# Replacement for the Halogenated Fire Suppressants: A Research Strategy and Plan

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## ABSTRACT

A consortium of industrial firms and Federal agencies has developed a plan to identify candidate fire suppressants to replace halons 1211 and 1301. The strategy is to conduct a program of closely-coordinated research, empirical testing, and analysis. The paper contains an outline of the 27-element plan.

## I. BACKGROUND

Because of their role in depleting stratospheric ozone, production of the current halogenated fire suppressants will likely be greatly reduced or phased out by the turn of the century. A consortium of concerned industrial firms has formed with Federal agencies to support a program to identify candidate replacement chemicals for halons 1201 and 1301.

The search for new fire suppressant chemicals is not likely to be brief or easy. Successful candidates must perform appropriately in tests for a wide variety of properties:

- fire suppression efficiency,
- ozone depletion potential,
- greenhouse warming potential,
- suppressant residue level,
- electrical conductivity,
- metals corrosion,
- materials compatibility,
- stability under long-term storage, and
- toxicity (inhalation and contact) of the chemical and its combustion products.

In addition, there is a practical benefit to identifying chemicals that are "drop-in" replacements for the current suppressants. This requires similar state and fluid mechanical properties. Satisfying this combination of demands will be distinctly more difficult than identifying, for instance, a new refrigerant, de-greaser, or aerosol propellant.

This program will identify acceptable candidate chemicals. To the extent that we only find choices of partially-desirable chemicals, the trade-offs will be clearly presented so that policy officials may make informed decisions. All information on chemicals and their test results will be in the public domain.

## II. RESEARCH STRATEGY

Our strategy is to conduct a program of closely-coordinated research, empirical testing, and analysis.

The principal output of the first four years of the program will be appropriate test methods and criteria, compilation of information, and knowledge for designing or selecting potential replacement chemicals.

A key intermediate accomplishment that will facilitate the development of alternative suppressants is a reliable predictive model for the effectiveness of fire suppression at full-scale. This will be supported by accurate input data and tested on the current halons. The predictive capability will then be tested on other candidate chemicals.

This concept is assumed necessary because: (a) a number of the more obvious chemicals have already been tested and found wanting, and (b) the environmental demands on the agents will likely change during the course of the program.

By the end of the seventh year, the possible alternative chemicals will be few and of high quality. At the end of the eleventh year, the success of a small number of chemicals will have been fully documented.

## III. RESEARCH PLAN

This plan is meant to be a "living" document. Breakthroughs will allow us to find more direct channels toward the conclusion; complications will necessitate further analysis and research.

The research plan begins with:

- A selection of trial chemicals and quick, relatively inexpensive performance screening tests to be run on them;

- A survey to identify the fire types for which halons are currently deployed and the requirements of a "drop-in" replacement agent;

- Research to identify the chemical, physical, and fluid mechanical properties of chemicals that would be most effective, economical, and safe; and
- Establishment of a systematic database to aid analysis of all pertinent information in support of the above.

These efforts will lead to the establishment of a reliable predictive capability for the effectiveness of fire suppression at full-scale and

experience with the behavior of various types of chemicals under tests for the other needed properties. These results will, in turn, guide improvement in both the successive selection of compounds and the tests for obtaining performance data. As the selected chemicals become better and fewer, the scale of testing increases, culminating in full-scale toxicity and fire suppression tests. A schematic of this approach is shown in Figure 1.

The plan consists of 27 elements. Figure 2 shows how these elements fit together and provide the basis for their successors. Figure 3 depicts the time line for these elements. The following is a brief description of each of the program elements.

1. Preliminary Screening Procedures and Criteria

   Determine the most appropriate, currently available screening methods for fire suppression efficiency, residue level and electrical conductivity, ozone depletion potential, greenhouse warming potential, metals corrosion, materials compatibility, stability under long-term storage, and toxicity (inhalation and contact); determine reasonable first approximations for ratings of acceptable performance for each screen.

2. Exploratory Candidate Set (Set A)

   (a) Identify and (b) screen ≈100 gases or liquids, covering a range of chemical and physical principles thought to affect flame suppression capability.

3. Analysis of Set A Data

Identify potential winners, if any; extract guidelines for selection of further candidates and for elimination of classes of compounds.

4. Candidate Agent Database

Create and maintain an accessible tabulation of all chemicals that have been or are being considered as fire suppressants; database to include physical and chemical properties and performance data from tests for parameters in element 1; all data to be referenced.

5. Fire Type Survey

Determine the generic types of fires for which current halon systems are designed.

6. Ozone Depletion Potential Analysis

Assess the capability of method(s) for determining ODP of current and potential alternatives to the current halons; determine best quick screen method and technical criterion for ODP.

7. Greenhouse Warming Potential Analysis

Assess the capability of method(s) for determining GWP of current and potential alternatives to the current halons; determine best quick screen method and technical criterion for GWP.

8. Rigorous Fire Suppression Screening Protocol

Develop a screening protocol for fire suppression effectiveness on liquid and solid fuels of gaseous and liquid agents that replicates larger scale results, but requires only a small quantity of agent.

9. Fire Suppression Modeling Assessment

Determine best computational approaches for "experiments" to optimize fire suppressant selection.

10. Upgrade of Preliminary Screening Methods

Review and upgrade, as needed, the previous screening protocols for assessing residue level, metals corrosion, materials compatibility, stability under long-term storage, electrical conductivity, and especially toxicity (inhalation and contact) of chemicals and combustion products; must use small quantities of chemical.

11. Chemical Kinetics of Suppression

Determine the chemical pathways and reaction rate data for flame extinction by potential halon replacements.

12. Thermal Effects of Suppressants

Determine the contribution of the heat capacity and thermal decomposition of molecules to suppression.

13. Agent Transport Physics

Develop numerical methods for calculating an agent's delivery characteristics as a function of its physical properties.

14. Thermodynamic and Transport Properties

Determine the data needed for the model in element 13.

15. Thermal Stability and Decomposition

Assess stability of replacement chemicals under long-term storage.

16. Modeling of Suppressants in Turbulent Fires

Develop computations of the injection into and distribution of extinguishing agents in a fire bed and adjacent fire plume.

17. Agent Entrainment in Turbulent Combustion

Determine experimentally the role of density and chemical heat release variations in flame suppression agents on their entrainment behavior in a turbulent fire plume and the effectiveness with which the agent is mixed molecularly with the plume gases.

18. Select and Procure Candidate Set B

Identify a set of ≈100 potentially successful candidate suppressants and obtain the quantities needed for screen testing as refined in elements 6-10.

19. Test Candidate Set B

Obtain performance data for Candidate Set B chemicals.

20. Analyze Data from Set B

Determine additional compounds for screen testing.

21. Test and Analyze Set C

Determine the performance of compounds in Candidate Set C.

22. Select Candidate Set D

Identify reduced list of compounds for further testing.

23. Medium Scale Test Protocols

Design more realistic, larger-scale, and potentially more costly fire suppression methods for testing.

24. Test Candidate Set D

More realistic data on Candidate Set D compounds.

25. Full-Scale Suppression Tests

Develop and perform realistic fire-suppression tests.

26. Full Toxicity Testing

Perform toxicity tests needed for acceptance of new agents.

27. Prepare Final Report