

**Protection, prevention and environmental impact of fire  
in a tyre storage**  
*SNCP experience feedback report*



## **Spray sprinkler system**

*Recommendations on fire protection in tyre  
storage facilities using spray sprinkler system*

**05**



## Summary sheet

### ■ Automatic fire ignition and extinguishing tests in tyre storage facilities.

- ✓ tyres stored on side, on tread and laced
- ✓ storage height up to 7.45 m
- ✓ ceiling height up to 12 m
- ✓ fire protection system using K11.2, K17 and K17 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 the three types of storage configurations: on side, on tread and laced
- ✓ the automatic extinguishing system acts efficiently with less water on on-side storage
- ✓ the automatic extinguishing system acts in the same way on both types of storage: on tread and laced
- ✓ the first spray sprinkler head opens before the flames lick the ceiling
- ✓ extinguishing efficiency is affected by the clearance
- ✓ the fire does not spread to another island 2.4 m away with the sprinklers operating

- ✓ at the same flow, with all other conditions being equal, a K17 (242) spray sprinkler is more efficient than a K11.2 (160)
- ✓ with spray heads in control mode, the quantity of burnt tyres is high: up to 10,000 kg of burnt tyres
- ✓ with spray heads in control mode, the quantity of smoke emitted is considerable; visibility in the building is poor and hinders fire-fighting operations
- ✓ the smoke emitted would not have any reversible, irreversible or lethal effects on the exposed population (SNCP/REX/ENV/02 – 2007/S, SNCP/REX/ENV/03 – 2007/S, SNCP/REX/ENV/04 – 2007/VC)
- ✓ the release levels in the extinguishing water are compatible with the daily limits authorised for industrial facilities, whereas fire extinguishing water is a one-off release and limited in time (SNCP/REX/ENV/02 – 2007/S, SNCP/REX/ENV/03 – 2007/S, SNCP/REX/ENV/04 – 2007/VC)
- ✓ using a wetting additive and K17 ESFR heads at 1.8 bar in an existing system dramatically improves extinguishing efficiency suppression mode is obtained and the quantity of tyres burnt is very low (10 kg), for a storage height of 7.45 m
- ✓ use of an additive in a sprinkler system must be made during the wetting phase. The foaming phase degrades the sprinkler system's efficiency (ancillary result of the prep tests prior to the full-scale tests)

## ***Recommendations***

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In existing storage facilities equipped with NFPA 13-compliant spray type sprinkler systems, both types of storage (on-tread and laced) can be used.

The increased discharge coefficient of the spray type heads (K17 instead of K11.2) enhances extinguishing efficiency for a given storage height.

By using an additive in its wetting phase and installing K17 ESFR heads in an existing system with spray heads delivering 36 l/min/m<sup>2</sup> of water density at ground level (with 1.8 bar pressure), storage height can be increased to 7.45 m while still achieving suppression mode.



# *Experience feedback report*

Réf : SNCP/REX-INC/05-2007

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

## ***I. Introduction***

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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.

Three tests were carried out by Michelin at Underwriters Laboratories in Chicago in 2002, paving the way for the CNPP tests and providing additional insight.

## 2. Test facilities

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### 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). During the tests these doors were 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 m<sup>2</sup> louvered lateral openings, kept closed for the tests
- 1 central 25 m<sup>2</sup> opening, kept 50–100% open depending on the test

### 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 spray sprinklers for the three CNPP tests 11 to 13. and with ESFR sprinklers for CNPP test 14.

The additive, selected by comparative testing for CNPP test 14, is Silv-Ex type used at 0.3% concentration.

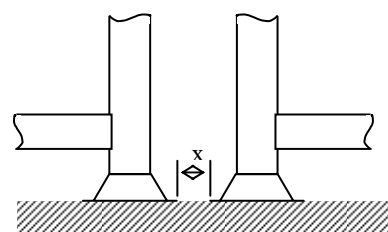
### 2.3 Tyre storage configurations

There were 4 to 5 levels of tyre storage (5.95 m or 7.45 m high), covering a floor area of 14 pallets. The tyres were arranged on side, on tread, and/or laced.

Two pallet designs was used, depending on the test:

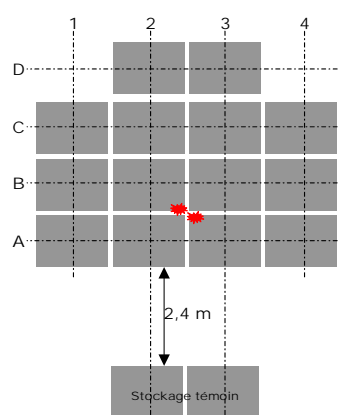
	Monoblock pallet	E4 folding pallet
Outside width between tyres	1.30 m to 1.43 m	1.20 m to 1.35 m
Inside width between uprights	1.24 m	1.05 m
Outside length	1.93 m	2.35 m
Inside length between uprights	1.74 m	2.20 m
Height	1.55 m	2.20 m

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, Ø = 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 pressure and flow rate; additive flow rate for test CNPP 14.

## 2.6 Video monitoring

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

## Appendices 1 to 4:

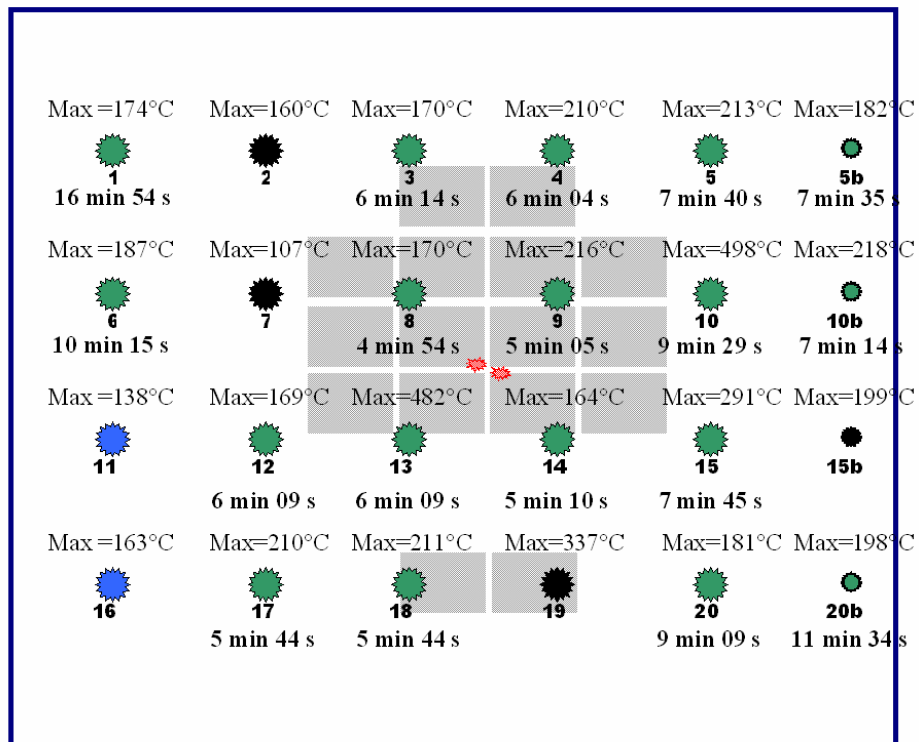
The appendices contain additional data for each of the 4 spray sprinkler tests (ESFR for VG4-1) conducted at the CNPP:




- ✓ 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 CNPP11 (VG3)

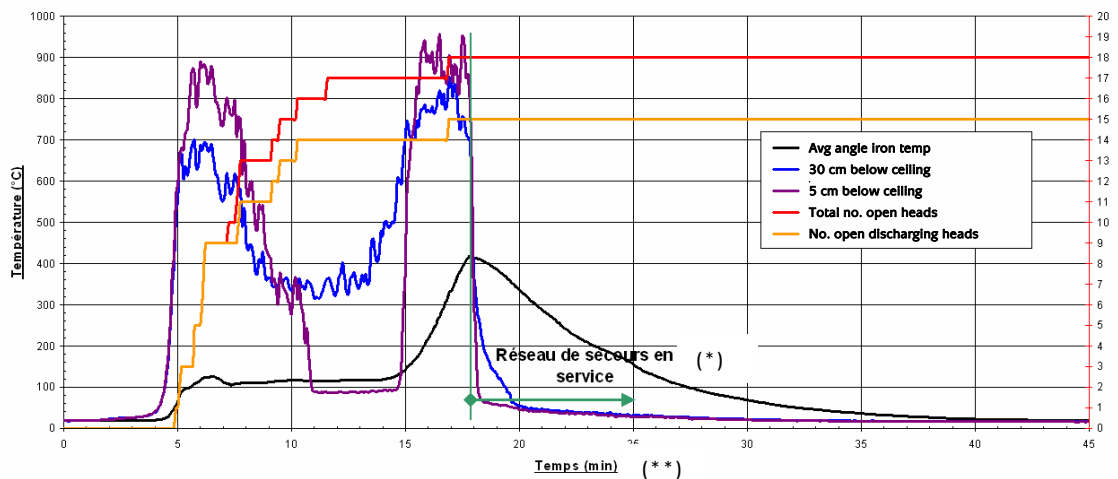
Tyre storage			
Tyre configuration	On tread	Number of tyres per pallet	32
Nominal storage height	5.95 m	<b>Monoblock</b> pallet levels	4
Nb of pallets on the ground	14	Total number of pallets	56
Spacing between pallets	x = 5 cm	Number of tyres stored	1 792
Storage configuration below ceiling		Ignition point between heads 8, 9, 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	4.25 m	Head (deflector) to ceiling clearance	0.3 m
Sprinkler type	K11.2 spray	Sprinkler K-factor	K = 161
Sprinkler RTI	105	Operating temperature	141 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 5251
Nominal sprinkler density	36 l.m <sup>-2</sup> .min <sup>-1</sup>	Sprinkler pressure	4.0 bar
Nominal flow per sprinkler	324 l/min	Extinguishing agent	Water only
Test conditions			
Test date	13/09/2005	Outside temperature	18 °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 400°C One of the ceiling structure temperatures exceeds 350°C		
Test results			
First sprinkler opened	4 min 54 s	Total no. of sprinklers open	18
Last sprinkler opened	16 min 54 s	Max temp 5 cm under ceiling	954 °C
Damage to test tyres	No	Max temp 30 cm under ceiling	851 °C
Avg max angle iron temp	420 °C	Time max temp attained	17 min 54 s
Max ceiling framework temp	260 °C	Time max temp attained	19 min 15 s
Total no. of pallets damaged	49	---	---
Equivalent no. of tyres burnt	994 tyres or 56 % of test stock		
<b>Extinguishing efficiency</b>	<b>Control mode not demonstrated for a sufficient time</b>		

North →



-  Unopened sprinklers
-  Open sprinklers
-  Sprinkler covered with soot

Temperatures / Open sprinkler heads



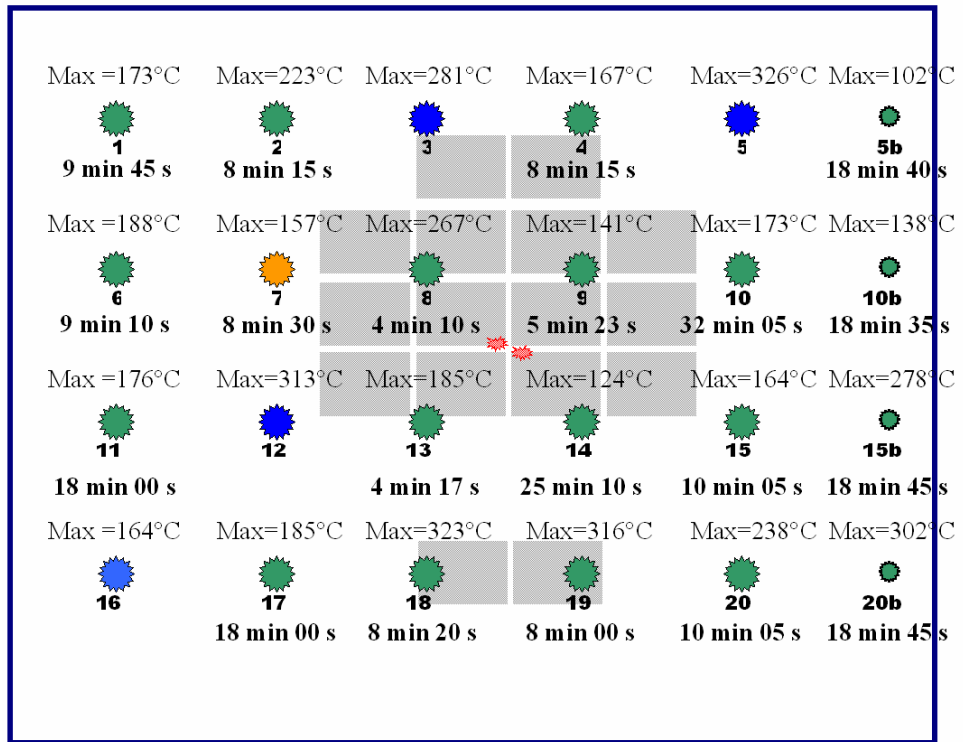
(\*) Emergency supply in service  
 (\*\*) Time (min.)



## Appendix 2 – Test CNPP12 (VG3-1)

Tyre storage			
Tyre configuration	On tread	Number of tyres per pallet	32
Nominal storage height	5.95 m	<b>Monoblock</b> pallet levels	4
Nb of pallets on the ground	14	Total number of pallets	56
Spacing between pallets	x = 5 cm	Number of tyres stored	1 792
Storage configuration below ceiling		Ignition point between heads 8, 9, 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	4.25 m	Head (deflector) to ceiling clearance	0.3 m
Sprinkler type	K17 <sup>(*)</sup> spray	Sprinkler K-factor	K = 242
Sprinkler RTI	105	Operating temperature	141 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 7251
Nominal sprinkler density	36 l.m <sup>-2</sup> .min <sup>-1</sup>	Sprinkler pressure	1.8 bar
Nominal flow per sprinkler	324 l/min	Extinguishing agent	Water only
Test conditions			
Test date	21/09/2005	Outside temperature	17 °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 400°C One of the ceiling structure temperatures exceeds 350°C		
Test results			
First sprinkler opened	4 min 11 s	Total no. of sprinklers open	20
Last sprinkler opened	32 min 05 s	Max temp 5 cm under ceiling	491 °C
Damage to test tyres	No	Max temp 30 cm under ceiling	360 °C
Avg max angle iron temp	95 °C	Time max temp attained	25 min 30 s
Max ceiling framework temp	66 °C	Time max temp attained	27 min 00 s
Total no. of pallets damaged	48	---	---
Equivalent no. of tyres burnt	695 tyres or 39 % of test stock		
<b>Extinguishing efficiency</b>	<b>Control mode achieved</b>		

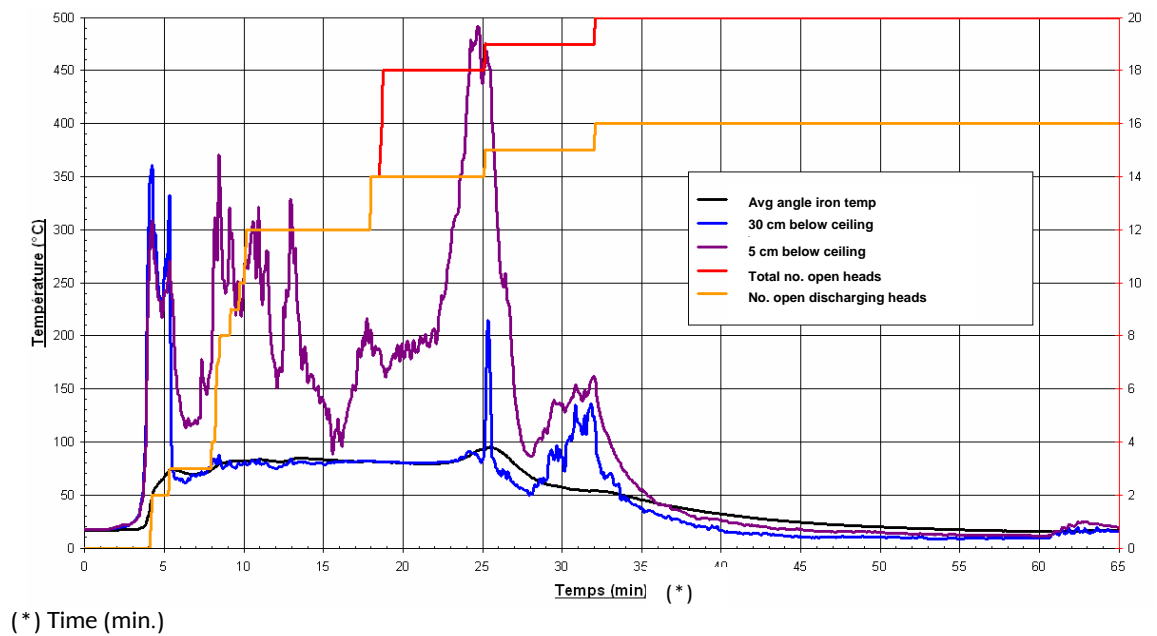
(\*): Sole parameter different from VG3



- Unopened sprinkler
- Open sprinklers
- Sprinklers with lodgement

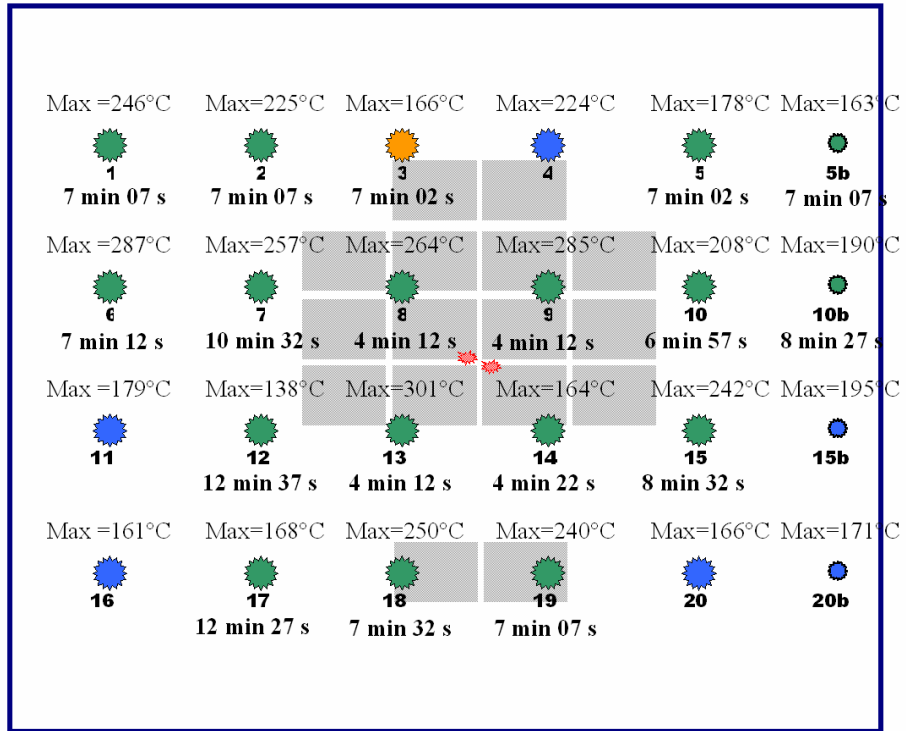
North

Temperatures / open sprinkler heads



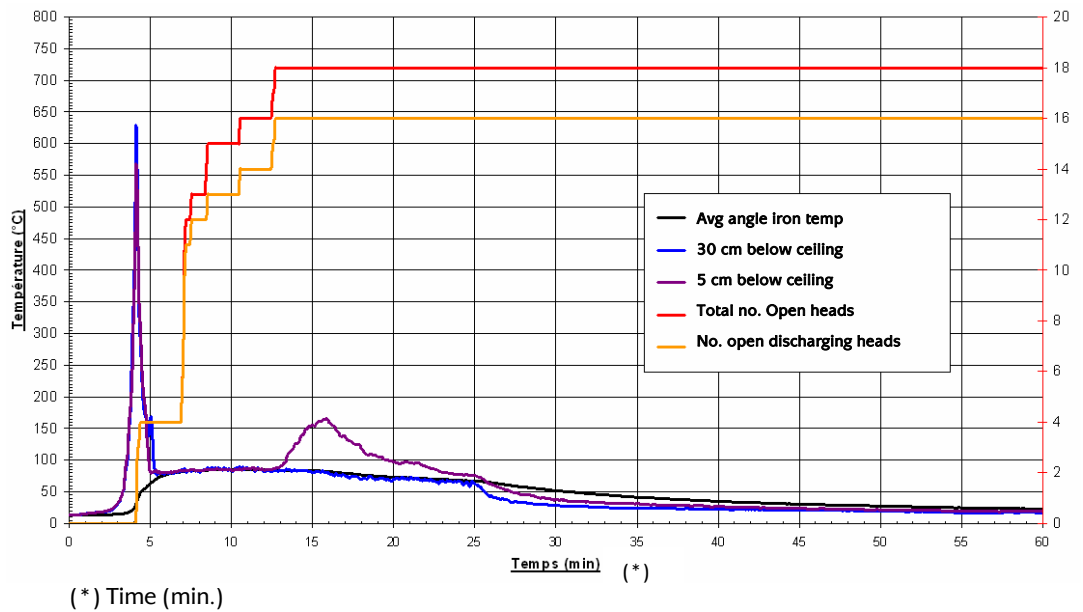
### Appendix 3 – Test CNPP13 (VG6-2)

Tyre storage			
Tyre configuration	Laced	Number of tyres per pallet	32 to 48
Nominal storage height	5.95 m	<b>Monoblock</b> pallet levels	4
Nb of pallets on the ground	14	Total number of pallets	56
Spacing between pallets	x = 5 cm	Number of tyres stored	2 294
Storage configuration below ceiling		Ignition point between heads 8, 9, 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	4.25 m	Head (deflector) to ceiling clearance	0.3 m
Sprinkler type	K17 spray	Sprinkler K-factor	K = 242
Sprinkler RTI	105	Operating temperature	141 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 7251
Nominal sprinkler density	36 l.m <sup>-2</sup> .min <sup>-1</sup>	Sprinkler pressure	1.8 bar
Nominal flow per sprinkler	324 l/min	Extinguishing agent	Water only
Test conditions			
Test date	30/09/2005	Outside temperature	15 °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 400°C One of the ceiling structure temperatures exceeds 350°C		
Test results			
First sprinkler opened	4 min 12 s	Total no. of sprinklers open	18
Last sprinkler opened	12 min 37 s	Max temp 5 cm under ceiling	565 °C
Damage to test tyres	No	Max temp 30 cm under ceiling	628 °C
Avg max angle iron temp	86 °C	Time max temp attained	11 min 20 s
Max ceiling framework temp	92 °C	Time max temp attained	17 min 45 s
Total no. of pallets damaged	45	---	---
Equivalent no. of tyres burnt	543.5 tyres or 24% of test stock		
<b>Extinguishing efficiency</b>	<b>Control mode achieved</b>		



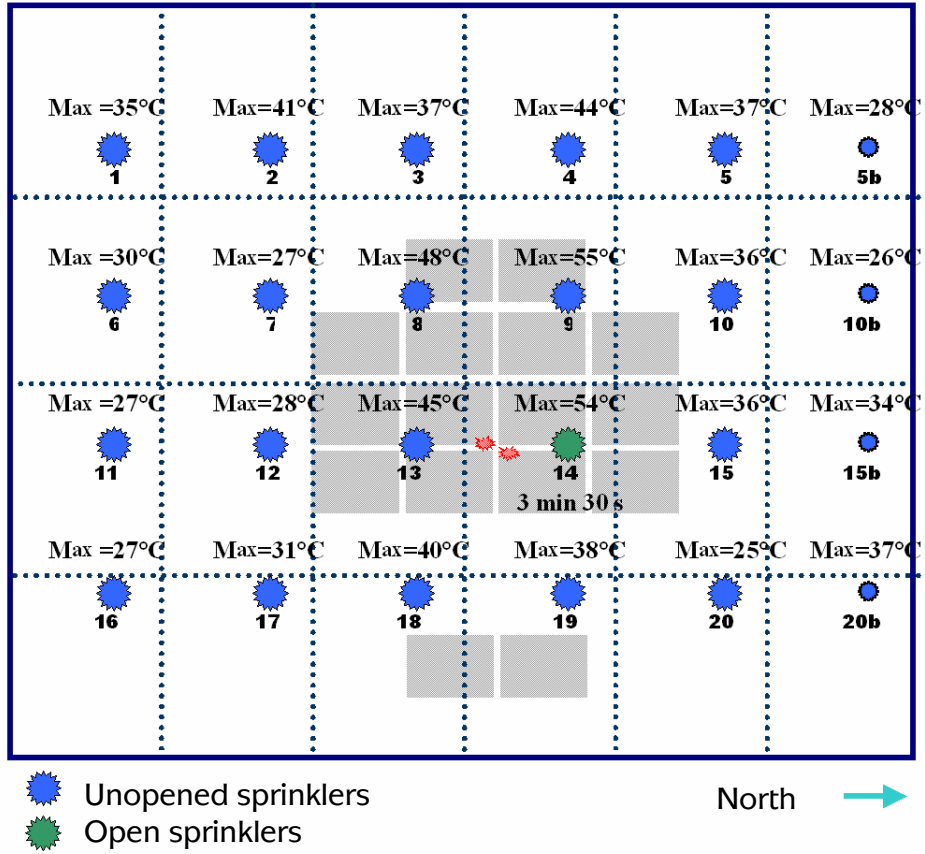
- Unopened sprinklers
  - Open sprinklers
  - Sprinklers with lodgement
- North →

**Temperatures / Open sprinkler heads**

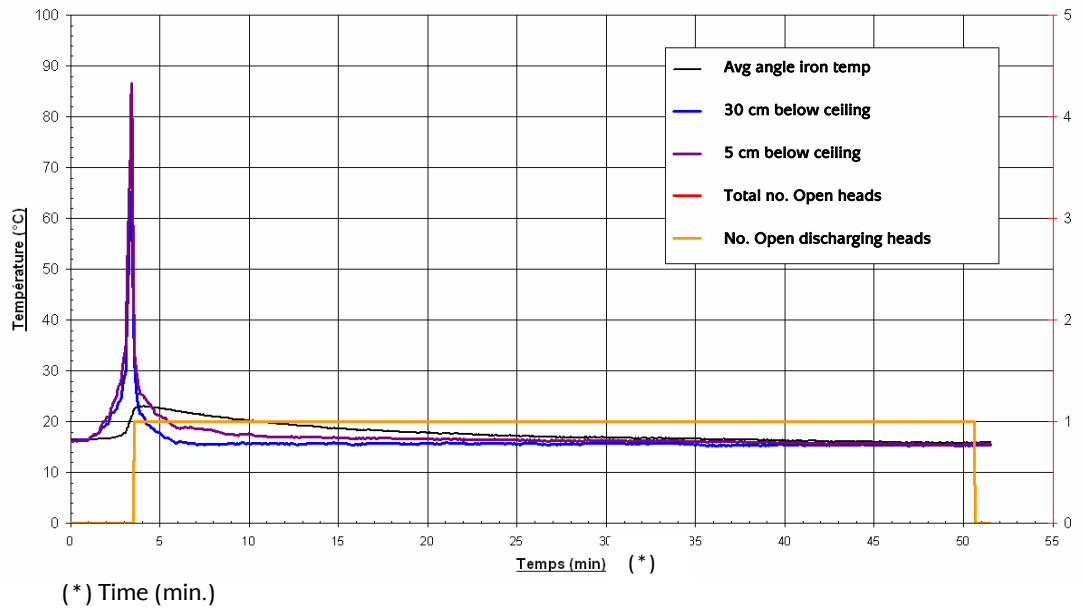


## Appendix 4 – Test CNPP14 (VG4-1)

Tyre storage			
Tyre configuration	On tread	Number of tyres per pallet	28 to 32
Nominal storage height	7.45 m	<b>Monoblock</b> 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	2 080
Storage configuration below ceiling		Ignition point between heads 13 and 14	
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	K17 ESFR	Sprinkler K-factor	K = 242
Sprinkler RTI	26	Operating temperature	74 °C
Sprinkler spacing	3 m x 3 m	Sprinkler SIN	TY 7226
Nominal sprinkler density	36 l.m <sup>2</sup> .min <sup>-1</sup>	Sprinkler pressure	1.8 bar
Nominal flow per sprinkler	324 l/min	Extinguishing agent	Water + 0.3% additive
Test conditions			
Test date	28/10/2005	Outside temperature	16 °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 30 s	Total no. of sprinklers open	1
Last sprinkler opened	3 min 30 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	23 °C	Time max temp attained	3 min 55 s
Max ceiling framework temp	16 °C	Time max temp attained	---
Total no. of pallets damaged	8	---	---
Equivalent no. of tyres burnt	1 tyre or 0.1% of test stock		
<b>Extinguishing efficiency</b>	<b>Suppression mode achieved</b>		



**Temperatures / open sprinkler heads**



***Appendix 5 : Summary table of CNPP and UL full-scale tests to optimise storage in existing warehouses***

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Test series involving existing warehouses:

- ✓ to optimise the storage capacity of existing warehouses
- ✓ to allow sprinkler-protected sites to be used as warehouses
- ✓ by controlling the effectiveness of automatic protection

Syndicat National du Caoutchouc et des Polymères – Fire Prevention and Protection Committee

Summary table of CNPP and UL full-scale tests to optimise storage in existing warehouses

Test series involving existing warehouses:

- to optimise the storage capacity of existing warehouses
- to allow sprinkler-protected sites to be used as warehouses
- by controlling the effectiveness of automatic protection

Tests date		UL 1 17/3/02	UL 2 23/3/02	UL 3 28/3/02	CNPP 11 (VG 3) 13/9/05	CNPP 12 (VG 3-1) 21/9/05	CNPP 13 (VG 6-2) 30/9/05	CNPP 14 (VG 4-1) 28/10/05
<b>Test objectives</b>		Test low value (24 l/min/m <sup>2</sup> ) required by NFPA Rule 13 - Table 12.4.2(b) on tread storage	Test the capacity of an 18 l/min/m <sup>2</sup> density sprinkler system with wetting agent additive on side tyres stored 7.3m high.	Test the improvement achieved when wetting agent is added to a 24 l/min/m <sup>2</sup> density sprinkler system (achieve control under UL1 test conditions)	Test NFPA rule (Table 12.4.2 (a), §5) with 4.25 m clearance, which corresponds to a 10.5 m-high warehouse (under NFPA 13, clearance limit is 3.1 m)	Find a solution for improving operating conditions with storage having the same characteristics as in test VG3 by increasing spray head K-factor.	Test the protection characteristics of test VG 3-1 with on-tread storage (NFPA 13 does not allow on-tread storage with spray sprinklers)	Test wetting agent additive with K17 ESFR heads on 7,5 m high storage.
<b>Storage arrangement</b>	<b>Type of storage</b>	on tread	on side	on tread	on tread	on tread	laced	on tread
	<b>Storage height (m)</b>	6,1	7,3	6,1	5,95	5,95	5,95	7,45
	<b>Ceiling height (m)</b>	8,2	8,5	8,2	10,5	10,5	10,5	12
	<b>Clearance (m)</b>	1,8	0,9	1,8	4,25	4,25	4,25	4,25
	<b>Number of pallets on floor</b>	3x5 + 3	2x5 + 3	4x3 + 1	3x4 +2	3x4 +2	3x4 +2	3x4 +2
	<b>Number of pallet levels</b>	4	4	4	4	4	4	5
<b>Sprinkler</b>	<b>Number of tyres</b>	2592	3276	1872	1792	1792	2294	2080
	<b>Sprinkler type</b>	spray	spray	spray	spray	spray	spray	ESFR
	<b>SIN number</b>				TY 5251	TY 7251	TY 7251	TY 7226
	<b>K-factor</b>	11.2 / 161	11.2 / 161	11.2 / 161	11.2 / 161	16.8 / 242	16.8 / 242	17 / 242
	<b>Operating temperature (°C)</b>	141	141	141	141	141	141	74
<b>Water</b>	<b>RTI</b>	105	105	105	105	105	105	26
	<b>Wetting additive (%)</b>	0	3 (Cold Fire)	3 (Cold Fire)	0	0	0	0.3 (SilvEx)
	<b>Actual head pressure (bar)</b>	1,8	1,1	1.1 then 1.8	4	1,8	1,8	1,8
	<b>Flow per head (l/min)</b>				324	324	324	324
<b>Fire</b>	<b>Water density at floor (l/min/m<sup>2</sup>)</b>	24	18,4	18.4 then 24	36	36	36	36
	<b>Location of ignition below heads</b>	between 4 heads	between 4 heads	between 4 heads	between 4 heads	between 4 heads	between 4 heads	between 2 heads
<b>Overall assessment of • test results</b>		Unsatisfactory control	Controlled	Controlled with 24 l/min/m <sup>2</sup>	Control mode not demonstrated for a sufficient time	Controlled	Controlled	Suppressed
<b>Findings main</b>	<b>Opening time 1st head</b>	3'12"	3'31"	2'56"	4'54"	4'11"	4'12"	3'30"
	<b>Number of heads open</b>	18	13	18	18	20	18	1
	<b>Max. angle iron temp (°C)</b>	678	311	334	420	95	86	23
	<b>Max ceiling gas temperature (°C)</b>	772	604	617	954	491	628	87
<b>Mass burned (kg,% test storage)</b>		unknown	unknown	unknown	9900 kg/56%	6900 kg/38%	5400 kg/24%	10kg/0.05%
<b>Lessons learned from test</b>		The dual water density requirements of 24 l/min/m <sup>2</sup> for 465 m <sup>2</sup> and 36 l/min/m <sup>2</sup> for 280 m <sup>2</sup> should be respected.  Note: The roof structure temperature exceeds 500°C at about 13', reaches 630°C at 16', and declines after the 18th head opens. Under these temperature criteria, control is unsatisfactory.	Control mode is achieved.  Using a wetting agent additive with 18 l/min/m <sup>2</sup> density sprinkler protection allows tyres to be stored on side to a height of 7.3 m	Control mode achieved with 24 l/min/m <sup>2</sup>  Using a wetting agent additive provides protection for this type of storage with a water density of 24 l/min/m <sup>2</sup> (in cases where the dual density required by the rule is unavailable).	Clearance is an important factor. The 3 m limit must be respected.  Note: The fire is under control for 15 minutes, after which it regains strength, probably when a pallet section collapses. Because the test was halted for safety reasons, it was not possible to learn whether control would have been regained.	Control mode is achieved.  Using 16.8K instead of 11.2K heads provides better control and allows for greater clearance. The droplets are probably larger and penetrate hot gases more easily.	Control mode is achieved.  Fire containment of laced tyre storage is similar to fire containment on tread tyre storage.	Suppression mode is achieved.  Storage can be increased in a warehouse protected by spray sprinklers at 36 l/min/m <sup>2</sup> by: - adding a wetting agent • - using K17 ESFR heads.  The test did not allow the influence of either of these 2 modifications to be determined.