SMALL SCALE TEST PROTOCOL FOR CLASS B FOAMS

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   3. Effect of expansion at constant flux density (diesel and aviation gasoline)
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1. INTRODUCTION

- Concentrates of Class-B fluorine-based foam formulations used to contain between 0.9 and 3% by weight of fluorosurfactants. Because of concerns about the polluting nature of fluorosurfactants, foam manufacturers have attempted to minimise the amount of fluorosurfactant used, introduce different surfactant chemistry (i.e., telomers in place of PFOS and PFOA), or replace fluorosurfactants with fluoropolymers.
- There is a growing number of manufacturers offering Class B-equivalent formulations with no fluorine content (e.g., RF from 3M, Ecopol from Bio-Ex).

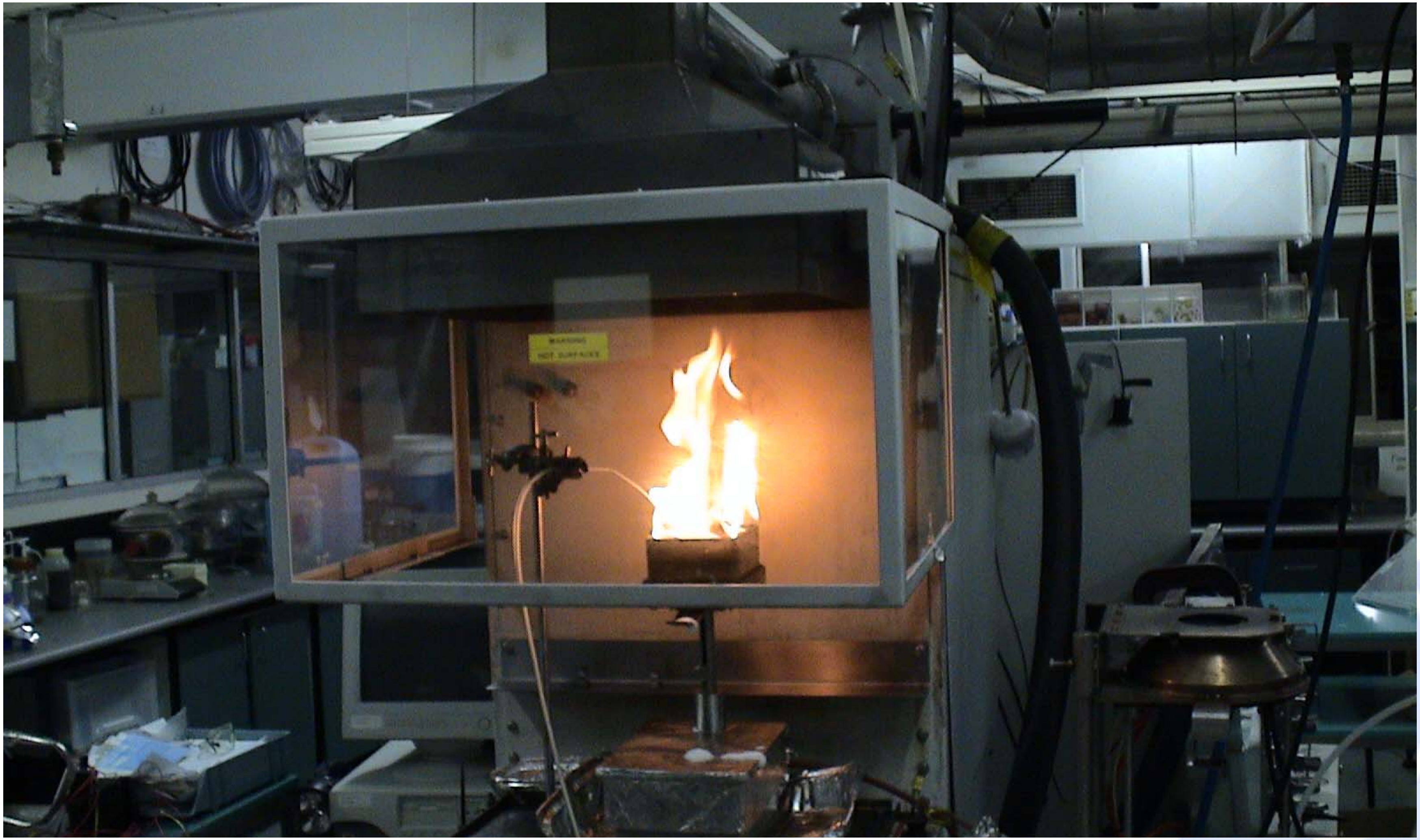
1. INTRODUCTION (2)

- Usually, a large number of suppression experiments is necessary to develop new foam formulations (using pan sizes of around 0.5 m^2 in surface area, as in DEF(AUST) 5603D, or ISO 7203), and then prove them in large scale testing (using pan sizes of between 2.8 and 4.65 m^2 in surface area, as in ICAO, IMO, ISO 7203, MIL-F-24385F, UL 162 or Lastfire protocols). Both types of experiments are expensive and time consuming.
- The objective of the present contribution is to develop a small-scale testing protocol that could be applied to screen a number of foam formulations, under laboratory conditions, yielding foam ranking comparable with that obtained from large scale testing.

2a. EXPERIMENTAL APPARATUS

- An inexpensive, small-scale test apparatus has been developed to assess fire suppression effectiveness and the efficiency of new formulations of Class B fire-fighting foams.
- The apparatus consists of square **pan of cross-sectional area** of 81.9 cm^2 and a foam generation rig able to deliver **flux densities** of between 0.375 and 3.75 kg m^{-2} min^{-1}, with independently controlled **expansion** of between 3 and 20. Flux densities and expansions can be adjusted independently.
- The pan is made of mild steel of 1.3 mm in thickness and features 4-cm lips.

2a. EXPERIMENTAL APPARATUS (2)

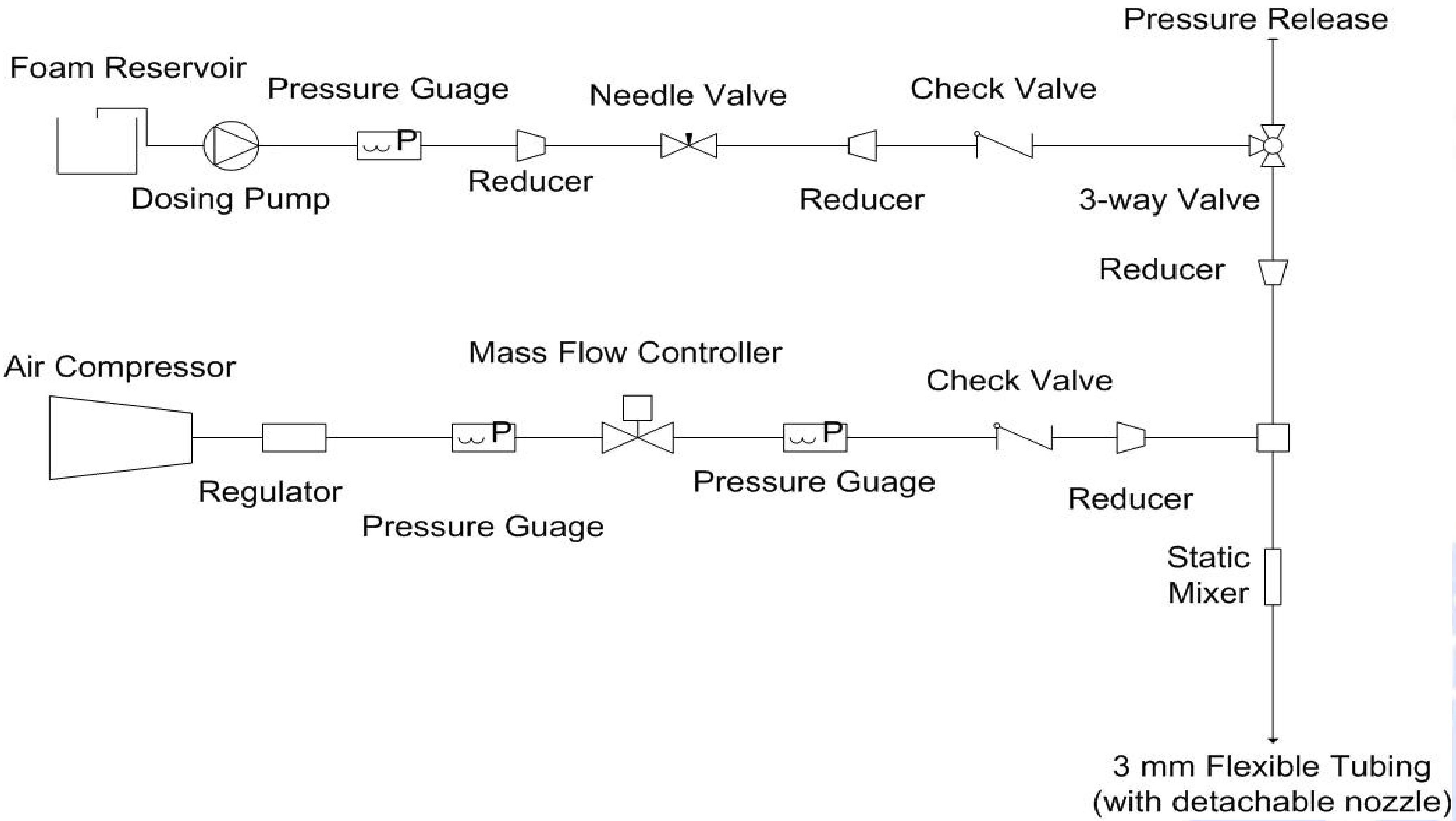


2a. EXPERIMENTAL APPARATUS (3)

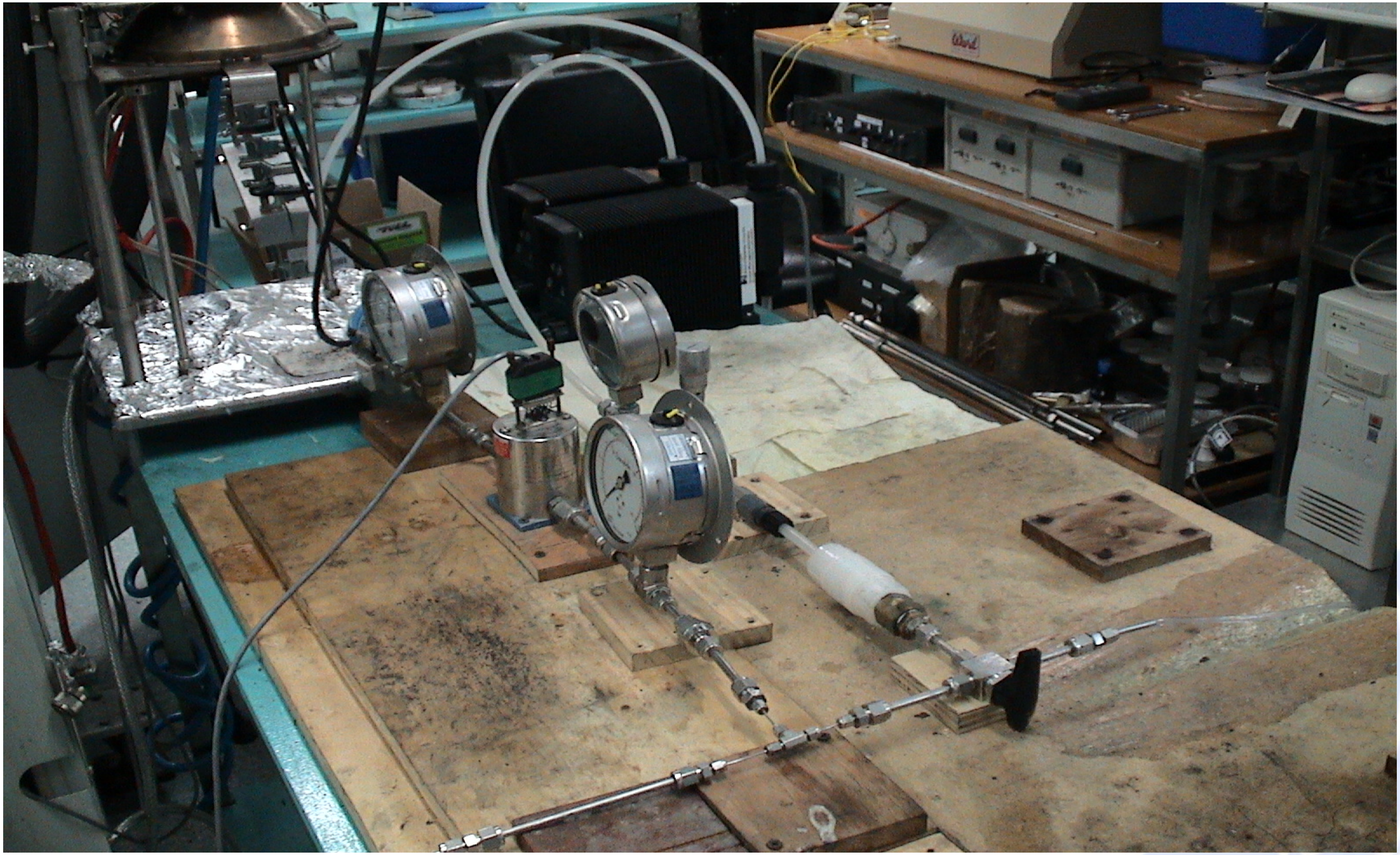
2a. EXPERIMENTAL APPARATUS (4)

- The foam generation manifold incorporates an airline equipped with a mass flow controller and a solution line instrumented with a needle valve, for precise proportioning of surfactant solution and compressed air. In essence, it is a miniature CAF (compressed-air foam) system.
- The airline includes a pressure regulator, a mass flow controller, pressure gauges and a check valve; the latter two for diagnostics and to ensure that the flow occurs in one direction only
- Likewise, the solution line includes a dosing pump, pressure gauges as well as check and shut-off valves.

2a. EXPERIMENTAL APPARATUS (5)



2a. EXPERIMENTAL APPARATUS (6)



2b. PROCEDURE

- The test procedure involves burning of 30 to 50 cm^3 of a hydrocarbon fuel. For diesel fires, 5 cm^3 of a 1:2 mixture of ethanol and toluene is also added, to facilitate rapid ignition.
- Fuel is floated on a water layer, 1 cm in thickness.
- Suppression commences 3 min after the ignition.
- Each experiment is duplicated, and on rare occasions, triplicated; especially if the results of the first two tests yield different results.
- Initially, the apparatus is preheated by burning the fuel, with no suppression.

2b. PROCEDURE (2)

- The cross-sectional area of the nozzle orifice is adjusted, to obtain required foam projection. The nozzle is made of plastic pipette's tip, with the tip cut to required size.
- Three foam formulations are considered:

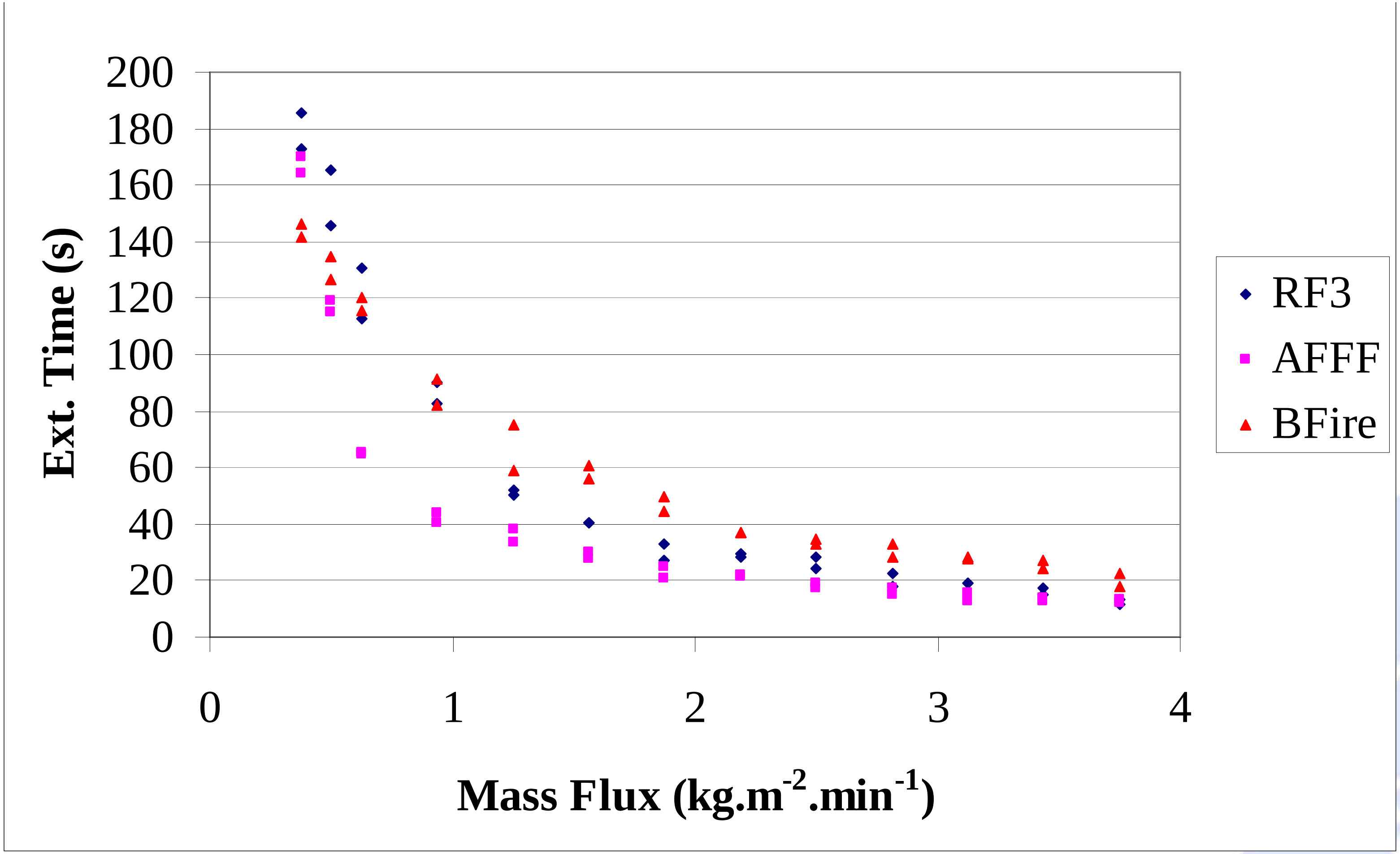
(i) **AFFF** (FC 600, until 2002 produced by 3M)

(ii) **RF3** (fluorine-free formulation introduced by 3M as environmentally benign replacement for PFOS-based formulations)

(iii) **BF** (bushfire foam, Class A formulation designed by 3M for suppression of forest fires in Australia).

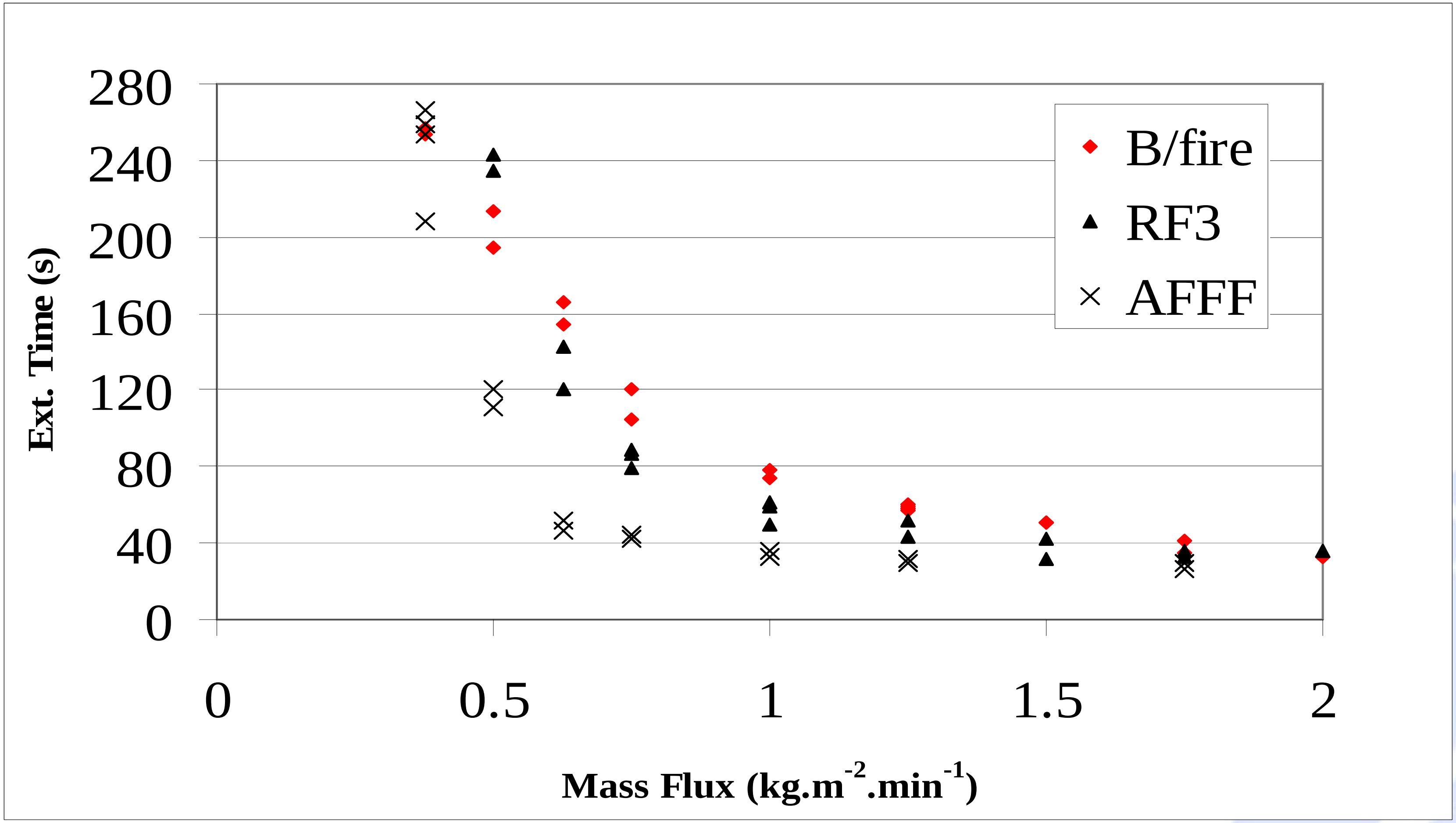
3. RESULTS AND DISCUSSION (1)

Diesel fire, $E = 9$, fuel = 30 cm^3



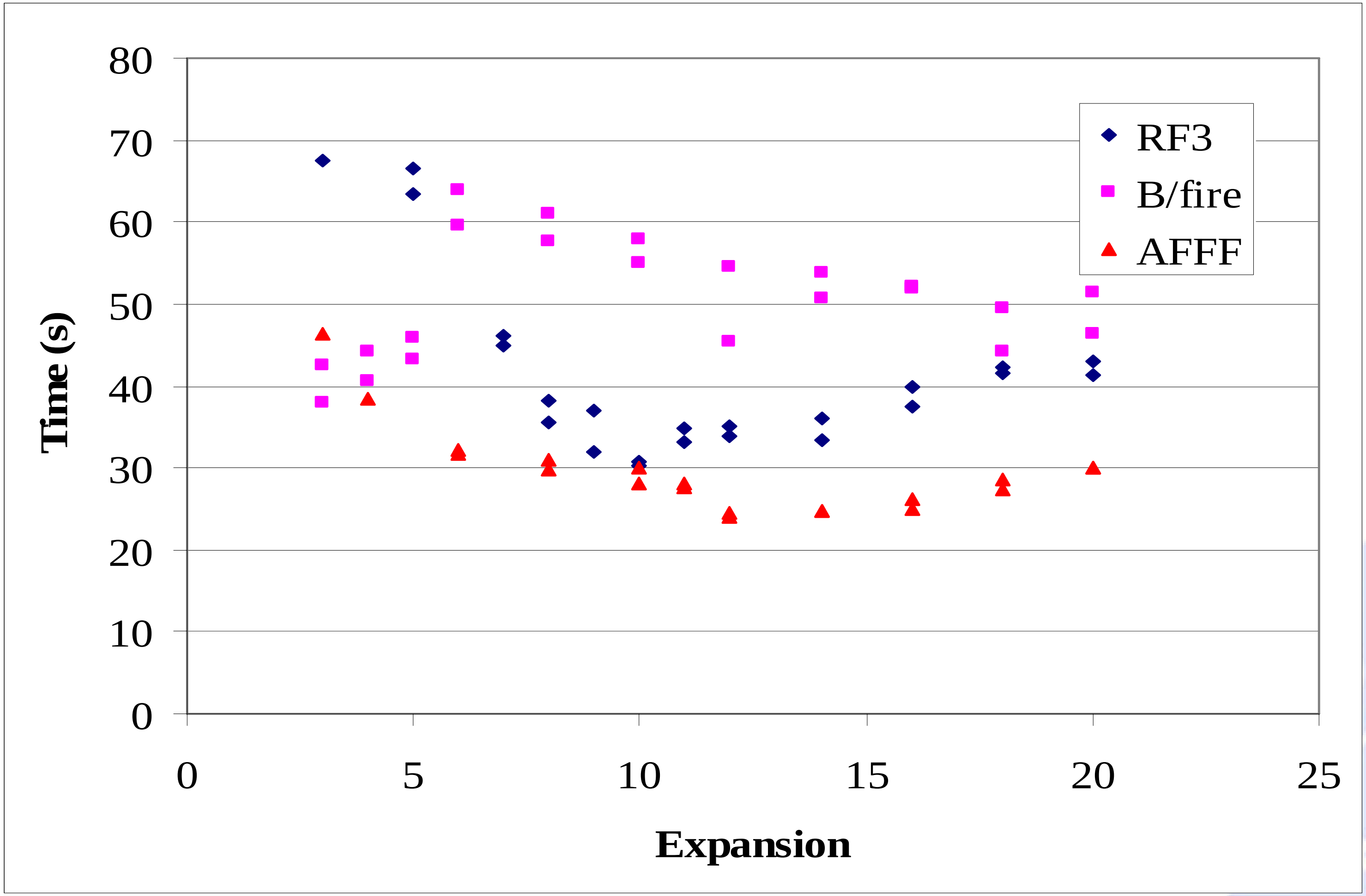
3. RESULTS AND DISCUSSION (2)

Aviation gasoline, *E* = 9, fuel = 50 cm^3



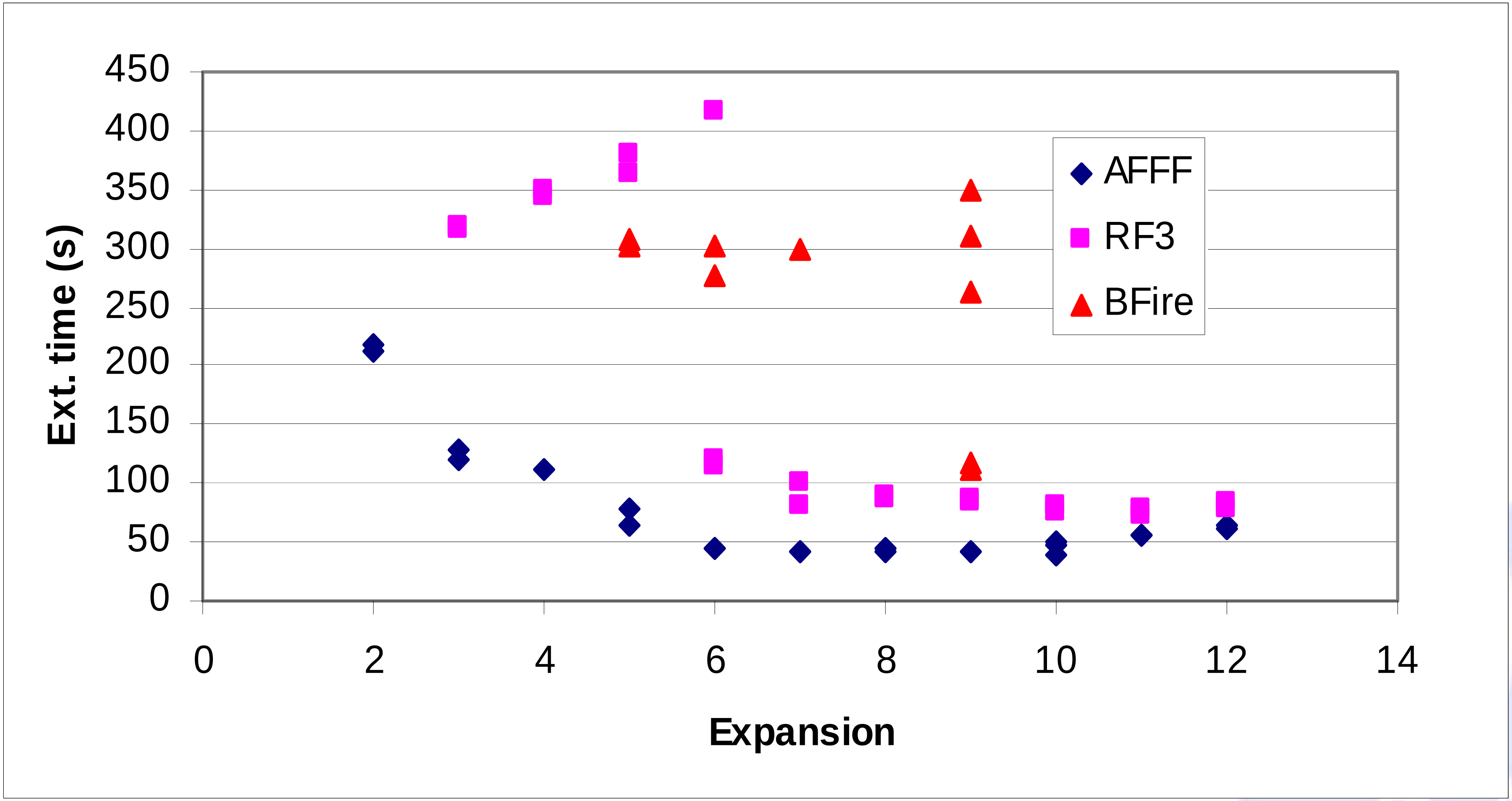
3. RESULTS AND DISCUSSION (3)

Diesel fire, flux = 1.5 kg m^{-2} s^{-1}, fuel = 30 cm^3



3. RESULTS AND DISCUSSION (4)

Aviation gasoline, flux = 0.75 kg m^{-2} s^{-1}, fuel = 50 cm^3



3. RESULTS AND DISCUSSION (5)

- The flux density approaches its critical value just below 0.375 kg m^{-2} min^{-1}, for all three formulations.
- At fluxes exceeding the critical flux, we obtain three distinct curves corresponding to the performance of each formulation. The apparatus yields foam ranking that would have been obtained in large-scale tests.
- As expected, the performance of Class A foam is substantially inferior to that of AFFF and RF3 foams. Especially, Class A foam fails to perform at lower expansions.

3. RESULTS AND DISCUSSION (6)

- In the present tests, AFFF (fluorine-based) does perform better than RF3 (fluorine-free).
- There is an optimum foam expansion for a given flux density for suppression of liquid-fuel fires.

4. CONCLUSIONS

- The present results demonstrate the capacity of the protocol for rapid assessment of foam formulations, at a fraction of the cost of large-scale tests.
- This feature is particularly useful to obtain performance ranking for a large number of experimental foam concentrates, necessary in the development of fluorine-free formulations.
- The small-scale tests yield all major characteristics associated with large-scale assessment of foams; such as the optimum foam expansion for a given flux density.

5. FURTHER DEVELOPMENT

- The effect of pan shape (square vs circular);
- The effect of pan material (steel vs brass);
- Investigation of burnback;
- Measurement of the heat release rate;
- Foam characterisation (drainage, bubble size distribution, physical parameter – e.g. dynamic surface tension and surface viscosity);
- Comparison of ranking the same formulations with the results of large-scale tests.