Fire Retardant tests

NoIgnis - SAFEMAX

FOREST FIRE RESEARCH CENTER

ASSOCIATION FOR THE DEVELOPMENT OF INDUSTRIAL AERODYNAMICS

ASSOCIATE LABORATORY FOR ENERGY TRANSPORT AND AERONAUTICS

8th May 2025

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Scope/Project	NoIgnis - SAFEMAX		
Date	8th May 2025	**Version** [1]	1
File name	Report NoIgnis_SAFEMAX_EN	**Type of document** [2]	Confidential

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Resume	This report presents the methodology and results regarding the tests of the fire retardant named *NoIgnis*, requested by SAFEMAX.

[1] *Nº (Draft / Final)*
[2] *Public / Confidential / Internal / Restrict*

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Contents

1. Scope

This report refers to the tests performed with the *NoIgnis* Fire Retardant, as requested by SAFEMAX. The tests evaluated the effect of *NoIgnis'* previous application on forest fuels during fire propagation. The CEIF team received the *NoIgnis* in two versions: *NoIgnis Ready to Use* (Líquid) and *NoIgnis in Powder to Mix*, which were tested.

The tests were performed in the Forest Fire Research Laboratory (LEIF) of the Association for the Development of Industrial Aerodynamics (ADAI) of the University of Coimbra (UC).

2. Disclaimer

The results of the fire-retardant testing described in this report are based on laboratory conditions. The product's performance may vary when applied in different environments, including different terrain types, vegetation, slopes, and both aerial and ground applications. The efficiency of the fire retardant under these varied field conditions may differ from laboratory results.

3. Methods

3.1. Test table and wind conditions.

All tests were performed in a fuel bed on a test table placed in a wind tunnel. The test table is 2.25 meters (m) in length and 0.49 m in width, and it was placed on a structure equipped with load cells to measure the mass of the fuel bed and its variation with a frequency of 1 Hz and a resolution of 18 g. The fuel bed was divided into two parts. The first, named starter bed, is 0.9 m in length, and the second, named treated bed, is 1.35 m in length. In the starter bed, the fuel did not have treatment, i.e., did not have retardant applied.

For all tests, the wind speed was set at 1 $m.s^{-1}$, flowing in the same direction as the fuel bed length and the fire propagation.

3.2. The *NoIgnis* fire retardant.

The *NoIgnis* was received in two versions: *NoIgnis Ready to Use* and *NoIgnis in Powder to Mix.*

Regarding the tests with the version *Ready to Use*, dilutions were not made. The fire retardant was applied as received.

In the tests with the *NoIgnis in Powder to Mix*, the*NoIgnis* ingredients were added to water. The order of mixing, proportion, and other issues were made exactly as recommended by SAFEMAX.

Diammonium phosphate - DAP, 10.6% (w/w), was used as a standard to assess the *NoIgnis* efficiency index. The acceptance of *NoIgnis* is provided by the comparable performance of DAP standard solution (US Forest Service, 2020).

3.3. Fuel bed.

The fuels used in the tests consisted of straw and pine needles (*Pinus Pinaster*), separately, in homogeneous mixtures, which were previously oven-dried at 80 ºC for at least 24 h.

The fire retardant *NoIgnis* was applied using a sprayer. The treated bed was divided into 3 parts, and the sprayer was weighed before and after the application on each part to ensure that the same amount of fire retardant was applied homogeneously in the entire treated bed. The tests were carried out with the application density of fire retardant equal to 0.8 $L.m^{-2}$ as recommended by SAFEMAX. The fuel bed density was 1 $kg.m^{-2}$.

After the application of the fire retardant, the treated bed was set in the oven to dry at 60ºC until the moisture content reached ≤ 6.5%. For tests with diammonium phosphate (DAP), the drying temperature was 45ºC.

The complete set of conditions for all the tests can be seen in Table 1.

Table 1 – Tests' conditions

Test	Retardant Version	Fuel	Moisture Content of Starter Bed (%)	Moisture Content of Treated Bed (%)
Test 1	In Powder to Mix	Straw	2.6	5.4
Test 2	In Powder to Mix	Straw	2.6	4
Test 3	In Powder to Mix	Straw	4.9	3.2
Test 4	-	Straw	3.5	-
Test 5	In Powder to Mix	Straw	3.5	5
Test 6	Ready to Use	Straw	2.2	5
Test 7	Ready to Use	Straw	2.2	3.7
Test 8	In Powder to Mix	Pine Needles	3.2	3.7
Test 9	Ready to Use	Straw	3.3	4.1
Test 10	Ready to Use	Pine Needles	3.3	3.9
Test 11	-	Pine Needles	4.5	-
Test 12	*DAP*	Pine Needles	4.5	4.5
Test 13	*DAP*	Straw	3	3
Test 14	-	Straw	5	-

3.4. Data acquisition

The mass loss ratio was collected through load cells under the test table.

The rate of spread was measured with a stopwatch, recording the cutting times of strings attached to the fuel bed at known distances.

The flame height was measured using a linear scale behind and perpendicular to the test table.

The fuel bed and flame temperatures were obtained using an infrared camera.

3.5. The criteria to recommend the fire retardant

We distinguish two situations in which the fire retardant can be recommended for use.

- **First case - the fire is not extinguished**.

  If the fire in the test bed is not extinguished when it enters the treated fuel bed, we use the calculated retardant efficiency index to recommend the fire retardant. Whenever the index of the *NoIgnis* is equal to or above the control test with DAP, then its use can be recommended.

- **Second case – the fire is extinguished**.

  If the fire is extinguished when it enters the treated fuel bed, the fire retardant used is fully effective, and there is no need to calculate the efficiency index. Thus, it is recommended for use.

3.6. Calculating the retardant efficiency index and μ

The efficiency index is calculated through the set of equations shown below (Ribeiro et al., 2006):

Mass loss reduction rate of treated fuels (M_L)

$$M_L = \frac{\text{weight of treated fuel} - \text{weight loss}}{\text{weight of treated fuel}}$$

Rate of area not burned (A_b)

$$A_b = \frac{\text{treated area} - \textit{burned area}}{\text{treated area}}$$

Rate of spread reduction (R_{ROS})

$$R_{RoS} = \frac{\text{RoS of not treated bed} - \text{RoS of treated bed}}{\text{RoS of not treated bed}}$$

Flame height reduction rate (R_F)

$$R_F = \frac{\text{Flame heigh of not treated bed} - \text{Flame heigh of treated bed}}{\text{Flame heigh of not treated bed}}$$

Efficiency Index (EI)

$$EI = \frac{R_F + R_{RoS} + A_b + M_L}{4}$$

Non-dimensional mass loss rate (μ)

$$\mu = \frac{mass - final\ mass}{initial\ mass - final\ mass}$$

4. Results

4.1. Tests with *NoIgnis Ready to Use*.

In the three tests performed with straw and *NoIgnis Ready to Use*, the fire-retardant effect was observed first, followed by flame extinction. In all three tests, the flames were extinguished before 45 cm of penetration into the treated bed, which reduced the burnt area by up to 77 % (Table 2).

In the test with pine needles and the *NoIgnis Ready to Use* (Test 10), the retardant effect was observed, but the flames were not extinguished. In this case, the efficiency index of *NoIgnis Ready to Use* was 58.6%, while the test under the same conditions using DAP was 34.5%. Comparing Test 10 to Test 11 (without treated bed), there was an 82 % reduction in the rate of spread, 89.3 % in average flame height, and 63 % in mass loss (Table 2).

Therefore, considering: i) the extinction of the flames in the tests with straw, and; ii) for the tests with pine needles, a higher Efficiency Index than that found in the tests with DAP; the use of *NoIgnis Ready to Use* is recommended.

4.2. Tests with *NoIgnis in Powder to Mix*.

In the four tests carried out with straw and *NoIgnis in Powder to Mix*, the flame retardant effect was observed. In three of the four tests, the flames were extinguished. In the three tests in which the flames were extinguished, they were extinguished before 45 cm of penetration into the treated bed, which represented a reduction in the burnt area of up to 86.7 %. In Test 1, in which the flames were not extinguished, the Efficiency Index was 58.5%, higher than that found in the test with DAP, which was 57.7% (Table 2), and the flames were not extinguished either.

In the tests with pine needles and *NoIgnis in Power to Mix* (Test 8), the retardant effect was observed, but the flames were not extinguished. In this case, the efficiency index of *NoIgnis in Power to Mix* was 50.3 %, while the test under the same conditions using DAP was 34.5 %. Comparing Test 8 to Test 11 (without treated bed), there was a reduction of 54.8 % in flame propagation speed, 66.7 % in average flame height, and 79.8 % in mass loss (Table 3).

Table 2

Tests with straw								
Test	Test 1	Test 13	Test 2	Test 3	Test 5	Test 6	Test 7	Test 9
NoIgnis	To Mix	DAP	To Mix	To Mix	To Mix	Ready to Use	Ready to Use	Ready to Use
Flame height reduction rate	88.0%	85.7%	-	-	-	-	-	-
Rate of spread reduction	76.8%	80.6%	-	-	-	-	-	-
Mass loss reduction rate of treated fuels	63.2%	64.4%	-	-	-	-	-	-
Rate of area not burned	4.8%	0.0%	86.7%	79.0%	77.0%	76.0%	74.0%	77.0%
EI	58.2%	57.7%	-	-	-	-	-	-
Extinguished Fire?	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Table 3

Tests with pine needles			
Test	Test 8	Test 10	Test 12
NoIgnis	To Mix	Ready to use	DAP
Flame height reduction rate	66.7%	89.3%	56.7%
Rate of spread reduction	54.8%	82.0%	8.8%
Mass loss reduction rate of treated fuels	79.8%	63.0%	72.7%
Rate of area not burned	0.0%	0.0%	0.0%
EI	50.3%	58.6%	34.5%
Extinguished Fire?	No	No	No

The Non-dimensional mass loss rate was reduced with the *NoIgnis* application, which can be seen in Figure 1, below.

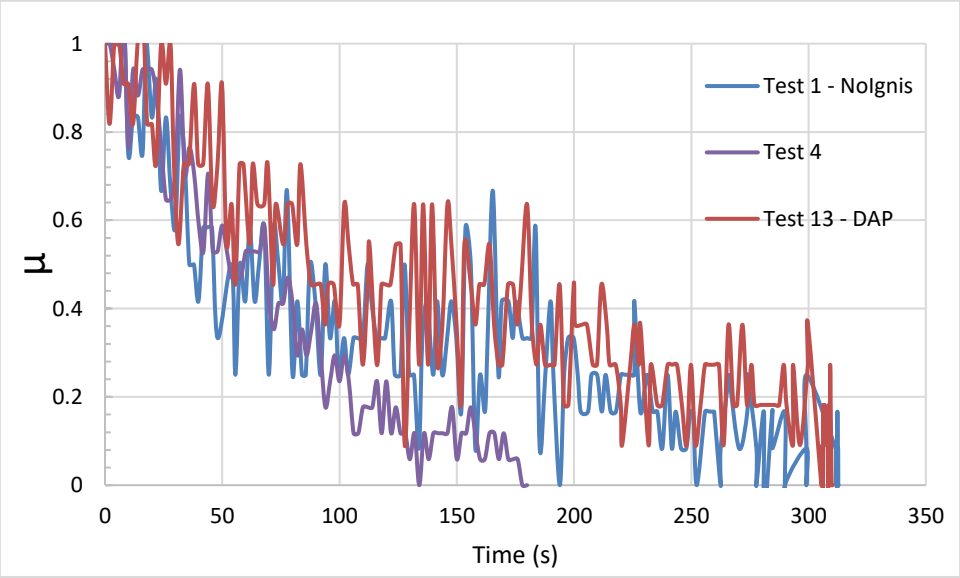

Figure 1. Non-dimensional mass loss rate for tests with straw and flames not extinguished.

A reduction of up to 219 ºC in the flame temperature of the treated bed was observed in the straw and pine needles tests for both versions of *NoIgnis* (Appendix 7.1).

Therefore, considering: i) the extinction of the flames in the tests with straw, and ii) regarding the tests with pine, for which a higher Efficiency Index than that found in the tests with DAP was obtained, the use of *NoIgnis Version in Powder to Mix* is recommended.

There was no significant difference between the versions *Ready to Use* and *in Powder to Mix*.

5. Conclusion

The results can be differentiated considering the desired effect in the combustion: retardant or extinction.

5.1. Retardant effect

The retardant effects of *NoIgnis* (both versions) presented acceptable results, and better than those found with DAP.

When the recommended dilutions are used, we can expect:

- A reduction in the flame temperature up to 219 ºC;
- A reduction in the rate of spread up to 82 %;
- A reduction in the flame height up to 89.3 %.

5.2. Extinguishing effect

The *NoIgnis* presented a burnt area reduction of the treated bed up to 86.7 %.

5.3. Difference between both versions and recommendation for use.

There was no significant difference between the *NoIgnis* versions: *Ready to Use* and *In Powder to Mix*.

The *NoIgnis Ready to use* and *In Powder to Mix* are recommended to be used.

6. References

Ribeiro, L.M., Xavier Viegas, D., & Batalha, M. (2006). Assessment of fire-retardant efficiency. In Domingos Xavier Viegas (Ed.), *V International Conference on Forest Fire Research*.

US Forest Service. (2020). *LF-2.1 Combustion Retarding Effectiveness - Laboratory Procedure STP-2.1, Combustion Retarding Effectiveness Contents*.

7. Appendix

7.1. Photos of some tests

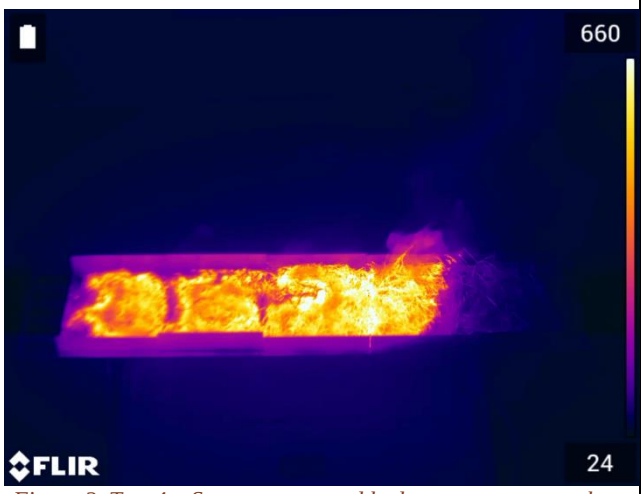

Figure 2. Test 4 – Straw, not treated bed, temperature equal to 660ºC

Figure 3. Teste 1 - Straw, with NoIgnis, at 441ºC

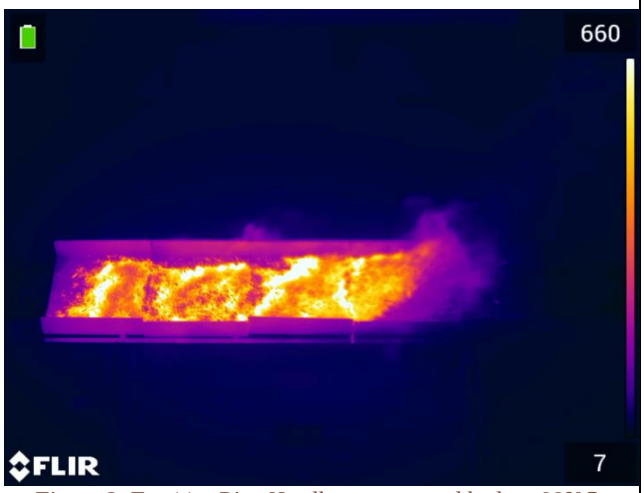

Figure 3. Test11 – Pine Needles, not treated bed, at 660ºC

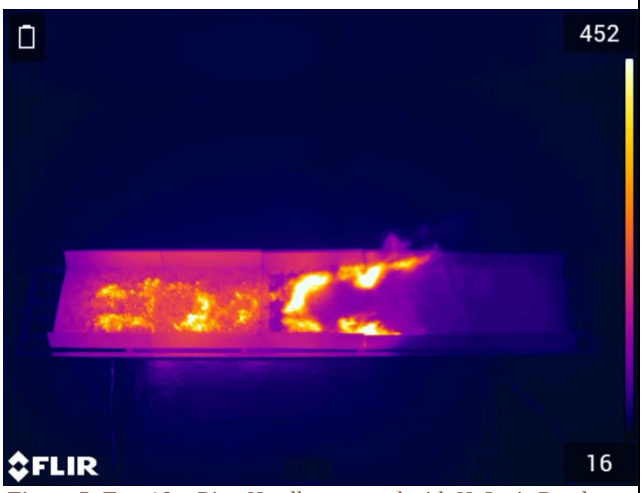

Figure 5. Test 10 – Pine Needles, treated with NoIgnis Ready to Use, at 452ºC

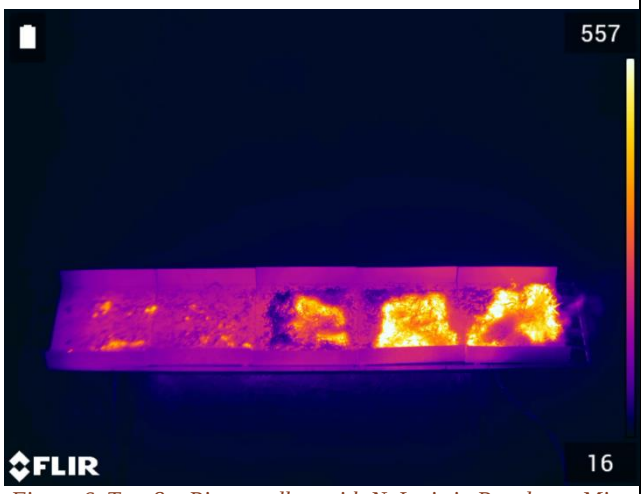

Figure 6. Test 8 – Pine needles, with NoIgnis in Powder to Mix at 557ºC

Figure 7. Test 2 – Straw, photo taken after flame extinction at the beginning of the treated bed

Figure 8. Test 5 – Straw, photo taken after flame extinction at the beginning of the treated bed

Figure 9. Straw, fuel bed not treated

Figure 10. Test 6 – Straw, time at which flames reached the interface between the starter bed and the treated bed with NoIgnis

Figure 11. Test 6 - Straw, time at which flames reached the middle of the treated bed with NoIgnis

Figure 12. Test 10 – Pine Needles, flame with high intensity and height at the end of the starter bed

Figure 13. Test 10 – Pine Needles, photo taken at the moment which flames are in the treated bed with reduced size of flames

7.2. Non-dimensional mass loss rate graphs

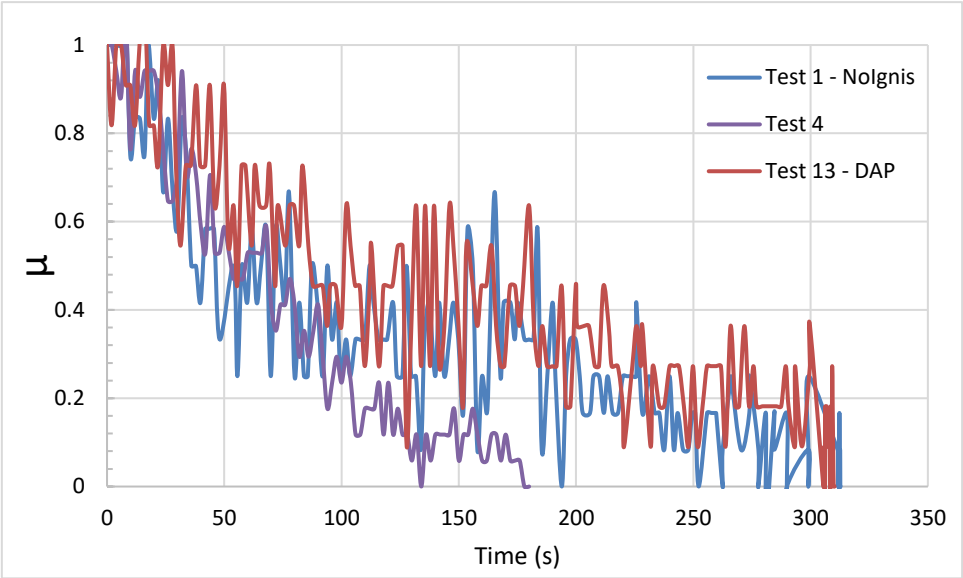

Figure 14. Non-dimensional mass loss rate for tests with straw and flames not extinguished.

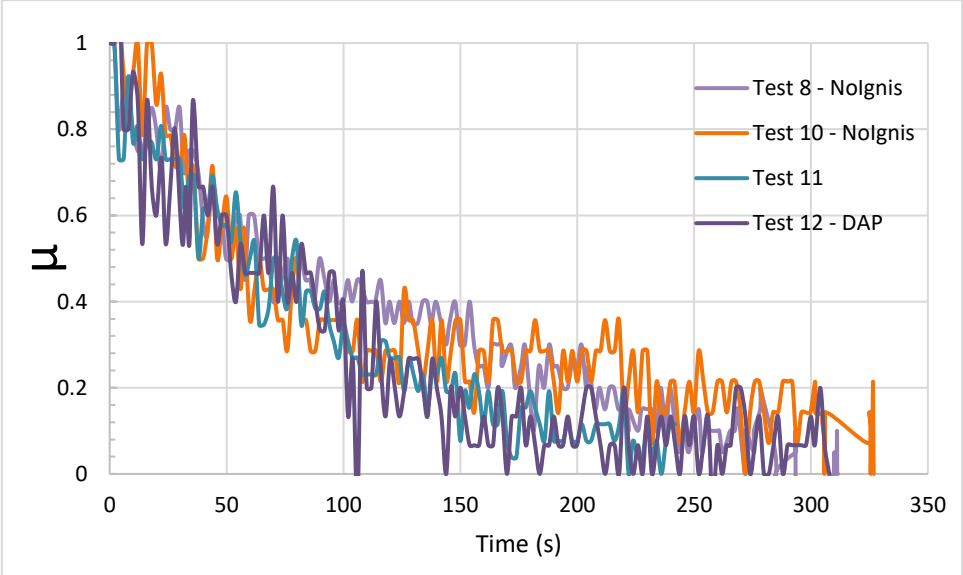

Figure 15. Non-dimensional mass loss rate for tests with pine needles and flames not extinguished.

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