Sprinkler Protected Car Stacker Fire Test

Prepared for: The British Automatic Fire Sprinkler Association

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Protecting People, Property and the Planet

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Executive Summary

The British Automatic Fire Sprinkler Association (BAFSA) requested BRE Global carry out a test to investigate the effect of a sprinkler system on the growth and spread of a fire in and between cars in a car park stacking system. This request followed the Communities and Local Government (CLG) Sustainable Buildings Division research programme titled Fire Spread in Car Parks. BAFSA wished to carry out an additional test using the CLG Car Stacker Rig in order to demonstrate the effect that a sprinkler system would have on the fire.

The test was designed to replicate the test carried out under the CLG program of research, but with the addition of a sprinkler system, designed and installed by BAFSA.

It is BRE Global's understanding that the system was designed by the client to be as consistent as possible with the prescriptive guidance given in BS EN 12845, LPC Sprinkler Rules. However, sprinkler protection of real car stackers will require the installation of a sprinkler system on a number of levels depending on the height of the storage. It was therefore considered appropriate by BAFSA to trial a number of hydraulic designs and sprinkler heads prior to the fire test.

A number of cold discharge tests were conducted with the installed sprinkler system to evaluate the water discharge profile from a number of different sprinkler heads spray patterns and arrangements. Based on the findings of the cold discharge testing a 15mm 68°C 'Conventional' type sprinkler model was selected as providing an optimised water discharge profile for the hazard. It was found in these tests that the 'Conventional' type sprinkler gave a water spray pattern that would wet adjacent cars and therefore would be expected to stop the fire spreading. The water supply provided by BRE was set to provide 1 bar of pressure at the most hydraulically remote sprinkler head when all of the sprinklers in the assumed maximum area of operation (AMAO) were discharging.

The fire test was carried out on Thursday 17th September 2009. The sprinklers controlled the fire within the car stacker, albeit with some fire spread from the lower, ignition car to the upper car, and after one hour of operation the sprinkler system was turned off. It was evident that the fire had been controlled but not extinguished by the sprinkler system. The sprinkler system was then reactivated and again rapidly controlled and contained the fire to within the body envelope of each car.

The sprinkler system considerably reduced the fire temperatures compared with the CLG test, and considerably reduced the overall visible size of the fire (although fire size has only been assessed qualitatively). Whilst the fire did spread to the upper vehicle, the upper vehicle did not become fully involved, so it is the opinion of BRE Global that the risk of fire spread beyond the test geometry (vertically or horizontally) to other nearby cars is significantly reduced by the presence of a sprinkler system.

The test has demonstrated the potential benefits of installing a sprinkler system into a car stacker, providing the system is designed for the specific risk and with the installation based on appropriate standards and guidance.

Contents

Introduction

The British Automatic Fire Sprinkler Association (BAFSA) requested BRE Global carry out a test to investigate the effect of a sprinkler system on the growth and spread of a fire in and between cars in a car park stacking system. This request followed the Communities and Local Government (CLG) Sustainable Buildings Division research programme titled Fire Spread in Car Parks (contract reference CI 71/5/35). During the CLG programme of research a fire test was conducted on two vehicles in a rig designed to replicate a car stacker.

The CLG test demonstrated the characteristics (rate of growth and spread, mechanism of spread, fire size, etc.) of a “typical” (but severe) fire breaking out in vehicles in a “typical” stacker. BAFSA wished to carry out an additional test using the CLG Car Stacker Rig, and replicating the earlier test. This was in order to demonstrate the effect that a sprinkler system would have on the fire. This report details the factual findings of the test.

Description of the project

Test design

The test was designed to replicate the test carried out under the CLG program of research (Ref.1), but with the addition of a sprinkler system, designed and installed by BAFSA.

The test rig was reinstated to the condition used for the CLG programme of testing, with the same stacker rig as had been used and a new 3m x 3m x 6m steel roof, as had been provided in the previous test (see Figure 1). The test was set up and run in the BRE Burn Hall under the 9 metre calorimeter hood.

The cars for this test were sourced and supplied by BAFSA.

- The lower car was a 1992 Land Rover Discovery (diesel engine).
- The upper car was a 2001 Ford Mondeo hatchback (petrol engine).
- Each of the cars had 20 litres of fuel in its fuel tank.

The ignition scenario for the test was designed to replicate that of previous tests. A number 7 crib, soaked in methylated spirit, was placed on the driver's seat of the Discovery. Note that the driver's seat was on the west side of the rig (see Figure 2). The driver's window of the Discovery was open. All other windows on the lower car and all of the windows on the upper car were closed. Note that during the CLG test both windows on the driver's side were open. The driver's side rear passenger window was directly adjacent to the ramp NW sprinkler so it was decided to close it for this test in order to provide a suitably challenging scenario for the sprinkler system.

Sprinkler system design

The European standard for the design, installation and maintenance of sprinkler systems, BS EN 12845 (Ref. 2), does not cover car stackers. Due to the diverse nature of car stacker arrangements and configurations, prescriptive sprinkler design and installation specifications are not yet possible. However 'standard' car parks are covered by the rules and are classified as an 'Ordinary Hazard 2' occupancy. The classification of fire hazard in the standard is used to determine the appropriate hydraulic design criteria for the system.

The sprinkler system for the test was designed and supplied by the BAFSA system providers and BRE Global understand it to be based on the following principles:

- Four sprinkler heads were necessary to protect each car and were to be located in the vicinity of each 'corner' above both cars.
- Sprinkler heads were not to be installed "directionally" (i.e. they were not to be installed pointing towards any particular part of the test rig or test vehicles).

- The system was to be designed to be as consistent as possible with an ‘Ordinary Hazard’ risk system, whilst making allowances for the vertical distribution of sprinkler heads in this test.

The installed system for the test is shown in Figure 1, Figure 2, Figure 3 and Figure 4.

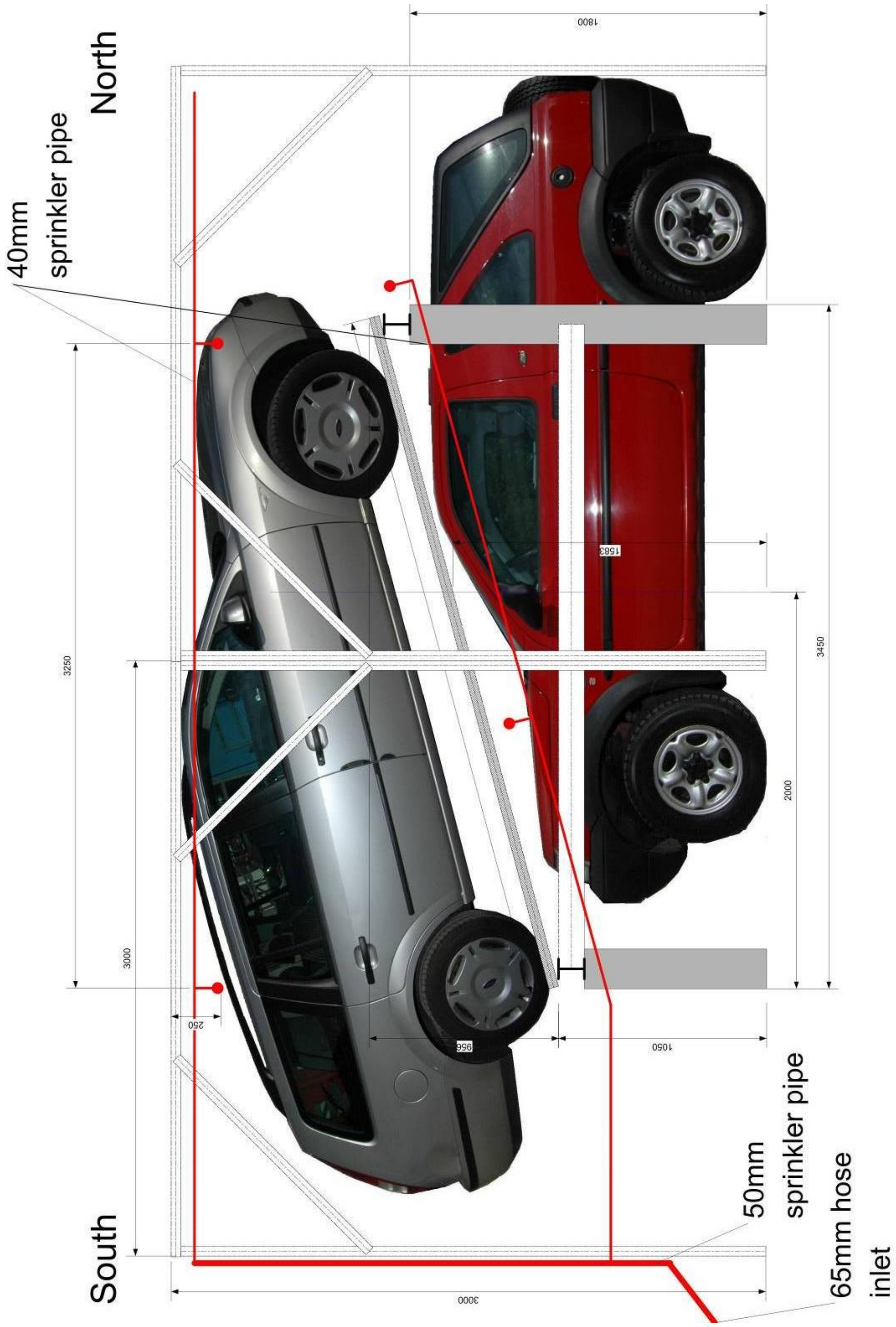

Figure 1 – Elevation of sprinkler layout, showing pipe sizes, sprinkler locations and orientations.

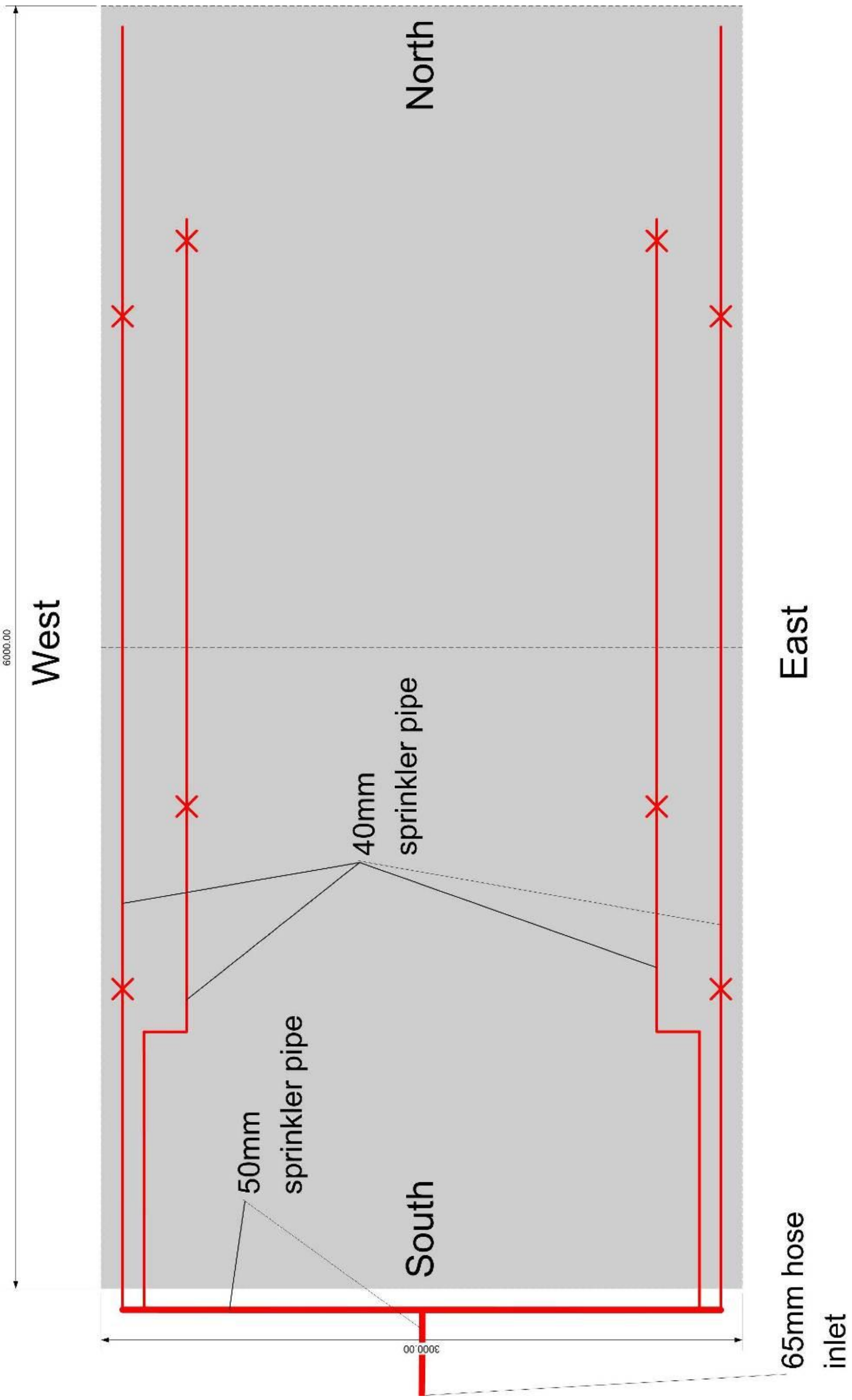

Figure 2 – Plan of sprinkler layout over roof slabs, showing sprinkler head positions, pipe sizes and orientation of rig.

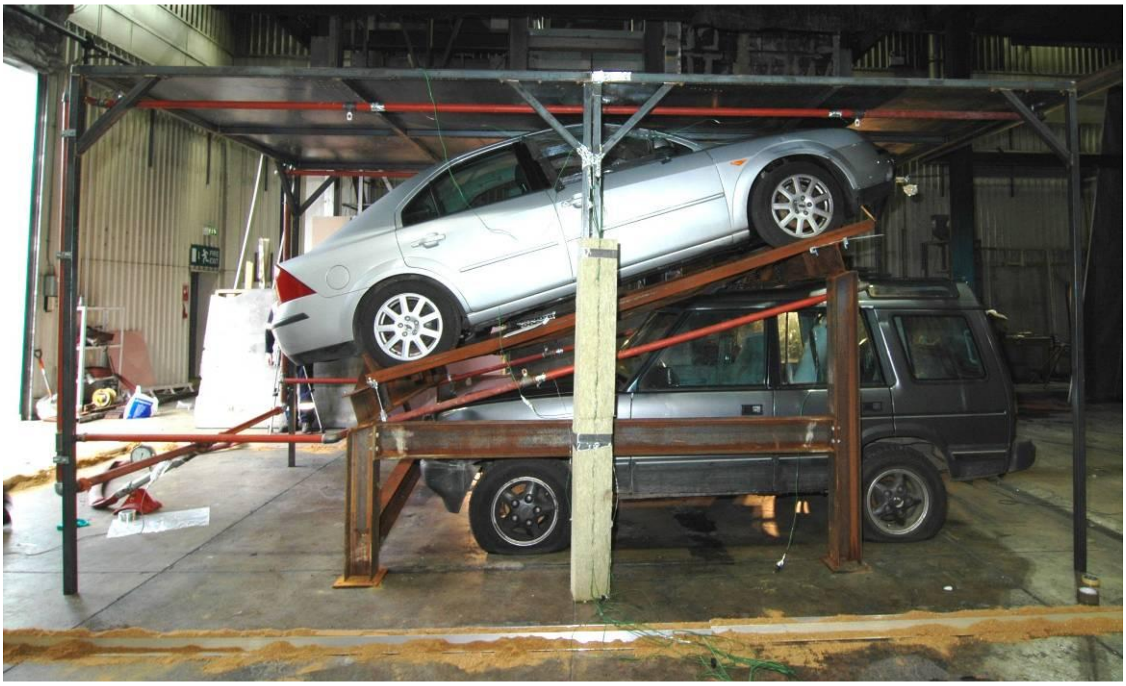

Figure 3 – Photograph showing test arrangement and sprinkler head positions (east side).

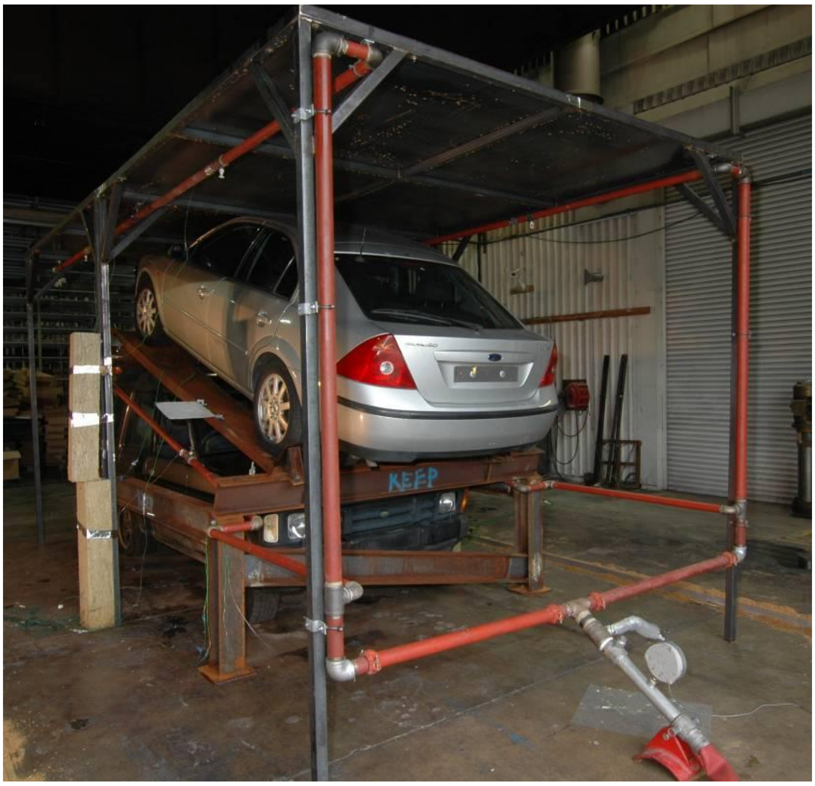

Figure 4 – Photograph of inlet (south) end of rig.

Instrumentation

The instrumentation for this test comprised eighteen thermocouples and two pressure transducers. Their locations and descriptions are given in Figure 5 and Table 1, as well as a flow meter associated with the BRE Burn Hall water pumping system used for the test.

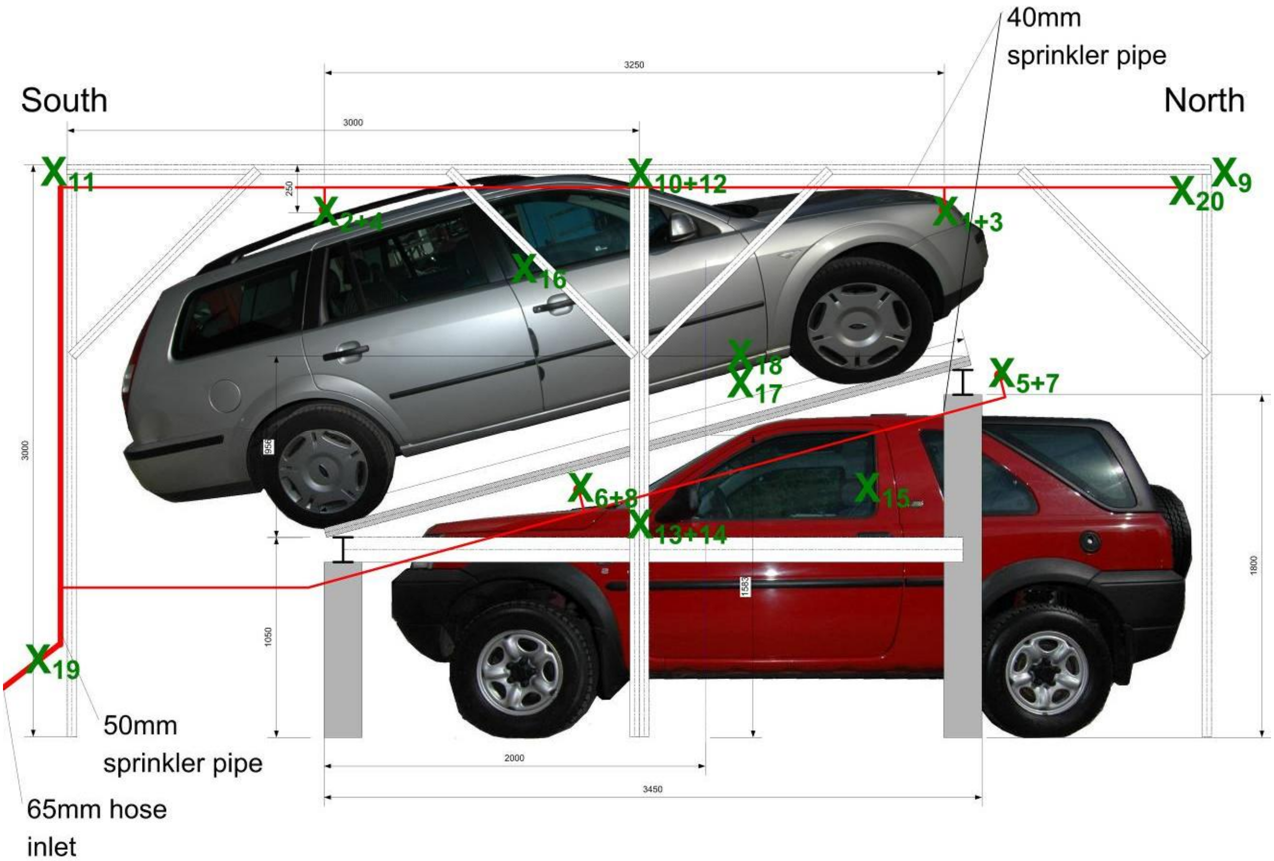

Figure 5 – Plan of instrumentation locations on rig

Table 1 – Descriptions of instrumentation locations from Figure 5.

1	Roof North-East sprinkler thermocouple	11	Roof South edge thermocouple
2	Roof South-East sprinkler thermocouple	12	Roof West edge thermocouple
3	Roof North-West sprinkler thermocouple	13	East side 1.2m thermocouple
4	Roof South-West sprinkler thermocouple	14	West side 1.2m thermocouple
5	Ramp North-East sprinkler thermocouple	15	Land Rover (lower car) interior thermocouple
6	Ramp South-East sprinkler thermocouple	16	Ford Mondeo (upper car) interior thermocouple
7	Ramp North-West sprinkler thermocouple	17	Upper car footwell lower surface thermocouple
8	Ramp South-West sprinkler thermocouple	18	Upper car footwell upper surface thermocouple
9	Roof North edge thermocouple	19	Sprinkler system inlet pressure transducer
10	Roof East edge thermocouple	20	Sprinkler system high level pressure transducer

Fire Test Procedure

Test operators and observers were given a safety briefing prior to the test. During the fire test observers and test operators were required to remain out of the main Burn Hall, in either the viewing galleries or on the Burn Hall apron. Hertfordshire Fire and Rescue Service were in attendance throughout the test for termination, either early or full-term. It was agreed that the test would be terminated if the test posed any threat to anyone present, or if there was any risk of damage to the BRE Burn Hall or to its smoke extraction and scrubbing system.

Findings

Sprinkler 'cold discharge' testing

Prior to the fire test a number of cold discharge tests were conducted by BAFSA with the installed sprinkler system to evaluate the water discharge profile from a number of sprinkler heads and arrangements.

For the tested scenario an operating pressure of 1 bar, with all eight sprinkler heads operating, was used as the base for the sprinkler system hydraulic requirements. Tests were run to determine the required pump output for the BRE Burn Hall pump to provide 1 bar pressure at the most hydraulically remote location from the system inlet (the roof NW sprinkler head) with all eight heads operational (the assumed maximum area of operation, AMAO). This pressure was agreed by BAFSA and BRE Global to be a suitable base for the hydraulic design. The BRE pump was therefore set to provide this pressure for the fire testing.

Based on the findings of the cold discharge testing, a 'conventional' sprinkler model was selected as providing an optimised water discharge profile for the hazard. The heads at high level were installed in the pendent orientation and the intermediate heads in the upright orientation. The sprinkler selected for the tests is shown in Figure 6.

Four heads were installed at high level under the ceiling arrangement in the pendent orientation. The distance between the underside of the ceiling and the sprinkler deflector plate (oriented in the pendent position) was approximately 225 mm for each head. The sprinklers were spaced 3250 mm (length; north-south) and 2600 mm (width; east-west) apart.

Four heads were installed at intermediate level, fixed to the stacker ramp in the upright orientation, to protect the lower car. The sprinkler system pipe was installed to follow the incline of the ramp supporting the upper car. The two lowest level heads were installed 1190 mm above the floor, towards the front of the low level car. The other two heads protecting the rear of the low level car were 1780 mm above the floor. These heads were spaced 2270 mm (length) and 2200 mm (width) apart.

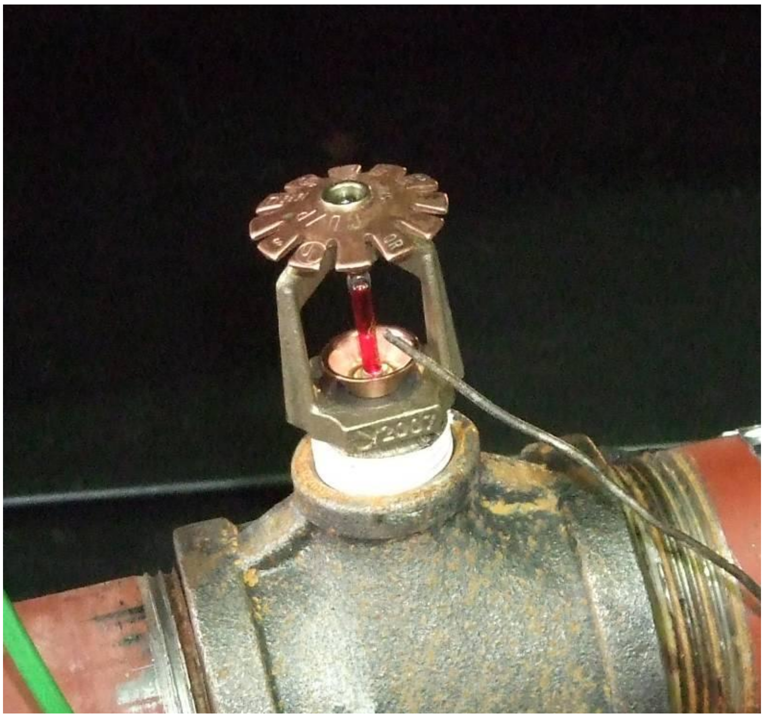

Figure 6 – Sprinkler head selected for testing

The sprinkler head used was a Tyco TY363-1-155 conventional sprinkler head. This sprinkler head had a K-factor of 80 with a quick response frangible bulb rated at 68 ^{o}C, approved by the Loss Prevention Certification Board (LPCB Ref. No. 094a/06 & 007k/04) as Quick Response.

It became apparent during the water testing that the intermediate level sprinkler heads were becoming wetted by the operation of the high level sprinklers. The BAFSA sprinkler system providers therefore installed a 'baffle plate' above each of the intermediate heads in an attempt to protect the sprinklers from direct water impingement, see Figure 7. However, the ability of the plates to prevent the heads from becoming wet was not clearly demonstrated (or assessed by BRE Global) during this trial phase.

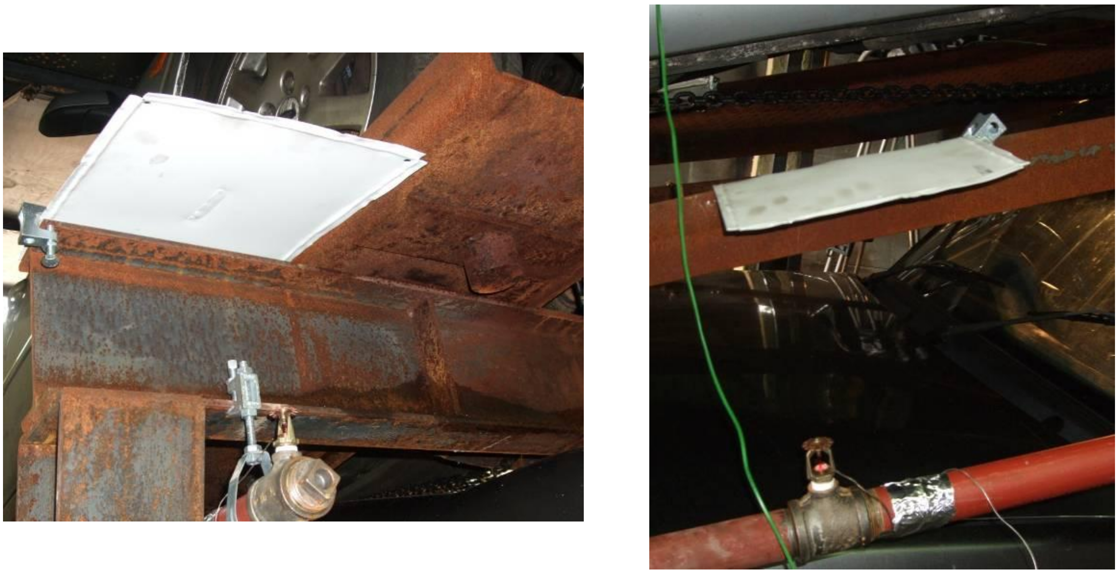

Figure 7 – Baffle plate installed above intermediate sprinkler head

Fire test – Observations

The fire test was carried out on Thursday 17th September 2009. The list of observers during the test is given in Appendix A to this report.

The test was initially run for 60 minutes following the first actuation of a sprinkler head. After this period it was agreed by BRE Global and BAFSA to continue the test without sprinklers for a further 10 minutes to investigate the potential for the fire to re-establish itself. Finally, the sprinkler system was reactivated for a 10 minute period to investigate the ability of the system to deal with the re-established fire. Observations and times for actuation of the sprinklers and system pump are presented in Table 2.

Table 2 – Observations and sprinkler actuations during fire test.

Time after ignition	Note	Label on graphs
0 minutes	Ignition	
3 minutes 45 seconds	Flames touching roof of Land Rover (lower car).	
4 minutes 12 seconds	Flaming outside of Land Rover driver's window.	
4 minutes	Land Rover windows fully obscured by black smoke filling interior of Land	

46 seconds	Rover.	
11 minutes 9 seconds	Flaming visible on underside of Ford Mondeo (upper car).	
13 minutes 6 seconds	Roof NW Sprinkler actuation - BRE pumps switched from recycle mode to fully on.	1
14 minutes 41 seconds	Roof NE Sprinkler actuation.	2
14 minutes 55 seconds	Land Rover front passenger window breaks. Flames extending out of window.	
22 minutes 47 seconds	Ramp NE Sprinkler actuation.	3
1 hour 13 minutes	System turned off (i.e. one hour after 1st actuation).	4
1 hour 16 minutes	Flaming out of Land Rover headlight/grille area.	
1 hour 23 minutes	System turned back on (i.e. one hour and ten minutes after 1st actuation). N.B. Ramp SE sprinkler actuated at some point between 73 and 83 minutes.	5
1 hour 33 minutes	System turned back off (i.e. one hour and twenty minutes after 1st actuation).	6
1 hour 40 minutes	Test terminated – damping down of residual fires by Herts Fire and Rescue Service	

After the test, examination of the vehicles indicated that the majority of the combustible materials in the Land Rover had been consumed or severely affected by fire. The Ford Mondeo had suffered significant damage to its engine bay. However, the interior of this car had not been affected by the fire.

Photographs of the test are shown below:

Figure 8 – Test in progress; 3 minutes 33 seconds from ignition

Figure 9 – Test in progress; 13 minutes 19 seconds from ignition

Figure 10 – Test in progress; 22 minutes 51 seconds from ignition

Figure 11 – Test in progress; 57 minutes 45 seconds from ignition

Figure 12 – Test in progress; 1 hour 23 minutes 9 seconds from ignition (sprinkler system off)

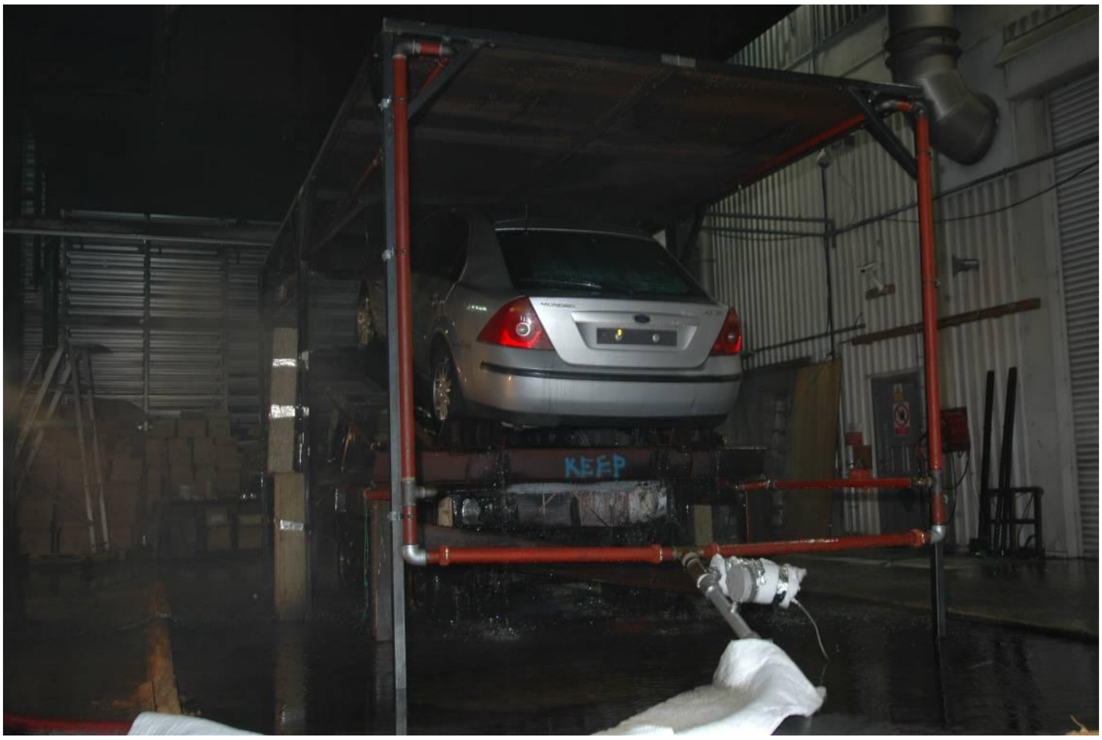

Figure 13 – Test in progress; 1 hour 34 minutes 58 seconds from ignition

Figure 14 – Damage to interior of Land Rover (lower car)

Figure 15 – Damage to underside and engine bay of Ford Mondeo (upper car)

Fire test – Data

The following graphs present the data that was obtained from the thermocouples and pressure transducers situated throughout the rig, as well as the flow measurements from the Burn Hall water pump system.

Note that the fluctuations on the temperature data are typical of sprinkler tests and tend to occur when thermocouples are wetted.

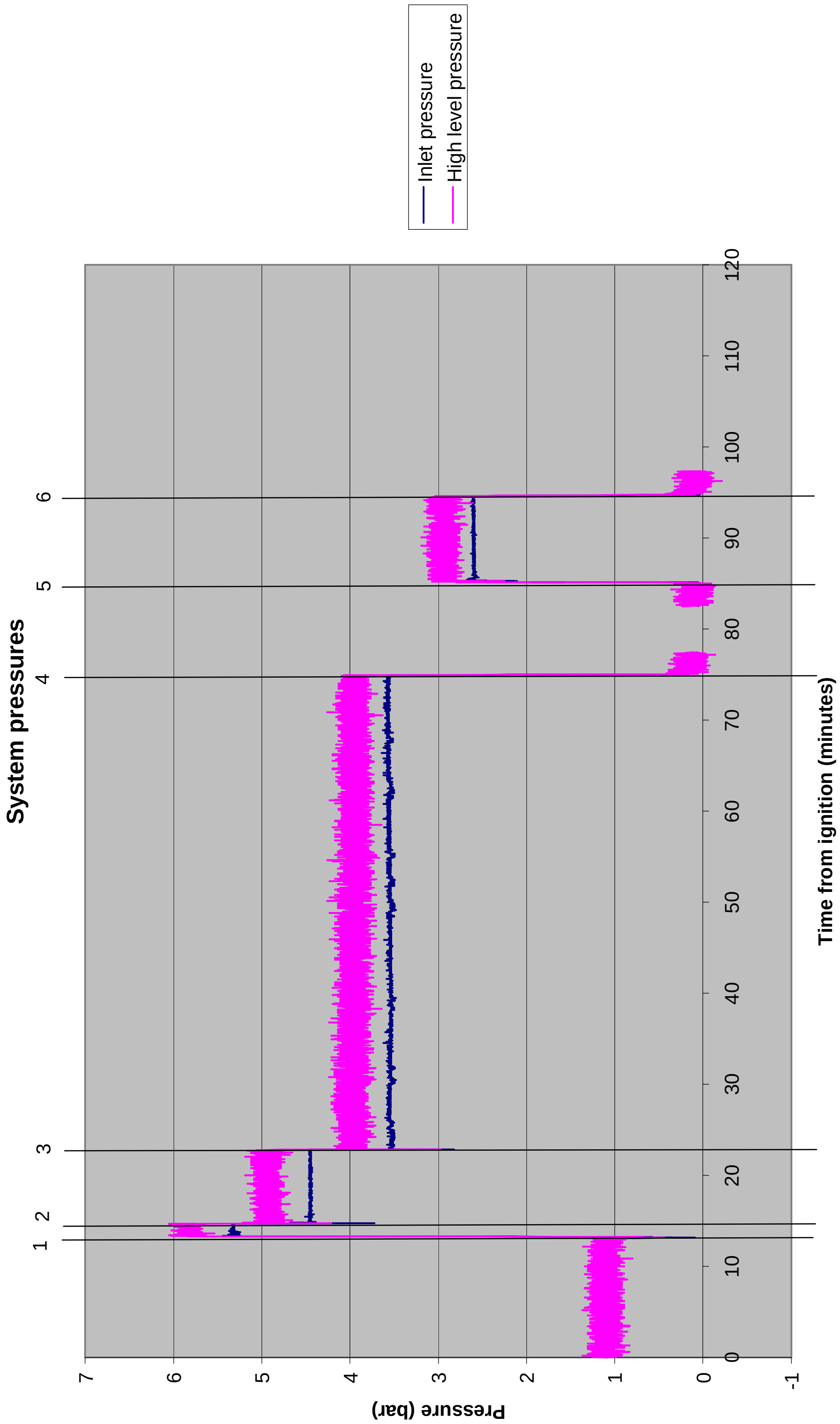

Figure 16 – System pressures at the 65mm hose inlet and at high level next to the NW roof sprinkler

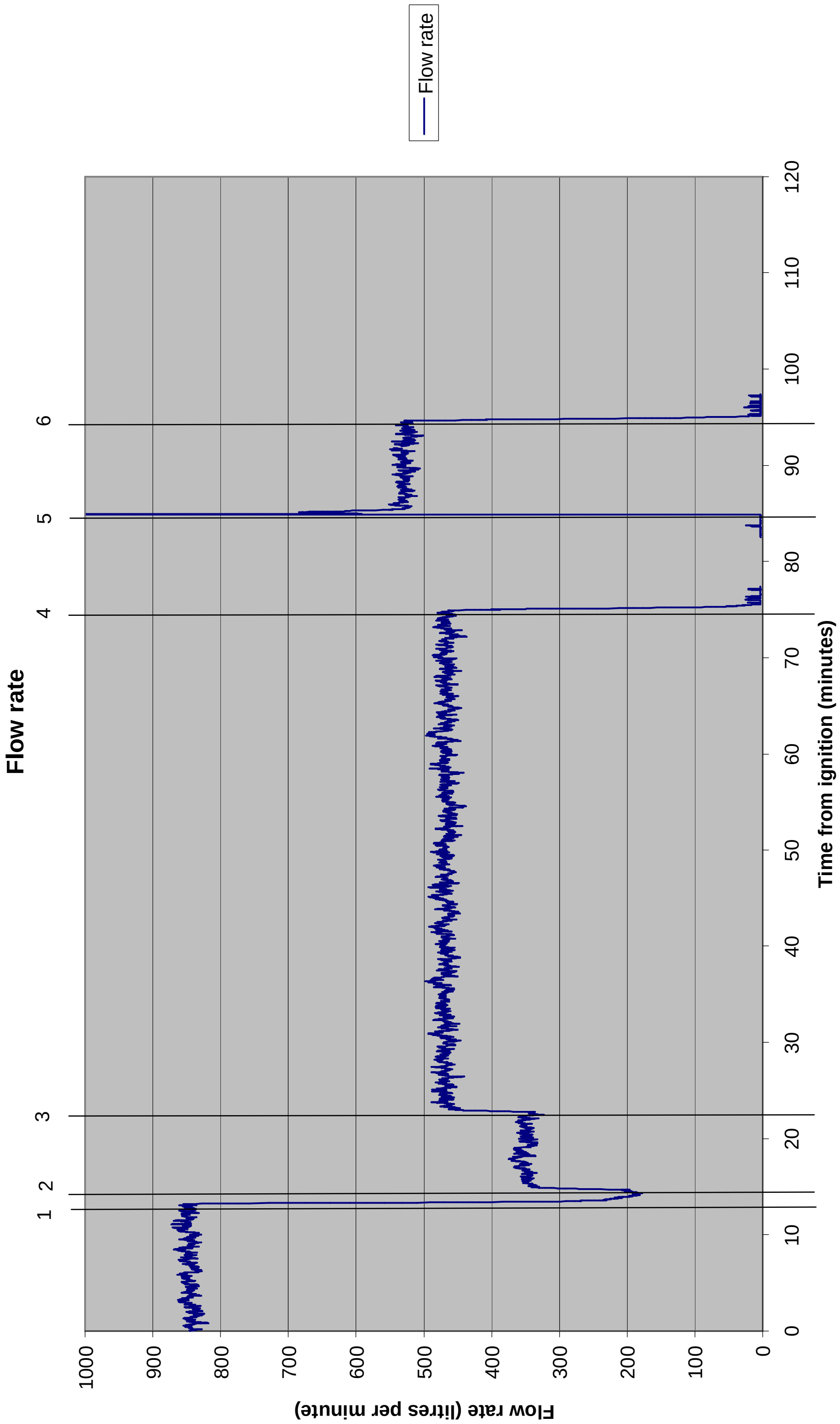

Figure 17 – System total flow rate

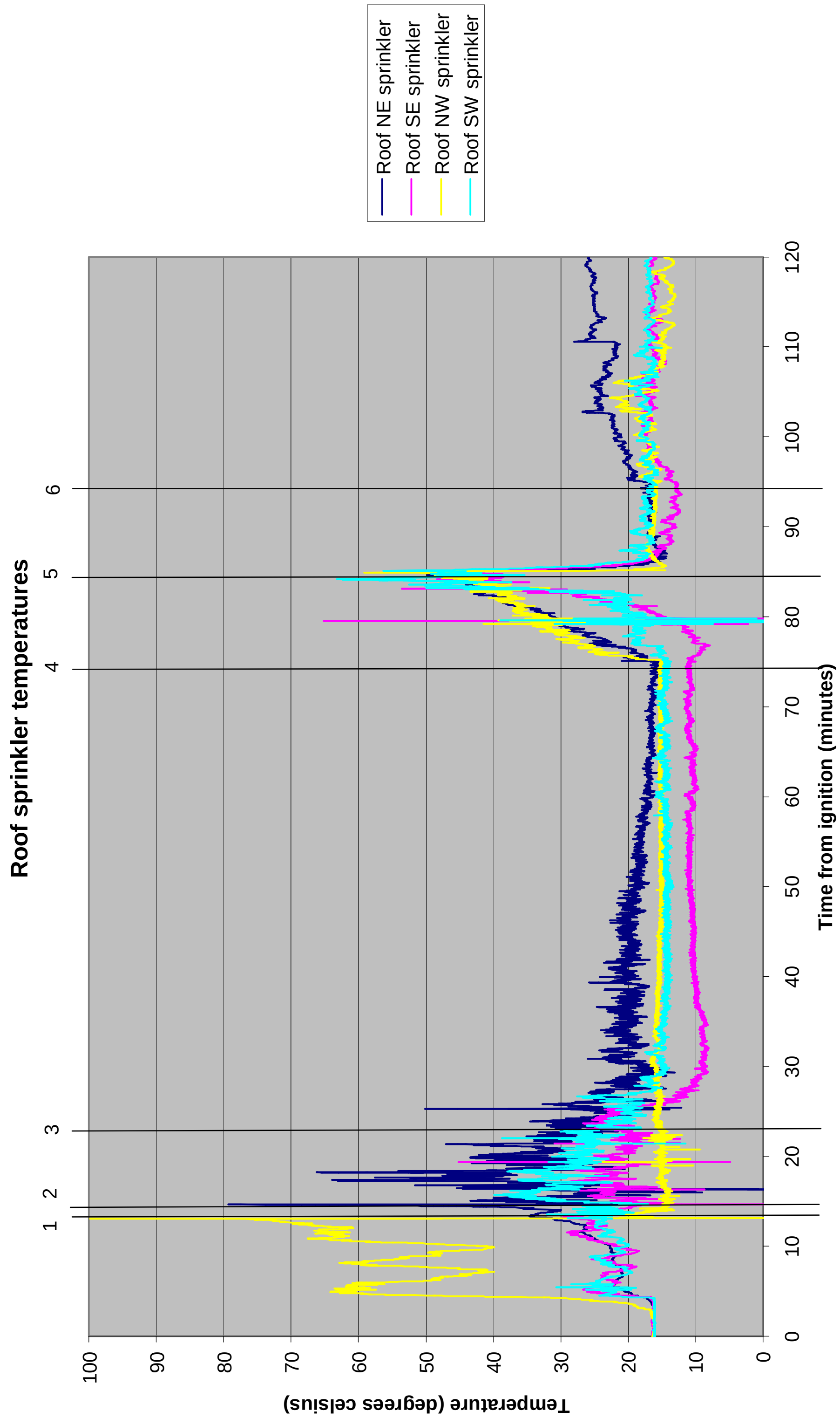

Figure 18 – Temperatures of the roof sprinklers

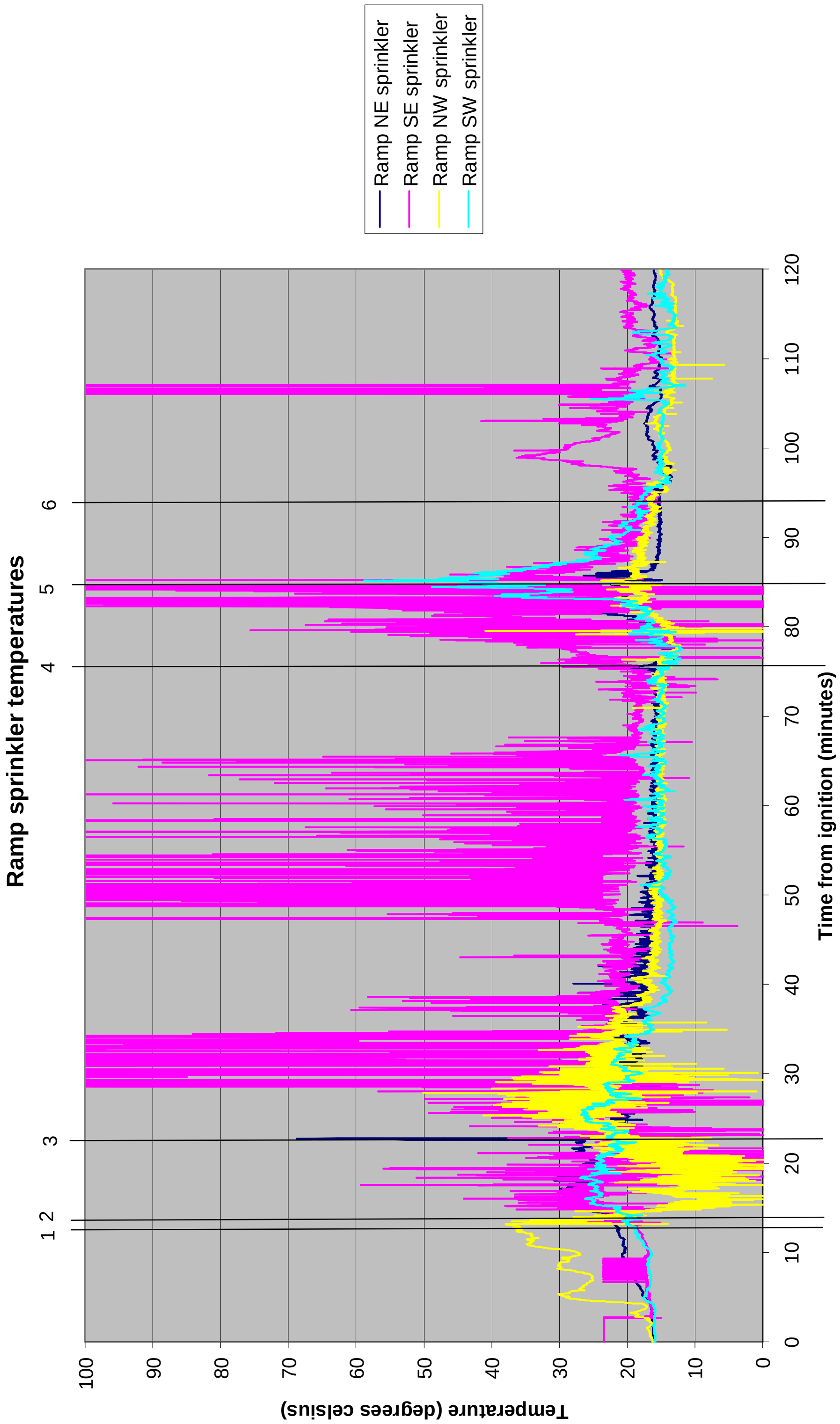

Figure 19 – Temperatures of the ramp sprinklers

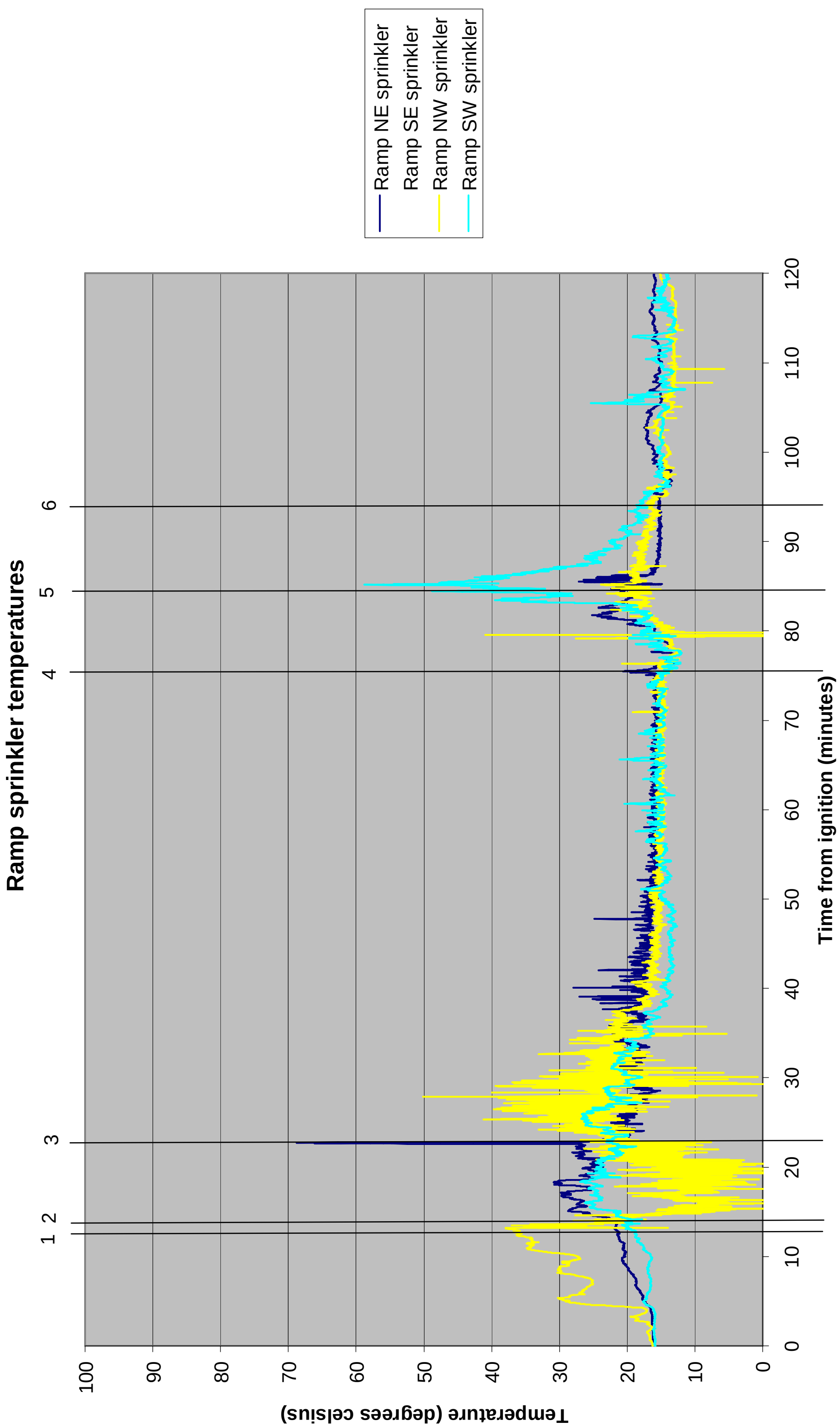

Figure 20 – Temperatures of the ramp sprinklers without ramp SE sprinkler

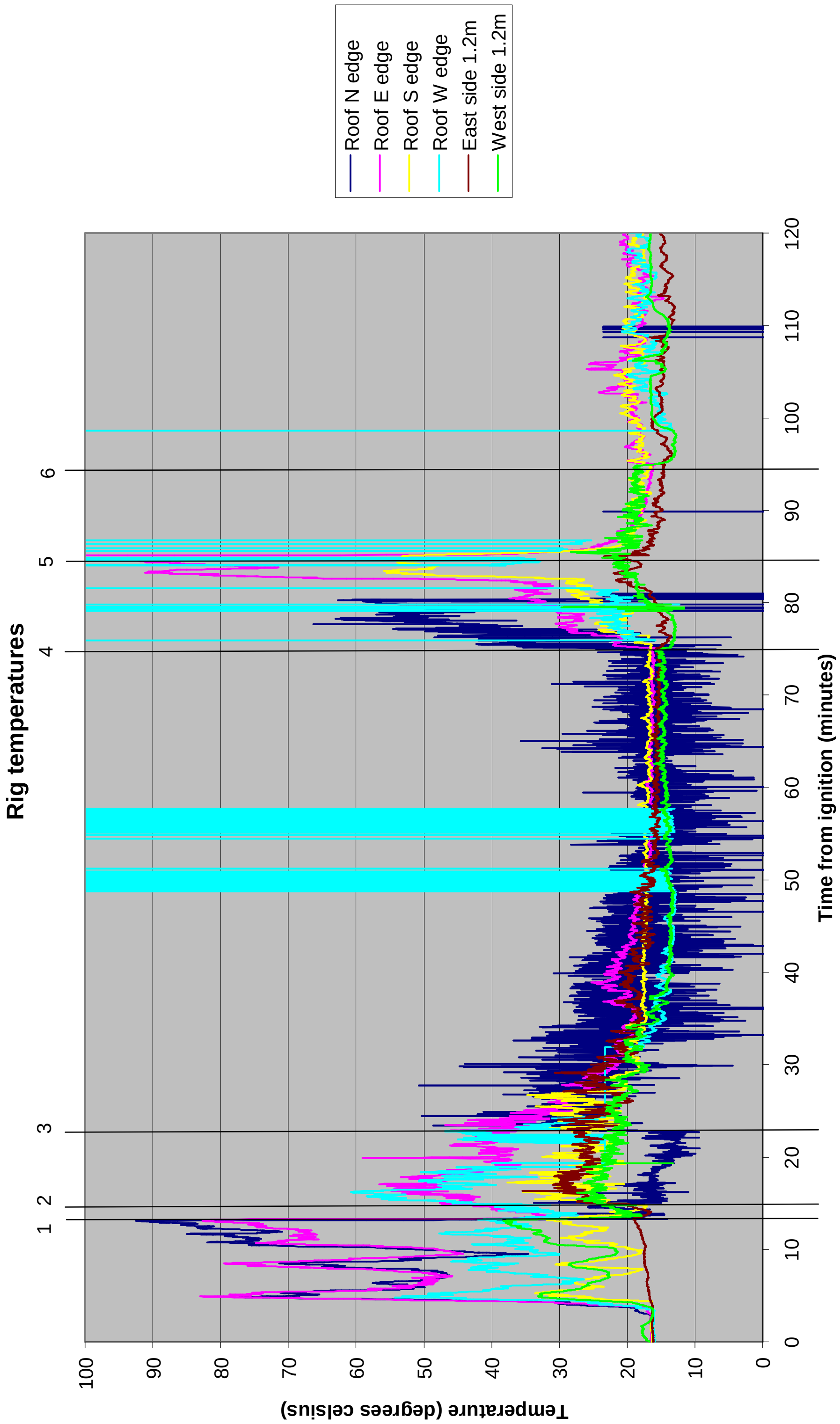

Figure 21 – Temperatures on the test rig

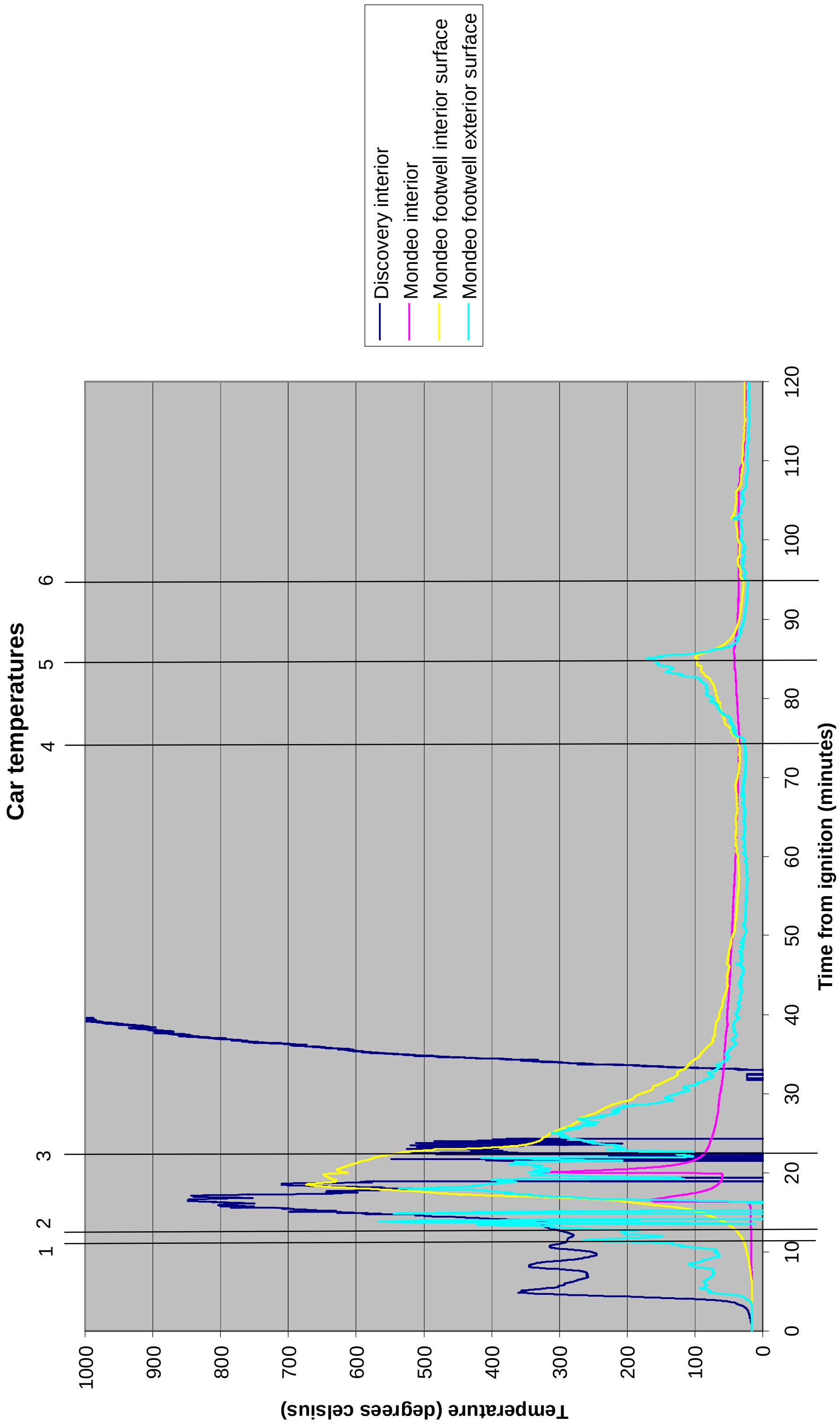

Figure 22 – Car temperatures (note different temperature scale)

Comparison with CLG Test

The following figures present comparable data plots and photos from the CLG (Ref. 1) and BAFSA tests.

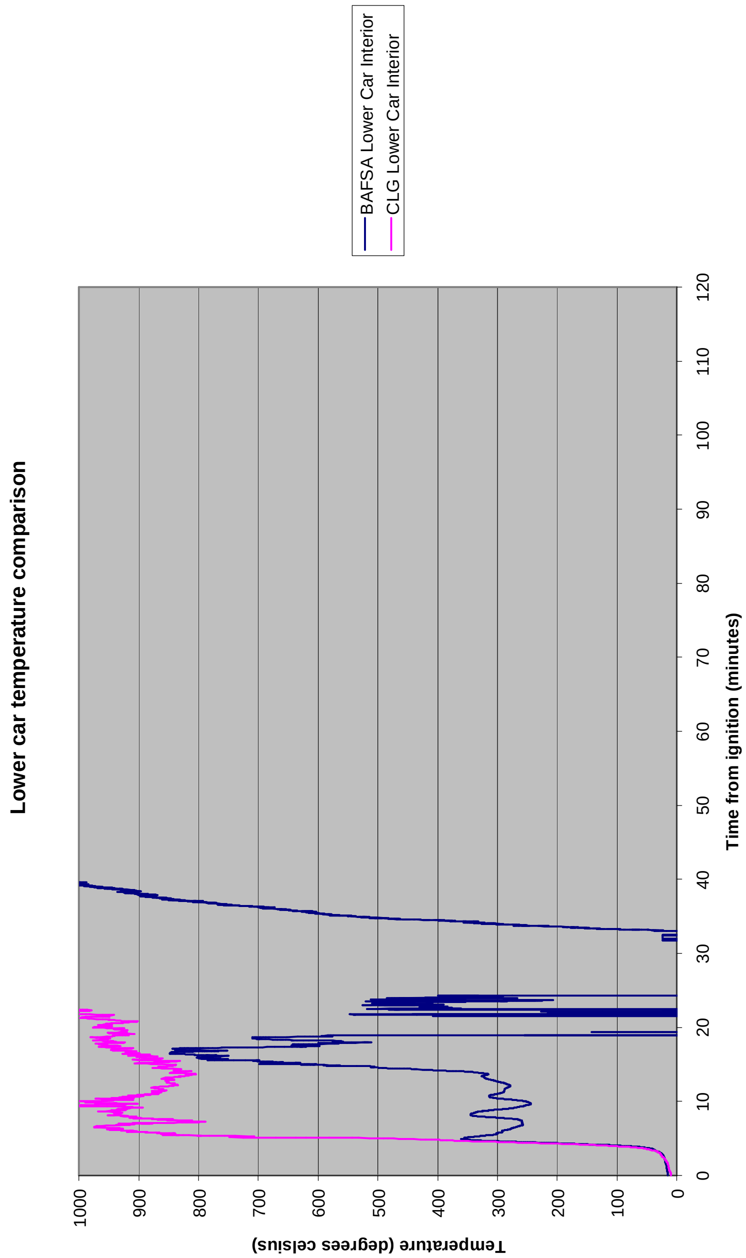

Figure 23 – Comparison between lower car temperatures during CLG and BAFSA tests

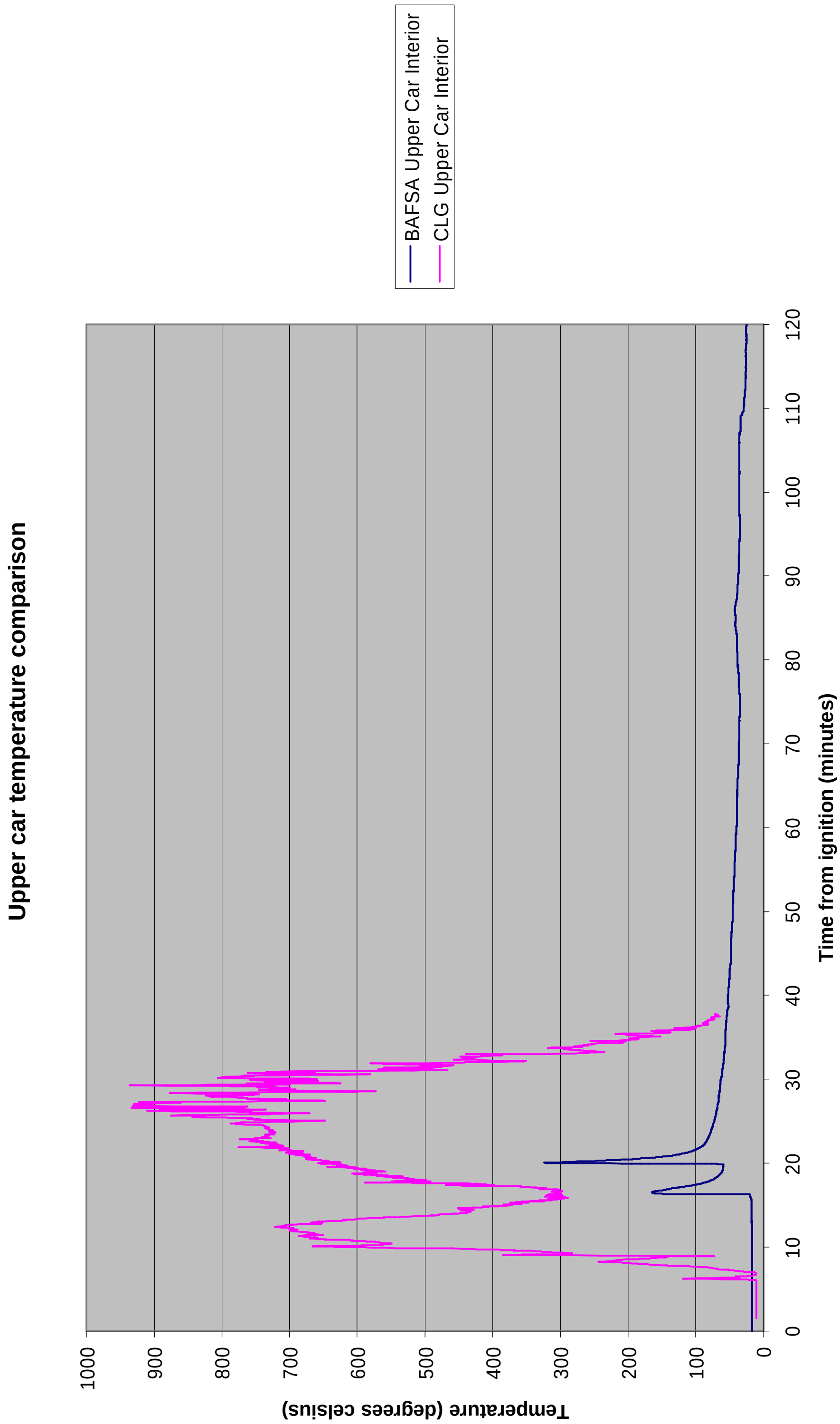

Figure 24 – Comparison between upper car temperatures during CLG and BAFSA tests

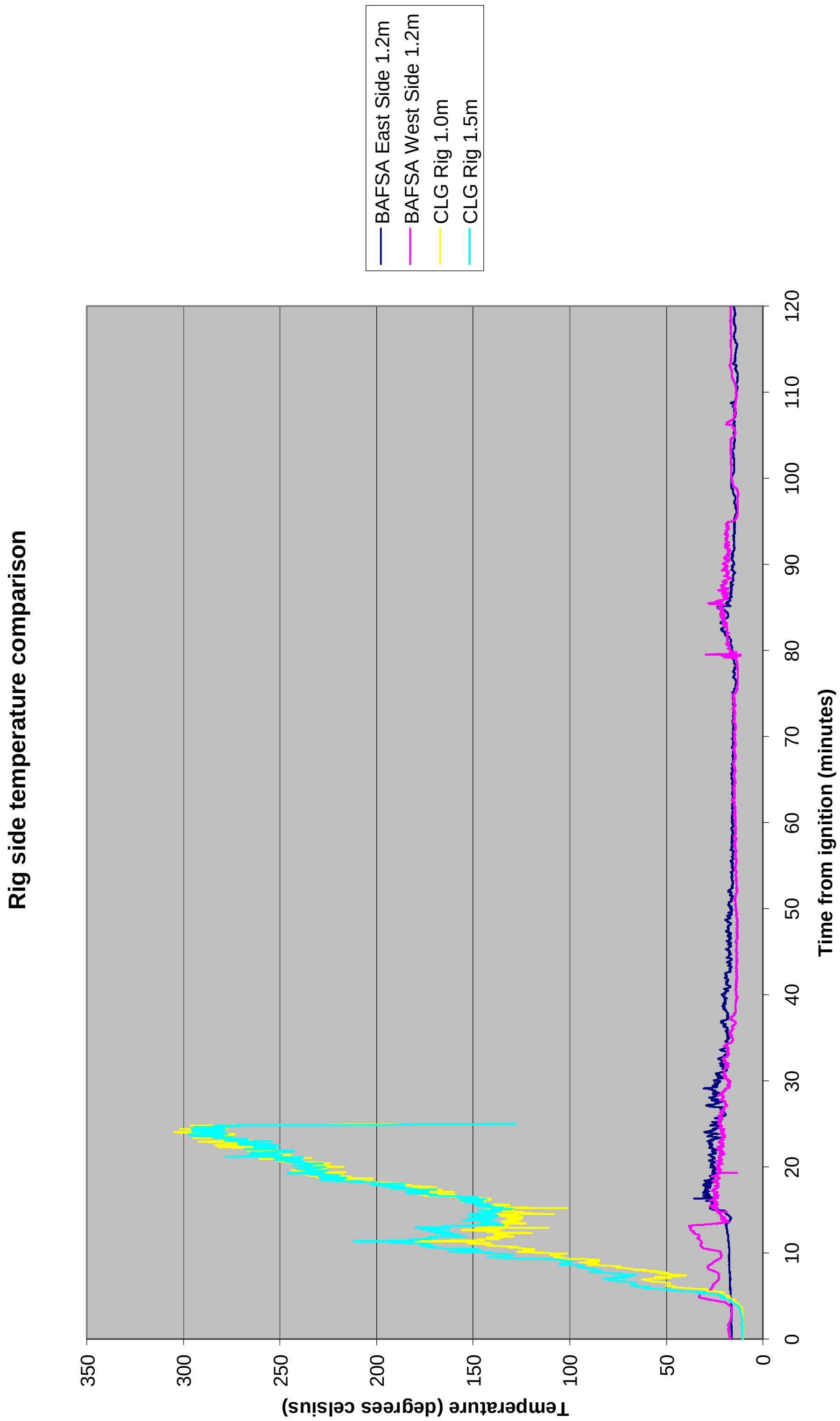

Figure 25 – Comparison between rig side temperatures during CLG and BAFSA tests

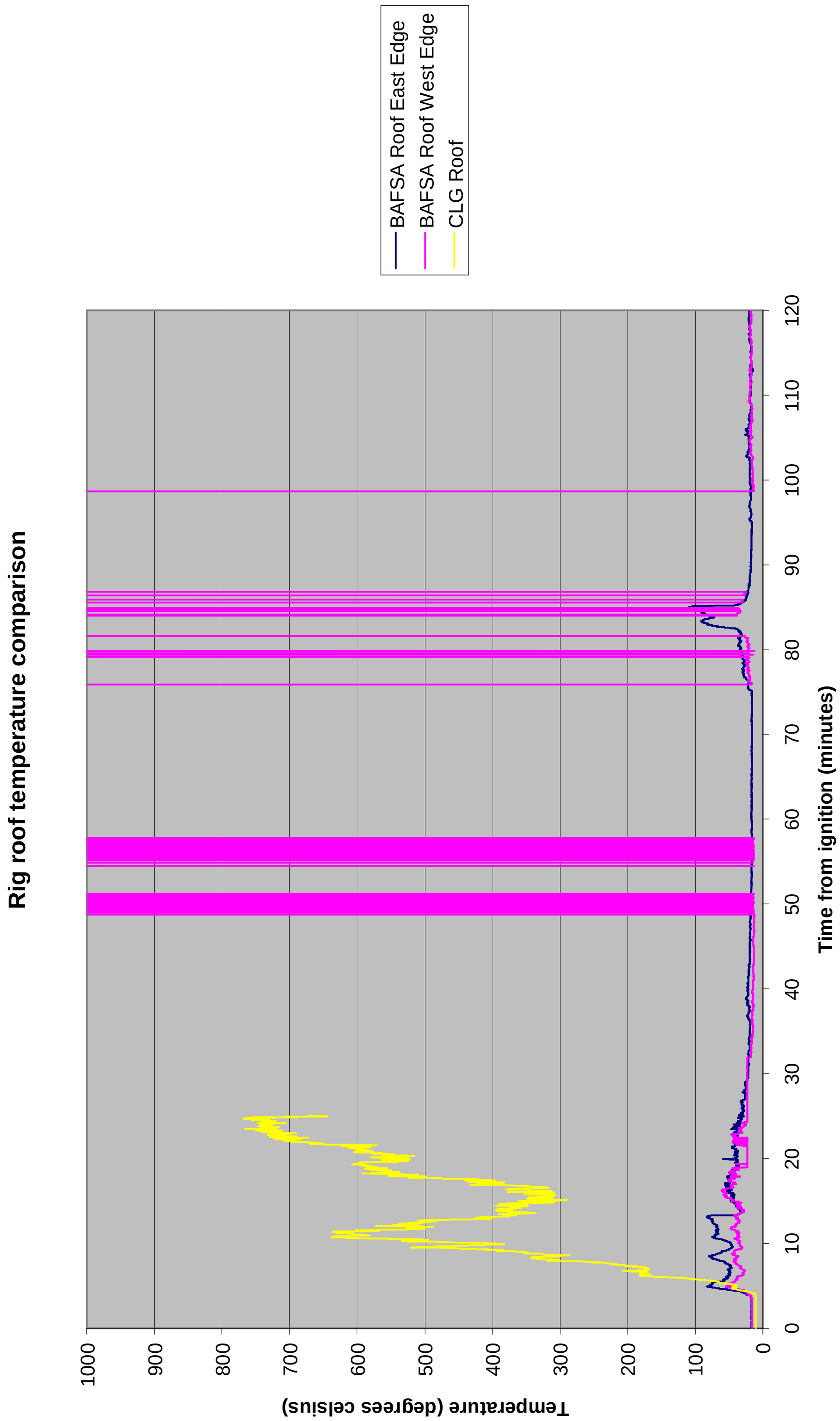

Figure 26 – Comparison between rig roof temperatures during CLG and BAFSA tests

Figure 27 – CLG test in progress; 20min 59secs from ignition

Figure 28 – BAFSA test in progress; 20 minutes 53 seconds after ignition

Discussion and Conclusions

- The fire test by BRE Global for the British Automatic Fire Sprinkler Association to look into the effects of a sprinkler system on the stacker fire scenario has been carried out successfully.
- The test replicated (within the normal limitations of fire experiments) the original stacker fire test carried out as part of the Communities and Local Government programme. The test setup was as similar as possible to the previous stacker test, similar cars were provided by BAFSA, and the same ignition scenario was employed.
- The sprinkler system was designed and installed by BAFSA members, based on appropriate current standards and guidance. The sprinkler system hydraulic requirement was set to provide 1 bar of pressure at the most hydraulically remote sprinkler location with all eight heads operating. The sprinkler system was broadly designed to provide a sprinkler head in the vicinity of each corner of each car.
- The fire in the lower car developed slightly more slowly than in the CLG test (almost certainly as a result of the rear offside window being closed, done to provide a greater challenge to the sprinkler system).
- The fire spread out of the windows of the lower car to the underside of the upper car (as before). Ignition of the upper car occurred.
- Sprinkler heads then operated and rapidly controlled and contained the fire to within the body envelope of each car, despite the fire spread to the upper car.
- After one hour of operation the sprinkler system was turned off. A fire grew in both the lower and upper cars, showing that these fires had been controlled but not extinguished by the sprinkler system. The sprinkler system was then reactivated and again rapidly controlled and contained the fire to within the body envelope of each car.
- The sprinkler system reduced the fire temperatures compared with the CLG test, and reduced the overall visible size of the fire (although fire size has only been assessed qualitatively).
- The sprinkler system resulted in substantial “fogging” and reduced the visibility of the fire compared with the CLG test.
- Whilst the fire did spread to the upper vehicle, the upper vehicle did not become fully involved, so it is the opinion of BRE Global that the risk of fire spread beyond the test geometry (vertically or horizontally) to other nearby cars is significantly reduced by the presence of a sprinkler system.
- The test has demonstrated the potential benefits of installing a sprinkler system into a car stacker, providing the system is designed for the specific risk and with the installation based on appropriate standards and guidance.

References

1. Fire Spread in Car Parks. Fire Safety Engineering Magazine. Article available online at http://www.fseonline.co.uk/articles.asp?article_id=8909

2. BS EN 12845:2004+A2:2009 Fixed firefighting systems – Automatic sprinkler systems – Design, installation and maintenance. BSI. 2009.

Acknowledgements

Special thanks go to Communities and Local Government, Sustainable Buildings Division, for permitting the use of their stacker rig for this test.

Thanks go to Hertfordshire Fire and Rescue Service (Garston Station) who were in attendance for the fire test.

The BRE Global project team comprised the following staff:

David Crowder	Project manager
Martin Shipp	Project reviewer
Kelvin Annable	Experimental full-scale test and sprinkler system support
Antonia Crawford	Experimental full-scale test
Carl Sherwood	Experimental full-scale test
Phil Clark	Test setup
Danny Hopkin	Test setup
Leah Amendt	Test setup
Bob Mallows	Video

Appendix A – Fire Test Observers

Ian Gough, British Automatic Fire Sprinkler Association

Steve Griffiths, Hall Fire Protection Limited

Joe McCafferty, Tyco Fire & Integrated Solutions

Steve Mills, West Midlands Fire & Rescue Service

Keiran Johns, Fire Defence Plc

Darko Petrovic, Fire Defence Plc

Dr James Marsden, Greater Manchester Fire & Rescue Service

Paul Hardy, Hertfordshire Fire & Rescue Service

Stuart Winter, Arup Fire

Graeme Flint, Arup Fire

Les Fielding, National Fire Sprinkler Network

Russell Dixon, Hall & Kay Fire Engineering