HYDROGEN VEHICLE FUEL SYSTEMS – LOCALIZED FIRE PROTECTION CONSIDERATIONS

Milestone 4

CYLINDER TEST VALIDATION REPORT

Submitted To:

Transport Canada
Road Safety

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1.0 INTRODUCTION

A localized fire test apparatus was constructed to meet the vehicle fire test conditions defined by OEM test data (see Figure 1). The localized fire test apparatus is designed to allow the testing of tanks with valve-mounted thermally-activated pressure relief devices (TPRDs). The intention is for the valve/TPRD end of the tank to be located in the ambient temperature condition (Section A in Figure 1). If a second TPRD is used on the opposite tank end, then that end is subjected to some amount of heating (Section C of Figure 1).

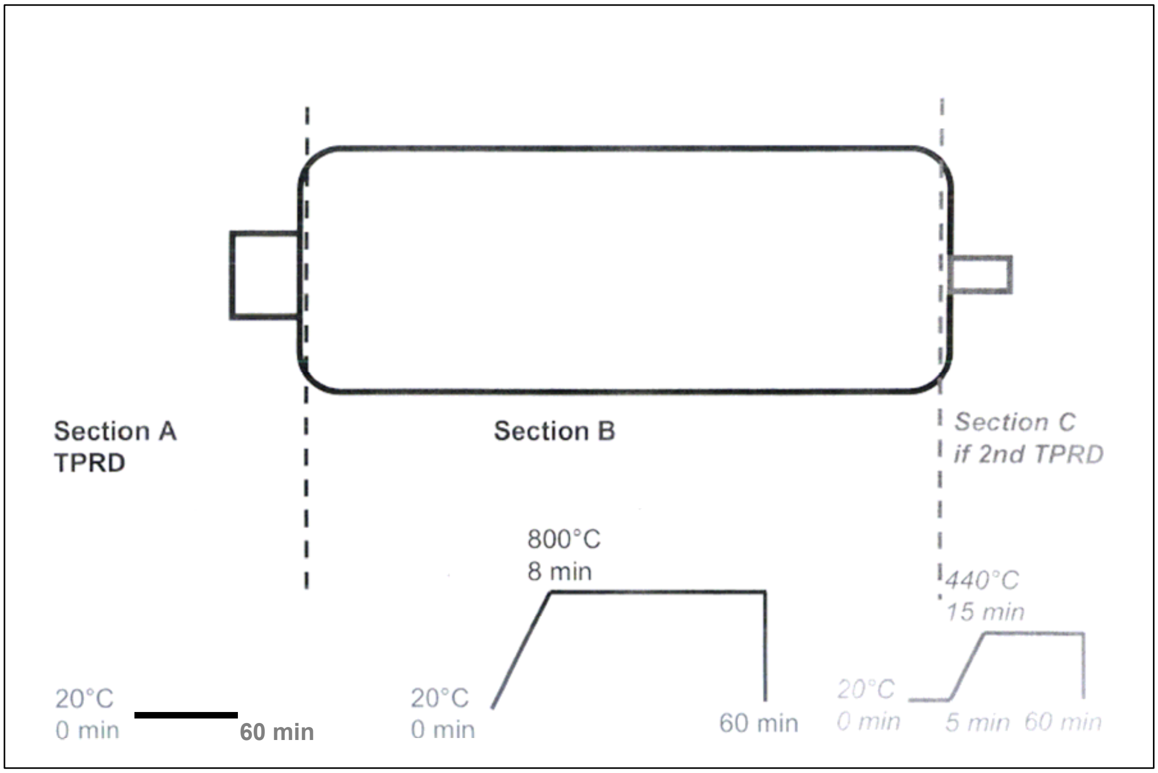

Figure 1 – Localized fire test temperature profiles

The localized fire test apparatus that was developed to achieve the required temperatures within the required time used a heated metal plate in contact with the fuel tank surface sidewall (see Figure 2). For the valve end, metal "prongs" were extended from the metal plate to transfer the required heat (see Figure 3). The purpose of using the metal plate is to allow close control of the temperature.

Temperatures on the sidewall were measured using thermocouples inserted in groves cut into the metal plate, between the plate and the tank surface (see Figure 4). Similarly, for the valve end a thermocouple is located between the "prong" and the valve surface.

Figure 2 – Overall view of localized fire test apparatus

Figure 3 – Temperature transfer “prongs” for the valve end

Figure 4 – Thermocouple locations in the metal plate.

2.0 TEST PROGRAM

The apparatus was tested in the field on two hydrogen tanks, one unpressurized, and the other pressurized with hydrogen. The unpressurized tank was a Pressed Steel Tank Type II design (24.8 MPa service pressure), with a steel liner hoop-wrapped with carbon fibre reinforcement. The test set-up (illustrated in Figure 5) was for the purpose of demonstrating that the temperature profiles could be achieved. For this reason, the tanks were tested with the valve/TPRD located in an area of heating (Section C of Figure 1), since it was apparent to anyone with bonfire test experience that the pressurized tank would rupture if the TPRD was placed in the ambient air condition (Section A of Figure 1). It was also unknown if a TPRD located in the medium heat area (Section C of Figure 1) would activate before the tank portion exposed to the higher test temperatures (Section B of Figure 1) would rupture.

Figure 5 – Test of Type II tank using oxy-propane burners on sidewall and propane torch on valve end.

The pressurized tank test was conducted using a Dynetek Type III design (20 MPa working pressure), with an aluminum liner fully-wrapped with carbon fibre reinforcement. The tank was protected by a TPRD made by VTI (glass bulb design) mounted on the valve end.

The test was initially performed with the tank pressurized to 14.5 MPa with hydrogen. However, the failure of a hose connection to the propane burner necessitated termination of the test. The pressure in the tank was reduced to 4.5 MPa for safety reasons, and the test was repeated (see Figure 6).

Figure 6 – Fire test of the Dynetek hydrogen tank.

3.0 TEST RESULTS

The test on the unpressurized tank confirmed the ability of the localized fire test apparatus to achieve the required temperature – time profile on the tank sidewall. In Figure 7, temperature (T-1, T-2 & T-3) on the tank sidewall reached 800°C within about 5 minutes, and was closely controlled to that temperature. The heating of the valve end (T-4) commenced after 5 minutes into the test, and reached 440°C after about 15 minutes. While this result did not meet the target of 440°C in 10 minutes, it was believed that a higher propane flow-rate would achieve the 10 minute time.

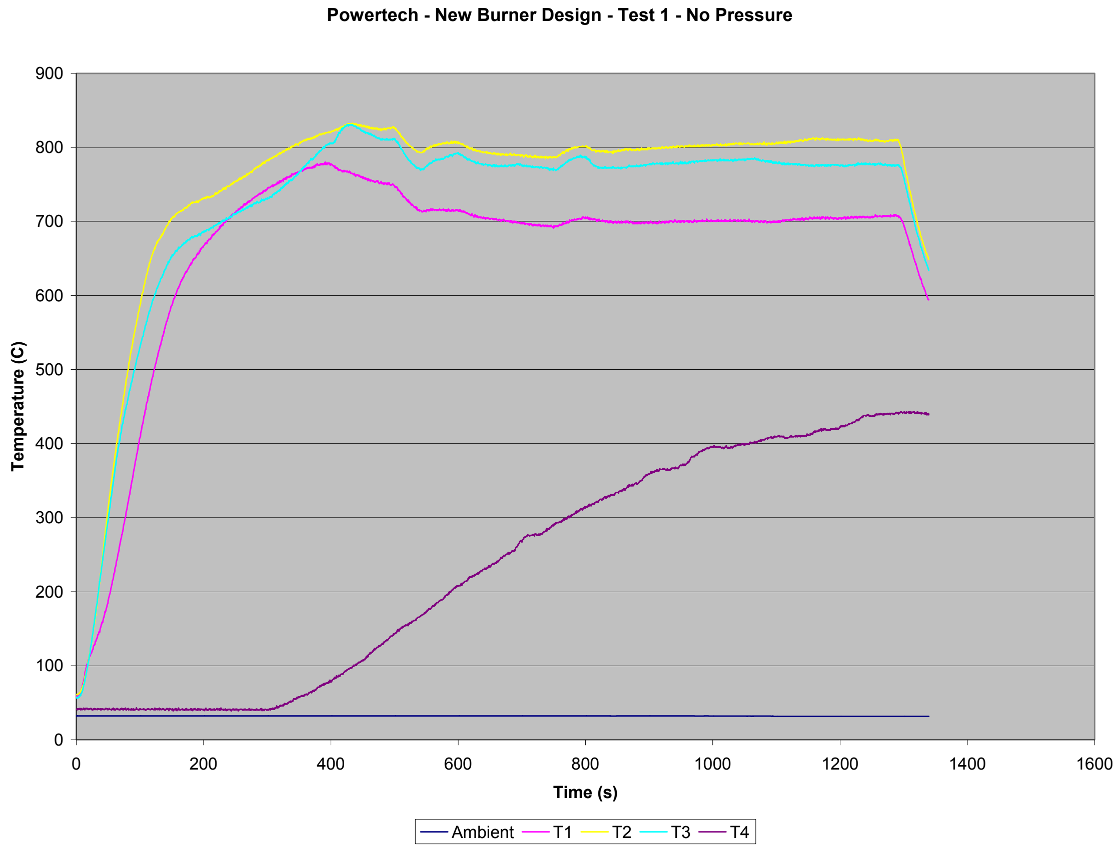

Figure 7 – Temperature-time profile for the unpressurized tank.

The second test on the pressurized hydrogen tank resulted in the pressure relief device activating some 6 minutes into the test soon after the valve end heating commenced. At the time of activation, the valve temperature was at about 225°C (see Figure 8). Note that the pressure trace has numerous "blip" due to electrical interference from radio transmissions.

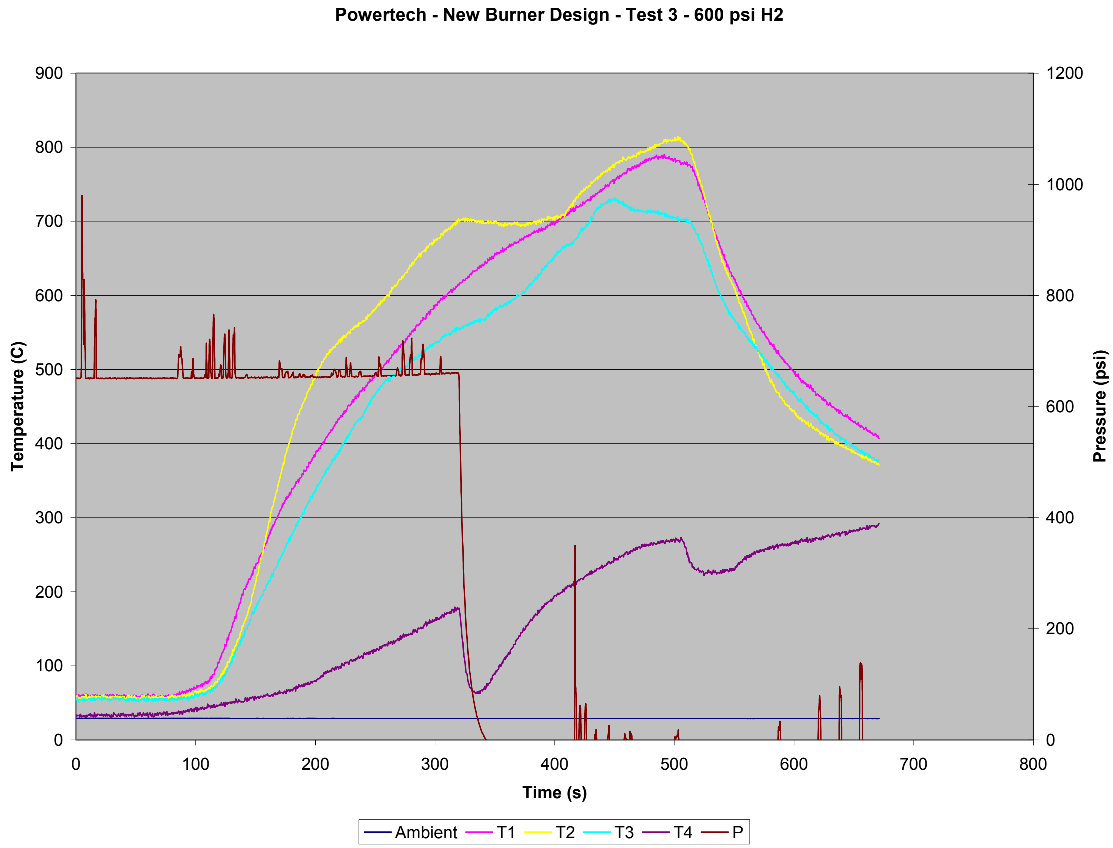

Figure 8 - Temperature-time profile for the pressurized tank

4.0 CONCLUSIONS

The test results demonstrate that it is possible to achieve and maintain the temperature profile on a test tank within specified time frames as defined in Figure 1. The test results also indicate that a tank protected with a TPRD and exposed to the “medium” heating regime as described in Section C of Figure 1, will protect a tank from rupture in a “high” heat regime as described in Section B of Figure 1.

Experience at Powertech involving the bonfire testing of many hundreds of compressed natural gas cylinders and hydrogen tanks suggests that performing this localized fire test with the TPRD located in the “low” heat area of Section A in Figure 1, will result in tank rupture. As a result, survival of this localized fire test will require the development of improved fire protection technologies, such as protective coatings, or the use of a remote heat detection system to activate TPRDs. Improvements in installation code requirements will also increase safety against localized fire effects.