Wildland-Urban Interface Virtual Essays Workbench

WUIVIEW

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Abstract	This document presents the facilities and equipment owned by ADAI team that will be available to the WUIVIEW Project activities.

(1) Draft / Final
(2) Public / Restricted / Internal

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1. Introduction

This document describes the facilities, equipment and instrumentation belonging to the Forest Fire Research Centre of the Association for the Development of Industrial Aerodynamics (ADAI/CEIF) that will be fully available to the development of the proposed activities and tasks of the Project.

The main facility of ADAI/CEIF is the Forest Fire Research Laboratory (LEIF) of the University of Coimbra, in Lousã (Central Portugal), that is possibly one of largest and better equipped facilities in the world applied to Forest Fire research. LEIF is an infrastructure created by ADAI/CEIF, with the support of the University of Coimbra and the Municipality of Lousã. It is specifically designed to support experimental research on forest fires, namely on fire spread properties. Its construction started in 1997 and it was inaugurated in 1999. After several changes of expansion and improvement, currently, LEIF occupies a covered area of $72x16m^2$ and a uniform height of 11m. The major part of the work performed here is comprised of laboratory scale experiments, where we can collect valid, reliable and controlled data about the tested phenomena during all the year, in any season, simulating the conditions observed in the real scenarios. In laboratory it is possible to fix the values of several parameters such as fuel load, bulk density, wind and slope and choose one of them, for instance the geometry of the fire front to change. This way it is easier to understand the effect of the chosen parameters. The laboratory is equipped with several test rigs and equipment that will be described in the following section.

2. Description of the main test rigs of LEIF

In this section the main test rigs of ADAI/CEIF will be enumerated and described.

2.1. Large Combustion Wind Tunnel

The large combustion tunnel is used to study the spread of fires under wind action. The tunnel has a work area of $6x8m^2$ with a cross section of $6x2m^2$ and is open on the top to avoid flow stratification and smoke accumulation in the combustion area. The wind generation is powered by two 37kW axial fans delivering a variable flow with a maximum value of 5m/s. It has side walls of tempered glass in one of the lateral sides to facilitate observation. Due to its considerable area of test it is a facility used for the analysis of several aspects related with forests fires as the analysis of transition from surface to crown fires, vorticity effects, tests of equipment of fire suppression and protection, tests of nozzles water dispersion, among many others.




2.2. Canyon Table

Metallic structure to analyze fire spread in slopes and canyons. With four triangular faces with edges of the triangles of 1.5 and 3m each; with a total aerea of $3x3m^2$inclinable independently from 0 to 40º; the set being inclinable from 0 to 40º; hydraulic commands to adjust table angles.

2.3. Canyon Table 4 – DE4

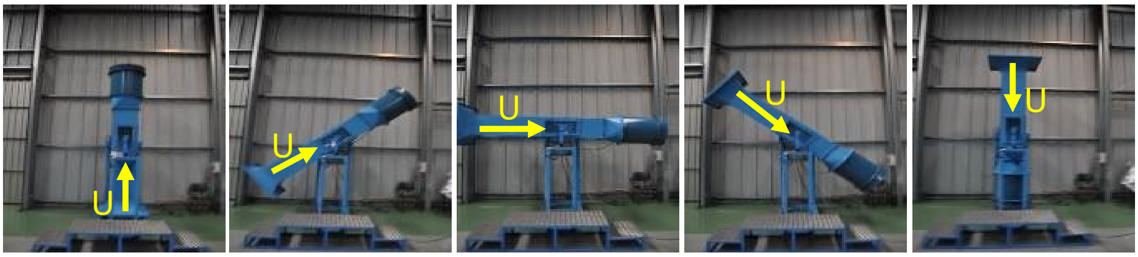
This Device is similar to the previous one but with only two rectangular faces of larger dimensions, in a total area of 6x8m^2, as scale and border effects can sometimes hinder the extrapolation of the assessments of fire behavior made from laboratory experiments to real fires.

2.4. Vertical Combustion Tunnel

Metallic structure to analyze combustion of particles transported by the plume of a fire. Equipped with an axial fan of 10kW to produce a controllable flow, up to 20m/s. Height: 6m and maximum cross section of $1x1m^2$.

2.5. Oblique Combustion Tunnel

Metallic structure to analyze combustion of particles transported by wind. Equipped with an axial fan of 10kW to produce a controllable flow up to 20m/s. Variable angle of inclination. Height: 4m and maximum cross section of 0.4x0.4m2.

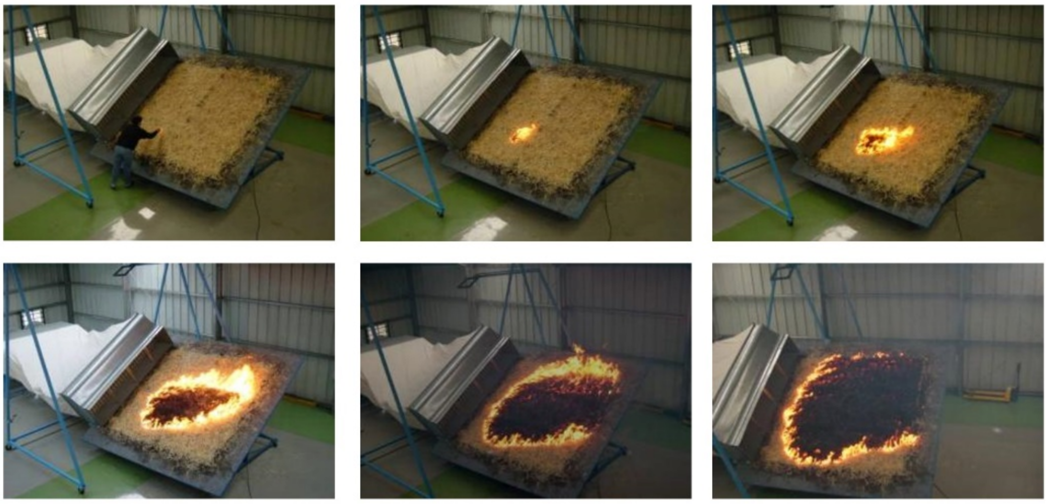


2.6. Dihedral Table

Changes in the topography can originate considerable differences in fire behaviour. In this table of two faces of $4x4m^2$, each face can be adjusted and form a ridge, a valley or a sloping hillside with constant or variable slope in the range of 0 to 45º.

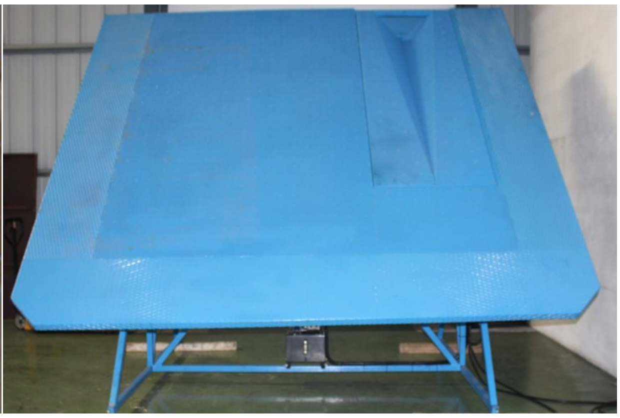
2.7. Slope and Wind Table

In nature and in most situations, fire spreads under the joint effect of wind and slope. This table allows the study of this combined effect, the simulation of various conditions of wind flow direction and intensity.



2.8. Slope and canyon Table

The slope and canyon table, witha area of 3x3m^2, was built in a way which allows to change the inclination and rotation of the slope, the angle and the geometry of the canyon. The testing table allows to change the angle of inclination of the slope between 0º and 45º and the angle of rotation between 0º and 360º. In this table it is possible to perform tests with fire propagation in the specific configuration of a hill bordered by a canyon.



2.9. Firewhirl generator

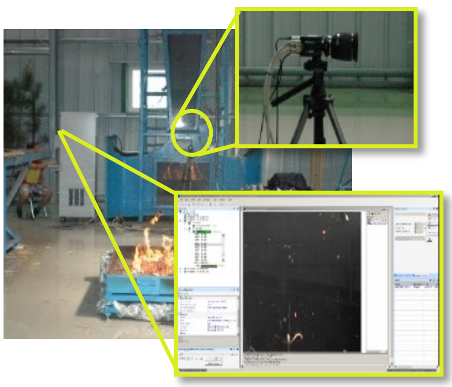
The Fire Whirl Generator (FWG) apparatus consists in a vertical tunnel with a quadrangular section of 1×1m^2, with a height of 6 m, with two sides made of tempered glass and the other two made of steel. The base of the FWG has a section of 2×2m^2 and 1.8 m height tapering to the 1×1m^2 section of the main channel section that is open at the top. Each corner of the channel has a vertical opening 10 cm wide to induce tangential air entrainment. Inside the base of FWG there is a platform of 1×1m^2 covered by ceramic tiles to support the fuel container. A set of four axial Rosenberg DR 630-4.6LA fans was attached to induce a tangential flow to create a forced vortex inside the combustion chamber.

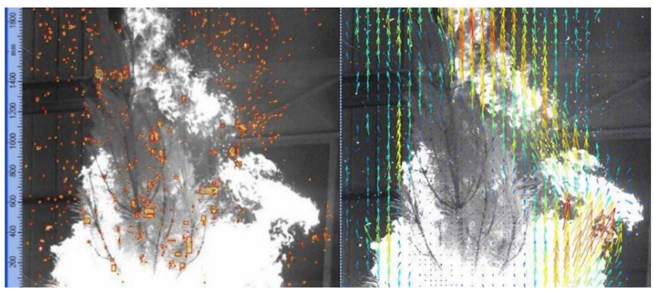
2.10. Platform of tree combustion

The main objective of this equipment is the study of spot fires. This phenomenon consists in the appearance of new ignitions caused by burning embers projected by a fire. Examples of potential embers are scales of pine cones or pieces of eucalyptus barks that can be released by the trees during a fire and that can be transported by wind, falling downstream, causing a new ignition. Spot fires are a very dangerous form of fire spread. In order to improve the knowledge of this very complex process a systematic research was started on the three main phases of the spotting process: ember formation, transport and landing. In this test rig we study the first process. It is possible to burn entire trees and register the mass loss of the tree and the particles emitted during the test.

2.11. Particle Image Velocimetry (PIV) System

Using an advanced Particle Image Velocimetry system (PIV) we can characterize the properties of the particles released from the combustion. The PIV is a technique providing instantaneous measurements of velocity vectors in a cross-section of a flow. This system is used in LEIF to track particles in the flow, like burning embers, in a technique called PIT. In LEIF we have two cameras with high frequency of acquisition (400Hz) connected to a workstation with high RAM capacity that allows the processing of the collected data.





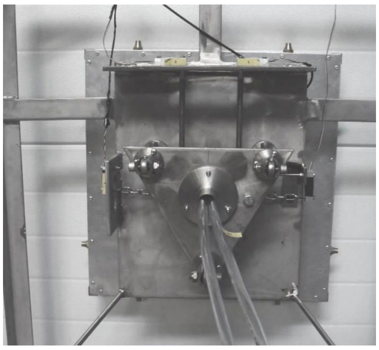
2.12. Ember Generator Device -Baby Dragon

An ember generator device, similar to one developed by the National Institute of Standards and Technology (NIST) in USA, was built and tested. The purpose of this device is to generate a large flow of small embers to assess the ignitability of surface fuels and of elements of houses.



2.13. Hydraulic tests system

The Hydraulic tests system is composed of a 5kW KSB electric water pump, controlled by a Movitec VF015/06 system, that provides a water flow with a nominal pressure of 8 bar and a nominal flow rate 12 m3/h. The water outlet from the pump is made through a pipe with a nominal diameter DN 50 coupled with a Storz union of 45. The system is equipped with a water reservoir with 2000 L of capacity. The hydraulic system also has a balance with load cells where we can determine the forces generated by the test of different types of nozzles, hoses or sprinklers. Several flow meters, pressure manometers and load cells area available for measurements.



Complementary with the previous system we have a vehicle mounted high-pressure pump (WATERAX BB-4-18VXT with a gas 4 - stroke engine) with a reservoir of 400 L. The maximum pressure is 30.3 bar and maximum flow is 394 L/min.

2.14. Fire Front simulator

The fire front simulator consist in a special designed concrete plataform with a usefull area of 20x11m^2, where a set of vertical metallic baskets are placed to hold forest fuels. The baskets have a total lenght of 10m and can creat flames of the same order. The specimens to tests (cars, caravans, fire enginess, etc) can be placed in a motorized track or can be placed fixed at a desired distance from the flames. The sistem can generate flames that realese a flux of order of 40 MW/m^2.

3. Sensors and monitoring devices

This section describes the sensors and monitoring devices (model, type, specifications) and data logging capacities (measured variable, data acquisition rate, precision, etc.) available at LEIF.

Model	Type	Specifications	Measured variable	Data acquisition rate
Gems 5266	Pressure transducer	50L Very Low Range Differential Pressure Transmitter (0 to 50 Pa)	Pressure	30Hz
BT.MiK.1.2.1,5.10000.MFATW0	K type thermocouple	TekOn-thermocouples, fiber glass and metallic shielded	Temperature	1
CS526	Mass loss	ATI	load	
SC 660	Thermographic images	FLIR SYSTEMS TM -IR Cameras	Temperature	30Hz
SC 640	Thermographic images	FLIR SYSTEMS TM -IR Cameras	Temperature	30Hz
SpeedSense 1040	Particle size and speed	Dantec Dynamics	Particle size and speed	400
SpeedSense 1020	Particle size and speed	Dantec Dynamics	Particle size and speed	400
Thermogage 1000-1		Total -flux Vatell	heat	1
Thermogage 9000-9	Heat flux sensor	Radiometer Vatell	heat	1
Vantage Vue Wireless Weather Station	weather datalogger	Davis Instruments- weather station	Temperature Wind speed and direction Humidity	
ML50 moisture analyzer	Moisture content	A&D	Moisture content	24Hz

67M25A-I40	Strain	JR3- Load balance	force	
S- pitot Tubes	Flow speed	Pitot tubes	Flow speed	30
Double S- pitot Tubes	Two directions Flow speed	Pitot tubes	Flow speed	30
Double S-pitot tubes	Two directions Flow speed	Pitot tubes	Flow speed	30
Ami 300	Flow speed Pressure Temperature	Multifunctional probe	Flow speed Pressure Temperature	1
D70	Photo Camera	Nikon Camera	Image	
V1	Photo Camera	Nikon Camera	Image	
572	Balance	Kern	Mass	
600-D06064	Oven	MEMMERL- oven	Drying operation	
NI cDAQ-9174	datalogger	NI- Chassi	Data acquisition	
NI 9205	voltage module	NI-module	voltage	
NI 9213	Temperature-module	NI-module	temperature	

4. Experimental protocols/procedures

Each test rig has unique experimental specificities, but all tests follow common procedures, briefly described in this section.

4.1. Fuelbed design

Depending on the test rig to be used, the shape and size of the fuelbed is designed. Fuel load per area unit is defined according to the test objectives. Fuel load is defined in terms of dry load. In order to compensate for the weight of water in the fuels, a calibration is made based on the fuel moisture measured before each test. Fuel moisture is measured with a A&D ML50 moisture analyser:

This fuel load compensation is used to guarantee that tests in each series are made with the same fuel load in a dry basis, independently of the fuel moisture content being different.

4.2. Ignition procedures

Ignitions are dependent on the test rig to be used and on the type of ignition needed. Linear ignitions are made with a wool thread soaked in a mixture of petrol and diesel oil. The line is then set on fire by an operator. Point ignitions are made with a cotton ball soaked in the same mixture, also being lit by an operator. In the cases when shrub baskets need to be set on fire, a gas lighter is used to directly ignite the fuels.

4.3. Registering propagation characteristics

4.3.1. Rate of spread

The values of the rate of spread (ROS) are evaluated in the laboratory by two techniques: thermocouple data acquisition and/or infrared images.

4.3.1.1. Thermocouples

Using thermocouples, the temperature is measured with a rate of acquisition between 1Hz to 30Hz using a multi-point system of K type thermocouples with fibber glass and metallic shields with seven filaments with a diameter of 0.2mm. The thermocouples are placed along axis of measurement with a known gap between them, they are connected to a NI cDAQ-9174 with a TC module NI 9213 that allows synchronous data-logging. From the thermocouples data and the time interval required for the fire to travel from one position to the next the ROS of the fire along the axis can be computed. The presence of the fire front is assumed for values of temperature above 350ºC that are considered as a sign of the existence of flame at the place and time of measurement.

4.3.1.2. Infrared Images

With infrared images (IR) it's possible to assess the fire front evolution during the experiments and to analyse the spatial distribution of temperature along the fuel-bed. To do so in the begining of a set of tests it is necessary to perform a calibration, acquiring images of a black and white sqaured check-board (visible images from the IR camera). After the calibration, and without moving the camera position, IR frames are acquired at desired framerates. In LEIF the following models of infra-red cameras are used: FLIR ThermaCam SC660 and SC640 . The image acquisition rate can be in the range of 1Hz to 30Hz . Post-processing the IR images the position of the fire perimeter at given times is reconstructed and the ROS at various positions of the fire perimeter can be computed. The threshold of 350ºC is used to avoid the obstruction of the view by the plume of the fire. This adjustment of the threshold can be set even after the recording of the images. Digital frames of IR imagery are stored on the PC hard disk, with the name corresponding to time *t*. ADAI/CEIF team has programmed a specific algorithm to allow the automatization of the whole process of image analysis, with perimeter reconstruction and ROS determination. For each point, the Cartesian coordinates of the frame are converted into true physical Cartesian coordinates in the plane of the combustion table. This conversion encompasses a simple but non-trivial image calibration technique in which the camera is assimilated to a pin-hole optical system without aberration. The fire line is described by an ordered set of points, in a Cartesian system OXY defined in the top plane of the fuel bed (parallel to the plane of the table. The program computes the ROS average and instantaneously the isochrones of the fire perimeter.

4.3.1. Residence time

The residence time can be defined by the duration of the combustion reaction at a given place inside the fuel bed. This residence time is measured in our laboratory, with K type thermocouples placed in the middle of fuel bed to record the fire front advance and temperature. Temperature values are collected with a frequency of 1 to 30 Hz with arrays of thermocouples disposed in the fuel bed and connected to a NI cDAQ-9174 with a TC module NI 9213.

When the fire front arrives near the thermocouples the temperature suffers a gradual increase, then when it reaches the thermocouple the temperature increases sharply and after the passage of the fire front it decreases. The time in which the temperature remains above a defined threshold corresponds to the residence time.

4.3.2. Flame geometry

By recording the tests with a high definition video camera and temporized shots taken with photographic high-performance digital cameras it is possible to determine the height of the flames and the angle of the fire fronts. To do so the cameras are placed perpendicularly to the expected direction of propagation. In a verticall plan the camera records a lateral view of the fire and provides data on the height and tilt angle of the fire front. From the side view, only the main flame is considered, in order to measure the geometrical properties of the flame. The flame height is defined perpendicularly using the reference grid similar to a check-board. The tilt of the flame is defined as the angle between the terrain and the surface of the flame.

4.3.3. Heat flux

4.3.3.1. Flux meters

The heat fluxes emitted from the flame front during the fire spread are measured with sets of heat flux sensor of Vatell (model TG1000-1 and radiometer TG9000-9) oriented facing toward the fire in a direction parallel to the fuel bed surface.

The sensors are connected to a model 9211 (±80 mV) from National Instruments that is plugged in a chassis 9174 also from NI, this allows the continuous measuring of the signal of the sensor with a frequency of 1 to 30Hz and loading and processing the data to a computer directly.

4.3.4. Convective flow velocity and direction

4.3.4.1. S - Pitot tubes

To estimate the flow velocity induced by the fire we use S Pitot tubes are used, connected by pipes to differential pressure transducers Gems 5266-50L Very Low Range Differential Pressure Transmitter (0 to 50 Pa). These transducers are connected to the NI cDAQ-9174 with a voltage module NI 9205 that performs the data-logging of the signal also with a frequency of 1Hz to 30Hz. The transducers are bi-directional, so the signal is positive in one direction and when it is in opposite it is negative.

4.3.5. Measurement of mass loss

To carry out this measurement, load cells (AEP transducers) with a resolution of 0.5 and a maximum load of 500 kg are used. The connection between the control software in a PC and the cells is done by USB cables. The load cells are placed under the corresponding structure where the tests are performed. Before the fuelbeds for the tests are prepared, the system should be reset to zero (tare). Immediately before of the ignition the user should start the acquisition process of the data with the Quick Analyser software.

5. Field tests rig

The *Gestosa* Experimental Field is an area of 20 ha located in the region of Lousã (Central Portugal), used for the experimental field tests since 1994. As a result of good institutional collaboration with the different public and private institutions, ADAI/CEIF has carried out experimental fire tests on a larger scale than the ones in laboratory. It's a mountainous area occupied by several types of shrub vegetation, where experimental models are validated and procedures and equipment that require scenarios with conditions close to those observed in forest fires are tested.