

Development and Characteristics of a Burner for Localized Fire Tests and an Evaluation of Those Fire Tests

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ABSTRACT

We have developed a new propane burner that satisfies the requirements of localized fire test which was presented in SAE technical paper 2011-01-0251. This paper introduces the specifications of this burner and reports its characteristics as determined from various fire exposure tests that we conducted in order to gather data. These tests included temperature and heat flux distribution on cylinder surfaces, which would be useful for the design of automotive compressed fuel cylinders. Our fire exposure tests included localized and engulfing fire tests to compare TPRD activation time, cylinder burst pressure and other parameters between different flame configurations and tests to identify the effects of an automotive compressed fuel cylinder on localized fire test results.

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INTRODUCTION

An automotive compressed fuel cylinder is fitted with a thermal pressure relief device (TPRD) to prevent explosion in the event of a fire. This is a safety device which detects the heat of fire and releases gas from inside the cylinder into the atmosphere. Cylinders used for compressed natural gas vehicles (CNGV) are required to undergo fire exposure tests in which the entire cylinder is heated (hereafter "engulfing fire exposure test") to verify its fire resistance. Application of these tests is also under consideration for automotive hydrogen cylinders.

However, a total of 26 CNGV cylinder accidents occurred during the period 2000-2008, of which about half were fire-related accidents. Some of the fire-related accidents were considered to have been caused by a localized fire positioned opposite to the thermally activated pressure relief device (TPRD), indicating the need to examine the effects of localized fires that cover only part of the cylinder.¹⁾ Transport Canada and NHTSA conducted research on localized fire tests to study bench test methods and mitigation devices. The SAE Fuel Cell Safety Working Group has

developed a proposal for a localized fire test, and this proposed procedure is presented in Reference 1.

A propane burner is used in these localized fire tests as the fire source as it is necessary to control the heated area and the temperatures of specified measurement points on the cylinder surface as time passes. However, the specifications of the gas burner to be used in these tests, including for its structure, have not been stipulated, and this may cause variations in the test results among different testing laboratories. Moreover, when localized fire tests are introduced, it will be impossible to give feedback concerning the fire-resistant design of the cylinder if the characteristics of the burner to be used are unknown.

The objective of the present study is to develop a new propane burner that satisfies the requirements of these localized fire tests. This paper introduces the specifications of this burner and reports characteristics, such as temperatures and heat flux distribution on the cylinder surface when exposed to fire, which would be useful for the design of fuel cylinders. Our fire exposure tests included localized and engulfing fire tests to compare TPRD activation time, cylinder burst pressure and other parameters between different flame configurations and to identify the effects of an

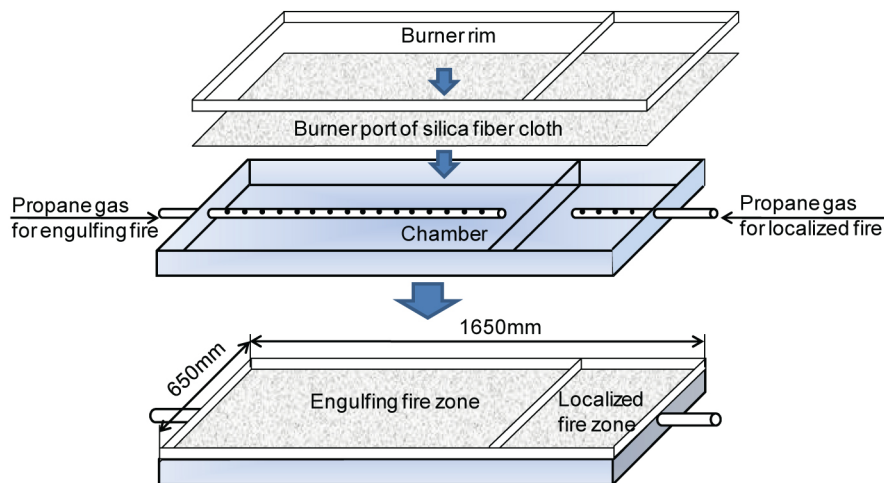


Figure 2. Main components of the propane burner

automotive compressed fuel cylinder on localized fire test results.

TEST METHOD

Localized fire exposure tests have not been formally established as of present. For the purposes of this paper, the temperature-time profile shown in Figure 1 is used to define localized fire tests and tests were carried out based on this profile.

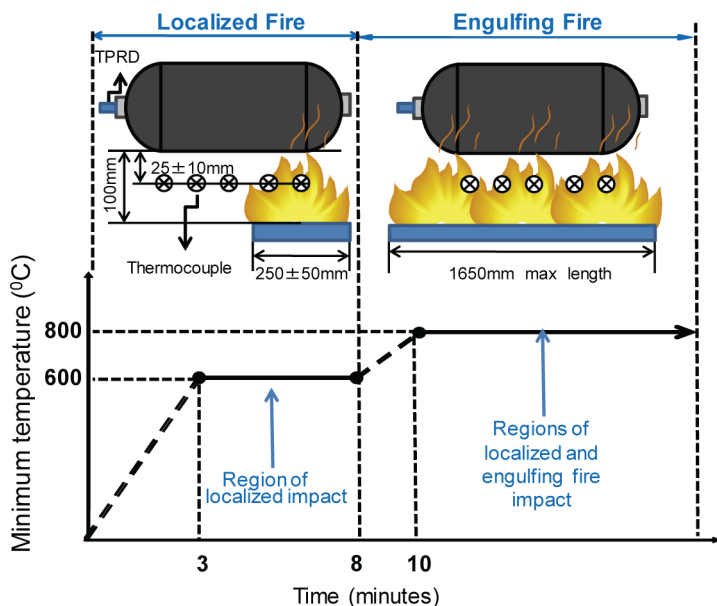


Figure 1. localized fire test method in this study¹⁾

The present study applied a localized fire mode for the first 8 minutes (minutes 0 to 8) and an engulfing fire mode from minute 8 onward. The temperatures shown in the figure above are measured using five or more thermocouples (two or more in the localized fire zone, and three or more in other zones at regular intervals of no more than 20 cm) installed

25±10 mm below the cylinder bottom (hereafter “thermocouple temperature of burner flame”).

In the localized fire mode, a fire source was placed farthest away from the TPRD fitted on the cylinder. The flame length of the localized fire measured 250±50 mm. The thermocouple temperature of the burner flame rose to 600°C or higher during the first 3 minutes, and the same temperature was maintained throughout minutes 4 to 8.

After the end of the first 8-minute period, the localized fire mode was shifted to an engulfing fire mode with a maximum flame length of 1,650 mm. The thermocouple temperature of the engulfing fire's burner flame surged to 800°C or higher by minute 10, after which the same temperature was maintained until the end of the test. The test was considered to have terminated when the TPRD activates and the cylinder's inner pressure subsequently declined to no more than 1 MPa.

BURNER FOR THE LOCALIZED FIRE TEST

We developed a propane burner that satisfies the heating conditions of the localized fire test. Figures 2 and 3 schematize the composition of the new burner and its fuel feeding system.

The propane burner comprises a) a chamber sectioned into a localized fire zone and an engulfing fire zone, b) burner ports of silica fiber cloth, and c) a burner rim. In the localized fire mode, the fuel line for localized fire was opened to produce flames in the localized fire zone alone. In the engulfing fire mode, the above fuel line was shut, and instead the fuel line for engulfing fire was opened to supply propane gas to and produce flames in both the localized and engulfing fire zones.

The primary characteristic of this burner is the use of burner ports made of silica fiber cloth (continuous heat resistance temperature: 1,000°C; thickness: 0.81 mm; weight: 807 g/m²) which ejects propane gas from the plethora of gaps

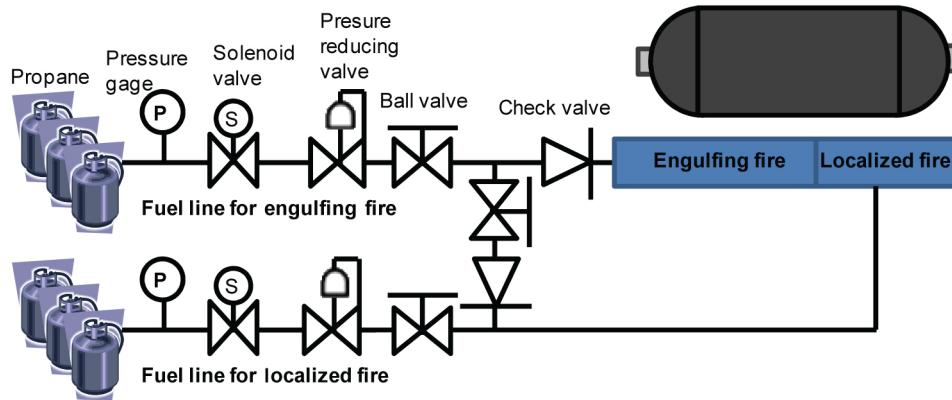


Figure 3. Fuel feeding system for the burner

that exist among the silica fibers, enabling the uniform heating that is required by the localized fire test. Among the other characteristics of the new burner, the burner can change the length of engulfing fire using a steel sheet placed over the silica fiber cloth, it has a simple structure with a small manufacturing cost, its cylinder fixing jig facilitates the adjustment of cylinder position and it can use test cylinders of different lengths and diameters.

Figure 4 shows the condition of the new burner with a cylinder in its test position, and Figure 5 the appearance of the test apparatus in the localized and engulfing fire modes.



Figure 4. Propane burner for localized fire test

BURNER FOR THE LOCALIZED FIRE TEST

To determine the characteristics of the propane burner that we had developed, a localized fire test was conducted under prescribed conditions in order to measure the thermocouple temperatures of the burner flame, as well as the temperature distribution and heat flux of the cylinder surface.

THERMOCOUPLE TEMPERATURES OF BURNER FLAME

To investigate if the propane burner could satisfy the thermocouple temperature of burner flame conditions for the localized fire test, a total of 9 thermocouples were installed, all 25 mm below the bottom of the cylinder as shown in Figure 6.

A steel cylinder of 300 mm in diameter and 800 mm in length was employed. Four temperature measurement points were set in the localized fire zone, and the remaining 5 points in the engulfing fire zone. The test was performed according to the conditions given in Figure 1. Namely, the cylinder was heated in the localized fire mode from minutes 0 to 8, after which the engulfing fire mode took over for an additional 4 minutes. Figure 7 shows the measurement results of the 9 thermocouples.



Figure 5. Appearances in the different fire modes