AD-A061 093 NAVAL WEAPONS CENTER CHINA LAKE CALIF F/G 13/2
BOUNDARY CONDITIONS FOR POLLUTION ABATEMENT OF FAST COOK-OFFS A--ETC(U)
OCT 78 D R CRUISE

UNCLASSIFIED NWC-TP-5989 NL

1 OF 1
AD
A061093

END
DATE
FILMED
2-79
DDC

NWC TP 5989

Boundary Conditions for Pollution Abatement of Fast Cook-Offs and Static Tests

by
D. R. Cruise
Advanced Technology Division
Propulsion Development Department

OCTOBER 1978

Approved for public release; distribution unlimited.

Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

FOREWORD

This study is intended as a guide for possible future work on the abatement of pollution during Navy testing operations in the San Bernardino County portions of the Naval Weapons Center (NWC). This work was performed during FY 1977 and was supported by the Western Division of the Naval Facilities Engineering Command (WESTDIVNAVFACENGCOM), San Diego, CA, under Project Number 132492.

This report has been reviewed for technical accuracy and completeness by William Dougherty (WESTDIVNAVFACENGCOM), Dr. Hugh Malone, Southern California Air Quality Management District (SCAQMD), and Crill Maples and Duane Williams of NWC.

Approved by
C. L. SCHANIEL, *Head*
Ordnance Systems Department
15 September 1978

Under authority of
W. L. HARRIS
RAdm., U.S. Navy
Commander

Released for publication by
R. M. HILLYER
Technical Director

NWC Technical Publication 5989

Published by . . . . Technical Information Department
Collation . . . . Cover, 31 leaves
First printing . . . . 255 unnumbered copies

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NWC-TP-5989	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (*and Subtitle*) BOUNDARY CONDITIONS FOR POLLUTION ABATEMENT OF FAST COOK-OFFS AND STATIC TESTS		5. TYPE OF REPORT & PERIOD COVERED FY 1977
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) D. R. Cruise		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Weapons Center China Lake, California 93555		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Naval Facilities Engineering Command Project no. 132492
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Weapons Center China Lake, California 93555		12. REPORT DATE October 1978
		13. NUMBER OF PAGES 60
14. MONITORING AGENCY NAME & ADDRESS(*If different from Controlling Office*)		15. SECURITY CLASS. (*of this report*) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

(12) 64 p. (9) Technical publication

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Boundary Conditions
Cook-Off
Pollution Abatement
Static Test

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

See reverse side of this form.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

403 019

(U) *Boundary Conditions for Pollution Abatement of Fast Cook-Offs and Static Tests*, by D. R. Cruise. China Lake, Calif., Naval Weapons Center, October 1978, 60 pp. (NWC TP 5989, publication UNCLASSIFIED.)

(U) The boundary conditions of military usefulness are considered for the static test of rocket motors and the fast cook-off of ordnance in fuel fires. A boundary may be geometrical, chemical, procedural or administrative in nature and represents a point beyond which the military value of the test is greatly diminished. In the case of administrative boundaries, it is possible that changes can be initiated at higher levels in the Navy Department. However, if a proposed pollution abatement device violates the other boundaries, the tests may no longer have any military value.

CONTENTS

INTRODUCTION

This report pertains to air pollution and proposed pollution abatement at two test activities in the San Bernardino County portions of NWC. The nature and purpose of these tests are described and the chronology of events leading up to the present study is presented.

One test activity is located at CT-4 (see Figure 1). Of principal concern, pollution-wise, are the "cook-off" tests that simulate aviation fuel fires on the flight deck of aircraft carriers. The fuel, designated JP-5, is a kerosene-type fuel manufactured according to Navy specifications. The Air Force uses a similar fuel called JP-4. Jet fuels in general are termed JP.

Ordnance items such as rocket warheads, bombs, ammunition, rocket propellants and any other item of a flammable or explosive nature that can be found on the deck of a carrier during flight operations are placed into the JP-5 fires at CT-4. The purpose of these tests is to: (1) observe how the ordnance behaves in the fire, (2) test improvements made on ordnance to withstand fires, and (3) determine the time available to fight a fire before detonation occurs.

The importance of the fuel fire tests is written in military history. During World War II the Battle of Midway[1] was going badly for the Americans until some opportune hits were made on the Japanese carriers while they were refueling their aircraft. The carriers were destroyed by fuel fires and exploding ordnance. Also, several fires occurred on American carriers in the Pacific during Viet Nam operations which caused heavy losses of men and material. These fires were not even the result of direct enemy action.

The other test activity is located at Skytop (see Figure 1). Here, Trident and other large rocket motors are static tested. By static test, it is meant that the motor is tied down and restrained from flight. (This description, while pictorial, does not begin to convey an idea of the mass of concrete abutments and other hardware, costing millions, that insure that the huge, powerful rockets remain secured to the ground.) Gauges and thermocouples are attached to the rocket motors to determine pressures, thrusts and temperatures during firing. These data measurements are used to predict, to a large extent, how the motor will perform in flight, thus reducing the number of flight tests required and providing information that could not otherwise be obtained. Trident and its predecessors, Polaris and Poseidon, are submarine-launched missiles designed to carry warheads great distances. NWC is the single location the Navy has available for static testing these missile motors.

The purpose of this report is to define the test boundaries beyond which abatement methods destroy the military value of the test. The boundary definition thus permits a more productive search for the proper pollution abatement technology.

A chronology of events leading to the present study effort is given so that prior related work may be cited and future duplication of effort can be avoided.

---

[1] *History of United States Naval Operations in World War II, Volume IV*, by Samuel Eliot Morison. Little, Brown and Company, Boston (1967).

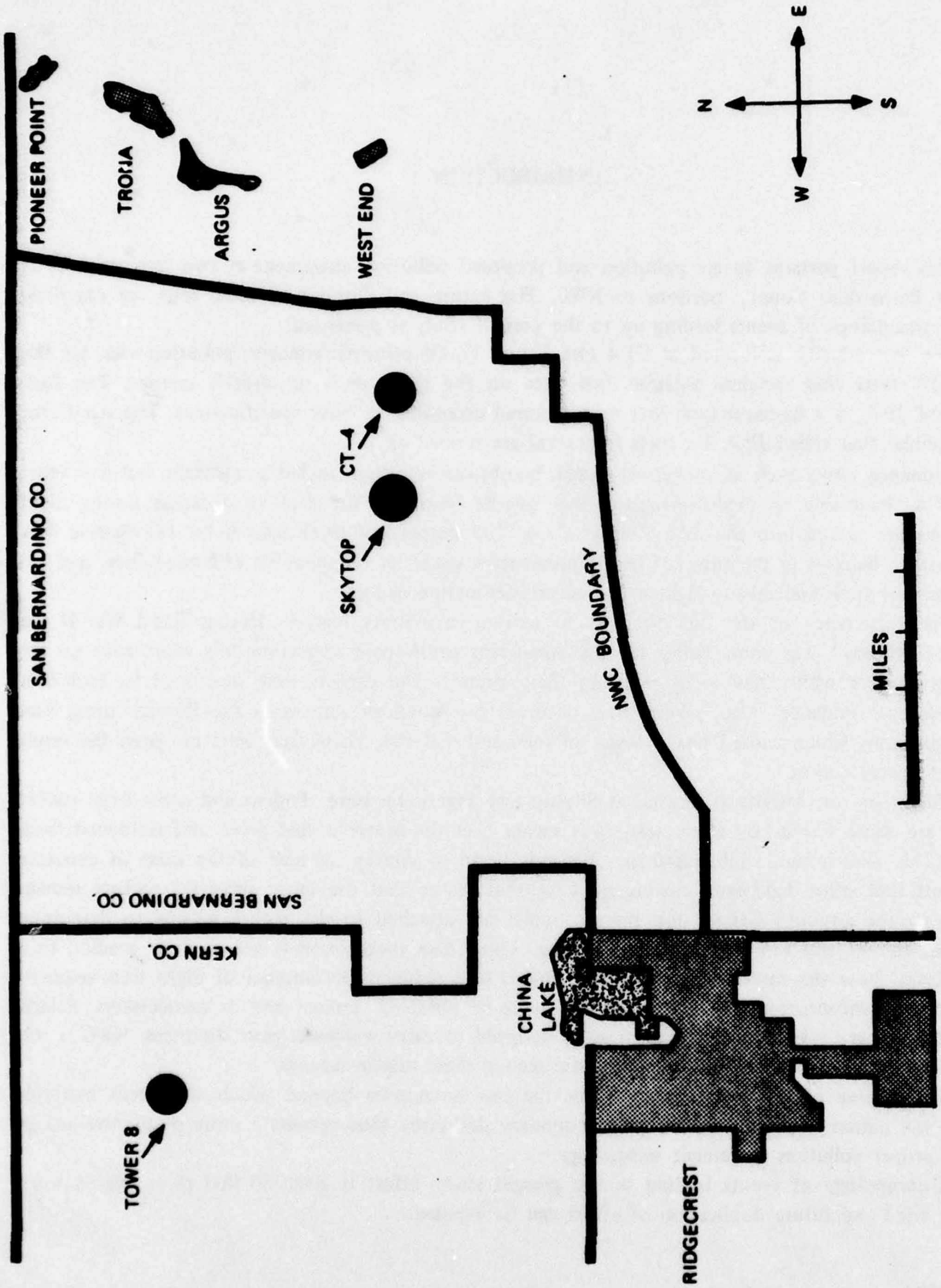

FIGURE 1. Portion of NWC Showing Certain Test Sites and Adjacent Community. (Drawn to scale)

12 February 1959

First Polaris motor static tested at Skytop, NWC.

1 May 1968

First simulation of a shipboard fire using JP-5 fuel; however, this was not the first cook-off test at NWC. Ordnance has been cooked-off using electric blankets, ovens and fuel fires since before 1952.

15 December 1972

Dr. W. Thielbahr, et al., reports radiative heat transfer to have a significant effect in JP fires[2] The heat flux is about 10 Btu/ft^2-sec and the optical thickness of such fires is about 3 feet. Radiative heat flux and the small optical thickness is caused by smoke particles; thus the smoke promotes heating effects which are difficult to simulate even with the hotter burning, but smokeless fuels such as propane.

12 December 1973

Final report on a Smoke Abatement Project issued by P. A. Davis, et al.,[3] describes a 6 week project conducted during June and July of 1973 to study possible abatement methods for CT-4 cook-off tests. Some well-instrumented experiments with afterburners and scrubbers were performed. (Further discussion of this work is presented later in this report).

19 December 1973

Executive Order 11752[4] (see Appendix A) is published to assure "that the federal government shall provide leadership in the nationwide effort to protect and enhance the quality of air, water and land resources..."

1 June 1974

NWC Technical Memorandum 2426 entitled *Survey and Evaluation of the Environmental Impact of Naval Weapons Center Activities*, by James R. Ouimette, is published.[5] This memorandum provides background about NWC history, test activities, wildlife, geology and demography.

5 June 1974

The Southern California Air Quality Management District (SCAQMD) issued a report on the technology required for the control of NO_x emissions from the Kerr McGee Corporation (KMC) coal-fired power plant. KMC has chemical refining operations 25 miles east of China Lake. It was reported that NO_x abatement costs KMC $5M. KMC operations and labor force have a two-fold importance to NWC: (1) emissions from NWC may inpinge on the residential and refining communities of Trona, Argus, West End and Pioneer Point (see Figure 1) and (2) people in that area perceive a double standard in pollution control standards for private industry and for the military.

[2] Naval Weapons Center. "Radiation Heat Transfer in JP Fires," by W. H. Thielbahr. China Lake, Calif., NWC, 15 December 1972. (NWC Memo Reg. 4544-2005, publication UNCLASSIFIED.)

[3] Naval Weapons Center. "Smoke Abatement Project Final Report," by Peggy A. Davis, et al. China Lake, Calif., NWC, 12 December 1973. (NWC Memo Reg. 4503-107, publication UNCLASSIFIED.)

[4] Executive Order No. 117524 (Federal Register, Vol 38, No. 243).

[5] Naval Weapons Center. *Survey and Evaluation of the Environmental Impact of Naval Weapons Center Activities*," by James R. Ouimette. China Lake, Calif., NWC, June 1974. (NWC TM 2426, publication UNCLASSIFIED.)

28 June 1974
First Trident Static test at NWC.

13 February 1975
Air Force interpretation of Executive Order 11752 led the Air Force Rocket Propulsion Laboratory (AFRPL) to seek a variance from the San Bernardino County zone of SCAQMD.

AFRPL is located 7 miles south of Boron, California and its easternmost portion extends into San Bernardino County. Static tests on large solid rocket motors are conducted at these sites, and the Air Force estimates that up to 350,000 parts per million (PPM) of hydrogen chloride (HCl) is emitted from the rocket nozzle during a firing. Because this concentration of HCl is in violation of Rule 74 of Section 24929, Health and Safety Code, which limits such stationary sources to 800 PPM HCl, the AFRPL initiated a feasibility and cost study of scrubbing devices which, if proven effective, possibly could be operational by 1982-1983

5 August 1975
Dr. R. Ulrich of NWC published a memorandum that questioned whether the use of JP fuels instead of propane was justified in the simulation of shipboard fires.[6] He cited an experiment with twenty JP tests and five propane tests in which propane tests were within the statistical variation of the JP tests.

26 August 1975
The Ballistic Test Branch of NWC reported that in calendar year 1974, 125,000 pounds of Trident propellant and 15,200 gallons of JP-5 were consumed during tests.[7] The report also stated that in the first half of 1975, the figures were 220,000 pounds and 9,800 gallons, respectively.

21 October 1975
Doris Bray of the "Trona Argonaut" newspaper sent a letter to SCAQMD concerning black clouds originating from NWC facilities near Trona. Maps and photos were enclosed and this question was posed: why must private citizens obey stricter rules than the U.S. Navy? The date of this letter coincided with the visit of Donald Thomas and Hugh Malone of SCAQMD to China Lake and Trona. While at Trona, NWC and SCAQMD people received a similar complaint from Leonard Harris of KMC (see 5 June 1974).

23 October 1975
The San Bernardino County Air Pollution Control Officer was directed to investigate the Navy operations that inspired Doris Bray's letter.

---

6 Naval Weapons Center. "Use of Propane Versus JP-4 or -5 in Cook-Off Testing," by Richard D. Ulrich. China Lake, Calif., NWC, 5 August 1975. (NWC Memo Reg. 45701-275-75, publication UNCLASSIFIED.)

7 Naval Weapons Center. "Code 4531 Consumed Energetic Materials (CY 1974 & 1st Half CY 1975)," by Roy B. Johanboeke. China Lake, Calif., NWC, 26 August 1975. (NWC Memo Reg. 4531-012-76, publication UNCLASSIFIED.)

24 October 1975

Charles O'Malley of SCAQMD wrote NWC requesting the Navy's interpretation of Executive Order 11752. NWC was also requested to determine in which county the incident reported by Doris Bray occurred.

11 November 1975

NWC Environmental Engineering Office studied the complaint and invited Pollution Control Officers to visit NWC.[8,9]

14 November 1975

The Ordnance Logistics Branch reported that 8920 pounds of explosives, 23,120 pounds of propellants and 24,000 pounds of contaminated material were disposed of by burning in 1974.[10] (The disposal of pyrotechnic "trash" is one source of smoke in San Bernardino County portions of NWC. The source was not addressed in this report because an abatement effort completely independent of this report is being pursued. For further details contact the Environmental Protection Office, NWC Code 26305.)

19 November 1975

San Bernardino County SCAQMD officials visited NWC and observed a cook-off test. W. Dougherty of WESTNAVFACENGCOM brought to light a Naval Operations Instruction[11] which states that Naval activities shall not apply for permits, licenses and variances from non-federal air pollution agencies. However, effort should be made to furnish all available information similar to that requested on a permit or license application.

25 November 1975

The San Bernardino Air Pollution Control Officer (SBAPCO) wrote the Naval Weapons Center stating the results of the visit. Three violations were cited:

1. Shipboard fire simulation violated rules on open fires and visible emissions.
2. Static tests of large rockets violated allowable level for certain contaminants (specifically HC1).
3. Disposal of pyrotechnic trash violated rules on open burning.

The SBAPCO also noted the conflict due to the Navy's interpretation of Executive Order 11752 (see 19 November 1975). The Pollution Control Officer suggested that NWC set forth a plan and timetable for compliance and San Bernardino officials would request variance on NWC's behalf for the period of the plan.

---

[8] Naval Weapons Center. "Recent Complaint Notices from Local Air Pollution Control Districts," by James R. Ouimette. China Lake, Calif., NWC, 11 November 1975. (NWC Memo 70305/JRO:vp, publication UNCLASSIFIED.)

[9] Naval Weapons Center. Letter from NWC Environmental Engineering Office to San Bernardino Zone, Southern California Air Pollution Control District. (NWC ltr 70305/JRO:rh dtd 11 November 1975.)

[10] Naval Weapons Center. "Code 4552 Consumed Energetic and Contaminated Materials from June 1974 to June 1975," by A.P. Holbert. China Lake, Calif., NWC, 14 November 1975. (NWC Memo Reg. 45-136-76, publication UNCLASSIFIED.)

[11] Chief of Naval Operations. OPNAV Instruction 6240.3D dtd 24 April 1975.

10, 21 December 1975

Public Works Officer brought citations of 25 November 1975 to the attention of the Head of the Propulsion Development Department.[12] He suggested a flexible compliance schedule. He further reported that J. Quimette (NWC) and W. Dougherty attended an SCAQMD meeting in which AFRPL made a presentation in support of variance.[13] He suggested that NWC support the AFRPL/EPA joint study on feasibility of scrubbers for rocket test stands.[14]

31 December 1975

NWC Technical Director stated "the carrier deck fire simulation probably should make smoke to promote realism".[15] (see 15 December 1972 and 5 August 1975.)

12 January 1976

Public Works Officer responded to Technical Director pointing out that the local officials (SCAQMD) were also acting for the Environmental Protection Agency and that a compliance schedule was mandated within the limits of existing technology.[16]

16 January 1976

An Environmental Impact Statement for static rocket tests at Skytop was issued.[17]

1 February 1976

Final report on *Environment Study of Toxic Exhausts* was issued.[18] This was performed by M. Nadler of NWC for H. Malone, then of AFRPL, now of SCAQMD. The 5-pound motors were of the same propellant formulation as the Air Force Titan III C booster. The exhaust products were captured and analyzed for their chemical constituents. Some of the data in this report is pertinent to the Navy's Trident tests.

2 February 1976

The Environmental Engineering Office wrote SCAQMD describing their progress.[19] Efforts were initiated involving literature searches, emissions inventories, presentation of material describing operations and the monitoring of pollutants.

---

[12] Naval Weapons Center letter 70305/JRO:rh:gtl, PW Serial 206, December 10, 1975. Subject: Results of recent visit by the San Bernardino Zone, Southern California Air Pollution Control District (SBAPCD).

[13] Naval Weapons Center letter 70305/JRO:rh, PW Serial 216, December 21, 1975. Subject: Further developments and trip report concerning non-complying NWC air pollution sources in San Bernardino County.

[14] Air Force Rocket Propulsion Laboratory. *Evaluation of Systems for Control of Emissions*, by Seymour Calvert. Edwards, Calif., AFRPL, August 1975. (Report PB-245590, publication UNCLASSIFIED.) (see also AEDC-TR-72-97).

[15] Naval Weapons Center. Manuscript note from the NWC Technical Director to the NWC Public Works Officer, December 1975.

[16] Naval Weapons Center. "Compliance with County air pollution regulations," by James R. Ouimette. China Lake, Calif., NWC, 12 January 1976. (NWC Memo 70305/JRO:gtl, publication UNCLASSIFIED.)

[17] Naval Weapons Center letter 45301/WWO:baj, Serial 299, January 16, 1975. Subject: Environmental Impact Statement for Trident Test Program at the Naval Weapons Center.

[18] Air Force Rocket Propulsion Laboratory. *Environment Study of Toxic Exhausts Final Report*. Edwards, Calif., AFRPL. (AFRPL-TR-76-13, publication UNCLASSIFIED.)

[19] Naval Weapons Center letter 70305/JRO:vp, 2 February 1976, to San Bernardino Zone, Southern California Air Pollution Control District.

31 March 1976

A Format of Scope was issued describing work to be done on a missile cook-off emission study. This was the first step toward funding work to be done either on Center or by off-Center contractors in abatement of emissions.

21 May 1976

SCAQMD approved Rule 441 which granted research exemptions to the Navy and Air Force for certain tests.[20] Compliance schedules for static test and cook-off were to wait final action on Rule 441.[21] The rule read:

The provisions of Regulation IV except Rule 402 shall not apply to experimental research operations when the following requirements are met:

(a) The purpose of the operation is to permit investigation, experiment or research to advance the state of knowledge or the state of the art; and

(b) The Air Pollution Control Officer has given written prior approval which shall include limitation of time.

The Air Pollution Control Officer shall not grant approval unless operation is conducted in a manner to minimize emissions into the atmosphere to the maximum extent possible.

11 October 1976

Contract work (considered on 31 March 1976) was scrapped in favor of a two-part effort. The first effort, on Center, was to define the boundaries of the tests which pollution abatement should not violate (i.e., this effort).[22] Following this, a contract was to be awarded off-Center in order to assess and determine if a realistic abatement technology exists. Because boundaries and definitions have been established, the search for a feasible technology should be more productive.

[20] Naval Weapons Center memorandum 70305/JRO:lda:gtl, PW Ser 298, 21 May 1976. Subject: Results of the Southern California Air Pollution Control District (SCAPCD) Board Public Hearing on 7 May 1976.

[21] Naval Weapons Center letter 70305/JRO:lda, Serial 3301, 21 May 1976, to San Bernardino Zone, Southern California Air Pollution Control District.

[22] Naval Weapons Center DD Form 1498, Work Unit Number 1324927, "Emission Studies." (see also NWC Memo 26305/TMD:gtl, 17 November 1976.)

FAST COOK-OFF TESTS

Fast cook-off tests are conducted at CT-4 two or three times a month; the Navy also conducts similar tests at Dahlgren, VA. Section 5.3.2.1 of WR50[23] deals with minimum safety standards for warheads and states, "the cook-off facility shall be capable of subjecting the warhead to continuous enveloping flame for a period of up to 15 minutes or until a reaction occurs in the warhead explosive. The warhead must be completely enveloped in flames at all times."

In the standard fast cook-off test, the weapon to be tested is instrumented with thermocouples and suspended 36 to 60 inches above a 20- to 35-foot, square test pan containing JP-5 fuel. After fuel ignition, temperatures in- and outside of the test weapon are recorded. Average flame temperatures, heat transfer characteristics, internal temperatures and time-to-reaction are obtained.

Fast cook-off tests produce a plume of black smoke. This black smoke has been the source of two complaints to air pollution authorities. The San Bernardino Zone, South Coast Air Quality Management District has cited these tests on two counts: Open Fires and Visible Emission. The specific rules read as follows:

Rule 57. Open Fires

(a) A person shall not burn or maintain or permit the maintenance of the burning of any combustible refuse in any open outdoor fire without first obtaining a permit from both the Control Officer and the fire protection agency with jurisdiction in the area.

Pursuant to Section 39077.4 of the Health and Safety Code, a burning permit may be granted only for:

(1) Prevention of a fire hazard which cannot be abated by any other means.

(2) Forest management burning.

(3) Instruction of public or industrial employees in the methods of firefighting.

(4) Agricultural operation in the growing of crops or raising of fowls or animals.

(5) Recreational activities of organized groups provided only clean wood is burned.

(6) Simulated conditions for an emergency exercise conducted by a governmental agency properly charged with this responsibility.

---

23 Department of the Navy. *Naval Weapons Requirements*, WR-50, 13 February 1964. Bureau of Naval Weapons, Washington, D.C. (Publication UNCLASSIFIED.)

(b) Open burning permitted in paragraph (a) is prohibited on "no-burn" days. The Control Officer may permit open burning for the instruction of firefighting personnel on a no-burn day when the delay of such training would cause severe problems in scheduling fire training.

(c) Information as to whether a day is a permissive-burn day or a no-burn day will be available at the District each morning by 8:00 a.m. In addition a forecast will be available at the District by 3:00 p.m. each day.

This Rule is effective September 10, 1974.

Rule 401. Visible Emissions

A person shall not discharge into the atmosphere from any single source of emission whatsoever any air contaminant for a period or periods aggregating more than 3 minutes in any 1 hour which is:

(a) As dark or darker in shade as that designated No. 1 on the Ringelmann Chart, as published by the United States Bureau of Mines, or

(b) Of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke described in subsection (a) of this rule.

The main purpose of the Navy's fast cook-off tests is to save lives. The need to perform these tests will continue indefinitely. New ordnance is continually being developed. To qualify for use aboard Navy planes these ordnance must be able to pass 5 minutes and even 10 minutes in JP fuel fire without detonating. A single test for a given item is not enough. Reliability theory demands that a sizable quantity be tested (the fact that 99 warheads fail to detonate in a fire does not matter if the 100th kills you).

This is a problem peculiar to the Navy. Air Force bases are of adequate size so they may "spread out". A fire on the runway does not make the Air Force happy, but their problems are small compared to the Navy's. A fire on the relatively small flight deck of a carrier (termed the "postage stamp" by World War II flyers) is a threat to the vessel and everybody aboard. As an example of what is at stake, Jane's *All the Worlds Fighting Ships* states that the aircraft carrier NIMITZ carries 6100 men and cost $594M. This does not include the cost of the aircraft.

The fact that the Navy sees a continuing need for fast cook-off tests precludes one course of action. When there does exist a final completion date, air pollution officials and the general public are often agreeable to the granting of a variance because they know that the source will eventually stop. In the Navy's fast cook-off tests there is an apparent conflict of interest between two factions, both of which are acting in the interest of the health and safety of men. The word apparent is used to avoid excluding the possibility that a solution exists that will not jeopardize either effort.

An effective solution must meet the following criteria: (1) should not diminish the military value of the test (2) should obey at least the letter of the law, and (3) should be palatable to the general public. Criterion (3) can be at least as hard to satisfy as (2). In any case, any and all contemplated solutions will be submitted to SCAQMD and thus the public will be informed of the alternatives being evaluated.

Seven possible approaches exist and are listed, not necessarily in the order of greatest promise as follows:

1. Use of afterburner scrubber techniques
2. Use of alternative fuels
3. Enclosure of facilities
4. Use of smoke-prohibiting additives
5. Use of computer simulation
6. Burning at night
7. Use of passive measures.

Although these approaches exhaust the author's inventory, this list should not be "stamped" complete.

The afterburner scrubber technique in approach 1 has been studied experimentally by P. A. Davis, et al. (see Footnote 3). Such techniques are already employed in smoke stacks. A scrubber alone is not effective unless water is injected near the burning surface. This cools the ordnance and destroys the value of the cook-off test.

There is some potential in the combination approach where smoke is first forced through a propane afterburner and then scrubbed with water. However, Davis et al., had difficulty in forcing most of the smoke through the apparatus. Also live ordnance was not tested during the study and these ordnance are quite capable of destroying such an apparatus on a regular basis. Even if these difficulties could be overcome, there may be difficulty conforming to Military Standards. Care must also be taken not to create more pollution (perhaps not visible) than is eliminated.

The use of propane instead of JP-5 would eliminate visible pollution immediately. Propane must burn in the range of 2200 to 2300°F to put the same heat flux into the ordnance as JP-5 which burns in the range of 1500 to 1700°F. This is because smoke radiates heat much better than a smokeless flame. Also the ordnance may be blackened by smoke which allows it to absorb heat better. The question of whether the time to reaction and the severity of reaction is the same in propane and JP fires has not been resolved at this point.

The apparent contradiction between the reports of Thielbahr and Ulrich (see Footnotes 2 and 6) can be attributed to the fact that they are both preliminary and indicate that further investigation is desirable. The experimental study of mechanisms can certainly be carried further and Thielbahr or others would be happy to do so if they received the necessary support.

It is desirable to expand on the statistical approach of Ulrich for two reasons: (1) the results <u>do</u> <u>not</u> <u>show</u> a difference, rather they <u>show</u> <u>there</u> <u>is</u> <u>no</u> difference between propane and JP-5--the comparison is subtle but important; (2) the fact that propane results fall within the range of JP-5 results does not mean propane predicts the worst possible JP-5 results. If a significant difference in minimum time-to-reaction can be determined, then a sample size can be determined so that a second experiment can show whether a statistical difference actually exists. Thus, further study could possibly lead to the use of an acceptable alternative fuel.

The NWC has no authority to change from JP-5 to propane in fast cook-off tests The test procedures are dictated by a document entitled *Military Standard 1648(AS)*, dated 28 March 1974. This document is reproduced in Appendix B.

The Military Standard originates from a higher authority, namely, the Naval Air Systems Command (NAVAIR) in Washington, D.C. Any proposed abatement procedure must conform either to MIL-STD-1648(AS), or NAVAIR or even higher authority (e.g., Secretary of the Navy) must be persuaded to change the Military Standard. Persuasion in the case of using propane instead of JP-5 would require either evidence that propane fires produce reliable results or directive action by that "even higher authority", and possibly, both.

The third possible approach is to enclose the facilities. This might be total enclosure such as building a structure similar to the Houston Astrodome over the test site. The windows of the dome would be closed during the test and not opened until the smoke particles have fallen out. A closed structure, of course, would be very vulnerable to shock waves emanating from detonation of high explosives. Partial enclosure might be used in conjunction with the afterburner scrubber technique to channel the smoke.

Both partial and total enclosure conceivably can be accomplished without violating MIL-STD-1648(AS). The reckoning factor is cost, not only the initial cost, but the cost of repairs and replacements due to exploding ordnance. One reason CT-4 was chosen for these tests is its remoteness; warhead fragments and casings sometimes travel miles due to explosions. The costs of initial construction and operational maintenance of such a facility would have to be measured against the potential environmental benefits which would be gained.

The fourth approach of using smoke prohibiting additives is really akin to using fuels that do not smoke. It also has the danger of producing more pollution than it inhibits. However, it is possible that a procedure based on this approach can be developed. Any proposed approach should be accompanied by an analysis based on the total air pollution problem and the costs of abatement. A methodology is presented in Appendix C that shows how to do such an analysis. This approach would insure that visible pollution is not abated at the expense of creating a great deal of invisible pollution.

The fifth approach is to do computer simulation in place of some or all of the fast cook-off tests. Computer codes actually exist that can predict time to reaction with some degree of accuracy.[24] However, no code at the present time predicts the severity of the reaction, and the final acceptance decision would not belong to a computer even if it could make such predictions. If one has twenty ideas and can only afford to develop three, then the computer provides a screening capability. Once a person has actually built the three ideas that the computer says are the best, then the picture changes. The computer simulation is no longer the best evidence of what the item can do. This comes from actually throwing it in the fire.

In other words, dollars can be risked on computer decisions but human lives cannot. In any case, the Military Standard would have to be changed and NAVAIR would certainly prefer propane over computers.

The sixth approach (burning at night) is not a viable one. It would eliminate the visibility of the pollution but would not comply with the regulations. Photographic coverage would be limited. In any case, the public would probably not consider this approach palatable.

---

[24] Pacific Missile Test Center. "Fast Cook-Off Characteristics of Air Launched In-Service Weapons," by P. McQuade and R. Slyker. Pt. Mugu, Calif., PMTC, December 1975. (PMTC-TP-75-22, Rev. 1, publication UNCLASSIFIED.)

Passive measures are defined here as those that do not achieve the letter of the law but which offer some advantages over the present situation. These are possible interim measures that can be employed while the technology for a permanent solution is being evolved. One passive measure would be to burn only when the wind is not blowing toward Trona and the other small towns east of the Center. However, test procedures currently require that the wind virtually not be blowing at all (less than 4 knots). If the wind direction must also be specified, the ability to perform the test is greatly restricted.

Burning at night can be considered as a passive measure. Smoke particles at great dilution (less than 260 $\mu g/in^3$) meet federal ambient air quality standards. However, the impact is even further minimized if the particles fall out at night when people are indoors rather than in the daytime when their activities take them outside. Neither of these passive measures is under consideration by NWC. One passive measure currently being employed is the use of propane whenever possible in preliminary tests, leaving JP-5 for the final qualification tests.

It should be noted that NWC is working on another project that would in theory eliminate both the pollution and shipboard fires. It consists of putting additives into JP-5 that would inhibit its susceptibility to igniting when spilled. Some success has been reported. However, it is unlikely that the danger of shipboard fires can be eliminated entirely, even in peacetime. In wartime an enemy will certainly attempt to start fuel fires; therefore, fast cook-off tests will always be needed.

Other fast cook-off tests are performed at NWC on a less frequent basis (fewer than one/month). These are performed in a large cage at Skytop. The cage is 35-ft high, 35-ft wide and 40-ft long. Two sides are solid steel; the other two sides and the top are steel submarine netting held in place by steel girders. The remaining test setup is similar to that at CT-4.

The cage is used to determine if a missile will fly-away before it detonates. The cage assures that the missile will not go far. In a real fire it is (relatively) more dangerous for the missile to fly-away and possibly strike other areas.

This cage does pose additional problems for abatement procedures. It has been noted that, after a number of tests, the steel girders 30-35 feet above the fuel will soften and sag a foot or two.

The boundary conditions for a proposed abatement procedure for fast cook-off are:

1. Test procedures must continue to predict accurately the behavior of bombs, warheads, air-launched missiles, ammunition and other ordnance in JP-5 fires. In particular, these procedures will predict: (a) the minimum time (as distinguished from the average time) to reaction; and (b) the severity of the reaction which must be determined as accurately as the present test procedures.

2. If condition 1 can be performed according to Military Standard 1648(AS), fine; otherwise, NAVAIR and/or higher authority must be persuaded to change the standard.

3. The methodology of Appendix C (or one that serves the same purpose) must be performed using repeatable test results to show that Rules 57 and 401 are obeyed to the letter and that no pollution of some other nature is brought in which violates Federal, State, or local regulations.

4. Abatement hardware must be repairable or replaceable within a week after damaging encounters with detonating ordnance.

5. Abatement costs must be within the limits of abatement appropriations.

6. Abatement procedures must be palatable to the general public.

The following information may be useful in achieving condition 1 by using scrubber-afterburner techniques with or without partial enclosure (see Figure 2).

1. The apparatus to be tested should be at least two optical thicknesses (6 feet) above the ordnance to avoid altering the results.

2. The flow and convection of air, fuel vapors and smoke should not be altered near and up to six feet above the ordnance.

3. If the apparatus is vulnerable to open flame, it should be at least 35 feet above the pan. Steel softens and deforms up to this point.

4. It is an educated guess that 1000 feet vertical height would save the apparatus from most detonations. No data are available as to the minimum height to save it from all detonations.

It is the author's opinion that most of the promise for a successful project is limited to the first three approaches. Of these, it is suspected that the afterburner-scrubber approach will cause more problems than it solves and that containment will be too expensive. The use of propane is by default the best choice and it is recommended further that research be conducted into cook-off mechanisms and a larger statistical experiment to determine if propane can reliably predict minimum time to detonation by some formula. Then the results can be presented to the people who write military standards.

This section concludes with a visual description of a fast cook-off test that was performed on 30 June 1977 at CT-4.

The test began at approximately 0930 and was viewed from a distance of two miles. The flames were easily visible to the naked eye and leapt from ten to twenty feet high. The smoke began virtually at ground level and mixed with the flames until it cleared the top of the flames. The smoke was a dark grey that was definitely closer to black than to white. It rose first as a cylindrical plume.

A minute or two into the test a deflagration occurred. It was clearly audible and lasted 2 or 3 seconds. (A deflagration is much more gentle than a detonation but like a detonation it results from the combustion of a pyrotechnic material.) Remarkably the deflagration abated the smoke for 15 or 20 seconds without putting out the fire.

The test lasted between 10 and 15 minutes. The smoke spread out upon reaching about 500 feet and at this point the background clouds could be seen through the smoke. The smoke persisted as a nearly stationary puff for about 30 minutes and was not esthetically pleasing. The latter stages of the smoke would certainly be seen from the vicinity of Trona. Possibly the earlier stages and certainly the flames were hidden by intervening high ground.

The fire went out of its own accord when the fuel was consumed. The test site was not approached for four hours for reasons of safety.

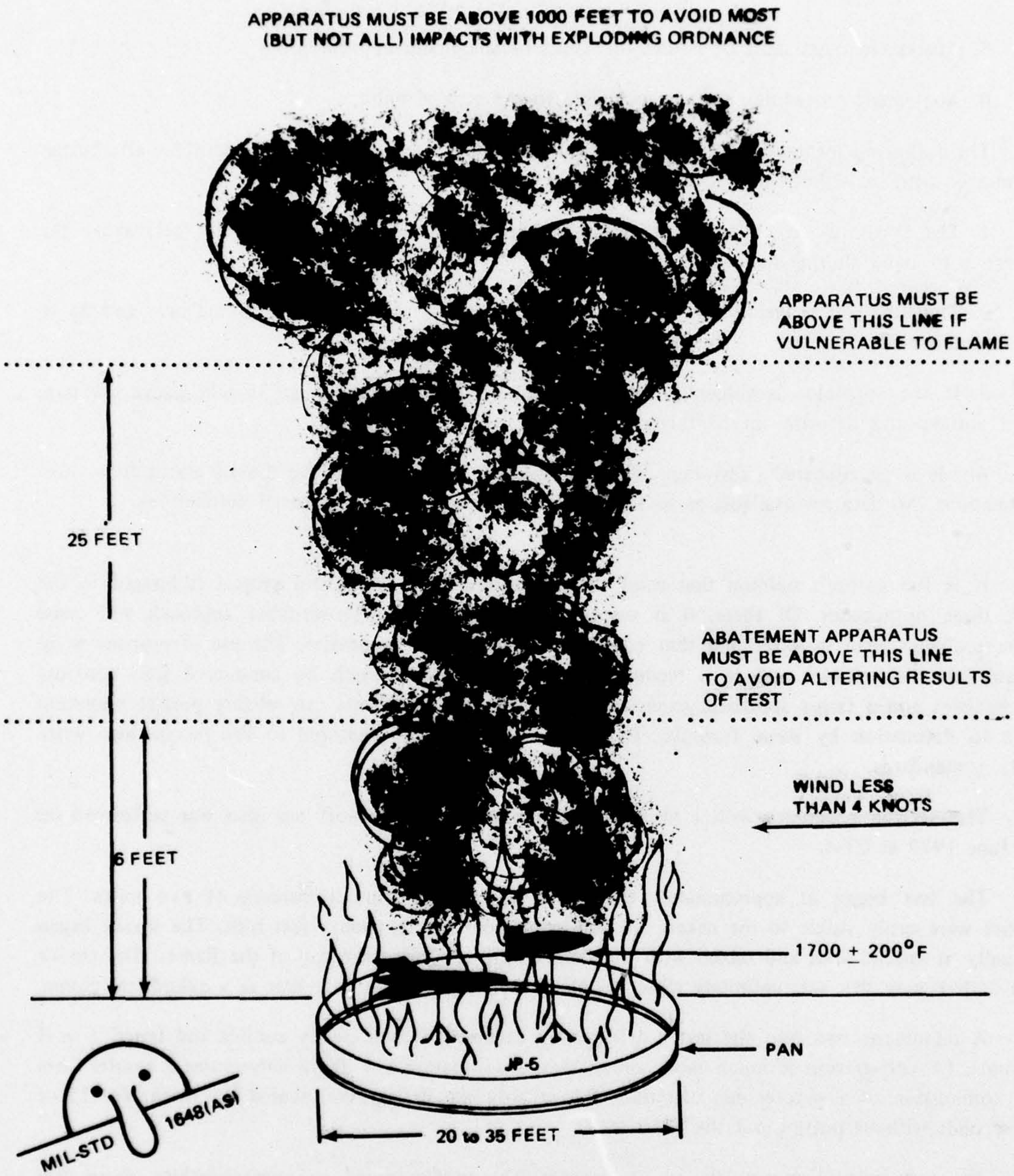

FIGURE 2. Fast Cook-Off Test.

STATIC TESTS

Skytop is the only Navy facility that can conduct static tests of large rocket motors. After the Hercules Inc. static testing facilities were destroyed by explosion in May 1974, NWC was selected after a nationwide survey to continue the firings and thus maintain the timetable for Trident development.

Currently an average of about two Tridents are fired each month. Other rockets are also fired and motor size runs the gamut from 5- and 8-inch guided projectiles to the first stage Trident which weighs more than 20 tons.

Motors are most often fired in the horizontal position. However, test requirements may necessitate that they be fired in some other position; e.g., nozzle up, nozzle down and virtually any elevation angle in between.

Variations in size and elevation angle must be considered when designing a retrofitted abatement device. The possibility of a catastrophic failure (i.e., detonation) must also be considered although the probability is far slighter than in fast cook-off tests.

Before proceeding with boundary conditions, a short discussion is provided on the type of data obtained from the tests. Trident tests serve as the most important example.

Data acquisition and assessment is the name of the game in the static tests of rocket motors. A continuous measurement of a single variable is called a "channel of data" or a "trace". A transducer does the measuring; it may be a force gauge, a pressure gauge, a displacement gauge, a thermocouple or sometimes a microphone. The voltage output of the transducer is "sampled" at short intervals of time (on the order of 1/1000 of a second) and converted into numbers. The stack of numbers obtained from a single transducer during a single test is the channel of data, and when the voltage is plotted versus time it is called the trace.

Data assessment is a computational procedure that obtains meaningful information from the acquired data. For the most part, it predicts how the rocket would have performed had it actually been allowed to fly.

The most important channel is axial thrust. It is essential that this measurement be accurate. In a single test, the accuracy desired is 1/5 of a percent. By averaging the results of many tests, the error can be reduced even further. The amount of thrust determines how far the rocket will fly and how well the contractor has fulfilled his contract.

Internal pressures are also measured. The combination of thrust and head-end pressure describes how well the nozzle performs. In developmental tests, particularly of liquid propellant and airbreathing rockets where the nozzle performance is well known, head-end pressures often suffice and axial thrust measurements are not mandatory. In such tests, abatement would be much easier. However, in the final qualification (solid propellant) tests performed at Skytop, axial thrust must be measured accurately.

Other quantities measured include thrust vector control (steering) displacements, deformations and temperatures. Also, extensive audio and visual coverage of the firings are required by the test plan.

Any abatement procedure that does not alter or modify the data acquisition and assessment does not destroy the military value of the test because the military value lies in the data. By way of definition, any abatement procedure that does not alter the data can be called a Class I procedure.

A Class II abatement procedure is one that alters some of the data but, through computational techniques and probably additional measurements, it can be estimated what the undisturbed data would have looked like.

A Class II procedure would pose a problem similar to not following military standards for cook-offs. NWC follows a detailed test plan supplied by the contractors. The contractors in turn write their test plan so that they may fulfill their contracts with the Naval Material Command (NAVMAT) in Washington, D.C. Again, as in cook-off, the authority for changing procedures falls within the Navy Department, but NWC itself does not have the authority to change the test plan. This means that a Class II procedure must provide evidence that the undisturbed data can be well estimated, and NAVMAT must be convinced to allow the contractors to change the test plan.

A scrubber such as evaluated by AFRPL is at best a Class II procedure. To capture the plume, a diffuser must be employed; and to correct the axial thrust data for the influence of the diffuser, the effective ambient pressure must be measured. Because of the diffuser, the effective ambient pressure is not the same as the barometric pressure.

The author is not aware of any accurate method of measuring effective ambient pressure unless an airtight shroud beginning at the diffuser and enclosing the entire rocket motor is installed (see Figure 3). In this case the leads to most of the transducers must pass through the shroud and audio and visual coverage must be scrapped.

The AFRPL has published a *preliminary report* (see Footnote 14) which describes a scrubbing experiment with small liquid motors. Personal communication with the AFRPL since that time indicates that: (1) scaling from small to large motors will be very costly; (2) solid rockets that produce aluminum oxide burn out the demister which is a vital part of the scrubber; and (3) no tests were conducted that measured axial thrust. Judgements and decisions based on this work should await the final report.

The boundary conditions for static test pollution abatement can now be stated.

1. The test data must be obtained as accurately as at present. These channels of data are required by the test plan and usually include: axial thrust, side forces and/or displacements, head-end pressures and a gamut of other internal pressures, thrust vector control measurements, deformations and displacements at specified sites, temperatures at specified sites, an audio pickup and visual coverage.

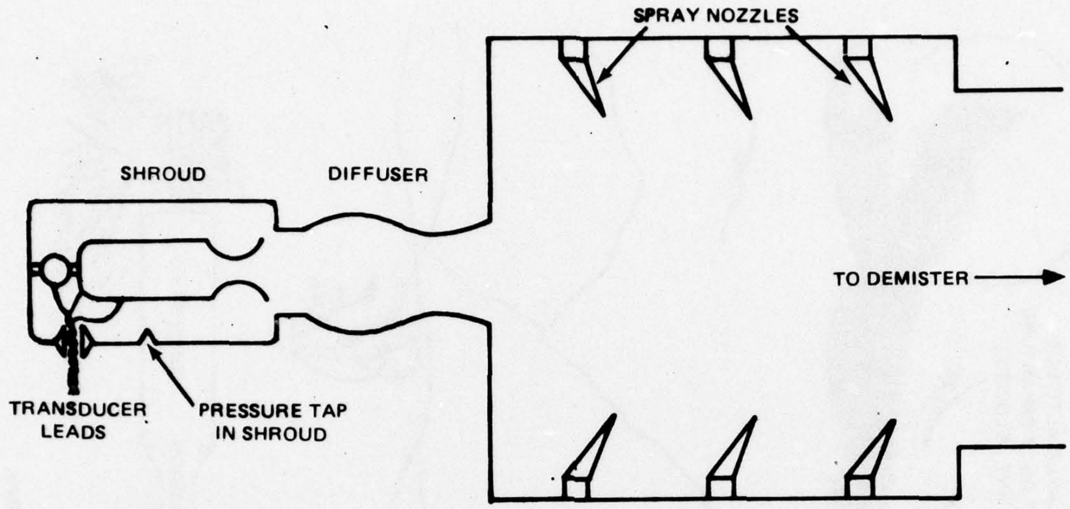

FIGURE 3. Scrubbing Apparatus for Static Test Showing Shroud Enclosure.

2. If the abatement procedure does not alter the data there is no problem. If it does, additional measurements and computational procedures must be developed and proven which accurately estimate the original data. Procedure modifications must be cleared with NAVMAT.

3. The amount of HCl emitted into the atmosphere must be reduced below the 800 PPM legal limit and procedures must not in turn cause some other pollutant to violate federal, state or local limits.

4. Abatement procedures must not unduly delay the test or defeat the temperature conditioning required by the test plan.

5. Cost must be within the limits of appropriations.

6. The possibility of catastrophic failure must be considered and a contingency plan developed.

7. Abatement procedures and hardware must be adaptable to variations in the size and firing angle of the rocket motors.

Some analytical work has been performed to determine the dispersion, composition and concentration of the exhaust emissions in rocket exhaust plumes. The results lead to a possible passive measure that might be employed while awaiting more direct abatement technology.

Static tests lend themselves to far more accurate computer analysis than do cook-off tests. The rocket exhaust goes through the five regimes, or states (see Figure 4). The first regime is the combustion process that takes place inside the motor. Computer analysis determines the flame temperature and the combustion products more accurately than they can be measured.

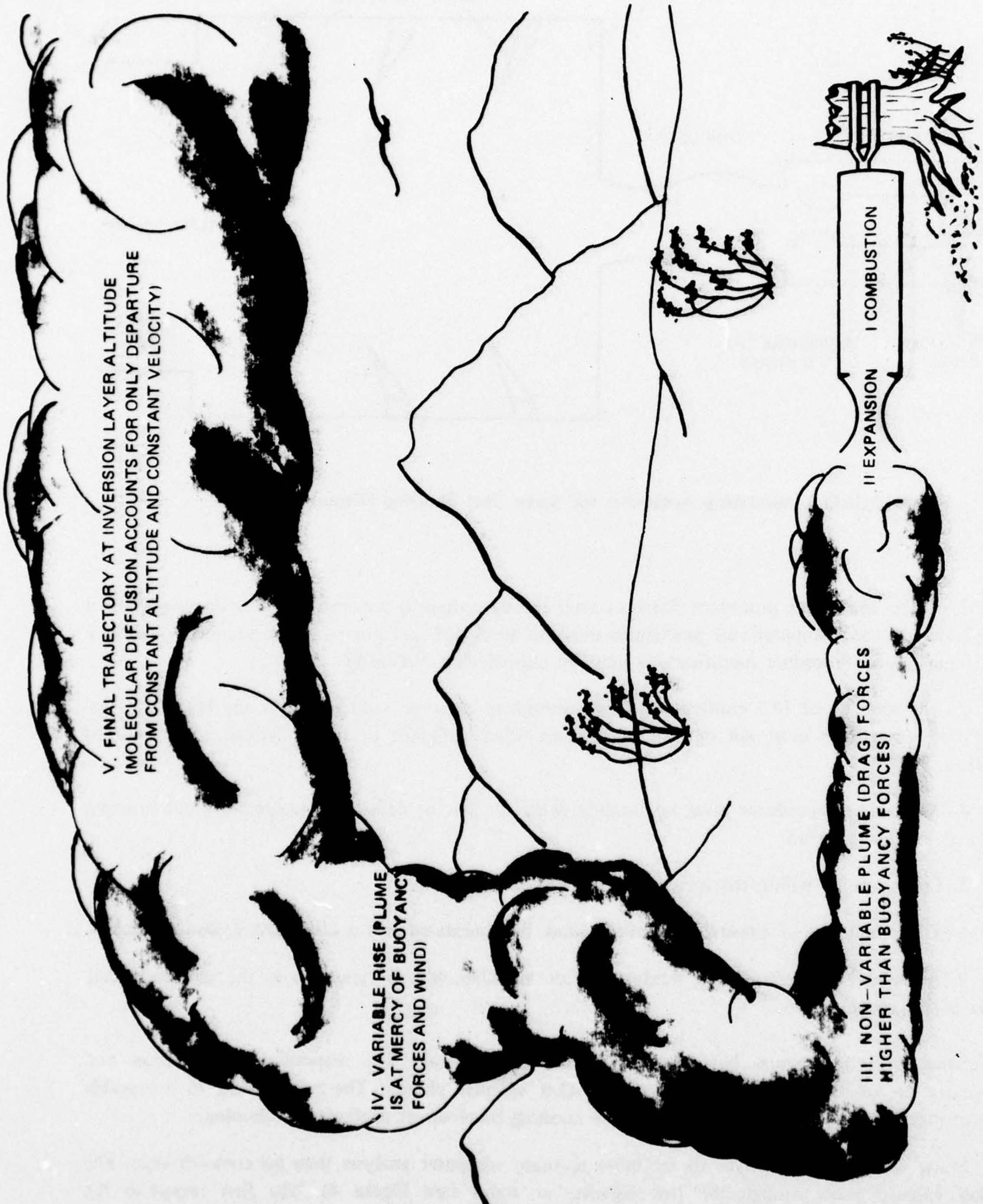

FIGURE 4. Idealized Rocket Exhaust Trajectory.

The second regime is the expansion of the combustion products through the nozzle. Computer analysis evalutes this and determines what the greatest amount of axial thrust that is possible for the particular propellant and nozzle combination. No rocket motor ever delivers the greatest possible thrust. Therefore, it must be static tested to determine the nozzle efficiency. This efficiency will likely be in the range 90 ± 9%. Computer analysis predicts the major combustion products that enter the atmosphere at the end of the nozzle. The amount of HCl generated by a Trident motor are:

1st Stage	20,000 PPM
2nd Stage	25,000 PPM
3rd Stage	11,000 PPM

(The amounts have been adjusted upwards to compensate for uncertainties in the analysis. They, therefore, represent upper limits.)

It can be noted that these figures are much less than the 350,000 PPM of HC1 that the Air Force rocket motors are producing (see Introduction) but NWC is still producing 14 to 31 times the legal limit of 800 PPM HCl at the nozzle exit plane.

The third regime varies only slightly (with barometric pressure) from test to test. It is termed the non-variable part of the plume because momentum is so high that winds and buoyant forces have no effect. The third regime is assumed to begin at the nozzle exit plane and to end when drag forces (which are absorbing the momentum) become less than the buoyant force that causes the plume to rise.

The chemistry and physics that occur in the third regime have been analyzed using the Low Altitude Plume Program (LAPP).[25] The results at the end of the third regime are shown in Table 1.

TABLE 1. Results of the Third Regime.

Stage	Distance, ft	Velocity, ft/sec	Plume Radius, ft	Density, g/cm^3	AL_2O_3 PPM	HC1, PPM	CO, PPM	NO_x, PPM
I	355	74.7	52.5	0.000889	1121	61	12	2
II	263	74.7	38.9	0.000889	1150	76	12	2
III	153	74.7	22.6	0.000889	1121	31	12	2

Some comments and further results pertaining to the third regime can be put forth:

1. The visibility of the plume is due to the small particles of aluminum oxide (Al_2O_3) which are nearly white.

[25] Air Force Rocket Propulsion Laboratory. *L.A.P.P. - A Fast Computer Program for Non-Equilibrium Rocket Plume Predictions*, by R.R. Mikatarian et. al. Edwards, Calif., AFRPL, August 1972. (AFRPL-TR-72-94, publication UNCLASSIFIED.)

2. The HCl at this point is below emission standards. A scheme that would comply with the emission standards is to fire rocket motors within a huge cylinder which is open on both ends, longer than regime III and so wide that it does not affect the plume. However, such a scheme would not abate any pollution; it would only change the definition of where it entered the atmosphere.

3. The amounts of other pollutants such as carbon monoxide (CO) and oxides of nitrogen (NO_x) are very small. A first stage Trident emits only 4 pounds of NO_x and 28 pounds of CO. These values are calculated for the end of the third regime by the computer. Official and unofficial vehicles in NWC and vicinity are estimated to emit 1 ½ tons of NO_x and 20 tons of CO daily.

4. The greatest danger presented to living things by the plume at the end of regime III is its velocity and temperature (634 K). These properties are sufficiently large to cause instant death.

Discussion of pollutant levels at the nozzle exit plane (beginning of the third regime) or elsewhere in the third regime is of academic interest only as no living creature could survive the heat and velocity of the rocket plume anyway. The area of practical interest is in the fourth regime as the plume rises and is dissipated in the atmosphere. By this point, as stated above, the various pollutant levels are well below emission standards. It should also be noted that the emissions occur only during the actual motor firings which are of short duration and limited in number. The total time of emissions during rocket motor firings for a year would only total approximately 10 minutes.

The fourth regime is the buoyant rise of the cloud. As the cloud rises from ground level (assuming a horizontal firing) to the inversion layer that usually exists around 4000 to 5000 feet in the vicinity of NWC, it is displaced horizontally by the winds which vary in direction and speed with altitude.

The fourth regime can be evaluated by the computer provided that meteorological data are available. It happens that meteorological data are always taken before Trident firings so that the possibility of damage by sonic booms can be evaluated. Thus, the same data gathered to determine blast damage potential can be used to predict the transport of exhaust products and their concentrations at any downwind point.

A passive abatement measure is therefore available. The computer predicts if the plume will dissipate over unpopulated Navy-owned land, and the firing officer can then decide whether or not the test should be delayed.

A computer program actually has been developed which evaluates regimes IV and V, given the starting conditions at the end of regime III from the LAPP program. Meteorological data are used which have been gathered at Tower 8 (see Figure 1) approximately 2 hours before the test. The time error can be corrected by standard forecast techniques and the error in distance between Tower 8 and Skytop has been shown to be insignificant at altitudes more than a few hundred feet above ground level. The program uses a simple entrainment model for regime IV and computes size, position, altitude and pollutant versus time. The analysis for regime V consists only of noting the wind vector at maximum altitude and extrapolating it. Further diffusion is not estimated.

More sophisticated computer programs have been developed for different plume problems and they represent an "off the shelf" technology. Improvements can be made in the present program but in its present state it shows that the problem is solvable and thus far it has done a good job. The program appears in Appendix D, and some predicted results appear in Appendix E.

I have no other list of possible abatement procedures such as those presented under Cook-off. No class I procedures are known at this time. The scrubber technique is the only class II procedure that is known and it looks as though there will have to be more advances in its technology before it becomes practical.

Another suggestion has been made[26] that would be difficult to classify. It is a "Pollute now, scrub later" plan. The static test would be performed as usual. Afterward a plane such as those that combat forest fires would fly over and spray the plume with water droplets. The HCl has a great affinity for water and there is reason to suppose that the idea might work. The water containing HCl would fall out on Navy land and be neutralized by the alkaline desert soil. Uncertain at this time is how well it would work and whether it would be approved by the SCAQMD. Such a procedure probably would not take aluminum oxide out of the plume although some actual tests would have to be made before any questions can be answered with certainty.

[26] Personal communication with Mr. Stuart H. Breil, NWC Applied Research and Analysis Branch.

BIBLIOGRAPHY

Affens, Wilbur A. and Homer W. Carhart, *Flammability of Aircraft Fuels*, Fire Technology, Vol. 5, No. 1, p. 16, February 1969.

Air Force Weapons Laboratory, *Quantitive Evaluation of Smoke Abatement System for Crash/Rescue Training Fires*, Haney, James T. and William T. Ristau, Technical Report N. AFWL-TR-73-106, May 1973.

Allan, Donald S. and Sami Atallah, *Safe Separation Distance from Liquid Fuel Fires*, Fire Technology, Vol. 7, No. 1, p. 47, February 1971.

Ames Research Center, *Analytic Modeling of Intumescent Coating Thermal Protection System in a JP-5 Fuel Fire Environment*, Clark, Kimble J., et al., NASA Chemical Research Projects Office, Moffett Field, Calif., 94035, June 1974, Contract NAS2-7709.

Bagnetto, Lucien, *Smoke Abatement in Gas Turbines*, Phillips Petroleum Company, Research and Development Report 5291-69.

Belason, B., et al., *A Fire Simulation Facility for Materials Response Testing*, Fire Technology, Vol. 6, No. 3, August 1970.

Blinov, V. I. and G. N. Khudiakov, *Certain Laws Governing Diffusive Burning of Liquids*, Fire Research Abstracts and Reviews, Vol. 1, No. 2, p. 41, January 1959.

Canfield, J. A. and L. H. Russell, *Measurements of the Heat Flux Within a Luminous Aviation Fuel Flame*, Prepared for presentation at the September 1969 meeting of the Eastern Section of the Combustion Institute. See also L. H. Russell Thesis submitted to the Graduate Faculty of the School of Engineering, University of Pittsburgh, 1970.

Hilado, Carlos J., *The Multicapacity Fire Test Method*, Fire and Flammability, Vol. 7, p. 248, April 1976.

Darwin, Robert L., *Improved Aircraft Carrier Fire Protection*, Approach, p. 40, December 1969.

Heat Transfer in Fire, Vol. 95, Series C, No. 2, p. 145, May 1973.

Fenimore, C. P. and G. W. Jones, *Coagulation of Soot to Smoke in Hydrocarbon Flames*, Combustion and Flame, Vol. 13, p. 303, June 1969.

General Dynamics Corp., *Development of HCl and HF detection system,* Bartle, E., et al., AFRPL-TR-71-59, June 1971.

Glassman, Irvin, et al., *Physics of Flames,* Guggenheim Laboratories Report No. 952, Department of Aerospace and Mechanical Sciences, Princeton University, Princeton, New Jersey, September 1970.

Gordon, William and Robert D. McMillan, *Temperature Distribution Within Aircraft-Fuel Fires,* Fire Technology, Vol. 1, p. 52-61, February 1965.

Langley Research Center, *The Production of Nitric Oxide in the Troposphere as a Result of Solid-Rocket Motor Afterburning,* Stewart, Roger B. and Richard I. Gomberg, NASA Technical Note, NASA TN D-8137, Hampton, VA., 23665, March 1976.

Lie, T. T., *Characteristic Temperature Curves for Various Fire Severities,* Fire Technology, Vol. 10, No. 4, p. 315, November 1974.

Monsanto Research Corp., *An Assessment of Instrumentation and Monitoring Needs for Significant Air Pollutants Emitted by Air Force Operations and Recommendations for Future Research on Analysis of Pollutants,* Parts, Leo, et al., Dayton, Ohio, ARL-TR-74-0015, Interim Report, January 1974.

Naval Air Test Center, *F-4J/J79-GE-10 Smoke Abatement System; Installation, Test and Evaluation of, First Report (Final),* Report No. S7-159R-70.

Naval Research Laboratory, *Flammability and Combustion Research at NRL,* Carhart, H. W. and J. E. Johnson, Naval Research Reviews, Vol. 23, No. 6, p. 15, June 1970.

Naval Research Laboratory, *Toxicity and Fire Hazards Associated with Shipboard Materials,* NRL Memorandum Report 1816, Washington, D. C., September 18, 1967.

Naval Weapons Center, *Predictions of Growth and Dispersion of Rocket Exhaust Clouds From Surface Launched Missiles,* Victor, A. C., NWC Technical Memorandum 3200, China Lake, CA., 93555, June 1977.

Naval Weapons Laboratory, *Simulation of the Thermal Response of Ordnance Immersed in Large Aviation Fuel Fires,* Russell, L. H., and J. A. Canfield, Dahlgren, Virginia, NWL Technical Report TR-2661, January 1972.

Nimmo, B., et al., *Ecological Effects and Environmental Fate of Solid Rocket Exhaust,* Florida Technological Univ., NITS Report N75-19616, October 1974.

Parker, Robert O., *Calculating Thermal Radiation Hazards in Large Fires,* Fire Technology, Vol. 10, No. 2, May 1974.

Richard, J. M., *Inclined Buoyant Puffs*, J. Fluid Mechanics, Vol. 32, 1968, pp. 681-692.

Rome Air Development Center, *HCL Measurements Study*, Kauffman, James W., et al., RADC-TR-75-147, Griffiss Air Force Base, New York, 13441.

Saalfeld, Fred, *NRL Investigates Shipboard Hazards* Naval Research Reviews, Vol. 24, No. 12, p. 16, December 1971.

Sato, A., *A Correctional Calculation Method for Thermocouple Measurement Of Temperatures in Flames*, Combustion and Flame, Vol. 24, p. 35, 1975.

Sliepcevich, C. M. and J. R. Welker, *Burning Rates and Heat Transfer from Wind-Blown Flames*, Fire Technology, Vol. 2, No. 3, p. 211, August 1966.

Space and Missile Test Center, *PH Monitor of Air Pollutants*, Hendel, Frank J., SAMTEC-TR-75-190, Vandenberg AFB, CA., 93437, March 1975.

The Aerospace Corp., *Predictions of the Terminal Altitude and Size of Large Buoyant Clouds Generated by Rocket Launches*, by W. S. Hart, El Segundo, CA., Aerospace Report No. TR-0066 (5115-10)-1, Air Force Report No. SAMSO-TR-70-207, May 1970.

Thomas, P. H., *Behavior of Fires in Enclosures-Some Recent Progress*, Fourteenth Symposium (International) on Combustion Proceedings, p. 1007, The Combustion Institute, Pittsburgh, Penn., 1973.

Turner, J. S., *Buoyant Plumes and Thermals*, Annual Review of Fluid Mechanics, Vol. 1, 1969, pp. 29-43.

U.S. Air Force, *Air Pollutant Emissions from JP-4 Fires Used in Fire Fighting, Training, USAF Environmental Health Laboratory*, Suggs, Harry J., McClellan Air Force Base, Project Report No. 71 M-23, November 1971.

U.S. Environmental Protection Agency, *Compilation of Air Pollution Emission Factors*, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, April 1973.

Wright Air Development Center, *Research on the Flammability Characteristics of Aircraft Fuels*, Jones, G. W., et al., Technical Report 52-35, Wright-Patterson AFB, Ohio, June 1952.

APPENDIX A. EXECUTIVE ORDER NO. 11752

December 19, 1973, 38 F.R. 34793

PREVENTION, CONTROL, AND ABATEMENT OF ENVIRONMENTAL POLLUTION AT FEDERAL FACILITIES

By virtue of the authority vested in me as President of the United States of America, including section 301 of title 3 of the United States Code,[58] and in furtherance of the purpose and policies of the Clean Air Act, as amended (42 U.S.C. 1857)[59], the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251)[60], the Solid Waste Disposal Act, as amended (42 U.S.C. 3251)[61], the Noise Control Act of 1972 (42 U.S.C. 4901)[62], the Marine Protection, Research, and Sanctuaries Act of 1972 (16 U.S.C. 1431)[63], the Federal Insecticide, Fungicide, and Rodenticide Act, as amended by the Federal Environmental Pesticide Control Act of 1972 (7 U.S.C. 136)[64], and the National Environmental Policy Act of 1969 (42 U.S.C. 4321)[65], it is ordered as follows:

Section 1. **Policy.** It is the purpose of this order to assure that the Federal Government, in the design, construction, management, operation, and maintenance of its facilities, shall provide leadership in the nationwide effort to protect and enhance the quality of our air, water, and land resources through compliance with applicable standards for the prevention, control, and abatement of environmental pollution in full cooperation with State and local governments. Compliance by Federal facilities with Federal, State, interstate, and local substantive standards and substantive limitations, to the same extent that any person is subject to such standards and limitations, will accomplish the objective of providing Federal leadership and cooperation in the prevention of environmental pollution. In light of the principle of Federal supremacy embodied in the Constitution, this order is not intended, nor should it be interpreted, to require Federal facilities to comply with State or local administrative procedures with respect to pollution abatement and control.

Sec. 2. **Definitions.** As used in this order:

(1) The term "Administrator" means the Administrator of the Environmental Protection Agency.

(2) The term "Federal agencies" means the departments, agencies, establishments, and instrumentalities of the executive branch.

(3) The term "State, interstate, and local agencies" means any of the following:

(A) a State agency designated by the Governor of that State as an official State agency responsible for enforcing State and local laws relating to the prevention, control, and abatement of environmental pollution;

(B) any agency established by two or more States and having substantial powers or duties pertaining to the prevention, control, and abatement of environmental pollution;

(C) a city, county, or other local government authority charged with responsibility for enforcing ordinances or laws relating to the prevention, control, and abatement of environmental pollution; or

(D) an agency of two or more municipalities located in the same State or in different States and having substantial powers or duties pertaining to the prevention, control, and abatement of environmental pollution.

(4) The term "facilities" means the buildings, installations, structures, land, public works, equipment, aircraft, vessels, and other vehicles and property, owned by, or constructed or manufactured for the purpose of leasing to, the Federal Government.

58. 3 U.S.C.A. § 301.
59. 42 U.S.C.A. § 1857.
60. 33 U.S.C.A. § 1251.
61. 42 U.S.C.A. § 3251.
62. 42 U.S.C.A. § 4901.
63. 16 U.S.C.A. § 1431.
64. 7 U.S.C.A. § 136.
65. 42 U.S.C.A. § 4321.

30

(5) The term "United States" means the fifty States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Trust Territory of the Pacific Islands.

Sec. 3. **Responsibilities.** (a) Heads of Federal agencies shall, with regard to all facilities under their jurisdiction in the United States:

(1) Ensure that applicable standards specified in section 4 of this order are met on a continuing basis.

(2) Cooperate with the Administrator and State, interstate, and local agencies in the prevention, control, and abatement of environmental pollution and, in accordance with guidelines issued by the Administrator, provide to the Administrator and to those agencies such information as is necessary to determine compliance with applicable standards. Such cooperation shall include development of an abatement plan and schedule for meeting applicable standards.

(3) Present to the Director of the Office of Management and Budget, annually, a plan to provide for such improvement in the design, construction, management, operation, and maintenance of existing facilities as may be necessary to meet applicable standards specified in section 4.

(4) Consider the environmental impact in the initial stages of planning for each new facility or modification to an existing facility in accordance with the National Environmental Policy Act.

(5) Include with all budget requests for the design and construction of new facilities or for modification of existing facilities funds for such measures as may be necessary to meet applicable standards specified in section 4. Budget requests shall reflect the most efficient alternative for meeting applicable standards.

(6) Consult, as appropriate, with the Administrator and with State and local agencies concerning the best techniques and methods available for the prevention, control, and abatement of environmental pollution.

(7) Ensure that any funds appropriated and apportioned for the prevention, control, and abatement of environmental pollution are not used for any other purpose unless permitted by law and unless specifically approved by the Office of Management and Budget.

(b) Where activities are carried out at Federal facilities acquired by leasing or other Federal agreements, the head of the responsible agency may at his discretion, to the extent permissible under applicable statutes and regulations, require the lessee or permittee to assume full responsibility for complying with standards for the prevention, control, and abatement of environmental pollution.

(c) Heads of Federal agencies responsible for the construction and operation of Federal facilities outside the United States shall assure that such facilities are operated so as to comply with the environmental pollution standards of general applicability in the host country or jurisdictions concerned.

(d) The Administrator shall:

(1) Provide technical advice and assistance to the heads of Federal agencies in connection with their duties and responsibilities under this order.

(2) Maintain such review of Federal facilities' compliance with the standards specified in section 4 as may be necessary.

(3) Provide liaison as required to assure that actions taken by Federal agencies pursuant to this order are coordinated with State, interstate, and local programs for the prevention, control, and abatement of environmental pollution.

(4) Mediate conflicts between Federal agencies and State, interstate, or local agencies in matters affecting the application of, or compliance with, applicable standards specified in section 4.

(5) Develop in consultation with the heads of other Federal agencies a coordinated strategy for Federal facility compliance with applicable standards specified in section 4 which incorporates, to the maximum extent practicable, common procedures for an integrated approach to Federal agency compliance with such standards, and issue such regulations and guidelines as are deemed necessary to facilitate implementation of that strategy and to provide a framework for coordination and cooperation among the Environmental Protection Agency, the other Federal agencies, and the State, interstate, and local agencies.

(6) Maintain a continuing review of the implementation of this order and, from time to time, report to the President on the progress of the Federal agencies in implementing this order.

Sec. 4. **Standards.** (a) Heads of Federal agencies shall ensure that all facilities under their jurisdiction are designed, constructed, managed, operated, and maintained so as to conform to the following requirements:

(1) Federal, State, interstate, and local air quality standards and emission limitations adopted in accordance with or effective under the provisions of the Clean Air Act, as amended.

(2) Federal, State, interstate, and local water quality standards and effluent limitations respecting the discharge or runoff of pollutants adopted in accordance with or effective under the provisions of the Federal Water Pollution Control Act, as amended.

(3) Federal regulations and guidelines respecting dumping of material into ocean waters adopted in accordance with the Marine Protection, Research, and Sanctuaries Act of 1972, and the Federal Water Pollution Control Act, as amended.

(4) Guidelines for solid waste recovery, collection, storage, separation, and disposal systems issued by the Administrator pursuant to the Solid Waste Disposal Act, as amended.

(5) Federal noise emission standards for products adopted in accordance with provisions of the Noise Control Act of 1972 and State, interstate, and local standards for control and abatement of environmental noise.

(6) Federal guidance on radiation and generally applicable environmental radiation standards promulgated or recommended by the Administrator and adopted in accordance with the Atomic Energy Act, as amended (42 U.S.C. 2011), and rules, regulations, requirements, and guidelines on discharges of radioactivity as prescribed by the Atomic Energy Commission.

(7) Federal regulations and guidelines respecting manufacture, transportation, purchase, use, storage, and disposal of pesticides promulgated pursuant to the provisions of the Federal Insecticide, Fungicide, and Rodenticide Act, as amended by the Federal Environmental Pesticide Control Act of 1972.

(b) In those cases in which there are no environmental pollution standards as specified in subsection (a) for a particular geographic area or class of Federal facilities, the Administrator, in consultation with appropriate Federal, State, interstate, and local agencies, may issue regulations, which shall be published in the FEDERAL REGISTER, establishing environmental pollution standards for the purpose of this order.

Sec. 5. **Exemptions.** (a) The heads of Federal agencies, in consultation with the Administrator, may, from time to time, identify facilities or uses thereof which are exempted from applicable standards specified in section 4 in the interest of national security or in extraordinary cases in which it is in the paramount interest of the United States. No such exemptions shall be made except as are permissible under applicable Federal law.

(b) In any case in which the Administrator does not agree with a determination to exempt a facility or use thereof from the provisions of this order, the head of the Federal agency making such a determination must have the approval of the Director of the Office of Management and Budget to exempt that facility or use thereof; except that, the Administrator is solely responsible for approval of exemptions under section 18 of the Federal Insecticide, Fungicide, and Rodenticide Act, as amended by the Federal Environmental Pesticide Control Act of 1972.

(c) The heads of Federal agencies shall present to the Director of the Office of Management and Budget at the end of each calendar year a report of all exemptions made during that year, together with the justification for each such exemption.

Sec. 6. **Saving Provisions.** Except to the extent that they are inconsistent with this order, all outstanding rules, regulations, orders, delegations, or other forms of administrative action issued, made, or otherwise taken under the order superseded by Section 7 hereof or relating to the subject of this order shall remain in full force and effect until amended, modified, or terminated by proper authority.

Sec. 7. **Order Superseded.** Executive Order No. 11507 of February 4, 1970[66], is hereby superseded.

RICHARD NIXON.

THE WHITE HOUSE,
December 17, 1973.

APPENDIX B. MILITARY STANDARD 1648(AS), CRITERIA AND TEST PROCEDURES FOR ORDNANCE EXPOSED TO AN AIRCRAFT FUEL FIRE.

MIL-STD-1648(AS)
28 March 1974

DEPARTMENT OF THE NAVY
NAVAL AIR SYSTEMS COMMAND

Washington, D.C. 20361

Criteria and Test Procedures for Ordnance Exposed
to an Aircraft Fuel Fire

MIL-STD-1648 (AS)

1. This Military Standard is approved by the Naval Air Systems Command and is mandatory for use by all Groups and Field Activities of the Naval Air Systems Command.

2. Recommended corrections, additions, or deletions should be addressed to: Commander, Naval Air Systems Command (AIR-532), Washington, D.C. 20361.

FOREWORD

This Military Standard establishes criteria and test procedures to judge whether air-launched ordnance when encompassed in a fuel fire has sufficient resistance to detonation. Several catastrophic accidents aboard carriers have resulted from ordnance detonating in fires while attempts were being made to extinguish the fire.

The Russell Panel Report to Review Safety in Carrier Operations after the Forrestal accident, and the Report to the Navy Laboratory Research Planning Panel for Enhanced Carrier Survivability, recommended that all weapons used aboard carriers be afforded fire survivability. The Naval Weapons Cook-off Program Plan, as approved by the Chief of Naval Material, establishes the cook-off program to correct in-service air-launched ordnance cook-off times. The original cook-off plan did not provide detailed criteria and test procedures for judging ordnance survivability nor did it provide fire survivability standards for development of future ordnance.

MIL-STD-1648 (AS)
28 March 1974

CONTENTS

1. SCOPE

1.1 Scope. This Standard establishes the criteria and procedures for determining the reactions of air-launched ordnance when engulfed in an aircraft fuel fire.

1.2 Classification. This Standard applies to the following ordnance items which contain explosives, propellants, and other energetic material:

(a) Air-launched guided missiles, rockets, bombs, flares, dispensers and targets.

(b) Aircraft gun ammunition.

2. REFERENCED DOCUMENTS

2.1 Not applicable.

3. DEFINITIONS

3.1 Interpretation. The following definitions apply in the interpretation and application of this Standard:

(a) Burning reaction. The process wherein the ordnance energetic material undergoes combustion. During this reaction, the energetic material enclosure may open up and vent. The item remains in position although it may fall due to structural failure. The burning reaction presents a minimal hazard to fire fighting personnel.

(b) Deflagration reaction. The process wherein the ordnance energetic material undergoes rapid combustion and ruptures its enclosure. The item or major parts thereof may be thrown up to 50 feet by the reaction. No damage due to blast effects or fragmentation. Fire fighting personnel may be endangered or inhibited by expansion of fire and burning material and parts being thrown about.

4. REQUIREMENTS AND CRITERIA

4.1 Test safety requirements. This Standard requires the performance of ordnance cook-off tests wherein field test personnel and equipment will be exposed to potentially extreme hazards. Consequently, the test activity is responsible for formalizing and issuing general and specific guidance, safety criteria, procedures, instructions, precautions, and other related safety information essential to the safe performance of the tests.

4.2 Ordnance requirements. Two ordnance items shall be tested in two separate fires as prescribed by this Standard. These items shall be production units or pre-production units built to the same drawings and specifications as the production unit and configured as a complete round as normally found on the aircraft on the flight deck. Electronic or other sections not containing energetic material may be geometrically and thermally simulated. If alternate components containing energetic material (MK or MOD) could be selected, the two ordnance test items shall be comprised of those components demonstrated, or judged, to yield the most violent reaction in a fuel fire. Component level tests during the design phase shall be conducted with the component as a part of a simulated round.

4.3 Ordnance passing criteria. Ordnance shall be judged to have passed the fuel fire test if the following criteria are achieved:

(a) During the first 5 minutes of the test, the severity of the reaction shall be no greater than that for a burning reaction (par. 3.1 (a)). Burning reactions are acceptable any time during the test.

(b) After the first 5 minutes and until the test ordnance returns to ambient temperature, the severity of the reaction shall be no greater than that for a deflagration reaction (par. 3.1 (b)).

5. TEST PROCEDURES AND DATA RECORDS

5.1 Description of test. The test consists of engulfing the ordnance for at least fifteen minutes in a fuel fire and recording its reaction as a function of time. Liquid fuels are normally contained in a specially prepared film lined earthen test pan. The ordnance is suspended 3 feet above the fuel in an attitude and position similar to those which would be encountered on an aircraft on a flight deck. The test is terminated upon completion of the reaction(s) of the ordnance.

5.2 Test Specification.

5.2.1 Test facility. Test facility construction shall be designed to provide a heat source which completely engulfs the ordnance at the specified flame temperature. Minimum cross section dimensions of the test pan are 4 feet x 4 feet.

5.2.2 Fuel. JP-5 aircraft fuel shall be used when available or JP-4 fuel as an alternate. The quantity of fuel used should be sufficient to ensure a fire that engulfs the entire ordnance unit for at least 15 minutes.

5.2.3 Flame temperature rise rate. The flame temperature should reach 1000°F within 30 seconds after ignition as measured by any two thermocouples. Time over 30 seconds until flame temperature reaches 1000°F shall be subtracted from the time of reaction.

5.2.4 Average flame temperature. An average flame temperature of at least 1600°F as measured by all valid thermocouples at the test item without contribution of the burning ordnance will be considered a valid test. This temperature is determined by averaging from the time the flame reaches 1000°F until all ordnance reactions are completed or until 15 minutes has elapsed.

5.2.5 Ordnance suspension. The ordnance suspension system shall be designed in such a manner as to represent the configuration of the ordnance service suspension system. The suspension method shall not interfere with heating of the ordnance. The horizontal center line of the test ordnance shall be located 3 feet above the fuel surface. If the ordnance falls from the support while being heated, it shall not totally submerge in the fuel.

5.2.6 Thermocouples. A minimum of four thermocouples shall be located 4 to 8 inches outside the ordnance skin for each item tested. The thermocouples shall be positioned on each end and side of the ordnance skin in a horizontal plane through the ordnance center line. Thermocouple readings shall be made and recorded at least once every 5 seconds throughout the duration of the 15 minute fire.

5.2.7 Camera coverage. A color motion picture camera (12 fps or greater) or closed circuit color T.V. shall be used to photograph each test. Still photos shall be taken to show test set up prior to test.

5.2.8 Sound pressure measurements. Sound pressure measurements shall be made to aid in determining the severity of reaction(s).

5.2.9 Witness plates. Eight 3 x 3 feet witness plates shall be placed 360° around the item on the ground level and within 25 feet of test item. These witness plates shall be composed of 1/16 inch cold rolled steel.

5.3 Air pollution control devices. Air pollution control devices shall be used when practicable. Any air pollution control device or technique used in conjunction with fast cook-off testing must not alter the rate of heat transfer to the test item(s).

5.4 Data records.

5.4.1 Pretest data. Pretest data shall include the following:

(a) Item(s) designation including fuze and other components.

(b) Item(s) lot number and/or serial numbers.

(c) Location and size of defects if any, in test item(s).

(d) Type of energetic material and weight.

(e) Total weight.

(f) Date of manufacture.

(g) Date of test.

(h) Type of fuel for fire.

(i) Quantity of fuel.

(j) Pan size.

(k) Meteorological data (temperature, humidity, wind velocity and direction).

(l) Drawings and photos of test set up prior to test.

(m) Types of instrumentation and calibration charts.

5.4.2 Test data. Test data shall include the following:

(a) Time of ignition of fuel.

(b) Time at which thermocouples reach or exceed 1000°F.

(c) Times to weapon reaction(s).

(d) Type of reaction(s).

(e) Time to fuel burn-out.

(f) Time to subsequent weapon reaction(s).

(g) Type of subsequent reaction(s).

(h) Complete film coverage of test with indicated time.

(i) Still photos of test item(s) or remains after test and photos of test item position after test. An overview picture or drawing should show exact location of all remains after test with respect to original test item position.

(j) Size, number, and distribution of holes or fragment marks on witness plates.

(k) Sound pressure level in db's for duration of test.

(l) Temperature data for each thermocouple.

5.5 Final data report. All data acquired in paragraph 5.4 shall be made available in a test report for review by the developing agency to judge if the passing criteria is met.

5.6 Disposal of test ordnance. All tested ordnance items shall be disposed of as follows:

(a) Material which has ignited shall be permitted to burn out.

(b) Ordnance which has provided no reaction shall be disposed of preferably by using Explosive Ordnance Disposal (EOD) procedures and EOD certified personnel.

Custodians	Preparing Activity
Navy AS	Navy AS

PROJECT NUMBER: 1410-N034

☆ U. S. GOVERNMENT PRINTING OFFICE: 1974-713-154/5902

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL	OMB Approval No. 22-R255

INSTRUCTIONS: The purpose of this form is to solicit beneficial comments which will help achieve procurement of suitable products at reasonable cost and minimum delay, or will otherwise enhance use of the document. DoD contractors, government activities, or manufacturers/vendors who are prospective suppliers of the product are invited to submit comments to the government. Fold on lines on reverse side, staple in corner, and send to preparing activity. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements. Attach any pertinent data which may be of use in improving this document. If there are additional papers, attach to form and place both in an envelope addressed to preparing activity.

DOCUMENT IDENTIFIER AND TITLE
MIL-STD-1648(AS) Criteria and Test Procedures for Ordnance Exposed to An Aircraft Fuel Fire

NAME OF ORGANIZATION AND ADDRESS	CONTRACT NUMBER
	MATERIAL PROCURED UNDER A ☐ DIRECT GOVERNMENT CONTRACT ☐ SUBCONTRACT

1. HAS ANY PART OF THE DOCUMENT CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?
   A. GIVE PARAGRAPH NUMBER AND WORDING.

   B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES

2. COMMENTS ON ANY DOCUMENT REQUIREMENT CONSIDERED TOO RIGID

3. IS THE DOCUMENT RESTRICTIVE?

   ☐ YES ☐ NO *(If "Yes", in what way?)*

4. REMARKS

SUBMITTED BY *(Printed or typed name and address - Optional)*	TELEPHONE NO.
	DATE

DD FORM 1426 1 JAN 72

MIL-STD-1648 (AS)
NOTICE 1
5 January 1977

MILITARY STANDARD

CRITERIA AND TEST PROCEDURES
FOR ORDNANCE EXPOSED TO
AN AIRCRAFT FUEL FIRE

TO ALL HOLDERS OF MIL-STD-1648:

1. Make the following pen and ink change:

a. Cover page: Change "FSC MISC" to "FSC-1410".

2. Add a new paragraph to the following page:

a. Page i, paragraph 2, delete and substitute:

"2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ENGINEERING SPECIFICATIONS AND STANDARDS DEPARTMENT (CODE 93) NAVAL AIR ENGINEERING CENTER, LAKEHURST, N. J. 08733, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter".

3. THE FOLLOWING PAGES OF MIL-STD-1648 HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
1	5 January 1977	1	28 March 1974
1a	5 January 1977	None	None

4. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

5. Holders of MIL-STD-1648 will verify that page changes and additions indicated above have been entered. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the Military Standard is completely revised or canceled.

Custodian
Navy - AS

Preparing Activity
Navy - AS

FSC-1410

MIL-STD-1648(AS)
5 January 1977

1. SCOPE

1.1 Scope. This Standard establishes the criteria and procedures for determining the reactions of air-launched ordnance when engulfed in an aircraft fuel fire.

1.2 Classification. This Standard applies to the following ordnance items which contain explosives, propellants, and other energetic material:

(a) Air-launched guided missiles, rockets, bombs, flares, dispensers and targets.

(b) Aircraft gun ammunition.

2. REFERENCED DOCUMENTS

2.1 Not applicable.

3. DEFINITIONS

3.1 Interpretation. The following definitions apply in the interpretation and application of this Standard. Severity of explosive reaction increases from (a) to (e):

(a) Burning reaction. The process wherein the ordnance energetic material undergoes combustion. During this reaction, the energetic material enclosure may open up and vent. The item remains in position although it may fall due to structural failure. The burning reaction presents a minimal hazard to fire fighting personnel.

(b) Deflagration reaction. The process wherein the ordnance energetic material undergoes rapid combustion and ruptures its enclosure. The item or major parts thereof may be thrown up to 50 feet by the reaction. No damage due to blast effects or fragmentation. Fire fighting personnel may be endangered or inhibited by expansion of fire and burning material and parts being thrown about.

(c) Explosion. Violent pressure rupture and fragmentation of munition case with resulting air shock. Most of metal case breaks into large pieces which are thrown about with unreacted or burning explosive. Some blast and fragmentation damage to environment. Fire and smoke damage as in deflagration. Severity of blast could cause minor ground ground crater, or small depression on flight-deck or carrier if munition is large bomb.

Supersedes page 1 of 28 March 1974

(d) Partial Detonation. Only part of total explosive load in munition detonates. Strong air shock and small as well as large case fragments produced. Small fragments are similar to those in normal munition detonation. Extensive blast and fragmentation damage to environment. Amount of damage and extent of breakup of case into small fragments increases with increasing amount of explosive detonated. Severity of blast could cause large ground crater, or large flight-deck hole on carrier if munition is large bomb: hole size depends on amount of explosive that detonates.

(e) Detonation. Munition performs in design mode. Maximum possible air shock is formed. Essentially all of case is broken into small fragments. Blast and fragment damage is at maximum. Severity of blast causes maximum ground crater or flight-deck hole capable by the munition involved.

4. REQUIREMENTS AND CRITERIA

4.1 Test safety requirements. This Standard requires the performance of ordnance cook-off tests wherein field test personnel and equipment will be exposed to potentially extreme hazards. Consequently, the test activity is responsible for formalizing and issuing general and specific guidance, safety criteria, procedures, instructions, precautions, and other related safety information essential to the safe performance of the tests.

New page

APPENDIX C. METHODOLOGY FOR DECISION ON OPTIMUM COOK-OFF POLLUTION ABATEMENT TECHNIQUE.

(Excerpted from NWC Memorandum Reg. 4503-107 of 12 December 1973. *Smoke Abatement Project Final Report,* by Peggy A. Davis, Paul R. Owens, A. Raymond Kelso and James R. Ouimette.)

Since smoke is only one of many pollutants for which legal standards exist, the cook-off smoke abatement is really a multi-dimensional, or total air pollution problem. By employing a technique to abate one pollutant one may find that another has been aggrevated. One must be cognizant of this possibility since constraints on individual pollutants may be imposed by local regulations. In general, the solution to the JP-5 cook-off problem will involve the testing and evaluation of a number of abatement techniques, each having a different monetary cost. It is, therefore, necessary to have a decision framework which allows one to choose that technique which minimizes the total cost while still satisfying the constraints.

For a given pollution abatement scheme, i, certain costs and pollutant outputs result. This can be shown schematically as follows:

Pollution Abatement Technique
i $i=1,\ldots,n$

Pollutant Output, O_i

$$O_i = \sum_j A_{ij} X_j$$

Air Pollution Index I_i

$$I_i = \sum_j A_{ij} W_j$$

Total Costs C_i

$$C_i = \sum_k C_{ik}$$

In the schematic, the pollutant output for technique i is O_i. It is a matrix of emission factors, A_{ij}, for those pollutants, X_i, for which regulations and standards exist. The air pollution index, I_i, is a weighted sum of all the emission factors. W_j is a relative weight which is inversely proportional to the national secondary standard for the pollutants. It is given as follows:

j	Pollutant	W_j
1	NOx	1.00
2	SOx	0.38
3	Particulates	0.67
4	Hydrocarbons (THC)	0.63
5	Carbon monoxide	0.01

The most noxious pollutants are weighted the heaviest. The index is a single number whose value reflects the total output of all pollutants.

The total costs, C_i, of a given pollutant abatement scheme is the sum of all capital costs and future discounted operations and maintenance costs:

$$C_i = K_i + \sum_j M_{ij}/(1+r)\ j$$

K is the total capital costs, M_{ij} is the operations and maintenance cost in year j, and r is the discount rate $(0.05 \leq r \leq 0.10)$.

Many government entities, such as cities and counties, have regulations pertaining to smoke opacity, pollutant output concentrations, and discharge rates. All of these regulations may be put in the form of constraints on emission factors: $A_{ij} \leq A_j^*$, j = 1,...,5. In addition, some may even require the total pollutant discharge rate to be below a certain level:

$$\sum_j A_{ij} \leq B^*$$

Thus, the problem of determining the abatement technique which costs the least while satisfying the constraints takes on the following mathematical form:

Choose technique r such that $C_r = \min/(i=1),...,n \left\{ C_i = K_i + \sum_l M_{ie}/(1+r)^l \right\}$

subject to $A_{ij} \leq A_j^*$, j = 1,...,m

$$\sum_{j=1} A_{ij} \leq B^*$$

The mechanics of seeing how each abatement technique performs can be illustrated in Figure C-1. All techniques are tabulated and the one which is the cheapest while satisfying the constraints is chosen. The Air Pollution Index, while not serving as a regulatory constraint, nevertheless allows one to see how the mix of pollutants changes with each abatement method.

This decision framework is illustrated with an example using San Bernardino County APCD regulations and JP-4 cook-off pollution abatement techniques given in Kirkland AFB Technical Report No. AFWL-TR-73-106, "Quantitative Evaluation of Smoke Abatement System for Crash/Rescue Training Fires." It will be shown that San Bernardino County regulations can be put in the form of emission factors. One may then choose those abatement methods that satisfy the constraints.

By January 1, 1975, San Bernardino County ruled that smoke may not be darker than No. 1 on the Ringelmann Chart. The opacity R is directly related to the amount of particulates escaping per unit time. This in turn is directly related to the emission factor for particulates. Thus, the allowable emission factor for particulates is one function of the allowable Ringelmann shade:

$$R = f(A_3^* \; F^{-1}(R)$$

By January 1, 1975, San Bernardino County prohibits particulates in certain concentrations depending on the volume of gas discharged in the process. Using the Kirkland AFB report, it is assumed that 69,300 ft^3/min discharged. Then the maximum allowable particulate concentration is:

$$0.0395 \text{ grain/ft}^3 = 2560 \text{ micrograms/ft}^3$$

Using the Kirkland AFB report, this is equivalent to an emission factor of 42.5 lbs particulates per 1000 lbs fuel $(+A_3^*)$. This is about 33% that of an untreated fire.

San Bernardino County has no constraints on maximum allowable total pollutants discharged per unit time, although other counties may have. Thus, the only San Bernardino County constraints are on particulates, both the darkness and the weight. The constraint set, therefore, takes the form:

No.	Abatement Treatment Description	Resultant Emission Factors CO	THV	NOx	Part.	All Emission Factor Constraints Satisfied?	Air Pollution Index	Total Monetary Costs
1								
2								
.								
.								
.								
n								

FIGURE C-1. Format for Analysis of Abatement Alternatives.

$$A_{i3} \leq \min \left\{ f^{-1}(R=1),\ 0.0425 \text{ lb/lb fuel} \right\} = A_3^*$$

For convenience, let $A_3^* = 0.425$ lb/lb fuel.

For an untreated fire there is a mix of pollutants which result. The emission factors are given as follows:

Particulates	0.128 lb/lb fuel = A_{03}
NOx	0.00415 lb/lb fuel
CO	$>$0.56 lb/lb fuel
SOx	$<$0.001 lb/lb fuel
Hydrocarbons	0.37 lb/lb fuel

The untreated fire does not satisfy the constraint set since $A_{03} > A_3^*$.

The results of Kirkland AFB's different treatments are given in Table C-1. (Because a large portion of THC was in the form of "condensible" particulates, it was assumed here that they were eliminated in direct proportion to total particulates.) The table shows that all treatments satisfy the San Bernardino County particulate constraint, while technique No. 6 abates the most pollutants, as indicated by the Air Pollution Index. Therefore, if the costs were equal for all, No. 6 would be chosen, since all satisfy the constraints.

An attempt has been made in this section to present a decision framework for choosing an optimum cook-off abatement technique amont several alternatives. A decision model was stated in mathematical terms, consisting of a minimumization problem subject to constraints. An example was given showing how the model could be used in a real situation, using regulations imposed by San Bernardino County and water scrubbing treatment data from Kirkland AFB. This same technique can be easily extended to Navy JP-5 fires and other treatment techniques, such as afterburning.

TABLE C-1. Outcomes of Alternative Cook-Off Treatment Techniques.

Treatment number	Treatment description	Resultant emission factors in lb pollutant per 1000 lb fuel				All emission factor constraints satisfied?	Air pollution index
		CO	THC	NOx	Part.		
1	Untreated	>560	~137	4.15	128	No	182
2	Water mist, 1.05 lb H_2O/ft^2 min; deflectojet nozzle, 4(1/8 inch)	---	~ 37	3	34.2	Yes	45
3	Water mist, 1.20 lb H_2O/ft^2 min; deflectojet nozzle, 1(1/4 inch)	---	~ 33	3	30.5	Yes	40
4	Water mist, 1.40 lb H_2O/ft^2 min; deflectojet nozzle, 1(1/4 inch)	---	~ 45	2.9	42.0	Yes	56
5	Water mist, 0.75 lb H_2O/ft^2 min; parasol nozzle, 1(1/4 inch)	---	~ 22	0.06	20.2	Yes	26
6	Water mist, 1.0 lb H_2O/ft^2 min; parasol nozzle, 1(1/4 inch)	284	~19	0.012	17.6	Yes	23

APPENDIX D. PLUME PREDICTION PROGRAM

Program coded by James C. Mantz

```
-RUN,A 419111,1621027ANA5G,4535419,03,75/0     CRUISE    7372
-FOR,IS MAIN
C***   PREDICT PLUME POSITION
       INTEGER TH,THETAD,THETAM,TM,TS
       DIMENSION A(3),A0(3),R(3,4)
       COMMON ALPHA,AT(1000),CAPG,CAPT,GA(1000),I,N,THETA,THETAD,THETAM,
     1 V,WD(1000),WS(1000),Z
       READ 1000,B,U,DENT,T,TMAX,Y,X,ZBASE,Z,ZMAX,H,ALPHA,GAMMA,AL2O3,HCL
 1000  FORMAT()
       B0=B
       B1=B
       CAPW=B**2*U
       CAPV=B*U
       CAPF=B**2*U*32.14*DENT
       DO 10 I=1,1000
       READ(5,1010,END=20)GA(I),AT(I),WD(I),WS(I)
 1010  FORMAT(2(F10.0,10X),2F10.0)
       GA(I)=GA(I)+ZBASE
   10  WS(I)=WS(I)*1.68781
       PRINT 1020
 1020  FORMAT(-0ATMOSPHERIC TABLE IS TOO LARGE-)
       STOP
   20  N=I-1
       CALL LIP
       CAPT1=CAPT
       CAPG=32.14/CAPT1*((AT(I)-AT(I-1))/(GA(I)-GA(I-1))+GAMMA)
       TH=0
       TM=0
       TS=0
       PRINT 1030
 1030  FORMAT(-1-,3X,-TIME-,7X,-ALT.-,9X,-Y-,11X,-X-,6X,-AIR-,4X,-WIND-,
     1 6X,-WIND-,3X,-VERT.-,5X,-RAD.-,4X,-AL2O3-,5X,-HCL-,9X,-F-/46X,
     2 -TEMP.-,3X,-VEL.-,5X,-ANGLE-,4X,-VEL.-/2X,-(H/M/S)-,5X,-(FT.)-,
     3 7X,-(FT.)-,7X,-(FT.)-,4X,-(C)-,3X,-(FPS)-,5X,-(D/M)-,3X,-(FPS)-,
     4 4X,-(FT.)-,4X,-(PPM)-,4X,-(PPM)-/)
       PRINT 1040,TH,TM,TS,Z,Y,X,CAPT,V,THETAD,THETAM,U,B,AL2O3,HCL,CAPF
```

```
1040 FORMAT(1X,2(I2,-/-),I2,4X,F6.0,4X,2(F8.0,4X),F3.0,4X,F4.0,4X,I3,
    1 -/-,I2,4X,F4.0,4X,3(F5.0,4X),E9.4)
     LINE=5
     H2=H/2.
  30 Z=Z+H
     CALL LIP
     CAPG=32.14/CAPT1*((AT(I)-AT(I-1))/(GA(I)-GA(I-1))+GAMMA)
     A0(1)=CAPV
     A0(2)=CAPF
     A0(3)=CAPW
     DO 40 I=1,3
  40 R(I,1)=F1(A0)
     A(1)=A0(1)+H2*R(2,1)
     A(2)=A0(2)+H2*R(3,1)
     A(3)=A0(3)+H2*R(1,1)
     DO 50 I=1,3
  50 R(I,2)=F1(A)
     A(1)=A0(1)+H2*R(2,2)
     A(2)=A0(2)+H2*R(3,2)
     A(3)=A0(3)+H2*R(1,2)
     DO 60 I=1,3
  60 R(I,3)=F1(A)
     A(1)=A0(1)+H*R(2,3)
     A(2)=A0(2)+H*R(3,3)
     A(3)=A0(3)+H*R(1,3)
     DO 70 I=1,3
  70 R(I,4)=F1(A)
     CAPW=CAPW+H/6.*(R(1,1)+2.*R(1,2)+2.*R(1,3)+R(1,4))
     CAPV=CAPV+H/6.*(R(2,1)+2.*R(2,2)+2.*R(2,3)+R(2,4))
     CAPF=CAPF+H/6.*(R(3,1)+2.*R(3,2)+2.*R(3,3)+R(3,4))
     U=CAPV**2/CAPW
     B=CAPV/U
     IF(B.GE.B1)GO TO 80
     PRINT 1050
1050 FORMAT(-0PLUME IS AT OR NEAR MAXIMUM ALTITUDE-)
     GO TO 150
```

```
   80 B1=B
      RATIO=B0**2/B**2
      CONC1=AL2O3*RATIO
      CONC2=HCL*RATIO
      DO 90 I=1,3
      A0(I)=U
   90 R(I,1)=F2(A0)
      DO 100 I=1,3
      A(I)=A0(I)+H2*R(I,1)
  100 R(I,2)=F2(A)
      DO 110 I=1,3
      A(I)=A0(I)+H2*R(I,2)
  110 R(I,3)=F2(A)
      DO 120 I=1,3
      A(I)=A0(I)+H*R(I,3)
  120 R(I,4)=F2(A)
      T=T+H/6.*(R(1,1)+2.*R(1,2)+2.*R(1,3)+R(1,4))
      TS=T+.5
      TH=TS/3600
      TM=(TS-TH*3600)/60
      TS=TS-TH*3600-TM*60
      Y=Y+H/6.*(R(2,1)+2.*R(2,2)+2.*R(2,3)+R(2,4))
      X=X+H/6.*(R(3,1)+2.*R(3,2)+2.*R(3,3)+R(3,4))
      IF(LINE.LT.54)GO TO 130
      PRINT 1030
      LINE=4
  130 PRINT 1040,TH,TM,TS,Z,Y,X,CAPT,V,THETAD,THETAM,U,B,CONC1,CONC2,
     1 CAPF
      LINE=LINE+1
      IF(Z.LT.ZMAX)GO TO 140
      PRINT 1060
 1060 FORMAT(-0LIMITING ALTITUDE HAS BEEN ATTAINED-)
      GO TO 150
  140 IF(T.LT.TMAX)GO TO 30
      PRINT 1070
 1070 FORMAT(-0LIMITING TIME HAS BEEN ATTAINED-)
  150 PRINT 1080
 1080 FORMAT(-1-)
```

```
      CALL EXIT
      END
-FOR,IS LIP
      SUBROUTINE LIP
      INTEGER THETAD,THETAM
      COMMON ALPHA,AT(1000),CAPG,CAPT,GA(1000),I,N,THETA,THETAD,THETAM,
     1 V,WD(1000),WS(1000),Z
      DO 10 I=2,N
      IF(Z.LE.GA(I))GO TO 20
   10 CONTINUF
      PRINT 1000
 1000 FORMAT(-0Z HAS EXCEEDED THE TABLE LIMIT OF GEOPOTENTIAL ALTITUDE-)
      STOP
   20 CAPT=AT(I-1)+(Z-GA(I-1))/(GA(I)-GA(I-1))*(AT(I)-AT(I-1))
      V=WS(I-1)+(Z-GA(I-1))/(GA(I)-GA(I-1))*(WS(I)-WS(I-1))
      C=360.
      IF(ABS(WD(I)-WD(I-1)).LE.180.)C=0.
      THETA=WD(I-1)+(Z-GA(I-1))/(GA(I)-GA(I-1))*(WD(I)-WD(I-1)+C)
      IF(THETA.GE.360.)THETA=THETA-360.
      THETAD=THETA
      THETAM=(THETA-THETAD)*60.+.5
      RETURN
      END
-FOR,IS F1
      FUNCTION F1(A)
      INTEGER THETAD,THETAM
      DIMENSION A(3)
      COMMON ALPHA,AT(1000),CAPG,CAPT,GA(1000),I,N,THETA,THETAD,THETAM,
     1 V,WD(1000),WS(1000),Z
      GO TO (10,20,30),I
   10 F1=2.*ALPHA*A(1)
      RETURN
   20 F1=.5*A(2)*A(3)/A(1)**3
      RETURN
   30 F1=-CAPG*A(3)
      RETURN
      END
```

```
-FOR,IS F2
      FUNCTION F2(A)
      INTEGER THETAD,THETAM
      DIMENSION A(3)
      COMMON ALPHA,AT(1000),CAPG,CAPT,GA(1000),I,N,THETA,THETAD,THETAM,
     1 V,WD(1000),WS(1000),Z
      GO TO (10,20,30),I
   10 F2=1./A(1)
      RETURN
   20 F2=-V/A(2)*COS(THETA*1.745329E-2)
      RETURN
   30 F2=-V/A(3)*SIN(THETA*1.745329E-2)
      RETURN
      END
-MAP,I
-XQT
38.9,74.7,.1846,0.,7200.,186.,186.,0000.,2480.,25000.,100.,.116,.003,1150.,76.
   2185.     942.1       23.0       35.3      230.0        1.0    15  605   1
   3000.     914.4       17.5       21.7      307.3        2.6    15  605   2
   5000.     850.8       14.4       21.8       10.4       11.6    15  605   3
  10000.     708.7        7.5       24.6        1.7       27.5    15  605   4
  15000.     586.9       -1.6       30.5      333.6       26.9    15  605   5
  20000.     483.1      -12.3       36.3      325.1       40.8    15  605   6
  25000.     394.2      -23.6       38.8      343.5       40.9    15  605   7
  30000.     318.5      -36.1       65.0      348.5       50.1    15  605   8
  35000.     254.3      -49.2       73.0      339.3       47.1    15  605   9
  40000.     200.5      -59.6       65.7      344.5       64.6    15  605  10
-EOF
-FIN
```

APPENDIX E. PLUME PREDICTION RESULTS.

DEPARTMENT OF THE NAVY
NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555

IN REPLY REFER TO:
3245/DRC:csh
Reg. 3245-021-78
16 November 1977

From: D. R. Cruise, Applied Research & Analysis Branch (Code 3245)
To: Warren Oshel, Asst. Division Head (Code 62102).

Subj: Plume Prediction for Trident Firing

1. The plume prediction program was run prior to the Trident firing of 15 November 1977. The program predicted that the plume would rise to 4080 feet in 52 seconds and then proceed 20° east of south at nine miles an hour. The plume would thus pass over the CT1 turn-off thirteen minutes after firing.

2. The firing was observed at the second Salt Wells turn-off from the Skytop road. The 52 seconds was consistent with observation. The altitude could not be estimated.

3. A second observation site was then taken at the turn-off to CT1. The plume arrived eleven minutes after ignition and was more directly over CT rather than CT1. Because CT is very nearly south of the firing site, a directional error of about 20° is indicated.

4. Because weather is variable and because the program has simplifying assumptions, the author believes that the agreement is quite good.

DRCruise
D. R. CRUISE

Copy to:
32
324
3240 (Victor)
3241 (Hansen)
3245 (Lee, Cruise, Mantz, Breil, Davis)
621
62101
62102 (Matsuda, Miller)
6211
6234 (Vercy)

DEPARTMENT OF THE NAVY
NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555

IN REPLY REFER TO:
3245/DRC:mr
Reg. 3245-063-77
8 July 1977

MEMORANDUM

From: D. R. Cruise (Code 3245)
To: Warren Oshel (Code 62102)

Subj: Prediction of Plume trajectory for Trident Firing of 7 June 1977

Encl: Computer listing from Plume Prediction Program

1. Weather data taken on 7 June 1977 were used to predict the trajectory of a plume from the static test of a second stage Trident fired that same day. Visual observations were made to verify the results.

2. The weather data were taken from balloon tests in the vicinity of Tower 8 at 0830 by the meteorology unit (Code 6234). Data near the surface were adjusted by standard forecast techniques to 1100 hours.

3. The data were converted into tables and fed into the plume prediction computer program developed by Jim Mantz (Code 3245). The results are shown in the enclosure.

4. The program predicted that the plume would rise to an altitude of 4380 feet in the time of 87 seconds. At this point it would be displaced 458 feet north and 274 feet east of the test stand. It would then procede 12½ degrees east of north at 6 feet per second (4 miles per hour) at constant altitude while gradually dispersing in all directions. This would take it over the Argus range within NWC boundaries.

5. The program was run at 1014 and then the test was observed at 1057 from a distance of 5½ miles southwest of the test site (The water reservoir on R street near building CLPL 63).

6. The flame appeared as a bright light, easily visible through 5½ miles of daylight, and lasted about a minute. The cloud was just as visible and began rising immediately. At 70 seconds the cloud was still rising noticeably; at 110 seconds the head of the plume had definitely stopped rising and had begun its horizontal motion. These times bracket the 87 seconds predicted by the program.

7. The terminal altitude could not be estimated to any degree of accuracy but was about twice the difference between the firing elevation (2480) and the top of the volcanic hill (3478) left of the site. This puts it in the same "ball park" as the 4380 feet predicted by the program.

Reg. 3245-063-77
3245/DRC:mr

Subj: Prediction of Plume trajectory for Trident Firing of 7 June 1977

8. The cloud moved away from the observer and slightly left at a very slow rate. These observations agree qualitatively with the program.

9. The cloud was nearly white and remained a "single puff" for better than 20 minutes. It slowly spread out and got larger and more faint. After 20 minutes it would probably not catch the eye of someone who was not looking for it.

10. As nearly as it could be observed the program predicted the behavior of the plume. It would appear to be worthwhile to run the program before future tests. It remains to be seen how well the program will predict the plume in high winds.

D R Cruise
D. R. CRUISE

Copy to:
26305 (Dodson)
324
3240 (Victor)
3245 (Lee, Mantz, Klever, Breil)
3270 (Stayton)
621
62103 (Matsuda)
6211
6234

```
RUN ID: 420051   ACCOUNT: 152102/AKA9G   PROJECT: 451492OBLST

START 10:14:49 7 JUL  77  FIN 10:20:11 7 JUL  77   PRIORITY A

PAGES=11        CARDS: IN=172, OUT=0           PLOT REC=0

CAU TIME:               00:00:01.355  AT $.243/SEC = $        .46
MASS STRG/TAPE TIME:    00:00:07.012  AT $.085/SEC = $        .57
COVER TIME:             00:00:08.400  AT $.110/SEC = $        .98

TOTAL RUN TIME:         00:00:18.557      RUN COST = $       2.11

         CORE SURCHARGE    (1.2% OF CAU COST) = $        .01
                           PRIORITY A SURCHARGE = $       1.06

PRT/CRD/PLT EQUIP.:  59 BLOCKS     AT $.008/BLK = $        .55

                                     TOTAL COST = $       3.73
```

TIME (H/M/S)	ALT. (FT.)	Y (FT.)	X (FT.)	AIR TEMP. (C)	WIND VEL. (FPS)	WIND ANGLE (D/M)	VERT. VEL. (FPS)	RAD. (FT.)	AL2O3 (PPM)	HCL (PPM)	
0/ 0/ 0	2480.	185.	185.	29.	1.	198/55	75.	39.	1150.	75.	.5707+06
0/ 0/ 2	2580.	188.	187.	29.	1.	198/34	52.	59.	498.	37.	.5604+06
0/ 0/ 4	2580.	192.	188.	29.	2.	198/14	43.	78.	299.	19.	.6051+06
0/ 0/ 7	2780.	197.	190.	29.	2.	197/54	37.	95.	193.	13.	.6245+06
0/ 0/10	2880.	202.	191.	28.	2.	197/33	34.	111.	140.	9.	.5932+06
0/ 0/13	2980.	209.	194.	28.	2.	197/13	31.	128.	107.	7.	.5658+06
0/ 0/15	3080.	217.	195.	28.	3.	196/52	29.	144.	84.	6.	.5270+06
0/ 0/19	3180.	225.	199.	28.	3.	196/32	28.	150.	68.	5.	.4813+06
0/ 0/23	3280.	235.	202.	27.	3.	196/12	25.	175.	56.	4.	.4284+06
0/ 0/27	3380.	245.	205.	27.	3.	195/51	25.	193.	47.	3.	.3681+06
0/ 0/30	3480.	258.	210.	27.	4.	195/31	23.	210.	39.	3.	.3001+06
0/ 0/35	3580.	271.	214.	27.	4.	195/10	22.	228.	33.	2.	.2241+06
0/ 0/39	3580.	285.	218.	25.	4.	194/50	21.	247.	28.	2.	.1400+06
0/ 0/44	3780.	302.	224.	25.	4.	194/30	19.	258.	24.	2.	.4767+05
0/ 0/49	3880.	319.	229.	25.	5.	194/ 9	18.	292.	20.	1.	-.5304+05
0/ 0/54	3980.	339.	235.	25.	5.	193/49	15.	318.	17.	1.	-.1621+06
0/ 1/ 0	4080.	359.	242.	25.	5.	193/28	14.	351.	14.	1.	-.2794+06
0/ 1/ 5	4180.	383.	250.	25.	5.	193/ 8	12.	395.	11.	1.	-.4047+06
0/ 1/14	4280.	412.	260.	25.	6.	192/48	9.	470.	8.	1.	-.5375+06
0/ 1/27	4380.	459.	274.	25.	6.	192/27	4.	736.	5.	0.	-.6769+06

PLUME IS AT OR NEAR MAXIMUM ALTITUDE

INITIAL DISTRIBUTION

15 Naval Air Systems Command

AIR-03B (1)	AIR-510B (1)	AIR-5312 (1)
AIR-03P2 (1)	AIR-5108 (1)	AIR-53232 (1)
AIR-320 (1)	AIR-5109 (1)	AIR-5332 (1)
AIR-340B (1)	AIR-5203 (1)	AIR-5351 (1)
AIR-503 (1)	AIR-52032C (1)	AIR-5366 (1)

4 Chief of Naval Material
- MAT-030 (1)
- MAT-032 (1)
- NSP-27 (1)
- NSP-2731 (1)

1 Naval Facilities Engineering Command, Western Division, San Bruno (W. Dougherty)

5 Naval Sea Systems Command
- SEA-03 (1)
- SEA-031 (1)
- SEA-033 (1)
- SEA-04H (1)
- SEA-6531 (1)

3 Marine Corps Development and Education Command, Quantico (Marine Corps Landing Force Development Center

1 Air Test and Evaluation Squadron 5

1 Naval Air Development Center, Warminster (Code 3014)

1 Naval Ammunition Depot, Hawthorne (Code 05, Robert Dempsey)

1 Naval Explosive Ordnance Disposal Facility, Indian Head

1 Naval Intelligence Support Center (OOXA, CDR Jack Darnell)

1 Pacific Missile Test Center, Pt. Mugu (Code 2144, McQuaide)

1 Naval Ocean Systems Center, San Diego (Code 133)

1 Naval Ordnance Station, Indian Head (Code FS, A. T. Camp)

2 Naval Surface Weapons Center, Dahlgren Laboratory, Dahlgren
- Code DG (1)
- Code DG-50 (1)

1 Naval Surface Weapons Center, White Oak (WR-12, H. Heller)

1 Naval Intelligence Support Center Liaison Office (LNN)

1 Army Armament Materiel Readiness Command (AMSAR-SF)

4 Army Armament Research and Development Center (SMD, Concepts Branch)

2 Air Force Systems Command, Andrews Air Force Base
- DLFP (1)
- SDW (1)

2 Air Force Aero-Propulsion Laboratory, Wright-Patterson Air Force Base
- RJA (1)
- STINSO (1)

3 Air Force Armament Laboratory, Eglin Air Force Base
- DLDE (1)
- DLMI, Mr. Aden (1)
- DLODL (1)

1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (MKCC)

1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (MKP)

1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (R. Sute)

1 Foreign Technology Division, Wright-Patterson Air Force Base (Code PDXA, James Woodard)
1 Wright-Patterson Air Force Base
1 Defense Advanced Research Projects Agency, Arlington
12 Defense Documentation Center
1 Aeronautical Research Associates of Princeton, Princeton, NJ (H. Pergament)
1 Air Pollution Control Technology, San Diego, CA
1 Kerr-McGee Chemical Corporation, Trona, CA (Leonard Harris)
1 Southern California Air Quality District, San Bernardino, CA (Dr. H. Malone)
88 Chemical Propulsion Mailing List No. 271 dated October 1975, including Categories 1, 2, 3, 4, 5