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Experimental characterisation of ITER electric cables in postulated fire scenarios

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HIGHLIGHTS

- Power and control cables account for roughly 70% of all ITER fire loads.
- Industrial cables are tested to ensure ITER requirements are reflected in the procurement phase.
- Radiative heat flux leading to pyrolysis and/or ignition, flame propagation speed, generation of heat and mass loss are measured.
- Influence of cable shafts configurations on fire propagation is assessed.

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ABSTRACT

Power and control cables account for roughly 70% of all ITER fire loads. Fire experiments were executed at IRSN Cadarache to test several industrial cables in order to ensure that the specificities of the ITER project could be reflected in the forthcoming procurement phase. Experimental results are here summarised: radiative heat flux leading to pyrolysis and/or ignition, flame propagation speed, generation of heat by combustion, mass loss as well as gas and smoke releases. Also the influence on fire propagation of cable trays' geometry has been assessed: undoubtedly, vertical cable shafts promote fire propagation. Experimental data will be used to improve the current modeling of fire phenomenology and to assess propagation/impact on ventilation systems and Safety Importance Class (SIC) components with the ultimate target to avoid any potential release of radiological inventories.

1. Introduction

This paper presents the results of fire experiments carried out by IRSN in Cadarache (under contract with ITER IO). Four power cables and two control cables were tested in a small-scale facility (CARINEA). Four cables (three power and one control cables) were then selected to be further tested in a large-scale facility (SATURNE). For the purpose of these tests, all cables were categorised against EU/NF standards.

2. Small-scale fire tests (CARINEA facility)

The CARINEA facility consists of a source of ignition, a carousel device on which the cable samples are located, and a 1.5 m-diameter exhaust hood (Fig. 1).

The six tested cables are shown in Fig. 2. Power cables are composed of three conductors with their own insulation sheaths enveloped by an outer sheath (Table 1), while control cables have additional wires/sheaths (Table 2).

The heat flux reaching the cables' surface is controlled and maintained constant (a radiant panel is able to deliver a maximum, adjustable heat flux of 40 kW/m^2). Once pyrolysis starts and gas/smoke is released, an electric arc is induced to allow ignition. In some cases, there is ignition of gas and cables, while in others only a pyrolysis process is observed. In both cases the test is stopped (the radiant panel is switched off) when the measured gas/smoke release approaches zero.

Fig. 3 shows, as an example, the ACEFLEX cables during pyrolysis (see the 20×20-cm^2 carousel device in the center of Fig. 1) while Fig. 4 shows the cables' status once completely burned (i.e. after ignition).

Following the ASTM E 1623-04 protocol, 38 tests were carried out from May 10th to June 17th, 2011 (see reference [1] for details about the experimental protocol). Table 3 gives the ignition heat flux, IHF in kW/m^2. Note that for cable no. 2 the measurement of the ignition heat flux was affected by a high uncertainty: only 2

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Table 1
Chemical composition of power cables.

Power cables	Outer sheath	Conductors' insulation
TITANEX H07RN-F 3G2.5	PE[a], PA[b], $CaCO_3$, Talc[c]	PE, PVA[d], $CaCO_3$, Talc
ALSECURE 0.6/1 kV 3G2.5	PE, PVA, $CaCO_3$, $Al_2Si_2O_5(OH)_4$[e]	PE, $CaCO_3$
ACEFLEX RV-K 0.6/1 kV 3G2.5	PVC[f], phthalates[g], $CaCO_3$, talc	PE
FIREX PROTECH RZ1-K 3G2.5	PE, $CaCO_3$, PVA	PE, Talc

[a] Polyethylene: $-[-CH_2-CH_2-]_n-$.
[b] Polyamide: includes amide function, $-C(=O)-NH-$.
[c] Talc: product derived from SiO_2.
[d] Polyethylene vinyl acetate: $-[-CH_2-CH_2-]n-[-CH_2-CH-O-C(=O)-CH_3-]_m-$.
[e] Kaolinite: $Al_2Si_2O_5(OH)_4$.
[f] Polyvinyl chloride: $-[-CH_2-CHCl-]_n-$.
[g] Phthalate: $R-O-C(=O)-C_6H_4-C(=O)-O-R$.

Table 2
Chemical composition of control cables.

Control cables	Outer sheath	Conductors' insulation	Additional elements
SABIX	PE, $Al(OH)_3$, PVA	Talc, PP[a], PEP[b]	White wires between conductors made of cellulose
LC02162A	PE, $Al(OH)_3$, PVA	PE, PVF[c], Talc	White internal sheath made of PE, $Al(OH)_3$, PVA, Talc

[a] Polypropylene: $-[-CH_2-CH(CH_3)-]_n-$.
[b] Polyethylene–propylene: $-[-CH_2-CH_2-]n-[-CH_2-CH(CH_3)-]_m-$.
[c] Polyvinylidene Fluoride: $-[-CH_2-CF_2-]_n-$.

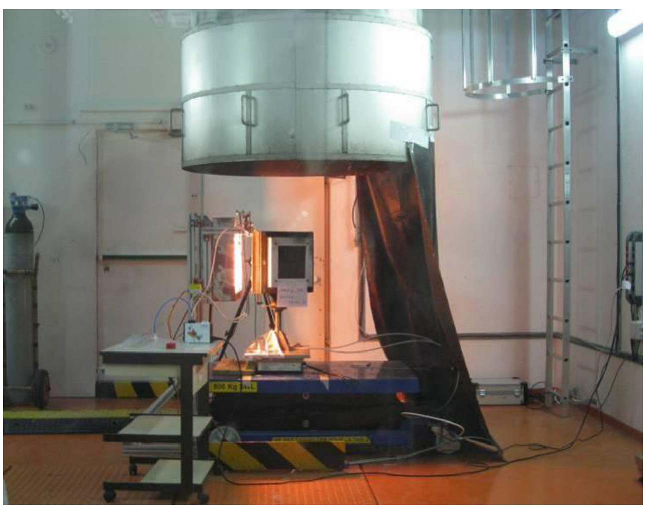

Fig. 1. CARINEA facility.

Table 3
Ignition heat flux.

Cable	Reference	IHF (kW/m^2)
No. 1	TITANEX29 H07RN-F 3G2.5	36 ± 1
No. 2	ALSECURE 0.6/1 kV 3G2.5	37 ± 3[a]
No. 3	SABIX D 345 FRNC TP ($4 \times 2 \times 0.34\,mm^2$)	39 ± 1
No. 4	ACEFLEX RV-K 0.6/1 kV 3G2.5	21 ± 2
No. 5	FIREX PROTECH RZ1-K 3G2.5	40[b]
No. 6	LC02162A ($3 \times 2 \times 0.5\,mm^2$)	24 ± 1

[a] Best estimation of the measurement error (which might be actually higher due to the fact that the maximum achievable incident heat flux was $40\,kW/m^2$).
[b] The measurement error is undetermined (see previous note).

of the 8 tests performed (with a heat flux ranging from 33.75 to $40\,kW/m^2$) led to cable ignition, therefore the measurement error is somehow undetermined since it was not possible to test the cable at higher heat fluxes (see note[1]).

[1] Best estimation of the measurement error (which might be actually higher due to the fact that the maximum achievable incident heat flux was $40\,kW/m^2$).

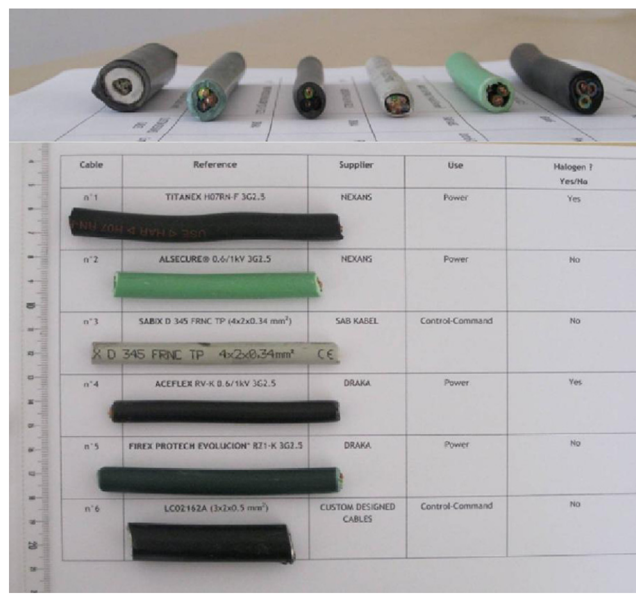

Fig. 2. Cables tested in the CARINEA facility.

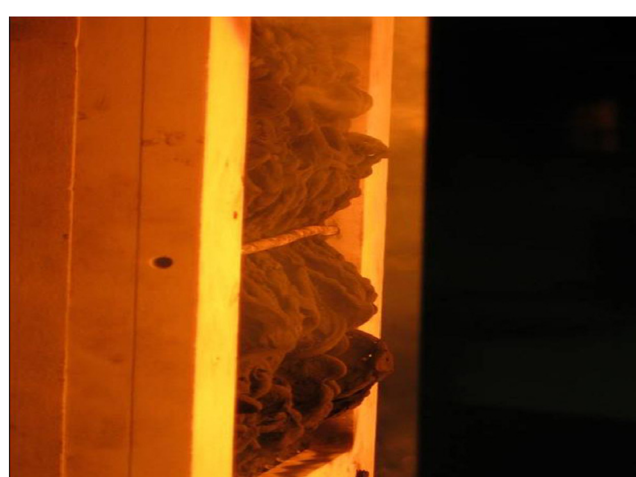

Fig. 3. ACEFLEX cables undergoing pyrolysis ($20 \times 20\,cm^2$ sample).