to that specific vehicle installation configuration, then the test setup may also include other vehicle components in addition to the hydrogen storage system. These vehicle components (such as shielding or barriers, which are permanently attached to the vehicle's structure by means of welding or bolts and not affixed to the storage system) must be included in the test setup in the vehicle-installed configuration relative to the hydrogen storage system This localized fire test is conducted on the worst case localized fire exposure areas based on the four fire orientations: fires originating from the direction of the passenger compartment, cargo/luggage compartment, wheel wells or ground-pooled gasoline.

In addition, the container is subjected an engulfing fire without any shielding components as described in paragraph "Engulfing fire test".

3. Test conditions

The following test requirements apply whether Method 1 or 2 (above) is used:

(a) The container assembly is filled with compressed hydrogen gas at 100 percent of NWP. The container assembly is positioned horizontally approximately 100 mm above the fire source.

Localized Portion of the Fire Test

(b) The localized fire exposure area is located on the test article furthest from the TPRD(s). If Method 2 is selected and more vulnerable areas are identified for a specific vehicle installation configuration, the more vulnerable area that is furthest from the TPRD(s) is positioned directly over the initial fire source.

(c) The fire source consists of LPG burners configured to produce a uniform minimum temperature on the test article measured with a minimum 5 thermocouples covering the length of the test article up to 1.65m maximum (at least 2 thermocouples within the localized fire area, and at least 3 thermocouples equally spaced and no more than 0.5 m apart in the remaining area) located 25 mm + 10 mm from the outside surface of the test article along its longitudinal axis. At the option of the manufacturer or testing facility, additional thermocouples may be located at TPRD sensing points or any other locations for optional diagnostic purposes.

(d) Wind shields are applied to ensure uniform heating.

(e) The fire source initiates within a 250 mm + 50 mm longitudinal expanse positioned under the localized exposure area of the test article. The width of the fire source encompasses the entire diameter (width) of the storage system. If Method 2 is selected, the length and width shall be reduced, if necessary, to account for vehicle-specific features.

(f) As shown in Figure 10, the temperature at the thermocouples in the localized fire area are increased continuously to at least 600 ℃ within 3 minutes of ignition, and a temperature of at least 600 ℃ is maintained for the next 5 minutes. The temperature in the localized fire area shall not exceed 900 ℃ during this period. Compliance to the thermal requirements begins 1-minute after entering the period with minimum and maximum limits and is based on a 1-minute rolling average of each thermocouple in the region of interest. (Note: The temperature outside the region of the initial fire source is not specified during these initial 8 minutes from the time of ignition.)

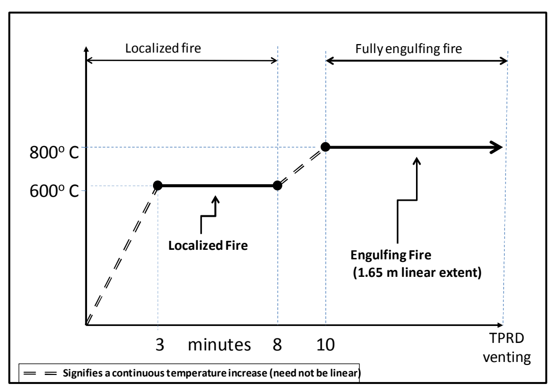


Figure 10. Profile of the flame temperature

4. Test Procedures

Engulfing Portion of the Fire Test

(g) Then within the next 2-minute interval, the temperature along the entire surface of the test article shall be increased to at least 800 ℃ and the fire source is extended to produce a uniform temperature along the entire length up to 1.65 meters and the entire width of the test article (engulfing fire). The minimum temperature is held at 800 ℃, and the maximum temperature shall not exceed 1100 ℃. Compliance to the thermal requirements begins 1-minute after entering the period with constant minimum and maximum limits and is based on a 1-minute rolling average of each thermocouple.

(h) The test article is held at temperature (engulfing fire condition) until the system vents through the TPRD and the pressure falls to less than 1 MPa. The venting must be continuous (without interruption), and the storage system must not rupture. An additional release through leakage (not including release through the TPRD) that results in a flame with length greater than 0.5 m beyond the perimeter of the applied flame must not occur.

5. Review

KATRI applied the above test to hydrogen storage tank of hydrogen fuel cell vehicle being developed through "Research on the development of safety-Assessment Procedures for HFCV" and the following picture shows hydrogen storage fire test equipment and test scene.

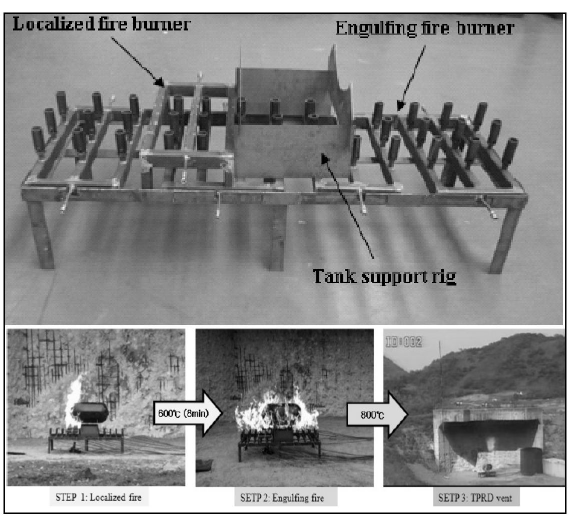


Figure 11. GTR/SGS-hydrogen storage fire test equipment and the test scene

Furthermore, KATRI paid attention to the combustion process and flame temperature control of GTR/SGS-test procedure for hydrogen tank in fire for the amendment of fire resistance test procedure of KMVSS traction battery as fire resistance test in outside was difficult on conditions according to the draft of ECE R-100.

As a result, it was possible to keep 800~1100 ℃ of flame temperature control as being able to regulate LPG and air content, be less influenced by wind as LPG was injected by a nozzle, and immediately extinguish the fire by fuel cut-off valve. Also, the speed of evaporation and difference of thermal distribution did not occur.

Draft Amendment of KMVSS Test Procedure

KATRI reflected flame temperature control of GTR/SGS-test procedure for hydrogen tank in fire to draft amendment of KMVSS test procedure and developed the test equipment verifying the measurement of temperature distribution and operational problems.

1. Test procedures

(a) The traction battery shall be placed on the test equipment. The traction battery shall be horizontal.

(b) The number of temperature sensors shall be at least 5. The sensor locations shall be representative locations which cover the whole area of traction battery. The sensor shall be placed 25 ± 10 mm downward from the bottom of traction battery.

(c) Whole bottom area of traction battery shall be uniformly heated by flames.

(d) Temperature shall reach 800 ℃ within 30 sec from ignition. Flames with temperature of 800 ℃ shall be maintained for 2 minutes, after that fuel supply shall be stopped. After 2 hours from the stop of fuel supply, the test shall be terminated. The temperature of flames shall not exceed 1100 ℃.

(e) Check the explosion of traction battery during the test.

2. Development of the test equipment

The dimension of the flame part for fire resistance test equipment was manufactured 2m x 2m in order that pack unit test for a large size of EV traction battery should be possible.

In addition, fire resistance test equipment was structurally possible to move into the flame part after the preparation of a test specimen so that the installation of a test specimen was easy and the interval of nozzles supplying LPG and air simultaneously was placed densely so that temperature should reach over 800 ℃ sufficiently. Moreover, detachable windbreak was installed to minimize wind effects and it was possible to extinguish the fire from control station by remote ignition and a cut off of fuel supply. Figure 12 represents the developed fire resistance test equipment.

Figure 12. Fire resistance test equipment according to the draft amendment of KMVSS test procedure

3. Test result

After manufacturing fire resistance test equipment, K-type thermocouple (1.5mm) was installed on five measurement points which could represent the whole dimension of a test specimen at the position of 25 mm from the bottom of a test specimen for mock-up fire resistance test.

Mock-up DUT was moved into the flame part and then, the temperature of all five points reached 800 ℃, which is the lowest limit of flame temperature, within 14 sec from supply of LPG and ignition and flames with temperature of 800 ℃ was maintained, satisfying the test conditions. The overall average temperature recorded 914℃ and the maximum flame temperature was 1052℃ until the stop of fuel supply.

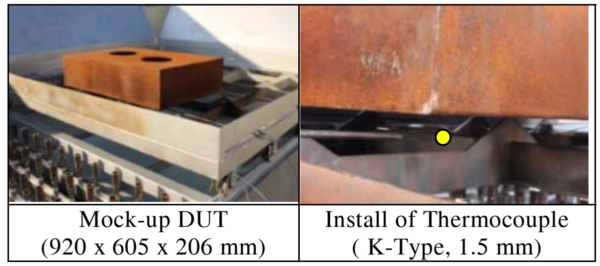


Figure 13. Test Configurations

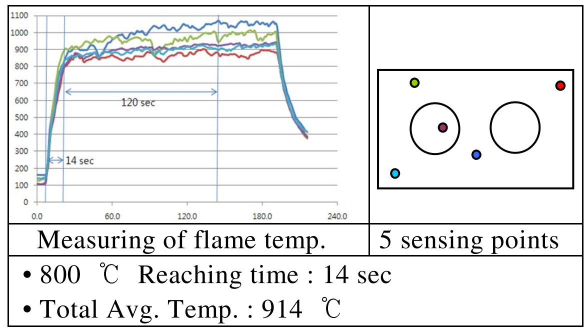


Figure 14. result of each points measuring flame temperatures

4. Review

Consequently, problems of the current KMVSS fire resistance test procedure, such as placement of large traction battery for EV and adjustment of a flame temperature, were completely resolved through the draft amendment of KMVSS fire resistance test procedure. And the developed test equipment satisfied the test conditions in regard to the draft amendment of test procedure.

CONCLUSIONS

The current procedure of KMVSS fire resistance test is appropriate for a small scale of HEV traction battery when a flame temperature control is adjusted and a test specimen is placed on the test equipment. However, a problem comes up when EV traction battery is tested, because it is so large and heavy that a test specimen is hard to be placed on the test equipment. Also, a flame temperature is difficult to adjust because top of the burner is open.

Consequently, KATRI recognized the need of the revision on the current test procedure and examined the validity of the application of ECE R-100 fire resistance test draft and GTR/HFCV-SGS Hydrogen Storage Fire Test procedure.

As examined previously, ECE R-100 fire resistance test procedure is very complicated compared to KMVSS.

KATRI carried out test according to draft of ECE R-100 fire resistance test procedure in outside and recognized difficulty to test by the draft. Despite of the weak wind, temperature curve could not be easily stabilized. Even though initial wind speed was lower than draft limitation, heat generated by flame caused turbulence due to the evaporation rate and difference of thermal distribution. However, reasonable flame temperature was acquired about 700 ℃ at the bottom of DUT in this test.

If ECE R-100 draft was adopted, then KATRI and vehicle or battery manufacturer have to construct an explosion proof indoor test facility including a large ventilation, emission and waste water disposal facility with an enormous expense.

KATRI performed test to hydrogen storage tank of hydrogen fuel cell vehicle being developed through "Research on the development of safety-Assessment Procedures for HFCV"

KATRI reflected flame temperature condition of GTR/SGS-test procedure for hydrogen tank in fire to the draft amendment of KMVSS test procedure. Major contents are heating temperature condition (800 ℃ ~ 1100 ℃), number of measuring point (at least 5) and DUT setting method. This heating temperature condition is more severe than ECE R-100 draft. And KATRI developed the test equipment through verifying conditions of flame temperature.

Consequently, problems of the current KMVSS fire resistance test procedure, such as placement of large traction battery for EV and adjustment of a flame temperature, were completely resolved through the draft amendment of KMVSS fire resistance test procedure. And the developed test equipment satisfied the test conditions in regard to the draft amendment of test procedure.

Lastly, KATRI proposes the test procedure according to Draft amendment of KMVSS which is simple, effective and economically viable while achieving the purpose of fire resistance test.

ACKKNOWLEDGEMENT

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