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EUFIRELAB:

**Euro-Mediterranean Wildland Fire Laboratory,
a “wall-less” Laboratory
for Wildland Fire Sciences and Technologies
in the Euro-Mediterranean Region**

Deliverable D-07-03

Wildland Fire Metrology: a State of the Art

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SUMMARY

This document presents a first approach to fire metrology and its state of the art. A more complete overview will be presented in Deliverable D-07-13. The topics covered here are concerned with experimental laboratory fires, micro-scale experimental field fires, and macro-scale experimental fires (prescribed burnings).

It highlights essential points on equipment and techniques used by research laboratories. The work of these laboratories provides data and information for fire scientists, forest fire modellers, forestry managers, and fire-fighters.

This document is divided into three main sections.

- the first recalls the timetable over which the tasks were accomplished;
- the second presents the state of the art in fire metrology carried out by partner members: this was done through a questionnaire that surveyed members on their instrumentation and comments on the techniques used:
 - the questionnaire itself, and
 - a summary of the responses (full responses of each research team are included in D-07-03_A);
- the third and final section of the deliverable presents an overview of the responses, presents some particular cases and draws some general trends, and outlines some provisional conclusions.

GLOSSARY

None

LIST OF ASSOCIATED DOCUMENTS

D-07-03_A: full responses of each partner to the questionnaire

1 INTRODUCTION

Experimental data are the necessary ingredients to understand the real world.

Models are built using a (limited) set of basic data, and further (more extensive) data is necessary to validate those models.

Concerning wildland fire as a subject of study, we see that the levels of description cover an enormous range, from the details of combustion physical-chemistry, up to the meteorological level where large fires occur.

Experimental work on fires can be carried out in the laboratory, where burned areas are of the order of a few square meters, and in the field, where the size of the experiments can go from small (a dozen square meters) to large (entering in the hectares range).

With respect to laboratory fires and small scale field experiments, measured parameters include very often flame temperature, rate of spread and flame geometry.

These are related to the fire effects and are important to predict fire consequences.

Another set of parameters, which are relevant to fire behaviour comprises, among others, wind speed, fuel moisture content, terrain slope, atmospheric temperature and humidity.

Concerning large scale experiments, another class of parameters which concerns the way the (large) fire affects the environment comes into play.

It includes gaseous combustion products and particulates existing in the near vicinity of the fire as well as emitted pollutants appearing at larger distances from the fire, affecting the air quality in a wider region.

Concerning the instruments themselves, one important division is made between intrusive (or invasive) and non-invasive instruments.

Any instrument which includes a solid probe (e.g. thermocouple, gas sampling probe,...) introduces some disturbance in the medium to be measured, while cameras (in the visible or I.R. range) obviously leave the flame or the flow undisturbed.

However, non-invasive measurements are very often (much) more expensive than invasive ones, so that a balance has to be established which takes into account the cost vs outcome ratio.

In addition, invasive instruments usually perform point measurements, while non-invasive techniques very often produce measurements integrated along the line of sight.

The partners who are the main contributors to WP7 are users of a wide range of instruments and devices and perform experiments from the laboratory bench scale to large field experiments.

This seems to be a representative sample of wildfire metrology.

Therefore, this first "state of the art" report (D-07-03) concerns essentially instruments and techniques used inside the consortium.

The final "state of the art" report, to be written at the end of the project (deliverable D-07-13) will also include devices and methodologies used by other groups in the scientific community outside the consortium.

The methodology to produce the present deliverable was the following:

1 A questionnaire was prepared and uploaded to the EUFIRELAB web site.

The questionnaire asked about the variables and/or properties that are measured or calculated.

For each property, it requested the main characteristics of the equipment used, its range of values and accuracy.

Finally, space was provided to accommodate information about methodologies, limitations and added value of each measuring technique.

The concerned partners downloaded the questionnaire, filled in the relevant information and uploaded their contributions to the same folder in the web site.

Based on these contributions, a draft was prepared and uploaded again for comments and suggestions.

A final version was written, taking into account the feedback received from the interested partners.

Deliverable D-07-03 is divided into three main sections.

The first describes the sequence of steps which lead to its preparation.

The second includes the questionnaire used and a summary of the responses to it (full responses of each partner are included in Annex 1).

The third section includes some comments about the information collected and draws some (provisional) conclusions

2 THE STATE OF THE ART AMONG PARTNER MEMBERS

2.1 THE QUESTIONNAIRE USED TO SURVEY MEMBERS

2.1.1 Introduction

The questionnaire is divided into three parts, each one consisting of a table.

The first lists the variables and/or properties that are measured or calculated.

The second lists the main characteristics of the equipment used, its range of values and accuracy.

The third provides information on methodologies, limitations, and added value of each measuring technique.

It should be noted that the fire metrology considered here is in the frame of experimental fires, both inside laboratories and in the open field.

The latter can be:

- micro-scale fires: the experiments occur over a short time period and the burn area is limited to about 5 to 10 m²), or
- macro-scale fires: the experiments occur over a longer time period, the burn area can exceed several hectares, and “real” fuel – standing vegetation – is used.

2.1.2 Questionnaire

- 1) In Table 1 place an “X” on the appropriate column if you measure or acquire that variable or property. If you feel the need to provide more information, add a “+” and insert a comment at the bottom of the table. If the information was already included in deliverables D-07-01 and D-07-06 (or any other), put the deliverable number in the last column.
- 2) For each row where you have put an “X”, fill in Table 2. Insert new table rows if required.
- 3) For the References mentioned in Table 2 which you believe need additional comments, use Table 3 to provide information on methodologies, limitations, added value of that technique, ... (Please limit each entry to 200 words, and insert extra rows if necessary).

Table 1: Type of device

Ref.	Variable or Property	If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature		
1.1	Air		
1.2	Flame		
1.3	Embers		
1.4	Fuel		
1.5	Soil		
2	Atmospheric pressure		
3	Heat flux		
3.1	From flames		
3.2	From embers		
4	IR radiation		
4.1	From flames		
4.2	From embers		
5	Images		
5.1	Still pictures		
5.1.1		Visible	
5.1.2		IR	
5.2	Movies		
5.2.1		Visible	
5.2.2		IR	
6	Wind		
6.1	Speed		
6.2	Direction		
7	Air humidity		
8	Fuel moisture content		
9	Fuel particles surface-to-volume ratio		
10	Fuel calorific value		
11	Rate of spread		
12	Flame geometry		
12.1	Flame height		
12.2	Flame length		
12.3	Flame angle		
13	Combustion gaseous products		
14	Combustion solid products		
14.1	Ash		
14.2	Unburned fuel		
Com:			

Table 2: Measured or acquired variable or property

Ref	Measured property	Device name	Main characteristics	Range of values	Accuracy

Table 3: More information

Ref.	Comments

2.2 SUMMARY OF THE RESPONSES TO THE QUESTIONNAIRE

2.2.1 Introduction

Among the members that were solicited to contribute, 8 responded (P007, P010, P011, P012, P013, P018, P022, P027)¹.

The results below, based on these responses, are presented in terms of both absolute numbers of users and % of respondents for the variable or property measured or calculated.

For the type of equipment, or computing method, the percentages refer to the number of teams that use it among the of teams that measure or calculate the concerned variable or property.

The full responses are included in Annex (D-07-03_A)

2.2.2 Variable or property measured or calculated

Variable or Property	Number	%
Temperature of the air	6	75.0
Temperature of the flame	4	50.0
Temperature of the embers	3	37.5
Temperature of the fuel	4	50.0
Temperature of the soil	3	37.5
Atmospheric pressure	2	25.0
Heat flux from flames	1	12.5
Heat flux from embers	1	12.5
IR radiation from flames	2	25.0
IR radiation from embers	2	25.0
Still pictures in the visible range	7	87.5
Still pictures in the IR range	4	50.0
Movies in the visible range	7	87.5
Movies in the IR range	4	50.0
Wind speed	6	75.0
Wind direction	5	62.5
Air humidity	6	75.0
Fuel moisture content	5	62.5
Fuel particles surface-to-volume ratio	4	50.0
Fuel calorific value	3	37.5
Rate of spread	6	75.0
Flame height	7	87.5
Flame length	6	75.0
Flame angle	6	75.0
Combustion gaseous products	2	25.0
Combustion solid products - ash	2	25.0
Combustion solid products – unburned fuel	3	37.5
Combustion solid products – suspended particles	1	12.5

¹ INRA's contribution has not been included in the analysis, but has been included in the annex

2.2.3 Type of equipment or computing method

Variable or Property	Type of equipment or computing method	%
Temperature of the air	Mercury thermometer	33.3
	Alcohol thermometer	16.7
	Electronic thermometer	50.0
	Thermocouple	50.0
	Automatic weather station	16.7
Temperature of the flame	Thermocouple	100.0
Temperature of the embers	Thermocouple	100.0
Temperature of the fuel	Thermocouple	100.0
Temperature of the soil	Thermocouple	100.0
Atmospheric pressure	Automatic weather station	100.0
Heat flux from flames	Heat flux sensor	100.0
Heat flux from embers	Heat flux sensor	100.0
IR radiation from flames	IR camera	25.0
IR radiation from embers	IR camera	25.0
Still pictures in the visible range	SLR camera	28.6
	Digital camera	85.7
	Telemetric camera	14.2
Still pictures in the IR range	IR camera	100.0
Movies in the visible range	Video camcorder	71.4
	Digital video camera	42.9
Movies in the IR range	IR camera	100.0
Wind speed	Mechanical anemometer	100.0
	Ultrasonic anemometer	33.3
	Hand-held hot-wire anemometer	16.7
	Automatic weather station	16.7
Wind direction	Wind vane	60.0
	Ultrasonic anemometer	40.0
	Automatic weather station	20.0
Air humidity	Wet & dry psychrometer	33.3
	Electronic hygrometer	66.7
	Capacitive hygrometer	33.3
	Fully integrated station	16.7
	Precision scale and oven	100.0
Fuel moisture content	Precision scale and oven	100.0
	Microtome and image analyser	33.3
Fuel particles surface-to-volume ratio	Lens with scale, callipers	33.3
	Vegetation morphology (photography)	33.3
	Adiabatic bomb calorimeter	50.0
	Vegetation morphology (photography)	50.0
Rate of spread	Visual observation (at post marks)	33.3
	Computed from flame "position vs time"	100.0
Flame height	Direct visual observation	87.5
	Computed from flame imaging	71.4
Flame length	Direct visual observation	28.6
	Computed from flame height and angle	28.6
	Computed from flame imaging	42.9
Flame angle	Direct visual observation	50.0
	Computed from flame imaging	66.7
Combustion gaseous products	FTIR spectroradiometer + IR source	50.0
	Flame ionization detection and Gas chromatography	25.0
	Ionic chromatography	25.0
	Chemiluminescence	50.0
Combustion solid products - ash	Precision scale	50.0
	Precision scale, oven	50.0
Combustion solid products – unburned fuel	Precision scale	50.0
	Precision scale, oven, post-fire inventory	50.0
	Callipers, post-fire inventory	50.0
	Post-fire inventory (non-burned area estimation)	50.0
	Beta gauge mass monitor	100.0
Combustion solid products – suspended particles	Beta gauge mass monitor	100.0

3 COMMENTS AND CONCLUSIONS

3.1 INTRODUCTION

In this section some comments will be given about the information gathered from the questionnaires.

Two documents have already been delivered concerning specific areas which fall within "Metrology", but deserved to be dealt with separately.

These are deliverables D-07-01 (Weather stations for lab and field experiments: the procedure of use) and D-07-06 (Radiotransmitter and GPS controller: principles and general presentation).

Two other deliverables are being prepared at the same time as the present one and cover material which is dealt with herein:

- D-07-04: Infra-red measurement devices: principles and basic results, and
- D-07-05: Infra-red cameras: principles and general presentation.

References to partners in the following text are related to any special contribution of that partner in the questionnaire (particularly in Table 3), which are fully displayed in the Annex to this document.

3.2 "FLAME AND FIRE" PROPERTIES

3.2.1 Temperature

All the partners who measure flame temperature use thermocouples for that purpose.

Data obtained can in some cases be affected by radiation and there are also problems concerning the thermocouple time response, which is related to the wire diameter and to the data sampling rate (P012).

In spite of the limitations of this technique, its low cost and simple use make these instruments a preferred tool for this type of measurement, as well as for embers, fuel and soil temperatures.

Ember temperatures can also be inferred from measurements of IR radiance, making some assumptions on the atmospheric transmission (P011).

For air temperature other instruments are used, which rely on different sensors (thermistors, resistance thermometers...).

The old (and reliable) mercury thermometer is also used for this purpose.

3.2.2 Flame geometry (flame height, length and angle)

Most of the partners measure (or estimate) these parameters.

In general, they can be estimated visually on the spot – using marked poles for size reference – or video recorded for later analysis and measurement.

The first approach is often followed in large field experiments (P018, P027) while recording and later analysis is used more in laboratory experiments.

When there is turbulence – and flames in fires are normally turbulent – some ambiguity may arise on defining these characteristics.

Averages of some sort have to be carried out (P010, P012) in order to obtain a value to characterise the whole experiment.

Also, flame length or flame height obtained from IR imaging are larger than those obtained from visible imaging (P011).

Flame geometry can also be obtained using more sophisticated methods (§ 4.2.3).

3.2.3 Rate of spread (ROS)

This is one of the most important characteristics of a wildland fire.

The faster the fire travels, the greater the danger associated with its propagation. Some of the considerations in 4.2.2 are relevant here.

These measurements are more difficult to perform in the field, because the driving wind is usually more erratic than in laboratory experiments.

In outside fires, it is often done by visual estimation, using marked references to assess the advancing fire front position.

Video recording and later analysis is also used.

In some cases, more sophisticated techniques have been used, combining information from different sensors (IR, visual) and all the data available using calibration methods, pre-processing, fuzzy logic, wavelets, and data fusion techniques, with location over the field given by georeferencing (P007).

Flame geometry (flame height, length and angle) is also computed using these methods.

Furthermore P007 has developed an experimental Fire Monitoring Tool to detect and monitor the fire and obtain fire characteristics (rate of spread, flame geometry ...).

3.3 FIRE CONDITIONING PARAMETERS

3.3.1 Air temperature and humidity

The atmospheric conditions have a strong influence on the development of a forest fire.

One of the most important is wind: velocity and (variable) direction (§ 4.3.2).

Air temperature and humidity are also relevant.

Virtually all partners that deal with experimental fires measure air temperature.

One partner (P027) that deals with larger field fires uses an automated station "Davis", complemented with portable thermo/hygrometer.

The other partners use mainly electronic thermometers.

When the air temperature is measured in a zone that is to be swept by the fire, the choice is the thermocouple.

Most partners also measure air humidity.

The most common measuring device is the electronic hygrometer.

Only one partner measures atmospheric pressure, although recognising that it seems to be without real importance (P027)

3.3.2 Wind speed and direction

Most partners measure wind speed due to the very strong influence it has on fire development.

The mechanical anemometer is a universal choice to measure wind velocity.

Usually, it is complemented (or complements) other instrumentation.

The partner that deals with larger experimental fires uses its automated station "Davis" (P027) located at 2-3 m above ground level at about 30-50 m from the fire upwind.

All partners that measure wind velocity also measure wind direction (P012 did not mention it explicitly because they use a wind tunnel where wind direction is conditioned – and known).

Wind vane is the most common choice, although ultrasonic anemometers and automated weather stations are also used.

3.3.3 Fuel properties

Forest fire is highly dependent on fuel properties.

All partners are aware of this, but not all determine those properties; instead, they send samples to other partners and use the values hence obtained (e.g. P012), or they estimate those properties from observation and literature correlations (e.g. P027).

Nevertheless, most of them measure fuel moisture content by weighing fuel samples before and after oven-drying them.

Temperatures in the oven vary between 60°C (P012) to 100°C (P010) with drying times around 24 hours for one-hour fuels (P012).

Surface-to-volume ratio requires special techniques.

One partner uses Microtome and image analyser (P010), another uses callipers and lens with scale (P018).

The same applies to the fuel calorific value, which is measured with an adiabatic bomb calorimeter (P10).

3.4 COMBUSTION PRODUCTS

3.4.1 Gaseous products

The main constituents of wildland fuel combustion products are carbon dioxide (CO₂) and water vapour (H₂O).

Putting aside the fact that they are greenhouse gases, they are not usually the main cause of concern.

Some minor constituents of the gaseous products are of much more concern due to the way they can affect people and the environment in general.

Some of them result from incomplete combustion, like carbon monoxide (CO), while others, like nitrogen oxides (NO_x) occur even if combustion is complete.

Two types of techniques can be used:

- a) radiation emission or absorption methods, that in general are only suitable for laboratory work, because they require very controlled conditions, and
- b) gas sampling techniques, followed by immediate or delayed analysis.

Only two partners are equipped to measure gaseous combustion products.

Using a technique of the first type, partner P011 can measure gas concentrations by absorption spectroscopy, using an IR source and a FTIR spectroradiometer.

This can only be used in laboratory flames.

Partner P022 can measure volatile organic compounds (VOC's) by sampling the combustion gases, storing the samples and using gas chromatography with a flame ionisation detector to analyse them.

To characterise the air quality in the region surrounding the fire, P022 also measures nitrogen dioxide (NO₂) and sulphur dioxide (SO₂) using ionic chromatography, nitrogen monoxide (NO) and nitrogen dioxide (NO₂) using chemiluminescence and carbon monoxide (CO) using IR absorption.

3.4.2 Solid products

3.4.2.1 Ash

Ash corresponds to the mineral content of the fuel and its amount is measured by 2 partners (P010 and P018) in small scale outside experiments, by weighing it at the end of the burn.

3.4.2.2 Unburned fuel

The same partners also weigh the amount of unburned fuel and P018 furthermore evaluates the size of unburned fuel by measuring with callipers.

On larger scale fires, P027 estimates the percentage of non-burned surface area.

3.4.2.3 Airborne particles

Being a characteristic feature of wildland fires, smoke is essentially a suspension of particles in the atmosphere.

These airborne particles are very detrimental to the air quality.

Smoke plume characteristics using visual video images are obtained by P007 using optical flow, wavelets and fuzzy logic methods.

P022 measures concentration of particles with diameter less than 2.5 µm or 10 µm, according to the sampling inlet in use.

Particle mass is determined by a beta gauge mass monitor, and the measurement is not influenced by the physico-chemical nature, colour or size of particulate matter.

3.5 IMAGING DIAGNOSTIC TECHNIQUES

The imaging techniques used among the partners are grouped in two categories: Visible and Infrared (IR) cameras and camcorders.

Their main application is to determine geometrical flame parameters, ROS and spatial temperature distribution.

3.5.1 Visible

Used for the majority of flame visualization needs and determination of ROS, most of the partners use conventional videos cameras (digital and Hi8), due to their ease of use and relatively low cost while producing very acceptable results.

In laboratory experiments digital cameras with 3 to 5 MP are used to obtain digital still images for further processing.

The results obtained from these techniques are based on direct image observation.

Some partners are also developing automatic image processing with the use of software tools.

3.5.2 Infrared

IR Cameras measure IR radiance (W/m^2sr). This can be translated to "brightness temperatures" (P011).

The main application for this technique (and also its main advantage) is to obtain a spatial distribution of flame temperature, which can be used to obtain flame visualisations.

This allows the determination of geometric parameters, although the concept of flame height can be somewhat ambiguous, since the method produces larger values for this parameter when compared with conventional cameras and visible measurement techniques (P011).

Application of these techniques to field measurements (P007) is reported in detail in Deliverable D-07-04.

3.6 CONCLUSIONS

A large number of variables and properties are measured and calculated in research work on forest fires.

The techniques used go from the very simple to the relatively complex.

This variation depends mainly on the conditions of application (laboratory or field work), on the background of the research team, and on cost considerations.

It should also be taken into account that costly/complex equipment usually requires a longer training period for the operator.

Interaction among teams with different backgrounds has proven to be fruitful.

Experiments carried out at the laboratory level are important because conditions can be closely controlled and monitored and it is easier to use complex instrumentation.

Experiments carried out in the field are important because fire conditions are closer to those found in real forest fires.

Working at different spatial scales enriches the knowledge about the relevant phenomena.

The instruments and techniques must be adapted to the objectives of the study, and these vary from one context to another.

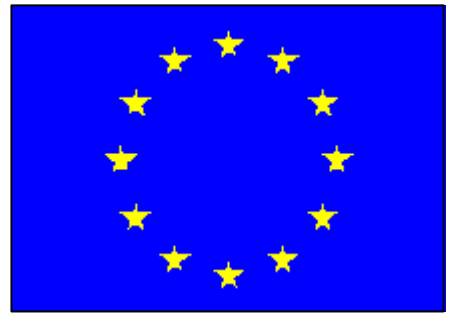
Different techniques are very often complementary in the way they produce information about the object of study.



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EUFIRELAB:

**Euro-Mediterranean Wildland Fire Laboratory,
a “wall-less” Laboratory
for Wildland Fire Sciences and Technologies
in the Euro-Mediterranean Region**

Deliverable D-07-03_A

**Wildland Fire Metrology: a State of the Art
Answers from the Partners**

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February 2004

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1 CONTRIBUTION USE-DISA (SEVILLA) P007

1.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air			
1.2		Flame			
1.3		Embers			
1.4		Fuel			
1.5		Soil			
2	Atmospheric pressure				
3	Heat flux				
3.1		From flames			
3.2		From embers			
4	IR radiation				
4.1		From flames			
4.2		From embers			
5	Images				
5.1		Still pictures			
5.1.1			Visible	X	
5.1.2			IR	X	D-07-04
5.2		Movies			
5.2.1			Visible	X	
5.2.2			IR	X	D-07-04
6	Wind				
6.1		Speed			
6.2		Direction			
7	Air humidity				
8	Fuel moisture content				
9	Fuel particles surface-to-volume ratio				
10	Fuel calorific value				
11	Rate of spread			X	
12	Flame geometry				
12.1		Flame height		X	
12.2		Flame length		X	
12.3		Flame angle		X	
13	Combustion gaseous products				
14	Combustion solid products				
14.1		Ash			
14.2		Unburned fuel			
Comments:					

1.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
5.1.1 & 5.2.1	Visible images	SONY DFW-VL500 digital color camera	1/3 CCD progressive scan 12x integrated and controllable zoom IEEE1394 interface DCAM compatible Resolution: 640x480 (YUV 4:2:2) 8 bit/pixel Frame rate: up to 30 fps		
5.1.1 & 5.2.1	Visible images	Pixelink PL-A741 digital monochrome camera	½ CMOS sensor IEEE 1394 interface, DCAM 1.13 compatible Resolution: 1280x1024, 10 bit/pixel Frame rate: up to 107 fps (640x480)		
5.1.2 & 5.2.2	Explained for deliverable D-07-04				

1.3 TABLE 3

Ref.	Comments
11 to 12.3	This is done using the combined information from different sensors (IR, Visual) and all the data available using calibration methods, pre-processing, fuzzy logic, wavelets, and data fusion techniques. Georeferencing and location over the field. It is represented in real time in a time scale of seconds at each meter of the area under consideration. Visual images are used to analyse the smoke column and its parameters.

2 CONTRIBUTION INIA-CIFOR (MADRID) P010

2.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air		X	D-07-01
1.2		Flame		X	
1.3		Embers		X	
1.4		Fuel		X	
1.5		Soil		X	
2	Atmospheric pressure				
3	Heat flux				
3.1		From flames			
3.2		From embers			
4	IR radiation				
4.1		From flames			
4.2		From embers			
5	Images				
5.1		Still pictures			
5.1.1			Visible	X	
5.1.2			IR		
5.2		Movies			
5.2.1			Visible	X	
5.2.2			IR		
6	Wind				
6.1		Speed		X	D-07-01
6.2		Direction		X	D-07-01
7	Air humidity			X	D-07-01
8	Fuel moisture content			X	
9	Fuel particles surface-to-volume ratio			X	
10	Fuel calorific value			X	
11	Rate of spread			X	
12	Flame geometry				
12.1		Flame height		X	
12.2		Flame length		X	
12.3		Flame angle		X	
13	Combustion gaseous products				
14	Combustion solid products				
14.1		Ash		X	

14.2	Unburned fuel	X
<p>Comments:</p> <p>Ref. 8, 9 and 10 are object of the deliverable D-02-02 "Physical, chemical and thermal characteristics of the wildland fuel particles" (this deliverable will be presented in April 2004). They are also contemplated in D-02-01 "Methods for wildland fuel description and modelling: a state of the art"</p>		

2.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
1.1	Air temperature	-Mercury thermometer Thermocouples	D07-01		
1.2	Flame temperature	-Data logger Thermocouples	See Table 3		
1.3	Embers temperature	-Data logger Thermocouples	See Table 3		
1.4	Fuel temperature	-Data logger Thermocouples	See Table 3		
5.1.1	Visible still pictures	-Digital camera	Olympus C-740 Ultrazoom		
5.2.1	Visible movies	-Digital video	Sony Handycam Digital 8		Zoom X100
6.1	Wind speed	-Mechanical anemometer -Sonic anemometer	D07-01		
6.2	Wind direction		D07-01		
7	Air humidity	-Psychrometer	D07-01		
8	Fuel moisture content	-Precision balance -Air oven	D-02-01 and D-02-02	-	
9	Fuel particles surface-to-volume ratio	-Microtome Image analyser	D-02-01 and D-02-02		
10	High calorific value	-Adiabatic bomb calorimeter	D-02-01 and D-02-02		
11	Rate of spread	-Wind tunnel -Scales	See Table 3		
12.1	Flame height	-Wind tunnel -Scales	See Table 3		
12.2	Flame length	-Wind tunnel -Scales	See Table 3		
12.3	Flame angle	-Wind tunnel -Scales	See Table 3		
14.1	Ash	-Wind tunnel	See Table 3		

14.2	Unburned fuel	-Precision balance -Wind tunnel -Precision balance	See Table 3
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2.3 TABLE 3

Ref.	Comments
1.1	Experimental burnings are conducted in a wind tunnel . This tunnel, in the open air, consists of a heat area with the following dimensions: 8.5 m long and a transversal section of 2 m x 3 m; on the ground there are eight independent small wagons 1.0 m long x 0.8 m wide and 0.25 m high, filled with sand, so they form a surface of 8.0 m x 0.8 m on which the fuel is arranged.
1.2	Meteorological variables, Air Temperature , Air humidity and Wind speed and direction out of tunnel are also measured.
1.3	During each test, temperature variations are recorded by a data logging system Datataker DT500.
1.4	Measurements are made by K thermocouples (diameter 1 mm). The location of the thermocouples can be modified according to the characteristics of the fuel complex to be tested, so it is possible to obtain Flame, Embers, Fuel and Soil Temperatures . The sampling frequency can be varied from 1 s.
6.1	The tunnel is equipped with a fan intended to create an air flow, feigning the action of wind within the heat area; the fan is controlled by an electronic system which enables to obtain wind speed values between 1 and 7 m s ⁻¹ in the central area of the heat area. Wind speed and direction are measured each meter at three heights with a Sonic Anemometer.
6.2	The moisture content of the fuel tested is determined by means of a representative sample, oven-dried at 100 °C. Said sample is taken immediately before ignition.
8	Rate of spread is calculated as the mean of partial rates of spread measured at each meter of the heat area.
11	Flame height and Flame angle are measured visually, at each meter of the heat area. Flame length is obtained through of them.
12.1	
12.2	
12.3	
14.1	Ashes and unburned fuel are weighted separately at the end of the burn.
14.2	

3 CONTRIBUTION UC3M-LIR (MADRID) P011

3.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air			D-07-01
1.2		Flame			
1.3		Embers			
1.4		Fuel			
1.5		Soil			
2	Atmospheric pressure				
3	Heat flux				
3.1		From flames			
3.2		From embers			
4	IR radiation				
3.1		From flames		X	
3.2		From embers		X	
5	Images				
5.1		Still pictures			
5.1.1			Visible	X	
5.1.2			IR	X	
5.2		Movies			
5.2.1			Visible	X	
5.2.2			IR	X	
6	Wind				
6.1		Speed			
6.2		Direction			
7	Air humidity				D-07-01
8	Fuel moisture content				
9	Fuel particles surface-to-volume ratio				
10	Fuel calorific value				
11	Rate of spread			X	
12	Flame geometry				
12.1		Flame height		X	
12.2		Flame length			
12.3		Flame angle			
13	Combustion gaseous products			X	

14	Combustion solid products		
14.1		Ash	
14.2		Unburned fuel	
Comments:			

3.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
4.1	IR radiation from flames	IR cameras	Several IR cameras operating in the 3-5 μm or 8 to 12 μm bands	Radiances from 10 ⁰ to 10 ⁴ W/m ² sr (equivalent to brightness T from room temperature to 1200K)	Depends on many parameters. Order of magnitude: less than 1% in radiance values.
4.2	IR radiation from embers	IR cameras	Id.	Id.	Id.
5.1.1	Still pictures visible	Digital camcorder	CCD 1Mpixel		
5.1.2	Still pictures IR	IR cameras	MIR & TIR bands, size aprox. 100Kpixel		
5.2.1	Movies visible	Digital camcorder	CCD 1Mpixel	Ordinary digital video	
5.1.2	Movies IR	IR cameras	MIR & TIR bands, size aprox. 100Kpixel	Number of frames per second depends on the camera, aprox. 50FPS	
11	Rate of spread	IR cameras	Deduced from observed position of fire front		Accuracy in fire front position depends on distance (angular accuracy aprox. 1mrad)
12.1	Flame height	IR & visible cameras			Variable (difficult to define)
13	Combustion gaseous products	FTIR spectroradiometer + IR source	Measured by absorption spectroscopy	1 to 1000 Ppm-m (parts per million · meter) Depends strongly on the compound	Several ppm-m

3.3 TABLE 3

Ref.	Comments
4.1	Cameras measure IR radiance (W/m^2sr). This can be translated to “brightness temperatures” and, with some assumptions on the atmospheric transmittance, to ember temperatures.
12.1	Flame height is not a very well defined concept. Larger in IR than in visible.
13	Only (concentration) times (optical path) can be measured. Can be used only for laboratory files in very controlled conditions

4 CONTRIBUTION IST/DEM (LISBOA) P012

4.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air		X	D-07-01
1.2		Flame		X	D-07-01
1.3		Embers			
1.4		Fuel		X	D-07-01
1.5		Soil			
2	Atmospheric pressure				
3	Heat flux				
3.1		From flames			
3.2		From embers			
4	IR radiation				
3.1		From flames			
3.2		From embers			
5	Images				
5.1		Still pictures			
5.1.1			Visible	X	
5.1.2			IR		
5.2		Movies			
5.2.1			Visible	X	
5.2.2			IR		
6	Wind				
6.1		Speed		X	D-07-01
6.2		Direction			
7	Air humidity			X	D-07-01
8	Fuel moisture content			X	
9	Fuel particles surface-to-volume ratio				
10	Fuel calorific value				
11	Rate of spread			X	
12	Flame geometry				
12.1		Flame height		X	
12.2		Flame length		X	
12.3		Flame angle		X	
13	Combustion gaseous products				
14	Combustion solid products				
14.1		Ash			

14.2	Unburned fuel
Comments:	

4.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
1.1	Air temperature	Electronic thermometer	Point measurements; Automatic mean calculation through a time interval	-20 to 70°C	±0,5°C T=0 to 50°C and ±0,7°C T<0°C and T>50°C.
1.1	Air temperature	Thermocouple	K type, 250 µm	-18 to 1370°C	±0.7°C *
1.2	Flame temperature	Thermocouple	K type, 250 µm	-18 to 1370°C	±0.7°C *
1.4	Fuel temperature	Thermocouple	K type, 125 µm	-18 to 1370°C	±0.7°C *
5.1.1	Still pictures (visible)	Digital camera	3.2 MP		
5.2.1	Movies (visible)	Video camera			
6.1	Wind speed	Hand-held hot-wire anemometer	Point measurements; Automatic mean calculation trough a time interval	0 to 20 m/s T=20 to 70°C; 0 to 10 m/s T=0 to 20°C;	0.01 m/s V<10m/s 0.1 m/s V>10m/s
7	Air humidity	Electronic hygrometer	Temperature and Relative air humidity measurements	0 to 100% relative humidity	±1%
8	Fuel moisture content	-	Precision scale and oven (seasoning kiln)	-	±1%
11	Rate of spread	-	From timed images of flame position	-	5% (say)
12.1	Flame height	-	From images of flame position	-	10% (say)
12.2	Flame length	-	From images of flame position	-	10% (say)
12.3	Flame angle	-	From images of flame position	-	10% (say)
*	The accuracy of the results for the thermocouples depends on both the polynomial interpolation used to convert mV to temperatures and the accuracy of the acquisition device. The result presented is based on the polynomial conversion. For the data logger used, this value can be higher depending on the sensibility chosen for the range of values to be measured. For example, an accuracy of 1.0°C is possible for a limited range of temperatures, corresponding to measured voltages of the order of magnitude of some mV. A lower accuracy of 3 to 4°C is the best that can be obtained for the full range of temperatures measured, implying voltages up to 50 to 60 mV.				

4.3 TABLE 3

Ref.	Comments
1.1	<p>When measuring air temperature with thermocouples in the vicinity of a flame, the thermocouples should be shielded. Alternatively, a correction for radiation can be applied, but this may be difficult if the flame is moving and/or turbulent.</p> <p>K type thermocouples are not ideal for air temperature, but are a perfectly acceptable choice to measure air and flame temperature.</p>
1.2	<p>The dimensions of the thermocouple's wire and bead depend on the purpose of the measurement and on the mechanical resistant required. If turbulent fluctuations are to be measured, the wire and bead diameters should not be larger than 75 μm and 150 μm, respectively. If mean values are needed (changing rapidly but not in the turbulent time scale), larger dimensions (up to 250 μm and 500 μm) are not only acceptable but preferable because the thermocouple itself provides the averaging effect needed.</p> <p>For sooty flames (like those found in forest fires), radiation correction is not necessary if/when the thermocouple is within the flame. Similarly, shielding is not needed either.</p>
1.4	<p>When measuring fuel temperature with thermocouples in the vicinity of a flame, the thermocouples should be shielded. Alternatively, a correction for radiation can be applied, but this may be difficult if the flame is moving and/or turbulent.</p> <p>K type thermocouples are not ideal for near-ambient temperature, but are a perfectly acceptable choice if the thermocouple has also to measure flame temperature.</p> <p>Ideally, the thermocouple should be imbedded in the fuel particle but as near the surface as possible.</p>
8	<p>Fuel moisture content can be obtained by weighing the fuel, then oven-drying it, and weighing it again. The weight difference is the water lost. The temperature and time duration in the oven depends on the fuel particle dimension. For "1 hour fuel", 60° C and 24 hours is perfectly adequate.</p>
11	<p>Rate of spread can be measured from the variation of flame position with time. Flame position can be obtained from a series of timed pictures (e.g. from a video). Velocity is obtained from the derivative of position with time.</p>
12.1	<p>Flame height can be measured from still pictures. However, for turbulent flames it cannot be obtained from a single picture, but from a number of pictures (more than 10, say), randomly selected. A single criterion has to be used to define the tip of the flame. We consider only the main body of the flame and disregard the flamelets.</p>
12.2	<p>Flame length can be measured from still pictures. However, for turbulent flames it cannot be obtained from a single picture, but from a number of pictures (more than 10, say), randomly selected. Alternatively, it can be obtained from flame height and flame angle.</p>
12.3	<p>Flame angle can be measured from still pictures. However, for turbulent flames it cannot be obtained from a single picture, but from a number of pictures (more than 10, say), randomly selected. A single criterion has to be used to define what the angle of the flame is. We consider the leading edge of the flame.</p>

5 CONTRIBUTION ADAI (COIMBRA) P013

5.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air		X	D01
1.2		Flame		X	D01
1.3		Embers		X	
1.4		Fuel		X	
1.5		Soil		X	
2	Atmospheric pressure				
3	Heat flux				
3.1		From flames		X	
3.2		From embers		X	
4	IR radiation				
3.1		From flames		X	D06
3.2		From embers		X	
5	Images				
5.1		Still pictures		X	
5.1.1			Visible	X	
5.1.2			IR	X	D06
5.2		Movies			
5.2.1			Visible	X	
5.2.2			IR	X	D06
6	Wind				
6.1		Speed		X	D01
6.2		Direction		X	D01
7	Air humidity			X	D01
8	Fuel moisture content			X	
9	Fuel particles surface-to-volume ratio			X	
10	Fuel calorific value				
11	Rate of spread			X	
12	Flame geometry				
12.1		Flame height		X	
12.2		Flame length		X	
12.3		Flame angle		X	
13	Combustion gaseous products				
14	Combustion solid products				

14.1	Ash
14.2	Unburned fuel
Comments: In Table 2 we give a list of sensors and measuring equipment that is used by ADAI.	

5.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
1.1	Air temperature	Temperature Sensor	Logotronic NTC Sensor	-10° a 85°C	± 0.1°C
1.2	Flame temperature	Thermocouple	OMEGACLAD T/C Wire-INC-K-MO-1		
3	Heat flux	Heat Flux Sensor	Vatell Thermogage 1000-1		
4 and 5	IR radiation IR Images	Ir camera	Thermovision 550-AGEMA	3.6 – 5 μm	
6	Wind: Speed and direction	Wind Speed and direction sensor	THIES4.3520.10.00 THIES	0.5 a 50 m/s 0° e 360°.	±0.5 m/s ±5°
7	Air humidity	ROTRONIC HYGROCLIP-S.	Capacitive hygrometer C-94	0 a 100%.	± 1.5%.
8	Fuel moisture content	Balance	AND: EY-220M HW-15K HF-2000E AD-47174		
11 and 12	Rate of spread	Video cameras Video Recorders	Sony Super Steady_Shot Handycam SVT-96LP (VHS) EV-C500E (Hi8)		

6 CONTRIBUTION XG-CIFL (LOURIZÁN) P018

6.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air		X	D-07-01
1.2		Flame		X	
1.3		Embers		X	
1.4		Fuel		X	
1.5		Soil		X	
2	Atmospheric pressure			X	
3	Heat flux				
3.1		From flames			
3.2		From embers			
4	IR radiation				
3.1		From flames			
3.2		From embers			
5	Images				
5.1		Still pictures		X	
5.1.1			Visible	X	
5.1.2			IR	X	
5.2		Movies			
5.2.1			Visible	X	
5.2.2			IR	X	
6	Wind				
6.1		Speed		X	D-07-01
6.2		Direction		X	D-07-01
7	Air humidity			X	D-07-01
8	Fuel moisture content			X	
9	Fuel particles surface-to-volume ratio			X	
10	Fuel calorific value				
11	Rate of spread			X	
12	Flame geometry				
12.1		Flame height		X	
12.2		Flame length		X	
12.3		Flame angle		X	
13	Combustion gaseous products				
14	Combustion solid products				
14.1		Ash		X	

14.2	Unburned fuel	X
Comments:		

6.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
1.1	Air temperature	Shielded thermohygrometer	Platinum wire thermistor Resolution: $\pm 0,5^{\circ}\text{C}$	-40 to 60°C	
1.1	Air temperature	Alcohol thermometer	Resolution: $\pm 1^{\circ}\text{C}$	-15 to 60°C	
1.1	Air temperature	Mercury thermometer	Resolution: $\pm 0,2^{\circ}\text{C}$	-15 to 60°C	
1.1	Air temperature	thermocouples	Type K inconel shielded (1mm diameter)	-270 to 1200°C	
1.2	Flame temperature	thermocouples	Type K inconel shielded (1mm diameter)	-270 to 1200°C	
1.3	Embers temperature	thermocouples	Type K inconel shielded (1mm diameter)	-270 to 1200°C	
1.4	Fuel temperature	thermocouples	Type K inconel shielded (1mm diameter) Resolution:	-270 to 1200°C	
1.5	Soil temperature	thermocouples	Type K inconel shielded (1mm diameter)	-270 to 1200°C	
2	barometric pressure		Part of automatic weather station Resolution: 0,1 hPa	880 to 1080 hPa	$\pm 1,7$ hPa
5.1.1	Still pictures	SLR camera	AF Interchangeable lenses 35 mm film		
5.1.1	Still pictures	Telemetric camera	Interchangeable lenses 35 mm film	Visible spectrum	
5.1.1	Still pictures	Digital camera	CCD sensor 3,2 Mpixels	Visible spectrum	
5.1.1	Still pictures	Digital camera	CCD sensor 4 Mega pixels		
5.1.2	Still pictures	Infrared camera	12 element HgCdTe sensor	3.5 to $5\ \mu\text{m}$ (-20 to 1500°C)	
5.2.1	Movies	Video camera	Hi8 (8 mm video format csette)		
5.2.1	Movies	Digital video camara	CCD sensor 450.000 pixels		
6.1	Horizontal	cup anemometer	Hand held device		

	Wind speed		Resolution: $\pm 0,1$ m/s		
6.1	Horizontal Wind speed	propeller anemometer	Hand held device. Resolution: ± 1 m/s		
6.1	Horizontal Wind speed	cup anemometer	Wind cups and magnetic switch. (Part of an automatic meteorological station) Resolution: $0,1$ m/s	0 to 78 m/s	$\pm 5\%$
6.1	Horizontal Wind speed	Ultrasonic anemometer	Part of automatic meteorological station Resolution ($0,01$ m/s)	0 to 60 ms	$\pm 4\%$ (20 m/s)
6.1	Horizontal Wind speed	Ultrasonic anemometer	Stand alone anemometer (needs a datalogger connected) Resolution: $0,01$ m/s	0 – to 60 ms	$\pm 1,5\%$ (0 to 20 m/s) $\pm 3\%$ (20 to 60 m/s)
6.1	Vertical Wind speed	Ultrasonic anemometer	Stand alone anemometer (needs a datalogger connected)		$\pm 3\%$
6.2	Wind direction	Wind vane	Wind vane and potentiometer. (Part of automatic meteorological station) resolution: 1° ($22,5^\circ$ between compass points)	0 – to 360°	$\pm 7\%$
6.2	Wind direction	Ultrasonic anemometer	Part of meteorological station Resolution: 1°	0 to 360°	$\pm 3^\circ$ (20 m/s)
6.2	Wind direction	Ultrasonic anemometer	Stand alone anemometer (needs a datalogger connected) Resolution: 1°	0 to 360°	$\pm 2^\circ$ (< 25 m/s) $\pm 4^\circ$ (> 25 m/s)
7	Air humidity	Hand held psychrometer		3 to 100%	
7	Air humidity	Shielded thermohygrometer	Film capacitor element. (Part of meteorological station) Resolution: 1%	0 to 100%	$\pm 3\%$
8	Fuel moisture content	Oven with air flow			
9	Fuel particles surface-to-volume ratio	lenses with scale, calipers	Geometrical method		
11	Rate of spread	Iron labelled posts	Visual observations		
11	Rate of spread	Video images			
12.1	Flame height	Iron labelled posts	Visual stimates		
12.1	Flame height	Video images			
12.2	Flame length	Iron labelled posts	Visual stimates		
12.2	Flame length	Video images			

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12.3	Flame angle	Iron labelled posts	Visual stimates
12.3	Flame angle	Video images	
14.1	Ash loading	Oven, Precission Balance	Post-fire fuel inventory
14.1	Ash mineral content	Oven, Precission balance	
14.2	Unburned fuel loading	Oven, Balance	Post-fire fuel inventory
14.2	Unburned fuel size	calipers	Post-fire fuel inventory
14.2	Unburned fuel branches tip diameter	calipers	

7 CONTRIBUTION UAVR-DAO (AVEIRO) P022

7.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air		X	D-07-01
1.2		Flame			
1.3		Embers			
1.4		Fuel			
1.5		Soil			
2	Atmospheric pressure				
3	Heat flux				
3.1		From flames			
3.2		From embers			
4	IR radiation				
3.1		From flames			
3.2		From embers			
5	Images				
5.1		Still pictures			
5.1.1			Visible		
5.1.2			IR		
5.2		Movies			
5.2.1			Visible		
5.2.2			IR		
6	Wind				
6.1		Speed		X	D-07-01
6.2		Direction		X	D-07-01
7	Air humidity			X	D-07-01
8	Fuel moisture content				
9	Fuel particles surface-to-volume ratio				
10	Fuel calorific value				
11	Rate of spread				
12	Flame geometry				
12.1		Flame height			
12.2		Flame length			
12.3		Flame angle			
13	Combustion gaseous products			+	
13.1		Emissions		X	
13.2		Air quality		X	

14	Combustion solid products			
14.1		Ash		
14.2		Unburned fuel		
14.3		Suspended particles	X	
Comments:				
13: The distinction between emissions and air quality measurements is made according to the distance from the emission source. The measuring equipments used and methodologies are specific for each one.				

7.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
1.1	Air temperature	DIDCOT DTS-5	Wet and Dry PT-100 thermometers in a Gill type radiation screen with water reservoir.	0 – 40°C	Not available
6.1	Wind speed	DIDCOT DWR-205	A three cup anemometer with contact closure output	0 – 50 m/s	Not available
6.2	Wind direction	DIDCOT DWR-105	A V tailed Vane with potentiometer output	0 – 359 °	Not available
7	Air humidity	DIDCOT DTS-5	Wet and Dry PT-100 thermometers in a Gill type radiation screen with water reservoir.	0 – 100 %	Not available
13.1	Volatile Organic Compounds (VOC's) concentration s	Tedlar sampling bags	- Analytical method: Gas Chromatography (GC); - Detector: Flame Ionization Detection (FID).	Not available	Not available
13.2.1	Nitrogen dioxide (NO ₂) and sulphur dioxide (SO ₂) concentration s	Radiello passive sampling system	- Analytical method: Ionic Chromatography; - Detector: Ionic Chromatographer from SHIMADZU.	- NO ₂ : 3 ppb / 24 h to 500 ppb / week; - SO ₂ : 5 ppb / 24 h to 250 ppb / week.	Not available
13.2.2	Nitrogen monoxide (NO) and nitrogen dioxide (NO ₂) concentration s	Environnement AC31M	- Dual chamber / single PM tube Graphic Liquid Crystal Display (LCD); - Interactive menu driven software; - Synoptic flow diagram display; - Remote troubleshooting diagnostics; - Auto-ranging;	Programmable 0-10 ppm	- Noise: 0.17 ppb - Lower detectable limit: 0.35 ppb - Response time: automatic and programmable (minimum

			<ul style="list-style-type: none"> - Automatic response time; - Real time calibration graph; - User programmable ranges and average times; - Built-in serial interface (RS232/RS422); - Built-in storage of the last 1500 average data. 		<ul style="list-style-type: none"> 20 s) - Zero drift: less than 1 ppb / 24 h - Span drift: less than 1% / 24 h - Linearity: \pm 1% of full scale
13.2.3	Carbon monoxide (CO) concentration	Environment CO11M	<ul style="list-style-type: none"> - Graphic LCD; - Interactive menu driven software with enhanced speed display; - Synoptic flow diagram display; - User programmable ranges and average times; <ul style="list-style-type: none"> - Auto-ranging; - Automatic response time; - Real time calibration graph; - Built-in storage of the last 1500 average data; - Built-in serial interface (RS 232/RS 422); - Automatic temperature, pressure compensation; - Remote troubleshooting diagnosis; - Full remote emulation of the analyser. 	Programmable 0-200 ppm	<ul style="list-style-type: none"> - Noise: 0.025 ppm - Lower detectable limit: 0.05 ppm - Response time: automatic and programmable (minimum 30 s) - Zero drift: < 0.1 ppm / week - Span drift: < \pm 1% / week
14.3	Concentration of particles with aerodynamic diameter lesser than 2.5 μ m (PM2.5) or 10 μ m (PM10)	Environment MP101M	<ul style="list-style-type: none"> - Weight measurement not influenced by the physico-chemical nature, colour or size of particulates - Very low activity C14 sealed flat source with long lifetime - Sample flow rate: high accuracy differential pressure method - Selectable PM10 or PM2.5 sampling inlets - Temperature-regulated sampling line to less than 3 to 5 °C above ambient temperature - Airflow rate control adjustable to \pm 2% according to the temperature at the sampling point. 	Programmable 0-10000 μ g.m ³	Not available

7.3 TABLE 3

Ref.	Comments
13.1	This equipment requires the use of an air-sampling pump (model: 224-PCXR8 from SKC).
13.2.1	<p>NO₂ and SO₂ are chemisorbed onto a triethanolamine (TEA) coated cartridge. The NO₂ is stored as the nitrite ion (NO²⁻) and the SO₂ is stored as the sulfite (SO³⁻) and sulphate (SO₄⁻²) ions. The various ionic species are recovered using water and are analysed by means of ion chromatography. The nitrate ion can be measured using visible spectrophotometry also. The chemical adsorption is selective for nitrogen dioxide and sulphur dioxide. Airborne nitrite, sulphate, and sulphite ions exist as salts in the particulate phase and are not able to cross Radiello's cylindrical diffusive surface.</p>
13.2.2	<p>- This instrument uses the Chemiluminescence principle of the NO with the presence of highly oxidising ozone molecules for the continuous measurement in ambient. It is equipped with a chamber for direct measurement of Nitrogen Monoxides and a chamber for Nitrogen Oxides via a molybdenum oven heated to 320°C for the conversion of NO₂ into NO.</p>
13.2.3	<ul style="list-style-type: none"> - Interference rejection ratio: H₂O: 70000 : 1; CO₂: 200000 : 1. - Linearity: ± 1% of F.S. - Averaging time: programmable from 1 to 9999 min. - Operating temperature: 10-35°C.
14.3	<ul style="list-style-type: none"> - Particle's mass determined by a beta gauge mass monitor. - Average time: 1/ 4, 1/ 2, 1, 2, 3, 6, 12, 24 h

8 CONTRIBUTION UNICE-GVE (NICE) P027

Remember it concerns only field conditions (wild bush), for P027.

8.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air		X	D_07_01
1.2		Flame			
1.3		Embers			
1.4		Fuel			
1.5		Soil			
2	Atmospheric pressure			X +	
3	Heat flux				
3.1		From flames			
3.2		From embers			
4	IR radiation				
3.1		From flames			
3.2		From embers			
5	Images				
5.1		Still pictures			
5.1.1			Visible	X	
5.1.2			IR		
5.2		Movies			
5.2.1			Visible	x	
5.2.2			IR		
6	Wind				
6.1		Speed		X	D_07_01
6.2		Direction		X	D_07_01
7	Air humidity			X	D_07_01
8	Fuel moisture content			x +	
9	Fuel particles surface-to-volume ratio			x +	
10	Fuel calorific value			x +	
11	Rate of spread			X	
12	Flame geometry				
12.1		Flame height		X	
12.2		Flame length		+	
12.3		Flame angle		x +	
13	Combustion gaseous products				
14	Combustion solid products				

14.1	Ash	
14.2	Unburned fuel	x +
<p>Comments:</p> <ul style="list-style-type: none"> - All “ x ” (instead of “ X ”) means the parameter is not systematically measured, depending on field experiment conditions, and not a priority.... - Atmospheric pressure is measured by automatic station, but seems to be without real importance. - Fuel particles surface-to-volume ratio and fuel calorific values are deduced from observed vegetation characteristics (literature) but not really used by us. - Flame length can be deduced from angle and height, anyway we don't use it systematically. 		

8.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
1.1	Air temperature	Automatic station “Davis” + “testoterm” portable thermo/hygrometer	Installed at about 30-50 m from the fire (sensor at 2 m upon ground level)	From about 5 to 20° C	0,1° C
2	Atmospheric pressure	Automatic station “Davis”	Installed at about 30-50 m from the fire (sensor at 0,5m upon ground level)	From 850 to 900 hPa (altitude); Generally 900 hPa	1 hPa
5	Images	Argentic and numeric camera			
6	Wind	Automatic station “Davis” + “Young” 3D cups anemometers + “Plastimo” hand hold anemometers	Davis station and one Young 3 D anemometer installed at about 30-50 m from the fire upwind (sensor at 2-3 m upon ground level) + second Young 3 D anemometer installed at about 10-15 m from the fire + “Plastimo” hand hold anemometers (on the side of the fire propagation)	From 0 to 12 m/s	?
7	Air humidity	Automatic station “Davis” + “testoterm” hand hold thermo/hygrometer	Installed at about 30-50 m from the fire (sensor at 2 m upon ground level)	From about 6% to 70%	About 1 – 2%, but more in very dry conditions (<20%)
8	Fuel moisture content	Steam room (113l)	Difference between wet and dry conditions of cut vegetation samples	Too low samples number	?
9	Fuel particles surface-to-volume ratio	Vegetation morphology (strates and spatial density) and species repartition estimated	Before burning, the parcel is observed and photographed. Conversion from literature.	Too low samples number	?
10	Fuel calorific value	Vegetation morphology (strates and spatial density) and species repartition	Before burning, the parcel is observed and photographed. Conversion from literature.	Too low samples number	?

11	Rate of spread	estimated Observation of flame position at 1 meter high every 5 or 10 meters	Marks (red and white stacks) are installed, forming virtual lines.	100 m to 3000 m/h	About 10%
12.1	Flame height	Eye observation	Average height on the virtual line, compared with marks	0,5 meter to 10 meters	10 % for instantaneous heights observed, 20 – 30 % for average values...
12.3	Flame angle	Eye observation	Average angle on the virtual line, compared with marks	From 25° to 90° (vertical)	10 % for instantaneous heights, 20 – 40 % for average values...
14.2	Unburned fuel	Eye observation	Estimation of non-burned percentage surface	From 5 to 15 %	10 %

8.3 TABLE 3

Ref.	Comments
6	We have a special interest for wind role on fire behaviour, and we try to study it very carefully (space and time dimensions) and to link its behaviour to rate of spread (ROS). We established that R.O.S. is better correlated to a low speed variability than to the average speed value (CARREGA P., 2002 : « Relationship between wind speed and the Rate Of Spread of a fire front in field conditions : an experimental example from the Landes forest ». IVth International Forest Fire Conference. Coimbra (Portugal). November 2002.) And we try to measure simultaneously wind direction and speed at very accurate time scale (1-2 s).
9 and 10	Fuel particles surface-to-volume ratio and Fuel calorific value : the errors are really higher in the field than in a laboratory... it depends also on experiment conditions : if the parcels limits of the experiment are fixed in advance, it is easier to do it. But, more often, our experiments are included in a prescribed burning procedure conducted by Forests National Office in France (ONF), and we usually learn only in the morning where the fire will be conducted. So we have only some minutes to estimate those parameters by observing wild vegetation, before beginning the burning.
12	Flame height and angle : instantaneous values are not too difficult to estimate, but the average value, resulting from observations on a line which measures about 10-20 m are subject to errors, because of the length of the line, and especially because of instantaneous behaviour differences due to fire induced winds, with vortices...

9 CONTRIBUTION INRA-URFM-PIF (AVIGNON) P001

9.1 TABLE 1

Ref.	Variable or Property			If "Yes" put an "X"	If in previous deliverable, write the deliv. number
1	Temperature				
1.1		Air		X	
1.2		Flame		X	
1.3		Embers		X	
1.4		Fuel		X	
1.5		Soil		X	
2	Atmospheric pressure			X	
3	Heat flux				
3.1		From flames			
3.2		From embers			
4	IR radiation				
4.1		From flames			
4.2		From embers			
5	Images				
5.1		Still pictures			
5.1.1			Visible	X	D-07-02
5.1.2			IR	X	D-07-02,D-07-04
5.2		Movies			
5.2.1			Visible	X	D-07-02
5.2.2			IR	X	D-07-02, D-07-04
6	Wind				
6.1		Speed		X	D-07-02
6.2		Direction		X	D-07-02
7	Air humidity			X	D-07-02
8	Fuel moisture content			X	D-02-01, D-07-02
9	Fuel particles surface-to-volume ratio				D-02-01
10	Fuel calorific value				
11	Rate of spread			X	D-07-02
12	Flame geometry				
12.1		Flame height		X	D-07-02
12.2		Flame length		X	D-07-02
12.3		Flame angle		X	D-07-02
13	Combustion gaseous products				
14	Combustion solid products				
14.1		Ash		X	D-07-02
14.2		Unburned fuel		X	D-07-02
<p>Comments: Accurate measurements are made during experiments under laboratory conditions in Les Vignères facilities. During field tests, the meteorological parameters are collected by the Campbell portable meteorological station described in D-07-02</p>					

9.2 TABLE 2

Ref.	Measured property	Device name	Main characteristics	Range of values	Accuracy
1	Temperature	Thermocouple	from 50 µm carried out by SD100 spot welder		
2	Atmospheric pressure	Wheel barometer			
5.1.1	Visible still images	FUJI NX-2900 digital color camera	1/1.7-inch CCD square pixel, 2.3 million pixels Fujinon optical 3X zoom lens Focus distance 7.4 to 22 mm 1800 x 1200 or 640 x 480 pixels TIF and JPEG file formats SmartMedia card		
5.2.1	Movies	SONY CCD-VX1E video camera recorder HI8 Handy cam PRO Numerical treatment CCD SONY SSM 14N5E	1/3, 3CDD recorder Zoom 5.5 to 66 mm TTL autofocus Zoom 5.5 to 72 mm		
5.1.2 & 5.2.2	IR images	FLIR Thermacam SC 2000	Detector type: Focal Plane Array, uncooled microbolometer 320 x 240 pixels Spatial resolution 1.3 mrad Spectral range: 7.5 to 13 µm		
6	Wind speed	VECTOR A100L2	Rotor type anemometer, 3-cup clockwise rotation	0.15 to 75 m/s	1%
6	Wind direction	VECTOR W200P	Potentiometer windvane	0.6 to 75 m/s	3°
7	Air temperature	HYGROMER MP100A	RTD Pt 100 1/3 DIN	-40 + 60°C	0.3°C
7	Air moisture content	HYGROMER MP100A	Rotronic Hygromer C94	0 – 100%	1% : 5-95% 2% <5% 2% >95%