PROGRAM TO STUDY MODEL FIRES AND FIRE EXTINGUISHING SYSTEMS FOR AIRCRAFT AND HELICOPTERS AT THE RD&PE ZVEZDA FULL-SCALE TEST FACILITIES

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More than 40 years of experience of "RD&PE Zvezda" JSC in the development of aviation fire extinguishing systems (FES) and the necessity of aircraft certification in the full-scale test facilities (sometimes in real aircraft) show that comprehensive development of FES, which takes into account design and operational features of the specific aerospace vehicle, can considerably improve real efficiency of the agent used. In some cases, when the weight limits are very stringent, it is possible to (1) abandon traditional methods of fire extinguishing, such as when the whole protected module is filled with the agent and the proper concentration of the agent is maintained for a certain period of time and (2) suppress fire by impulse discharge of the agent into the module protected. Such a method is particularly acceptable for modules with efficient ventilation systems, e.g., power plant modules of aviation engines. In the front portion of the module we create a zone (lock) of high agent concentration, which, while moving with the cooling air flow, provides efficient fire suppression.

At least the following two circumstances can be considered to corroborate fire suppression efficiency:

1. Methods of fire organization and suppression in the course of qualification testing. These methods provided for stabilization and switch-off of fuel supply in the seat of the fire 10-20 sec after FES actuation. Moreover, in some cases there was an invariant change of fuel flow rate before the final switch-off.
2. Statistical data, which include more than 100 successful suppressions with this method in six fighters as well as some cases of successful fire suppression with this method in real combat aircraft.

The careful investigation of this fire extinguishing method in aircraft and helicopters, in the power plant modules, will enable us to select the most acceptable substitute for current halons.

In joint activities with a potential partner, we could undertake the following:

1. Run test programs at our wind tunnels, which are able to create an air flow of 450 km/in over 15-m wide test objects
2. Carry out statistical processing of test results obtained at the RD&PE Zvezda test benches for various FES in the recent 10-15 yrs and to update methods of organizing model fires of several types, for example,
   -- small, local fires of high severity
   -- fires with surplus of fuel mainly in the whole module protected
   -- fires of maximum severity (heat-release rate) to evaluate repeated ignition from hot elements of the structure

Such an approach makes use of international experience in FES development and will he helpful in searching for halon alternatives.
The difficult task of searching for a suitable halon alternative was set for the international firefighting community by the Montreal Protocol, which saw its 10th anniversary in 1997. Accustomed in the last decade with the unique fire extinguishing properties of halons, FES designers demand maintenance of these properties from developers of alternative agents along with environmental protection. Unfortun-ately, wide-scale investigations carried out by the international community did not yield positive results.

None of the known alternatives meets all of these requirements:

- high fire extinguishing capacity and zero ODP
- low corrosivity and rapid removal from the atmosphere
- easy operation and adaptation to the current FES
- environmentally friendly production and low toxicity, including byproducts

At the same time, we believe that owing to improvements in fire suppression methods, some alternatives (e.g., C_2F_5H, C_3F_7H, C_4F_{10}, etc.) could have a rather high rating despite their low fire extinguishing capacity, if compared to halons.

The multiyear investigations and testing on development and certification of FES for aircraft and helicopters have made it possible to form a notion that sometimes untraditional decisions lead to unexpected but very promising results. This paper presents the results of just such untraditional decisions on suppression of fires organized at special full-scale test facilities or in a real aircraft under conditions simulating a real flight (Figure 1). Organization of fires on the ground in higher density conditions, while maintaining real air weight flow through a protected module, creates the hardest conditions for fire suppression (Figure 2).

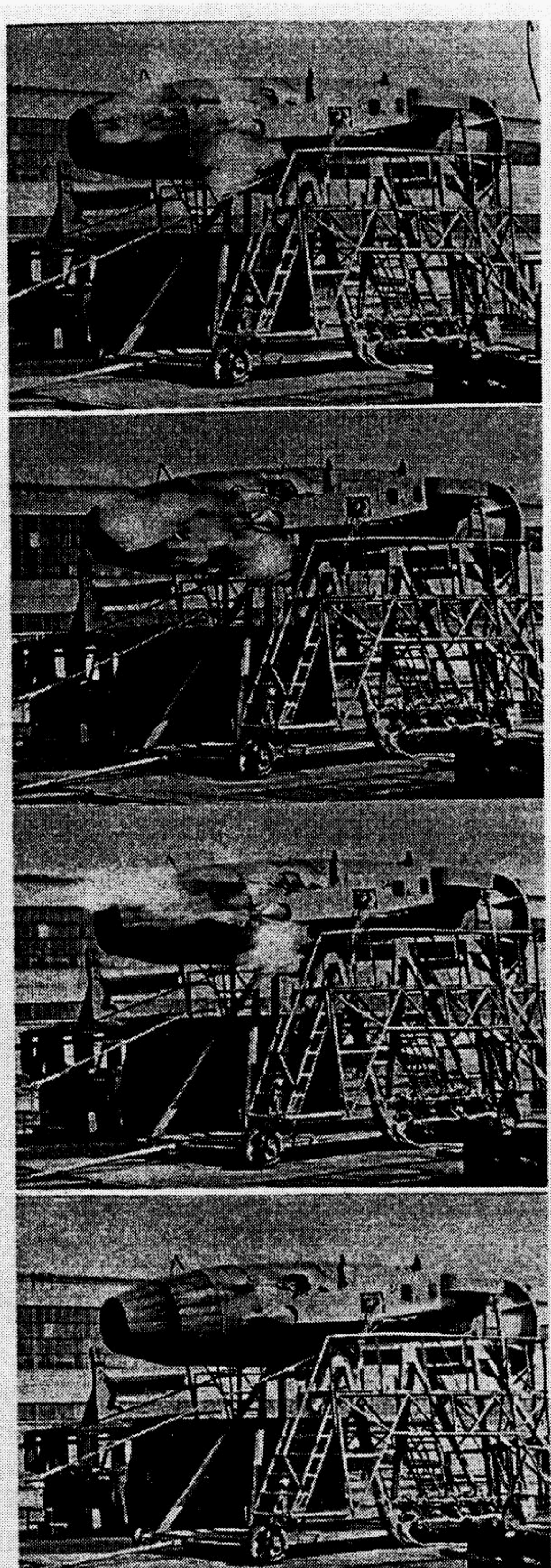
This paper considers two efficient ways to supply agent. We do not discuss the test methods further because some test fire parameters (e.g., fuel types, fuel supply techniques, fuel flow rate, times of fire development, temperatures in the fire zone and on module casing, etc.) are partly given in our paper [1].

The fire extinguishing systems (FES) charged with Halon 1301 and Halon 2402 were used for testing. Table 1 presents comparative results of FES testing during fire protection of the under-cowling space for power plants with the turbojets and by-pass turbojets in the aircraft of the USSR and Russian Air Force fighter class. In Table 1, the FESs are conditionally divided in two groups—those with **an** extensive supply of agent and those with an intensive supply of agent.

The extensive supply means the accepted **FESs** that provide for fire suppression and maintain the fire extinguishing concentration in the module for at least 2 sec are in accordance with the current requirements. An even distribution of the agent throughout the whole protected module is provided with several atomizing ring manifolds featuring a lot of holes. The manifolds are installed along the module (Figure 3).

The intensive supply means the impulse agent ejection can be provided in various ways, including ejection with an air **pressure** accumulator; ejection with a powder pressure accumulator; ejection from a tube-vessel with a plunger (wad); a fire extinguisher with an outlet section increased threefold, etc. In the intensive supply, one atomizing ring manifold that forms

Figure 1. General view of the engine simulator for a current REAF fighter.



Second 3 — Fuel inflammation

Second 5 — Fire development

Second 13 — Further fire development

Second 16 — Fire is suppressed

Fig 2. Fire suppression cinegram

TABLE 1. COMPARATIVE TEST RESULTS FOR THE MILITARY AIRCRAFT POWER PLANT FES.*

#	Air flow rate,† kg/s	FES with extensive agent supply			FES with intensive agent supply			Total test number	$\frac{m_{int}}{m_{ext}}$
		Agent	Time of	Flow rate,	Agent mass,	Time of ejection, s	Flow rate, kg/s		
1	2.6	8.5	1.9	4.5	4.8	0.7	6.0	21	0.50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.7	0.9	6.3	17	0.67
3	5.1	11.3	2.2	5.1	5.0	0.3	20	10	0.44
[illegible]	[illegible]	[illegible]	7.0	2.7	17	2.6	6.5	17	0.65
5	1.2	2.8	2.5	1.1	1.8	0.8	2.2	6	0.64
6	5.2	7.4	3.0	2.5	3.7	0.6	5.3	4	0.50

* All fires have been extinguished in the tests presented in the table.

† In our experiments the indicated nominal flow rate through the module was provided with air intakes whereas the actual flow rate was higher since there were holes simulating combat damage.

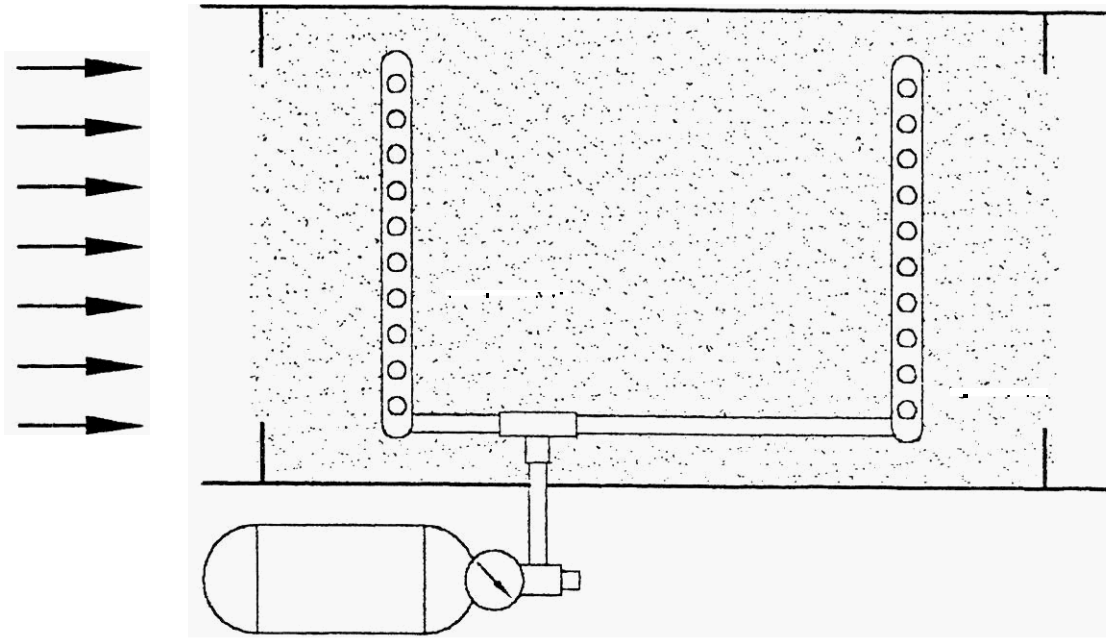


Fig 3. Fire extinguishing system for extensive supply of the fire extinguishing agent.

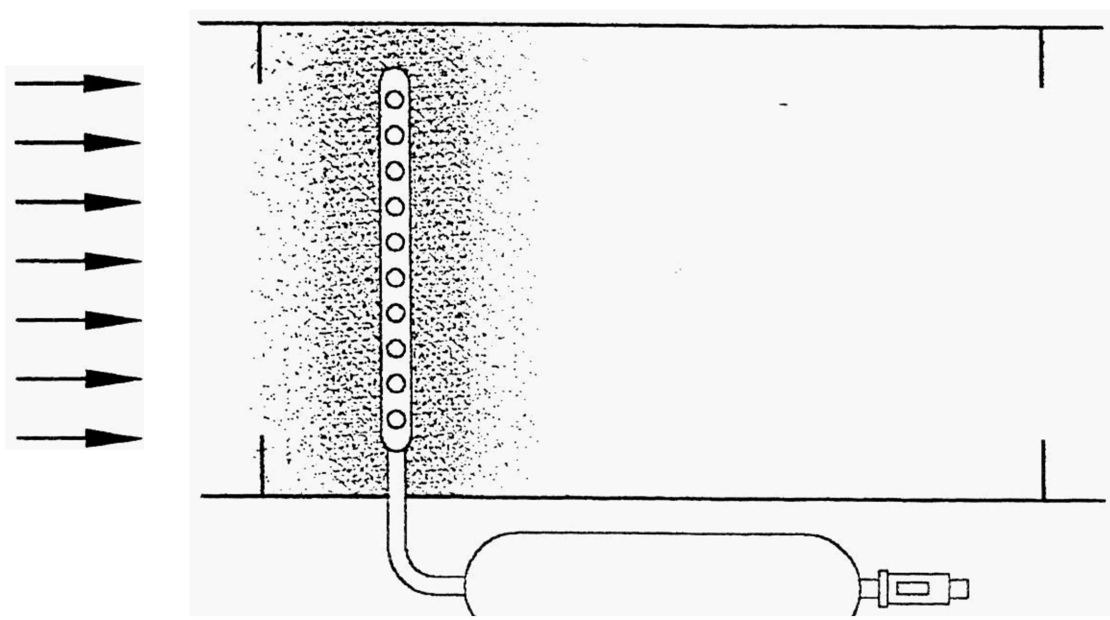


Fig 4. Fire extinguishing system for intensive supply of the fire extinguishing agent.

a gaseous "lock" of high concentration is preferable (Figure 4). This "lock" moves along the module with the cooling air flow and gets into all "shaded" places and suppresses the fire beds. **As** Table 1 shows, the agent ejection time during the intensive supply is 2-3 times less, and the agent consumption is correspondingly 2-3 times higher. The tests have shown that during the intensive supply, the total agent quantity can be decreased by 1.5 and even by 2 times.

The one-manifold FES with the intensive supply has some technological and weight advantages when compared with the extensive supply through the ramified atomizing manifolds. One more advantage of this method is that the amount of time the agent is in contact with the **flame** and hot surfaces is decreased, which results in a considerable reduction of the agent quantity decomposed by fire and, consequently, the quantity of toxic byproducts produced.

Our experience has shown that this method is the most efficient one for power plants with a high level of ventilation, which is characteristic of fighter aircraft plants.

Besides this limitation, there is an essential but, in fact, formal drawback of the intensive supply system. It is in violation of the requirements for maintaining fire suppression concentration in the module **for** at least 2 sec. This is why the intensive supply has been implemented in military aircraft, but has not been used in civil aircraft and helicopters.

Nevertheless, the careful investigation of this method for fire suppression in aircraft/helicopter power plant modules will apparently enhance possibilities both to select FES and more suitable halon alternative.

The authors propose to consider the further development of the above approach to fire extinguishment within the framework of the NGP Program [2].

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