SNCP
SYNDICAT NATIONAL DU CAOUTCHOUC ET DES POLYMÈRES

ETRMA
EUROPEAN TYRE & RUBBER manufacturers' association

Protection, prevention and environmental impact of fire in a tire storage

SNCP experience feedback report

ESFR sprinkler system

Recommendations on fire protection in tyre storage facilities using ESFR sprinkler system

06

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Summary sheet

- Automatic fire ignition and extinguishing tests in tyre storage facilities.

  - ✓ on-tread and laced configurations
  - ✓ storage height up to 8.75 m
  - ✓ ceiling height up to 12 m
  - ✓ fire protection system using K25 ESFR sprinklers

Lessons learnt from the tests

- ✓ tyres do not ignite easily without an accelerating agent
- ✓ pyrolysis is slow to set in
- ✓ the heat release rate is low for the first 3 minutes, then increases rapidly
- ✓ the fire's kinetics, development and heat release rate are similar for both types of storage configurations: on tread and laced
- ✓ the automatic extinguishing system acts in the same way on both types of storage
- ✓ the first ESFR sprinkler head opens before the flames emerge from the stock
- ✓ clearance, between 1.25 m and 4.25 m, has no measurable effect
- ✓ the fire does not spread to another island 2.4 m away with the sprinklers operating

- ✓ K25 ESFR sprinkler heads protect:
  - a storage height of 7.45 m in control mode, with a density of 52 l/min/m^2 at ground level (head pressure of 1.7 bar)
  - a storage height of 7.45 m in suppression mode, with a density of 67 l/min/m^2 at ground level (head pressure of 2.8 bar)
  - a storage height of 8.75 m in suppression mode, with a density of 91 l/min/m^2 at ground level (head pressure of 5.2 bar)
- ✓ the quantity of burnt tyres is low, around 600 kg in control mode, less than 150 kg in suppression mode
- ✓ the quantity of smoke emitted is low, visibility in the building remains sufficient for fire-fighting operations
- ✓ Since the quantity of burnt tyres is small, the potential impact is limited to the inside of the building. Atmospheric emissions have no impact on the environment or the population.
- ✓ Similarly, pollutants in the extinguishing water are negligible and below the daily limits authorised for industrial facilities.
- ✓ the temperature of framework elements is under 100°C and does not exceed 31°C in suppression mode

Recommendations

For new warehouses with up to 12 m of storage height, with K25 ESFR sprinkler systems:

- ✓ both types of storage can be used: on tread and laced
- ✓ a density of 67 l/min/m^2 at ground level (head pressure of 2.8 bar) protects a tyre storage configuration up to 7.45 m high, in suppression mode
- ✓ a density of 91 l/min/m^2 at ground level (head pressure of 5.2 bar) protects a tyre storage configuration up to 8.75 m high, in suppression mode

Experience feedback report

Réf : SNCP/REX-INC/06-2007

Automatic fire ignition and extinguishing tests in tyre storage facilities.

I. *Introduction*

Under the auspices of SNCP, a study group of tyre manufacturing, logistics and protection professionals met to further industry knowledge of fire hazard management in tyre storage facilities, specifically the performance of automatic water-based sprinkler systems.

The members of this partnership – the SNCP, Bridgestone, Goodyear-Dunlop, Hankook and Michelin, the logistic groups Afilog and Aliapur, and the manufacturer Tyco Fire & Building Products – have put together ambitious specifications for significant extinguishing tests. These tests cover various configurations for storing tyres and various sprinkler types and characteristics. The Centre National de Prévention et Protection (CNPP Entreprise) in Vernon then performed the tests.

The purpose of this experience feedback report is to present the main lessons learnt from analyses of the test results.

2. *Test facilities*

2.1 Test hall

The tests were conducted at the CNPP in test hall no. 3, measuring 30 m long, 20 m wide and 24 m high.

The test hall has metal walls and structural elements. Each of the hall's 4 facades is equipped with a rolling shutter (width: 4 m/height: 4.5 m) generally kept open at 40–50 cm from the ground to simulate air intake in a warehouse configuration.

The roof of the test hall is equipped with a smoke extraction system:

- four 5.2 m² louvered lateral openings, kept closed for the tests
- 1 central 25 m² opening, kept 50–100% open depending on the test

Test hall ground is equipped with a 64m² fire resistant material platform located in the middle of the hall.

2.2 Extinguishing system

A moveable 18 m x 15 m metal ceiling with an adjustable height of 9–12 m was installed in the centre of the test hall.

The ceiling was equipped with a 3 m x 3 m main pipework grid fitted with 20 pendant DN65 drops on which model TY 9226 ESFR, K25, RTI 26, 74°C, sprinklers were installed.

Main pipework is completed at its end with a 4 pendant antenna for warning sprinklers installation (same sprinklers used in test with reduced opening).

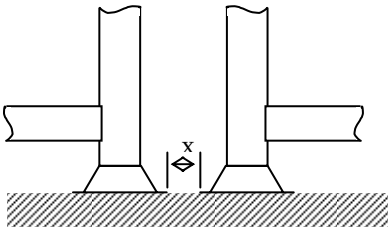
2.3 Tyre storage configurations

There were 4 to 5 levels of tyre storage (7.45 m or 8.75 m high), covering a floor area of 12 to 14 pallets depending on the test. The tyres were arranged on tread and/or laced.

Two pallet designs was used, depending on the test:

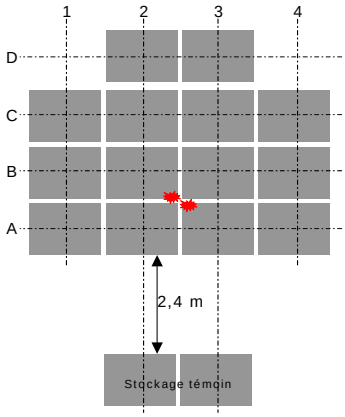
	Monoblock pallet	E4 folding pallet
Outside width between tyres	1.30 m to 1.43 m	1.20 m to 1.35 m
Inside width between uprights	1.24 m	1.05 m
Outside length	1.93 m	2.35 m
Inside length between uprights	1.74 m	2.20 m
Height	1.55 m	2.20 m

Spacing between pallets, measured at the base in both directions, varies from 1 to 27 cm depending on the tests (x in the diagram).



2.4 Ignition system

The fire ignition system consisted of cotton pellets, each soaked in 320 ml of fuel and enclosed in a plastic film bag (L = 15 cm, ∅ = 8 cm). Two igniters, each consisting of two pellets, were arranged at ground level at the intersection between pallets A20, A30, B20 and B30, in the free space between the pallets and positioned against the tyres.



2.5 Instrumentation

- 1 thermocouple per sprinkler head to detect its operating temperature
- 14 thermocouples in the storage
- 1 thermocouple at the top of the control storage area
- 2 thermocouples above the ignition point, close to the ceiling
- 5 thermocouples in a control angle iron placed against the ceiling above the ignition point
- 5 thermocouples in the roof's structural elements above the ceiling
- Water flow rate and pressure

2.6 Video monitoring

Each test was filmed by video cameras installed around the storage area.

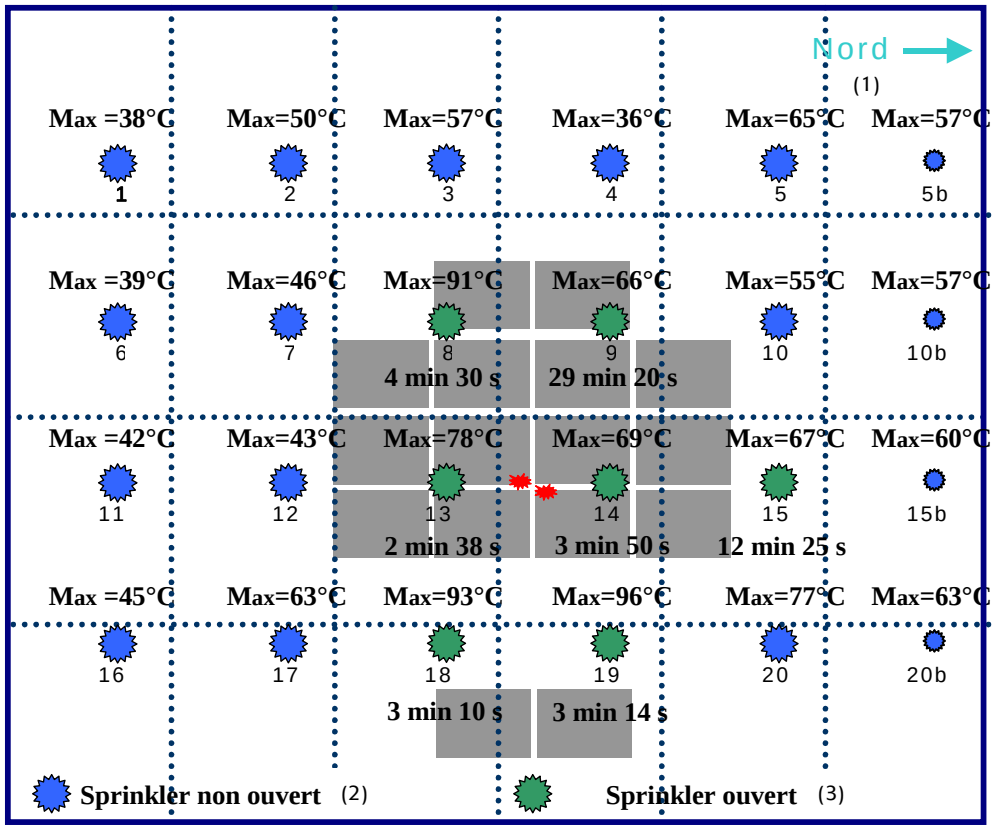
Appendices 1 to 5:

The appendices contain additional data for each of the five ESFR sprinkler tests:

- ✓ tables of parameters and results
- ✓ diagrams of open sprinkler heads and their opening times relative to ignition time 0
- ✓ superimposed curves for temperature and water discharge

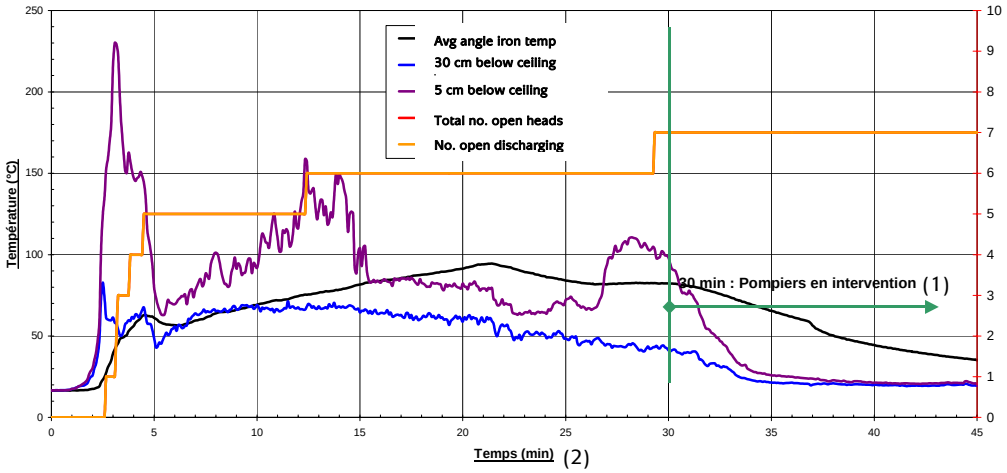
Appendix 1 – Test CNPP21 (VG7)

Tyre storage			
Tyre configuration	On tread	Number of tyres per pallet	36
Nominal storage height	7.45 m	**Monoblock** pallet levels	5
Nb of pallets on the ground	14	Total number of pallets	70
Spacing between pallets	x = 5 cm	Number of tyres stored	2 520
Storage configuration below ceiling		Ignition point between heads 13 and 14	
Extinguishing system configuration			
Ceiling height	9 m	Sprinkler head height (deflectors)	8.7 m
Clearance between deflectors and top of storage	1.25 m	Head (deflector) to ceiling clearance	0.3 m
Sprinkler type	K25 ESFR	Sprinkler K-factor	K = 363
Sprinkler RTI	26	Operating temperature	74 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 9226
Nominal sprinkler density	42 $l.m^{-2}.min^{-1}$	Sprinkler pressure	1.1 bar
Nominal flow per sprinkler	378 l/min	Extinguishing agent	Water only
Test conditions			
Test date	21/06/2005	Outside temperature	18 °C
Air intake	Natural; only north door open to 3 m from ground		
Smoke extraction	Natural, central vent 100% open		
Conditions for ending test	Avg temp at angle iron exceeds 638 °C One of the ceiling structure temperatures exceeds 350°C		
Test results			
First sprinkler opened	2 min 38 s	Total no. of sprinklers open	7
Last sprinkler opened	29 min 20 s	Max temp 5 cm under ceiling	230 °C
Damage to test tyres	No	Max temp 30 cm under ceiling	83 °C
Avg max angle iron temp	95 °C	Time max temp attained	21 min 25 s
Max ceiling framework temp	41 °C	Time max temp attained	22 min 05 s
Total no. of pallets damaged	22	---	---
Equivalent no. of tyres burnt	61 tyres or 2.5 % of test stock		
Extinguishing efficiency	**Control mode achieved**		



(1) North - (2) Unopened sprinklers – (3) Open sprinklers

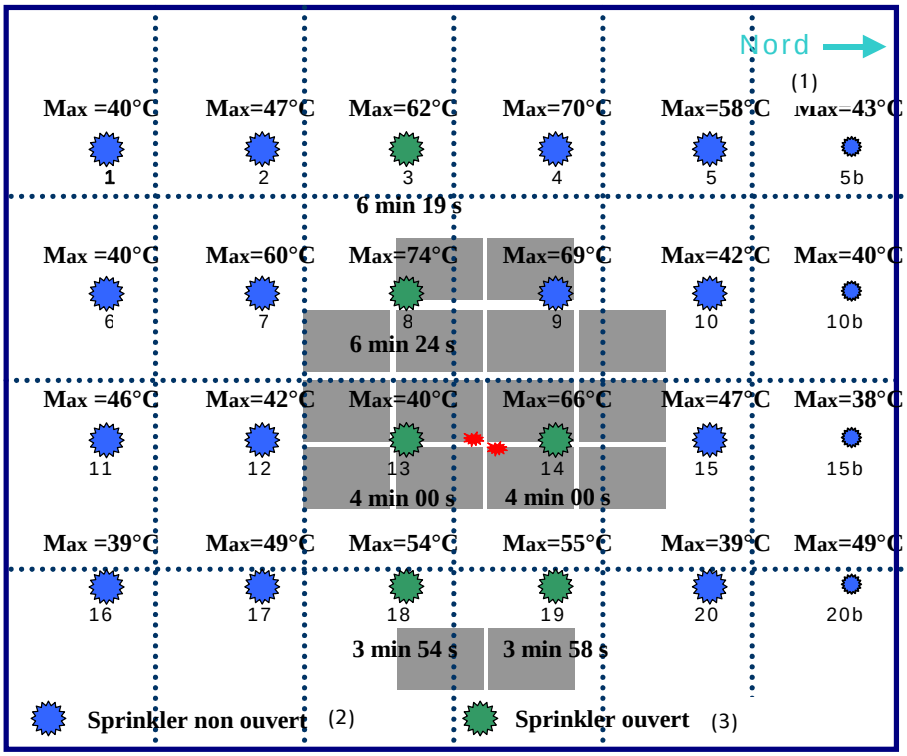
Temperatures / Open sprinkler heads



(1) 30 min : Operation by fire fighters - (2) Time (min)

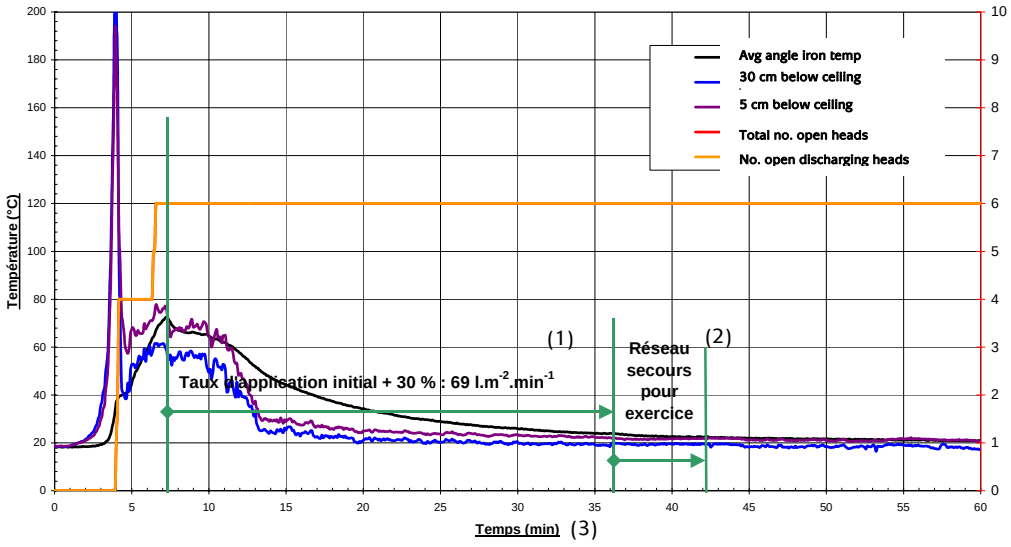
Appendix 2 – Test CNPP22 (VG10)

Tyre storage			
Tyre configuration	Laced	Number of tyres per pallet	40 to 48
Nominal storage height	7.45 m	**Monoblock** pallet levels	5
Nb of pallets on the ground	14	Total number of pallets	70
Spacing between pallets	x = 5 cm	Number of tyres stored	2 952
Storage configuration below ceiling		Ignition point between heads 13 and 14	
Extinguishing system configuration			
Ceiling height	9 m	Sprinkler head height (deflectors)	8.7 m
Clearance between deflectors and top of storage	1.25 m	Head (deflector) to ceiling clearance	0.3 m
Sprinkler type	K25 ESFR	Sprinkler K-factor	K = 363
Sprinkler RTI	26	Operating temperature	74 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 9226
Nominal sprinkler density	52 $l.m^{-2}.min^{-1}$ then 67	Sprinkler pressure	1.7 bar then 2.8
Nominal flow per sprinkler	468 l/min	Extinguishing agent	Water only
Test conditions			
Test date	29/06/2005	Outside temperature	19 °C
Air intake	Natural; 4 facade doors open to 40 cm above ground		
Smoke extraction	Natural, central vent 100% open		
Conditions for ending test	Avg temp at angle iron exceeds 638 °C One of the ceiling structure temperatures exceeds 350°C		
Test results			
First sprinkler opened	3 min 54 s	Total no. of sprinklers open	6
Last sprinkler opened	6 min 24 s	Max temp 5 cm under ceiling	193 °C
Damage to test tyres	No	Max temp 30 cm under ceiling	227 °C
Avg max angle iron temp	73 °C	Time max temp attained	7 min 15 s
Max ceiling framework temp	30 °C	Time max temp attained	14 min 20 s
Total no. of pallets damaged	22	---	---
Equivalent no. of tyres burnt	57 tyres or 2 % of test stock		
Extinguishing efficiency	**Control mode achieved with 52 l/min/m²** **Suppression mode achieved with 67 l/min/m²**		



(1) North - (2) Unopened sprinklers – (3) Open sprinklers

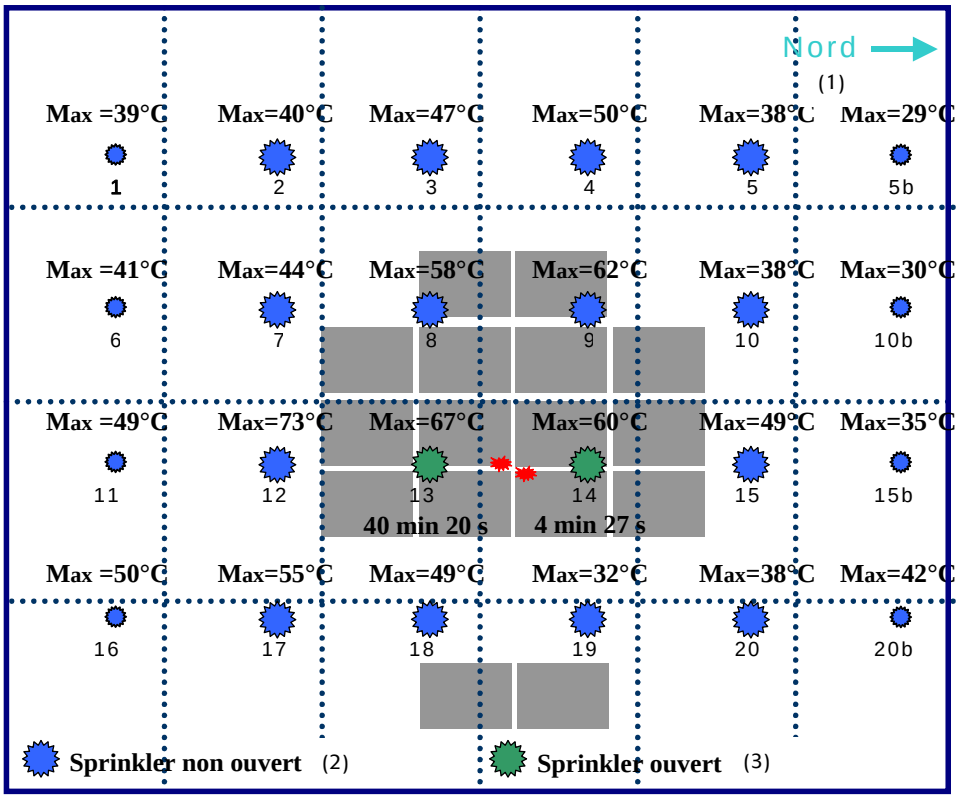
Temperatures / Open sprinkler heads



(1) Initial sprinkler density + 30 % : 69 $l.m^{-2}.min^{-1}$ - (2)Emergency supply for test
(3) Time (min)

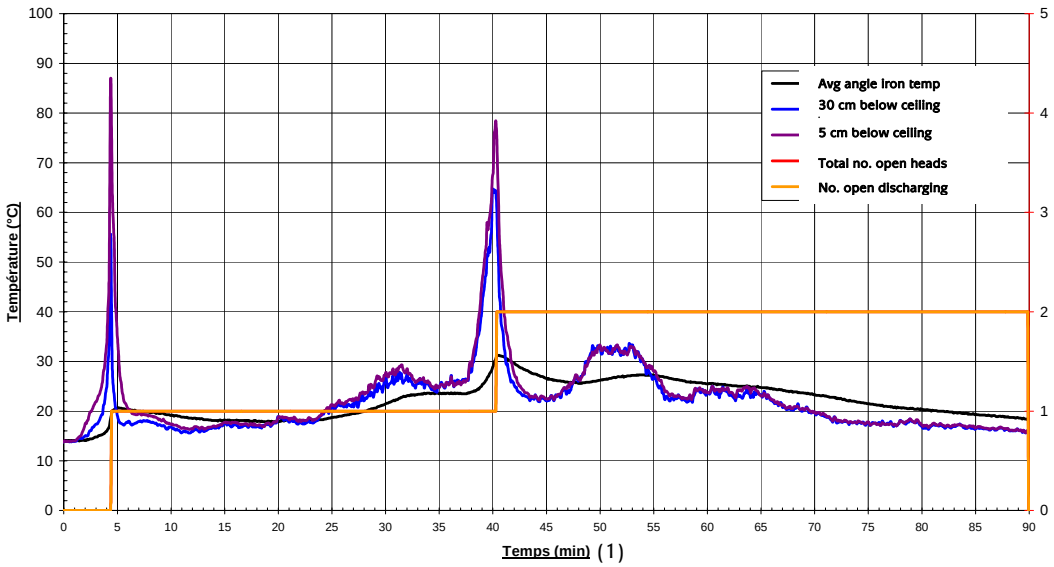
Appendix 3 – Test CNPP23 (VG7-0)

Tyre storage			
Tyre configuration	On tread	Number of tyres per pallet	32 to 36
Nominal storage height	7.45 m	**Monoblock** pallet levels	5
Nb of pallets on the ground	14	Total number of pallets	70
Spacing between pallets	x = 5 cm	Number of tyres stored	2 280
Storage configuration below ceiling		Ignition point between heads 13 and 14	
Extinguishing system configuration			
Ceiling height	10.5 m	Sprinkler head height (deflectors)	10.2 m
Clearance between deflectors and top of storage	2.75 m	Head (deflector) to ceiling clearance	0.3 m
Sprinkler type	K25 ESFR	Sprinkler K-factor	K = 363
Sprinkler RTI	26	Operating temperature	74 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 9226
Nominal sprinkler density	67 $l.m^{-2}.min^{-1}$	Sprinkler pressure	2.8 bar
Nominal flow per sprinkler	603 l/min	Extinguishing agent	Water only
Test conditions			
Test date	06/10/2005	Outside temperature	13 °C
Air intake	Natural; 4 facade doors open to 50 cm above ground		
Smoke extraction	Natural, central vent 50 % open		
Conditions for ending test	Avg temp at angle iron exceeds 400°C One of the ceiling structure temperatures exceeds 350°C		
Test results			
First sprinkler opened	4 min 27 s	Total no. of sprinklers open	2
Last sprinkler opened	40 min 20 s	Max temp 5 cm under ceiling	87 °C
Damage to test tyres	No	Max temp 30 cm under ceiling	65 °C
Avg max angle iron temp	31 °C	Time max temp attained	40 min 25 s
Max ceiling framework temp	24 °C	Time max temp attained	---
Total no. of pallets damaged	10	---	---
Equivalent no. of tyres burnt	14 tyres or 0.7 % of test stock		
Extinguishing efficiency	**Suppression mode achieved**		



(1) North - (2) Unopened sprinklers – (3) Open sprinklers

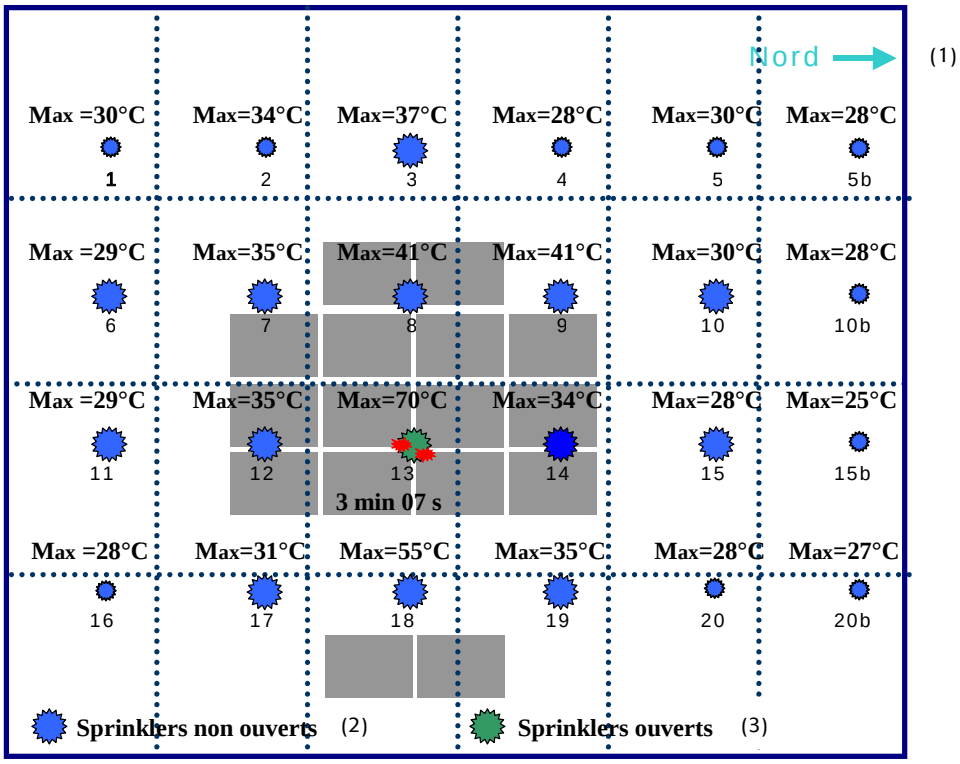
Temperatures / Open sprinkler heads



(1) Time (min)

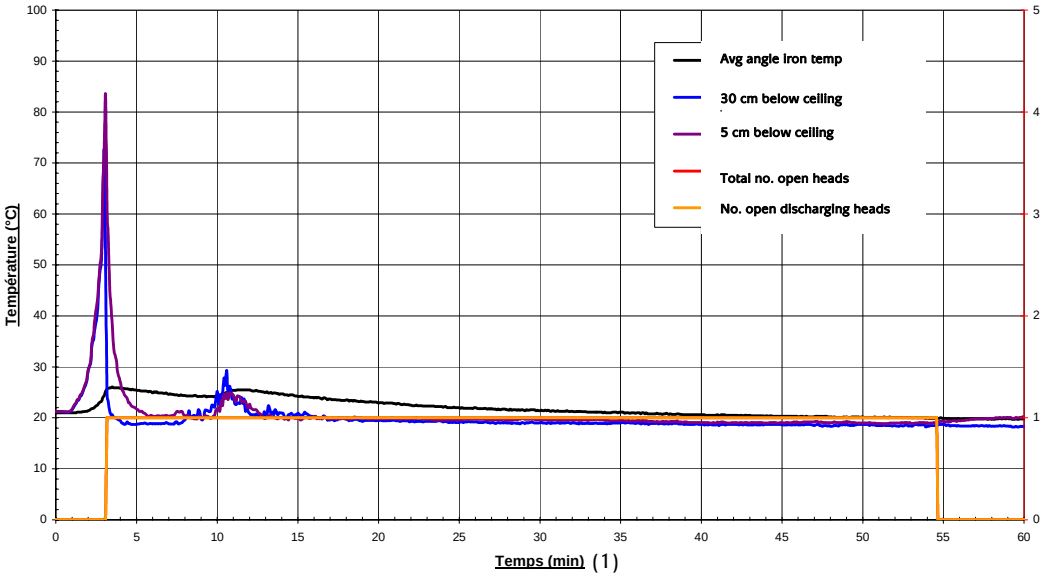
Appendix 4 – Test CNPP24 (VG8)

Tyre storage			
Tyre configuration	Mixed	Number of tyres per pallet	32 to 40
Nominal storage height	7.45 m	**Monoblock** pallet levels	5
Nb of pallets on the ground	14	Total number of pallets	70
Spacing between pallets	x = 5 cm	Number of tyres stored	2 444
Storage configuration below ceiling		Ignition point under head 13	
Extinguishing system configuration			
Ceiling height	12 m	Sprinkler head height (deflectors)	11.7 m
Clearance between deflectors and top of storage	4.25 m	Head (deflector) to ceiling clearance	0.3 m
Sprinkler type	K25 ESFR	Sprinkler K-factor	K = 363
Sprinkler RTI	26	Operating temperature	74 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 9226
Nominal sprinkler density	67 $l.m^{-2}.min^{-1}$	Sprinkler pressure	2.8 bar
Nominal flow per sprinkler	603 l/min	Extinguishing agent	Water only
Test conditions			
Test date	13/10/2005	Outside temperature	21 °C
Air intake	Natural; 4 facade doors open to 50 cm above ground		
Smoke extraction	Natural, central vent 50 % open		
Conditions for ending test	Avg temp at angle iron exceeds 400°C One of the ceiling structure temperatures exceeds 350°C		
Test results			
First sprinkler opened	3 min 07 s	Total no. of sprinklers open	1
Last sprinkler opened	3 min 07 s	Max temp 5 cm under ceiling	83 °C
Damage to test tyres	No	Max temp 30 cm under ceiling	73 °C
Avg max angle iron temp	26 °C	Time max temp attained	3 min 30 s
Max ceiling framework temp	22 °C	Time max temp attained	---
Total no. of pallets damaged	7	---	---
Equivalent no. of tyres burnt	6 tyres or 0.3 % of test stock		
Extinguishing efficiency	**Suppression mode achieved**		



(1) North - (2) Unopened sprinklers – (3) Open sprinklers

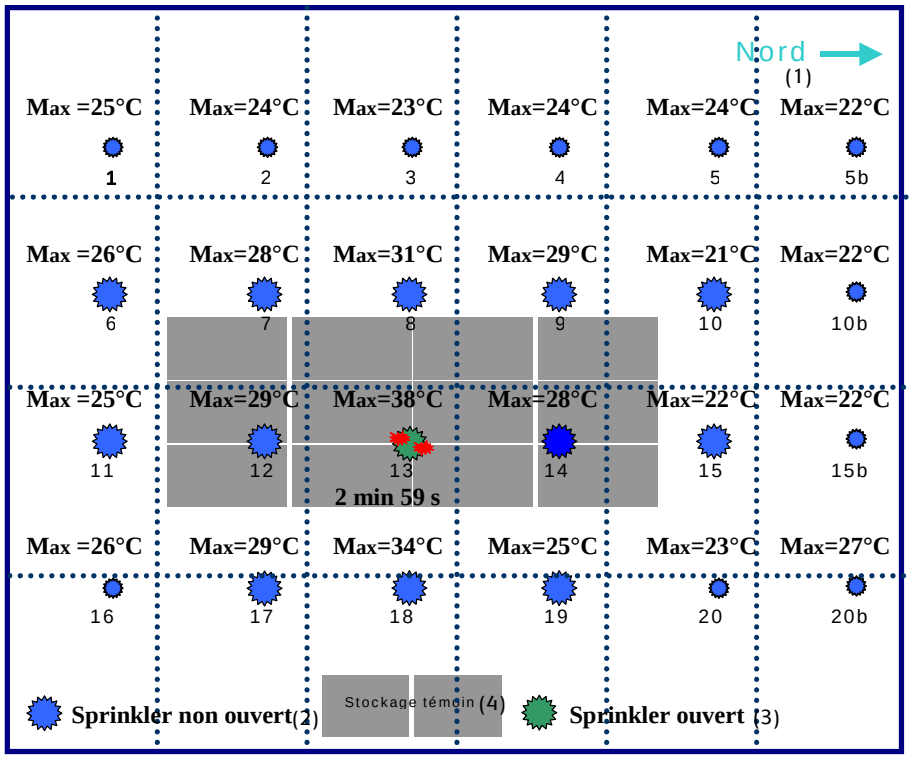
Temperatures / Open sprinkler heads



(1) Time (min)

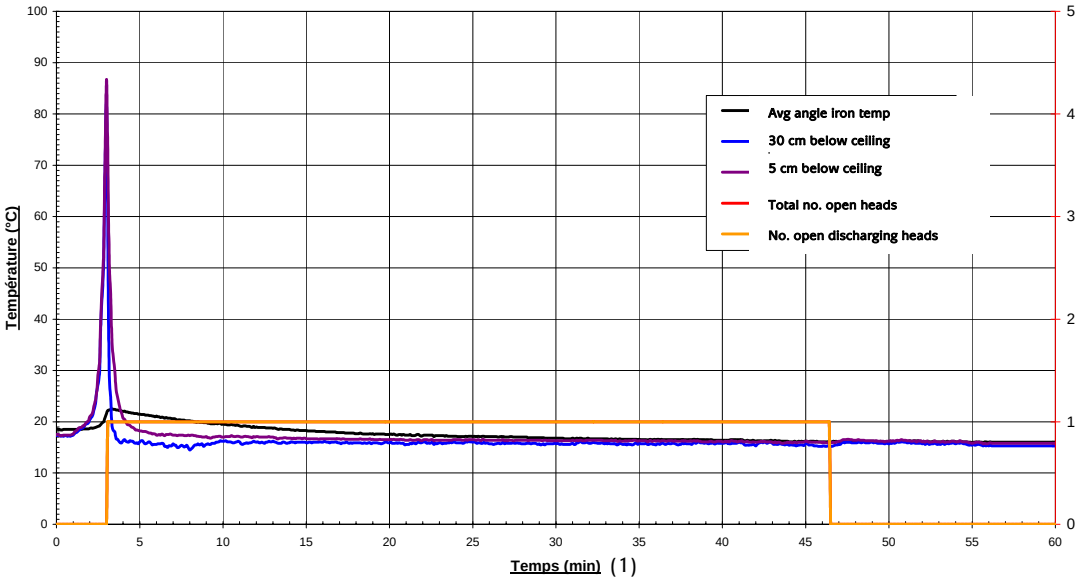
Appendix 5 – Test CNPP25 (VG11)

Tyre storage			
Tyre configuration	Laced	Number of tyres per pallet	56 to 96
Nominal storage height	8.75 m	**E4** pallet levels	4
Nb of pallets on the ground	12	Total number of pallets	48
Spacing between pallets	x = 1–27 cm	Number of tyres stored	3 799
Storage configuration below ceiling		Ignition point under head 13	
Extinguishing system configuration			
Ceiling height	12 m	Sprinkler head height (deflectors)	11.7 m
Clearance between deflectors and top of storage	2.95 m	Head (deflector) to ceiling clearance	0.3 m
Sprinkler type	K25 ESFR	Sprinkler K-factor	K = 363
Sprinkler RTI	26	Operating temperature	74 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 9226
Nominal sprinkler density	91 $l.m^{-2}.min^{-1}$	Sprinkler pressure	5.2 bar
Nominal flow per sprinkler	819 l/min	Extinguishing agent	Water only
Test conditions			
Test date	20/10/2005	Outside temperature	17 °C
Air intake	Natural; 4 facade doors open to 50 cm above ground		
Smoke extraction	Natural, central vent 50 % open		
Conditions for ending test	Avg temp at angle iron exceeds 400°C One of the ceiling structure temperatures exceeds 350°C		
Test results			
First sprinkler opened	2 min 59 s	Total no. of sprinklers open	1
Last sprinkler opened	2 min 59 s	Max temp 5 cm under ceiling	87 °C
Damage to test tyres	No	Max temp 30 cm under ceiling	82 °C
Avg max angle iron temp	23 °C	Time max temp attained	3 min 20 s
Max ceiling framework temp	19 °C	Time max temp attained	---
Total no. of pallets damaged	6	---	---
Equivalent no. of tyres burnt	7 tyres or 0.2% of test stock		
Extinguishing efficiency	**Suppression mode achieved**		



(1) North - (2) Unopened sprinklers – (3) Open sprinklers – (4) Control storage

Temperatures / Open sprinkler heads



(1) Time (min)

Appendix 6 : Summary table of CNPP full-scale tests using K25 ESFR sprinklers (to optimise new warehouses)

Test series to define protection characteristics for future warehouses:

- ✓ with K25 ESFR sprinklers
- ✓ for building heights up to 12 m
- ✓ for all types of tyre arrangement (on side, on tread and laced)
- ✓ for storage heights up to 8.75 m

Syndicat National du Caoutchouc et des Polymères - Comité de Prévention et Protection Incendie

Summary table of CNPP full-scale tests using K25 ESFR sprinklers (to optimise new warehouses)

Test series to define protection characteristics for future warehouses:

- ¤ with K25 ESFR sprinklers
- ¤ for building heights up to 12 m
- ¤ for all types of tyre arrangement (on side, on tread and laced)
- ¤ for storage heights up to 8.75 m

		Tests date	CNPP 21 (VG 7) 21/6/05	CNPP 22 (VG 10) 29/6/05	CNPP 23 (VG 7-0) 6/10/05	CNPP 24 (VG 8) 13/10/05	CNPP 25 (VG 11) 20/10/05
		Test objectives	Confirm NFPA Rule 13 on tread tyres	Confirm NFPA Rule 13 for laced tyres, using K25 heads. Test whether suppression mode is achievable with water density of 67 l/min/m^2.	Test whether suppression mode is achievable with water density of 67 l/min/m2 and a ceiling height of 10.5 m	Test whether suppression mode is achievable with a density of 67 l/min/m^2 and a ceiling height of 12 m for both laced and on tread storage.	Test whether suppression mode is achievable with a density of 91 l/min/m^2 and a ceiling height of 12 m for laced storage 8.75m high.
Storage		**Type of storage**	on tread	laced	on tread	laced and on tread	laced
		Storage height (m)	7,45	7,45	7,45	7,45	8,75
		Ceiling height (m)	9	9	10,5	12	12
		Clearance (m)	1.25	1,25	2,75	4,25	2,95
		Number of pallets on floor	3x4 + 2	3x4 + 2	3x4 +2	3x4 +2	3x4
		Number of pallet levels	5	5	5	5	4
		Number of tyres	2520	2952	2280	2444	3799
Sprinkler		**Sprinkler type**	ESFR	ESFR	ESFR	ESFR	ESFR
		SIN number	TY 9226	TY 9226	TY 9226	TY 9226	TY 9226
		K-factor	25.2 / 363	25.2 / 363	25.2 / 363	25.2 / 363	25.2 / 363
		Operating temperature (°C)	74	74	74	74	74
		RTI	26	26	26	26	26
Water (only)		**Actual head pressure (bar)**	1,1	1.7 then 2.8	2,8	2,8	5,2
		Flow per head (l/min)	378	468 then 600	603	603	819
		Water density at floor (l/min/m^2)	42	52 then 67	67	67	91
Fire		**Location of ignition below heads**	between 2 heads	between 2 heads	between 2 heads	beneath 1 head	beneath 1 head
		Overall assessment of• test results	Controlled	Controlled with 52 l/min/m2 Suppressed with 67 l/min/m^2	Suppressed	Suppressed	Suppressed
Findings main		**Opening time 1st head**	2'38"	3'54"	4'27"	3'07"	2'59"
		Number of heads open	7	6	2	1	1
		Time to open, heads 2 to n	3'10"/3'14"/3'50"/4'30"/12'25"/29'20"	3'58"/4'/4'/6'19"/6'24"	40'20"		
		Max. angle iron temp (°C)	95	73	31	26	23
		Max ceiling gas temperature (°C)	230	223	87	83	87
		Mass burned (kg,% test storage)	600 kg/2%	570 kg/2%	140 kg/0.6%	60 kg/0.3%	60 kg/0.2%
		Lessons learned from test	With 7 heads open, only control mode is achieved. Head 7 opens belatedly at 29'20", with the fire well-contained and with little strength. The suppression mode established by the rule cannot be confirmed with certainty.	With 52 l/min/m^2: Control mode is achieved (visual observation, low corner temperature, ceiling gas temperature greatly reduced). With 67 l/min/m^2, suppression mode is achieved. The fire's kinetic energy is similar for both types of storage, laced and on tread. The rule is confirmed using K25 heads.	Suppression mode is achieved. Clearance has no visible or measurable effect. The fire is shielded within the rolls of tyres until the top of the tyre is destroyed and water can get through. The fire does not travel to adjacent tyre rolls (top, bottom, left right), but can propagate through the ends of the rolls.	Suppression mode is achieved. Clearance has no visible or measurable effect. The fire's kinetic energy is the same for both types of storage, laced and on tread. The effectiveness of fire containment is the same in both cases.	Suppression mode is achieved.