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DEVELOPMENT OF A FOAM COMPATIBLE WITH DRY POWDER

I. Wilder

Naval Applied Science Laboratory
Brooklyn, New York

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Lab. Project 9300-55
Technical Memorandum 3
SF 020-03-03, Task 0605

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Material Sciences Division

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U. S. NAVAL APPLIED SCIENCE LABORATORY
BROOKLYN, NEW YORK

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Lab. Project 9300-55
Technical Memorandum #3

SUMMARY

A new fluorinated proteinaceous fire-fighting foaming agent, that is compatible with commercially available dry chemicals, has been developed. This extinguishant, which meets the fire requirements for conventional protein foams, will be used in a dual agent application system with potassium bicarbonate dry powder (Purple K). This dual agent application system will be demonstrated shortly at the U.S. Naval Damage Control Training Center, Philadelphia, Pennsylvania on a simulated shipboard engine room fire situation. Combined application of the new compatible foam and Purple K dry chemical appears to provide outstanding means for rapid control and security of flammable liquid fuel fires.

Two indoor laboratory-scale tests were devised which were found useful in screening candidate foam-liquid formulations for compatibility with dry chemicals. Also developed were three large-scale outdoor compatibility tests which represent various field fire-fighting practices incorporating the combined usage of foam and dry powder. The screening tests were found to correlate very favorably with the field compatibility tests.

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FIGURES

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ADMINISTRATIVE INFORMATION

Ref: (a) NASL Program Summary of 1 Dec 1965, Subproject SF 020-03-03, Task 0605
(b) NASL ltr 9380:IW:nr, Lab. Project 9300-55 of 19 Apr 1965
(c) Simons, J. H., Fluorine Chemistry, Vol. 5, p. 370, Academic Press, New York (1964)
(d) Spec O-F-555b of 11 Mar 1964; Foam-Forming Liquids, Concentrated, Fire Extinguishing, Mechanical
(e) Spec MIL-F-22287A (WEP) of 23 Nov 1962; Fire Extinguishing Agent, Potassium Dry Chemical
(f) Spec MIL-F-19563 (Aer), Amnd 1 of 3 Feb 1958; Fire Extinguishing Agent, Dry Chemical, Foam Compatible
(g) National Fire Protection Association (NFPA) Pamphlet No. 11, "Standards for Foam Extinguishing Systems", of Jul 1954
(h) Spec MIL-I-22023A of 2 May 1961; Insulation Felt, Thermal and Sound Absorbing Felt, Fibrous Glass, Flexible
(i) NAVSHIPYDNYK MATLAB ltr 946:IW:nt, 9930 of 26 Jul 1962
(j) NASL Program Summary of 1 Dec 1965, Subproject SF 015-07-01, Task 3346

1. Latest aid in combatting flammable liquid fuel fires aboard Naval surface vessels has come in the form of a new dry powder/compatible/fire-fighting foaming agent which was developed in accordance with the program guidelines set forth in reference (a). This report summarizes the investigative studies conducted to date by the U. S. Naval Applied Science Laboratory on this subject matter. The development of this new extinguishant was the result of a joint effort between this Laboratory and the National Foam System, Incorporated, West Chester, Pennsylvania. The compatible foam, initially reported in reference (b), will be used in a dual agent application system with potassium bicarbonate dry powder (Purple K). This system will provide vastly improved shipboard means for rapid and safe control and security of flammable liquid fuel fire situations.

BACKGROUND

2. It is widely recognized that potassium bicarbonate dry chemical (Purple K) provides the fastest knockdown and extinguishment of flammable liquid fuel fires, but dry chemical alone lacks the power to protect the fuel surface from reignition due to hot surfaces left in the fire area. Foam, on the other hand, has the advantage of sealing the fuel and preventing its reflash, but the fire-fighting action of this agent is relatively slow. During the past years there has been a steadily increasing interest by the fire engineering industry in the potential of using these two inherently different extinguishing materials on the same fire. This technique, generally known as combined agent attack, would utilize Purple K powder to effect rapid extinguishment and foam to seal the fuel and prevent its reignition. However, until the present compatible foam formulation was developed, attempts at combined use of the

commercially available foams and powders demonstrated an inherent incompatibility between these agents; that is, foam blankets were rapidly destroyed in the presence of the powders thereby eliminating their blanketing and non-reignition effect and establishing an extinguishment condition resembling that of the powder alone.

OBJECT

3. The objective of the work reported on herein was the development of a protein foam compatible with dry powder. The investigative studies leading to this development were conducted as part of an overall program, outlined in reference (a), for the development of superior fire extinguishment foams for shipboard use.

APPROACH

4. In searching to develop a foam with dry powder compatibility characteristics, two general approaches were explored. Initially, it was decided to determine whether dry powder compatibility could be achieved by varying certain factors connected with the basic foam-liquid manufacturing process, such as protein raw material, pH, quantity and nature of stabilizing salts, degree of hydrolysis, etc., and also by varying the type of foam produced from a given formulation by changing the condition of foam generation, e.g. nozzle pressure, foam-liquid/water ratio, bubble size, etc. This approach was followed concurrently with the exploration of foams to which various inert fluorocarbon additives were incorporated. These additives comprised a unique series of fluorine containing compounds which demonstrated outstanding surface activity in both water and foam-liquid. Small quantities of some of these additives imparted to the foam-liquid remarkably improved stability and, in certain cases, a surface barrier effect rendering the foam substantially inert to the bicarbonate salts, fluidizing agents and dyes used in dry chemical manufacture. When encouraging dry powder compatibility results were obtained with this fluorocarbon additive approach, the other approach described above, consisting of varying the basic foam-liquid manufacturing process, was discontinued and all effort was devoted to exploring the new fluorinated foam-liquid formulations. These formulations were prepared and furnished by the National Foam System, Incorporated under the technical guidance and stimulus of the U. S. Naval Applied Science Laboratory. As indicated in reference (c), it is to be noted that fluorocarbon compounds used for surface active purposes have two ends, one hydrophilic and one hydro and oleo phobic. These may be sketched as $Z\text{-}(CF_2)n\text{-}CF_3$ using Z to represent the water solubilizing group and a fluorocarbon chain (CF_3) for the hydrocarbon shedding end. In the development of the compatible foam-liquids, the effect of both variables was investigated as

well as the protein base material to which the surfactants were added. Numerous Z groups were investigated including derivatives of perfluoro carboxylic and sulfonic acids. Also investigated was the substitution of hydrogen and chlorine in the fluorocarbon end. An important factor effecting the utility of the final product was the length of the perfluorocarbon chain, $(CF_2)n$. In cases where the chain became too long, the material was found too insoluble to be useful. When the chain was too short, the formulation did not provide satisfactory fire-fighting effectiveness. Once the most suitable surfactant and chain length were determined, the final formulating problem was to satisfactorily incorporate this additive into the foam-liquid during the manufacturing process without unbalancing the equilibrium of the product.

DESCRIPTION

5. The dry powder/compatible/foam-liquid presently available from the National Foam System, Incorporated for use in 6% concentrations with fresh or sea water, is commercially designated as "XL-6". The exact chemical composition of this fluorinated foam-liquid formulation, (XL-6), is presently proprietary to the manufacturer and cannot be disclosed at this time. Some of the experimental National formulations reported on herein, which were furnished in the latter stages of the development of the XL-6 foam-liquid, are designated as C110-20 through C110-15. It should be noted that formulations C110-16 and C110-15 are, with minor modifications, similar in composition to that of the XL-6 material. The XL-6 and C110-20 through C110-15 formulations were compared in this investigation with currently approved conventional protein foam-liquids of different manufacture. These conventional competitive liquids, which are coded in Table 1, all conform to the requirements of the current foam-liquid specification, reference (d). The dry powders employed herein are also coded in Table 1 and include: (1) Powders "B" and "C" - two potassium bicarbonate base dry chemicals (Purple K), both of which meet the requirements of the potassium bicarbonate specification, reference (e) and, (2) Powder "A" - a sodium bicarbonate base dry chemical ($NaHCO_3$) which conforms to specification, reference (f), and which is designated by the manufacturer as foam compatible.

PROCEDURE

6. Conditions of Contact Between Foam and Dry Powder

In foam/dry powder dual agent applications, the dry chemical is generally used first to extinguish the fire or knock it down and sweep it back while the foam is used primarily to form a vapor tight blanket to prevent reflash of those fuel areas extinguished by the dry chemical and also to extinguish any residual fires. A secondary method in which this combination of agents could be used consists of foam as the primary extinguishant and the dry powder as the secondary agent applied afterwards to extinguish small flickers, inaccessible fuel pockets or pressure fires where spilled fuel is being force fed from a ruptured tank, pipe or flange.

7. Criteria for a Dry Powder/Compatible/Foam

To meet practical fire performance requirements, a compatible foam should be capable of withstanding substantial quantities of the dry chemical on top of the foam blanket as well as beneath it, without the foam losing its vapor sealing ability. Also, if there are any voids in the blanket, the presence of dry chemical in the immediate vicinity of the foam should not result in any significantly more rapid burn-back than would normally be experienced with the foam alone (without dry chemical present).

8. Foam/Dry Powder Compatibility Tests

The tests described below were planned to observe the compatibility of the experimental National foam-liquid formulations (as well as the conventional protein liquids) with dry chemical under various possible conditions of contact between these agents. The degree of compatibility of the foams in these tests was judged on the basis of the criteria established in paragraph 7 above. It should be noted that, in this development program, efforts were directed toward parallel testing procedures employing conventional protein foam-liquids under conditions identical to those to which the experimental fluorinated formulations were exposed.

a. NASL-Indoor Compatibility Tests

The following small-scale indoor laboratory tests were devised with an aim toward screening candidate dry powder/compatible/foaming agents to determine those most promising for additional larger-scale outdoor tests.

(1) Burn-Back Method. This test compares the time for complete destruction (burn-back) of a powder-contaminated-foam sample with the burn-back time of an uncontaminated-foam sample. Essentially, the test, which is illustrated in Figure 1, was conducted as follows: Five hundred milliliters of regular gasoline (motor vehicle grade) were placed in an 8" x 8" x 2" deep open top steel pan containing a vertical screened partition located 2" from an edge of the pan. The partition, which divided the pan into two compartments, 8" x 6" x 2" deep and 8" x 2" x 2" deep, was made of 16 mesh 0.018" diameter wire gauze. A premixed solution, consisting of 6% by volume of foam-liquid in fresh water at 68°F, was discharged through a 6 gpm

mechanical foam nozzle (Figure 3 of specification, reference (d)) at 100 psig. The foam generated from the nozzle was collected in a gentle manner, with a minimum of impingement, into a suitable container. The foam was then poured from the container into the 8" x 6" x 2" deep compartment of the partitioned test pan. Sufficient foam was added to completely fill this compartment, at which time the foam surface was leveled off. Twelve grams of dry powder were then sifted uniformly onto the foam through a 5" diameter - 80 mesh screen. One and a half minutes from the time of completion of foam collection in the container, the exposed gasoline in the 8" x 2" x 2" deep compartment of the test pan was ignited and the time noted for complete foam destruction or burn-back. A control test was also conducted wherein only foam (no dry powder) was used.

(2) Sealability Method. This test compares the sealability from fuel ignition of a powder-contaminated-foam sample with the sealability of an uncontaminated-foam sample. Basically, the test, which is illustrated in Figure 2, was conducted as follows: A premixed solution, consisting of 6% by volume of foam-liquid in fresh water at 68°F, was discharged through a 6 gpm mechanical foam nozzle at 100 psig. The foam produced in this manner was directed against the center of the vertical backboard of a foam collector (Figure 2 of specification, reference (d)). The backboard was positioned ten feet from the tip of the nozzle. The foam, upon striking the backboard, flowed into a trough and then into a 7-3/8" diameter by 2" deep foam sample container (shown in reference (g)) containing 210 milliliters of regular gasoline. Foam generation was halted when the container was filled, at which time the foam surface was leveled off. Ten grams of dry powder was then sifted uniformly onto the foam through a 5" diameter - 80 mesh screen. One minute after the time of filling the foam sample container, a lighted torch was passed continuously over the foam around the circumference of the container. During this period, the torch was passed within 1/4 inch of the surface of the foam. The test was halted and the time recorded when sustained ignition of the gasoline occurred. A control test, without the use of dry powder, was also conducted.

b. NASL-Field Compatibility Tests

The following outdoor tests were planned to represent possible field fire-fighting operations incorporating the combined usage of foam and dry powder.

(1) 3' x 3' Test. This test compares the area of burn-back (and thus the extent of foam destruction) of a foam exposed to a fuel surface previously extinguished by means of dry powder with the burn-back area of the same foam

exposed to an uncontaminated fuel surface. The test, which is illustrated in Figure 3, was made as follows: Seven gallons of regular gasoline were placed in a 3' x 3' x 3" high open top steel tank containing a 1" thick fiber glass mat (Type 1, Class 4) conforming to specification, reference (h). The above quantity of gasoline was found necessary to completely saturate the mat and at the same time cover its surface with an approximately 1/32" thick gasoline layer. The use of the mat was required in order to permit build-up of a sufficient dry powder layer, above the gasoline layer, to insure surface contact between powder and foam. The mat also provided a consistently uniform and reproducible surface, for containing the fuel, that could easily be discarded between tests. The test tank was positioned in a wind shielded area and the fuel in the tank was ignited. The fire was permitted to burn freely for 15 seconds prior to extinguishment with dry chemical. The powder was applied from a fully charged 5-pound pressurized-cartridge type extinguisher. Powder application was continued, after extinguishment of the test fire was effected, until complete discharge of the contents of the extinguisher. One minute from the start of powder application, a premixed solution, consisting of 6% by volume of foam-liquid in fresh or synthetic sea water at 68°F, was discharged through a 6 gpm mechanical foam nozzle at 100 psig. The foam produced in this manner was directed against a vertical backboard which was positioned ten feet from the tip of the nozzle and flush with the far edge of the test tank. The foam, upon striking the backboard, flowed into the tank. Foam flow to the tank was halted after 30 seconds, at which time the surface of the foam in the tank was leveled off. Five minutes after completion of foam application, an opening, 6" x 6", was made in the approximate center of the foam blanket and the exposed fuel surface was reignited. The reignited fire was permitted to burn for 5 minutes, after which the area of foam destruction or burn-back was determined. A control test was also conducted as described above with the exception that carbon dioxide was used in lieu of dry powder as the extinguishing agent.

(2) 10' x 10' Test. This test is basically a modification of the fire test specified in reference (d) including the application of a substantial quantity of Purple K dry powder to an aged foam blanket prior to cutting a void in the blanket and determining the foam's burn-back resistance. The test method, which is illustrated in Figure 4, was essentially as follows: One hundred gallons of regular gasoline were floated on 10" of water in a 10' x 10' x 3' high open top steel tank. The fuel was ignited and permitted to burn freely for 1 minute, after which a 6% solution of foam-liquid in water at 68°F was discharged through a 6 gpm mechanical foam nozzle at 100 psig. The nozzle was positioned in the middle of the windward side of the test tank with the nozzle tip about 16" directly over the top edge of the tank. The foam stream was directed across the fire to strike the approximate center of the

back-side of the tank, 12" above the fuel level. Foam application was continued for 5 minutes, the maximum time required by the specification, reference (d), for complete extinguishment of the above 10' x 10' test fire. Fifteen minutes after completion of foam application, 30 pounds of Purple K was discharged onto the foam blanket through a total flooding dry powder nozzle pointing downward and positioned in the center of the tank approximately 3' above the tank top. The powder was delivered at 2-3 pounds per second from a 30-pound pressurized-cartridge type extinguisher through associated piping leading to the flooding nozzle. An opening, 6" x 6", was then made in the approximate center of the powder-contaminated-foam blanket and the exposed fuel surface was reignited. The reignited fire was permitted to burn for 5 minutes, after which the area of foam destruction or burn-back was determined. Tests, as described above, were conducted using fresh and synthetic sea water with the foam-liquid both premixed with the water and also inducted into the water stream. Control tests were also made wherein no dry chemical was used.

(3) 20' x 20' Test. The technique used for this test was a combined agent attack on a 400 ft^2 fire with prime extinguishment provided by Purple K dry powder followed by foam for effecting extinguishment of residual fire areas and securing those fuel areas already extinguished by the dry chemical. Basically, the test, which is illustrated in Figure 5, was conducted as follows: Gasoline quantities ranging from 75 to 150 gallons were floated on 1/2" of water in a 20' x 20' x 6" high open top steel tank. After pre-burn times varying from 1/2 to 1-1/2 minutes, Purple K dry chemical alone was applied to initiate a knockdown of the fire. The powder was supplied from a nitrogen-pressurized-125 pound capacity-dry powder chamber through a dispersed pattern dry chemical nozzle at rates of 3-4 pounds per second. Powder application was continued for about 40 seconds, the time for complete discharge of the contents of the chamber. Ten to twenty seconds following start of powder application and after fire knockdown had begun, foam application was initiated. At this point, both powder and foam were applied simultaneously in a combined agent attack, and observation was made as to the time for complete extinguishment of the test fire. The extinguishment time was recorded as the elapsed time from start of powder application to fire extinguishment. Foam was discharged, for periods up to 1-1/2 minutes, from a dispersed stream foam nozzle at 50-60 gallons of solution per minute and 100 psig. Five minutes after completion of foam application, a sealability test was made wherein the foam blanket was probed with a lighted torch to determine the presence of flammable fuel vapors. The dual agent extinguishment test described above was conducted with a centrally located obstruction in the 20' x 20' test tank; this obstacle consisted of a 55-gallon drum (open on both ends) resting on its side on the deck of the tank. Similar extinguishment tests were made with both dry chemical

alone (without foam) and foam alone (without powder). The foam, for the above tests, was used in 6% concentrations in both fresh and synthetic sea water at 68°F.

9. Compatible Foam (XL-6) Tests

a. Foam-Liquid Specification Tests

Tests were conducted to determine the conformity of the XL-6 foam-liquid with the requirements of the foam-liquid specification, reference (d). The XL-6 material was subjected to the procedures covered in the specification with the exception of the test of paragraph 3.3 (compatibility of foam-liquids with competitive liquids) which is required in qualification approval testing only. The XL-6 foam was also subjected to the "corrosion to aluminum" test of reference (i). Although this test is not currently included in the present foam-liquid specification, it has been established that it will be incorporated at the time of the next specification revision.

b. NASL-30' x 30' Spill Fire Tests

Supplementary tests were conducted with the XL-6 foam to determine its fire-fighting effectiveness on a large area spill fire. Seventy five gallons of gasoline were poured on a wetted 900 ft^2 concrete area. The fuel was ignited and pre-burned for 30 seconds. A 6% premixed solution of the XL-6 formulation in synthetic sea water at 68°F was applied to the fire through a dispersed stream foam nozzle at 50-60 gallons of solution per minute and 100 psig. Observation was made as to the time for complete extinguishment of the test fire. Also, a sealability determination was made wherein a lighted torch was periodically passed over the residual foam blanket to determine whether the foam provided a vapor seal against fuel reignition.

RESULTS

10. Foam/Dry Powder Compatibility Tests

a. NASL-Indoor Compatibility Tests

Typical compatibility results of the indoor tests, using the fluorinated experimental formulations and the conventional foams with Purple K and sodium bicarbonate dry chemical, are shown in Table 2.

b. NASL-Field Compatibility Tests

Typical compatibility results of the outdoor field tests, using the experimental and conventional foams with the various dry chemicals, are contained in Table 3.

c. A summary tabulation of indoor and field compatibility test data, showing average values for the conventional foams and the compatible (XL-6) formulation with Purple K and sodium bicarbonate dry chemical, are outlined in Table 4.

11. Compatible Foam (XL-6) Tests

a. Foam-Liquid Specification Tests

The results of the specification tests on the XL-6 formulation are contained in Table 5.

b. NASL-30' x 30' Spill Fire Tests

The XL-6 foaming agent was found to readily extinguish the 900 ft^2 spill fires within 30 seconds and provide good quality vapor securing foam blankets to the extinguished fuel areas.

ANALYSIS

12. Foam/Dry Powder Compatibility Tests

Examination of the foam/dry powder compatibility results and test methods, contained herein, indicate the following:

a. NASL-Indoor Compatibility Tests

(1) Burn-Back Method

(a) The time for complete foam destruction (burn-back) in the control runs (without powder) averaged 9 minutes for all the foams tested.

(b) Upon the addition of sodium bicarbonate dry chemical to the foams, the time for complete foam destruction averaged about 4.7 minutes for the conventional foams as compared to 8.5 minutes for the XL-6 formulation.

(c) Upon the addition of Purple K powder to the foams, the burn-back time averaged approximately 2.1 minutes for the conventional foams as compared to 6 minutes for the XL-6 material.

(2) Sealability Method

(a) The time for sustained gasoline ignition in the control runs (without powder) averaged approximately 10 minutes for the conventional foams as compared to 13.5 minutes for the XL-6 foam.

(b) Upon the addition of sodium bicarbonate dry chemical to the foams, the average time for sustained gasoline ignition occurred in about 5.5 minutes for the conventional foams as compared to 12.2 minutes for the XL-6 formulation.

(c) Upon the additipn of Purple K dry chemical to the foams, the average time for sustained gasoline ignition occurred in approximately 1 minute for the conventional foams as compared to about 7.7 minutes for the XL-6 material.

b. NASL-Field Compatibility Tests

(1) 3' x 3' Test

(a) Contact of the foams with uncontaminated fuel surfaces (no powder present) resulted in burn-back areas averaging about 0.8 ft^2 for the conventional foams and approximately 0.6 ft^2 for the XL-6 foam.

(b) Contact of the foams with fuel surfaces previously extinguished with sodium bicarbonate dry chemical resulted in burn-back areas averaging approximately 1.5 ft^2 for the conventional foams as compared to 0.7 ft^2 for the XL-6 material.

(c) Contact of the conventional foams with fuel surfaces previously extinguished with Purple K dry powder resulted in 100% destruction of each foam blanket (9 ft^2) within the 5-minute burn-back period.

(d) Contact of the XL-6 formulation with fuel surfaces previously extinguished with Purple K dry powder resulted in burn-back areas averaging about 1 ft^2.

(2) <u>10' x 10' Test</u>

(a) The 5-minute burn-back areas in the control runs (no powder present) averaged approximately 0.9 ft^2 for the conventional foams as compared to 0.7 ft^2 for the XL-6 foam.

(b) Application of Purple K dry chemical to the conventional foams resulted in 100% destruction of each foam blanket (100 ft^2) within the 5-minute burn-back period.

(c) Application of Purple K dry powder to the XL-6 formulation resulted in burn-back areas averaging about 0.9 ft^2.

(3) <u>20' x 20' Test</u>

(a) The 20' x 20' tank fires, using foam alone, were extinguished in an average time of approximately 1.1 minutes by the conventional foams as compared to 0.8 minutes by the XL-6 material. The residual blankets formed by each of these foams were found to provide satisfactory sealability against fuel reignition.

(b) The 20' x 20' tank fires were not, in most cases, extinguished when using conventional foams in combination with Purple K dry chemical; in the isolated tests wherein extinguishment was effected by the dry powder alone, no vapor sealing blanket was furnished by the foam. In this connection, it should be noted that Purple K not only destroys a conventional foam blanket that has already been formed (as evidenced by the results of the 10' x 10' tests indicated in paragraph 12b(2)(b) above) but also prevents build-up of an ordinary foam blanket when these two agents are used in combination for the extinguishment of flammable liquid fuel fires.

(c) In the dual agent tests with the XL-6 foam and Purple K dry powder, extinguishment of the 20' x 20' fire was effected in an average time of about 0.45 minutes. The resultant foam blankets in these tests, though thoroughly contaminated with Purple K, provided vapor securing surfaces for periods of well over 20 minutes.

(d) In the 20' x 20' tests conducted with Purple K alone, only the fires in about 20% of the tests were extinguished within 40 seconds, the time for complete discharge of the contents of the powder extinguisher used in these tests.

c. The two indoor-foam/dry powder compatibility tests (Burn-Back and Sealability), reported on herein, were found to be simple, duplicable, laboratory tests useful for primary selection and screening of candidate dry powder/compatible/foams and for batch testing of foams of similar formulation. The compatibility results obtained using these two screening tests were found to compare favorably with those of the outdoor field tests.

d. No significant differences in foam compatibility were found between the two competitive potassium bicarbonate dry chemicals investigated herein.

e. No significant differences in dry powder compatibility were found between fresh and sea water solutions of the foams investigated herein.

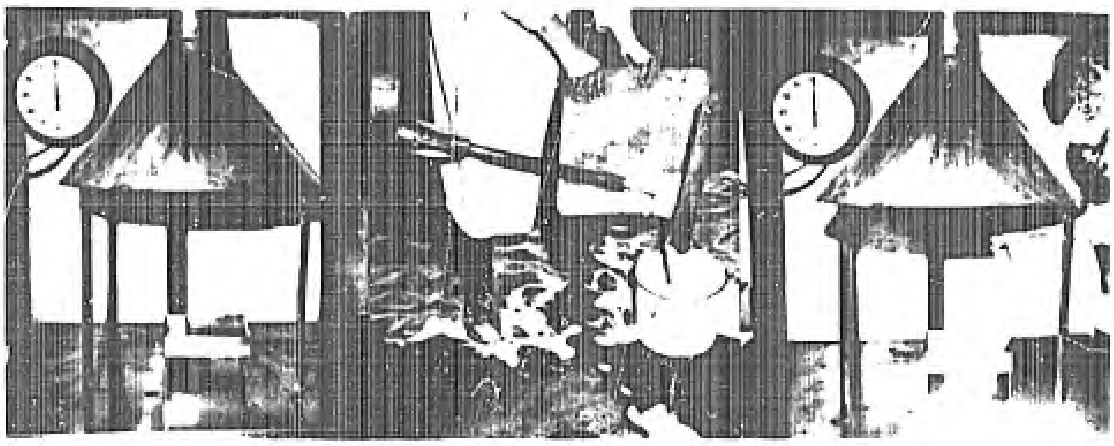
13. Compatible Foam (XL-6) Tests

a. Foam-Liquid Specification Tests

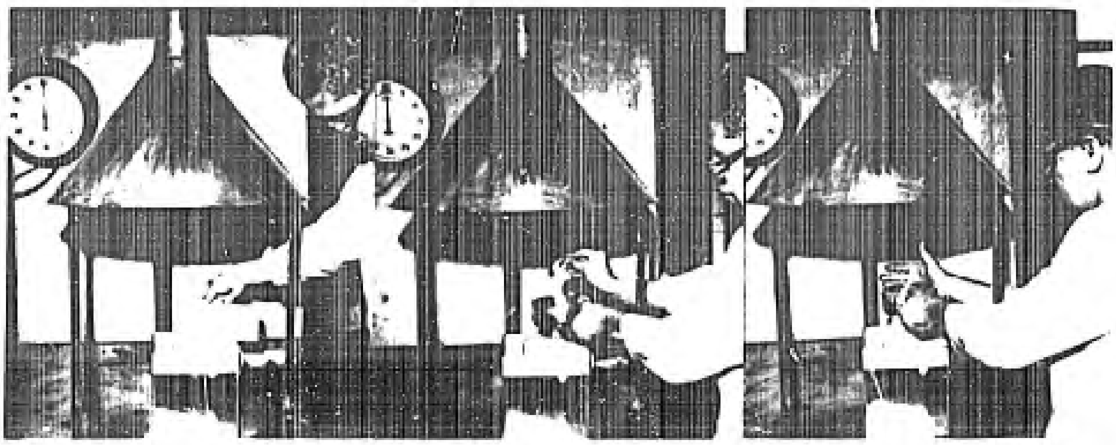
With the exception of the tests of paragraph 3.3 of the specification, reference (d), which were not conducted, the XL-6 formulation was found to be in conformity with the specification requirements (including those of the "corrosion to aluminum test").

CONCLUSIONS

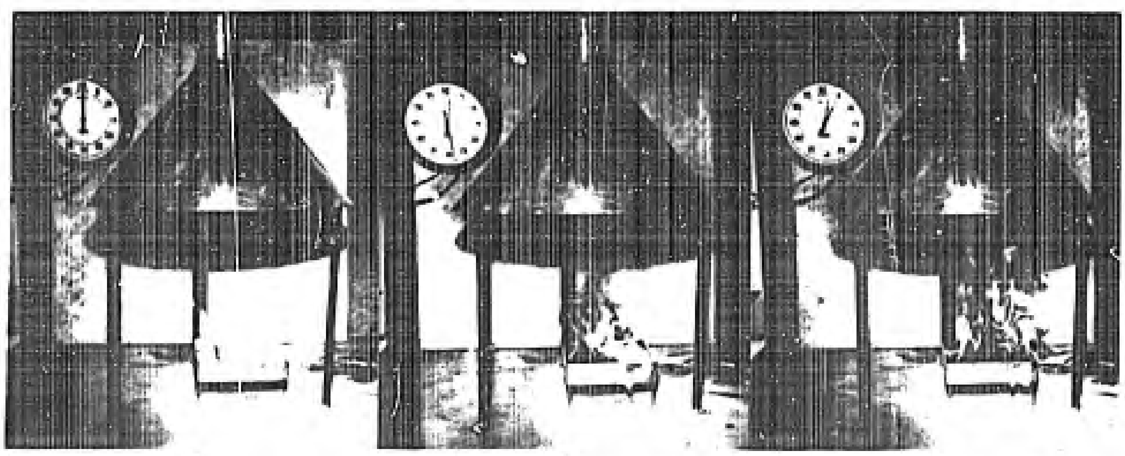
14. The new National XL-6 formulation offers for the first time a protein foaming agent with outstanding potassium and sodium bicarbonate dry chemical compatibility characteristics. As evidenced by an analysis of the results presented herein, problems of foam collapse, normally encountered where dry chemical powders and conventional protein foams are used together, are practically non-existent with the new compatible foam.



1. TEST PAN WITH FUEL
2. FOAM COLLECTION
3. FILLING TEST PAN WITH FOAM



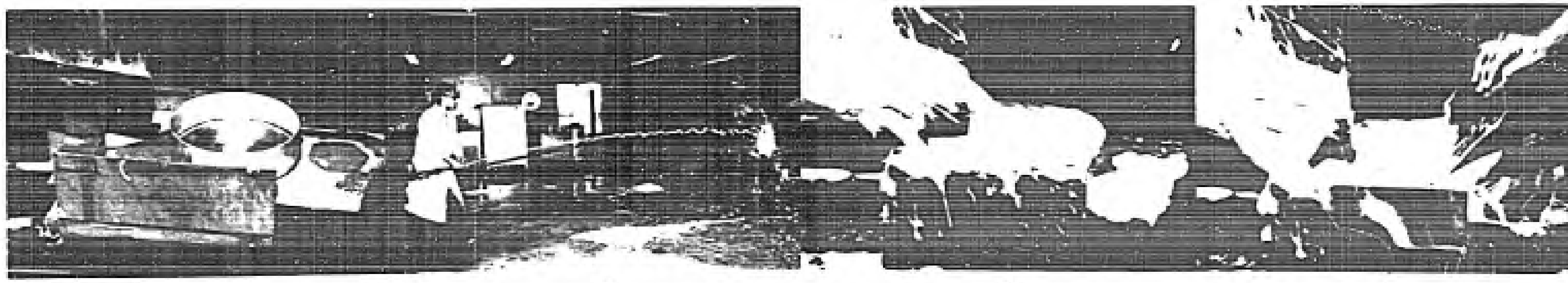
4. LEVELLING FOAM
5. 6. DRY POWDER APPLICATION



7. 8. 9. PROGRESSION OF BURN-BACK AREA FOR TYPICAL CONVENTIONAL FOAM

PHOTO L-19920-1

FIGURE 1- NASL INDOOR COMPATIBILITY TEST-BURN-BACK METHOD

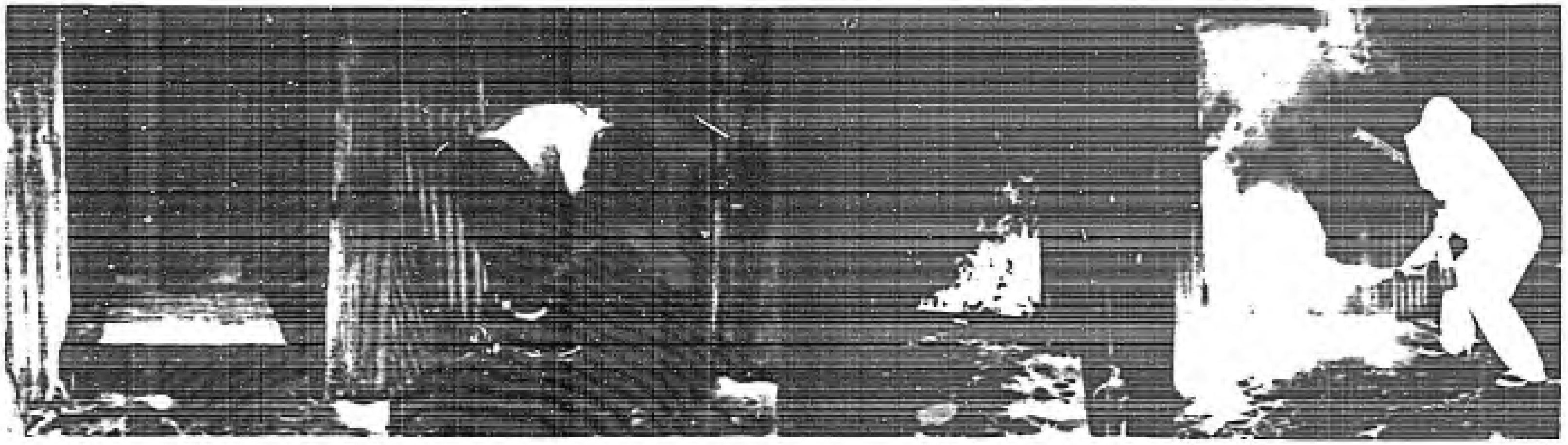


1 TEST PAN WITH FUEL — 2 FOAM APPLICATION — 3 FILLING TEST PAN WITH FOAM — 4 LEVELLING FOAM

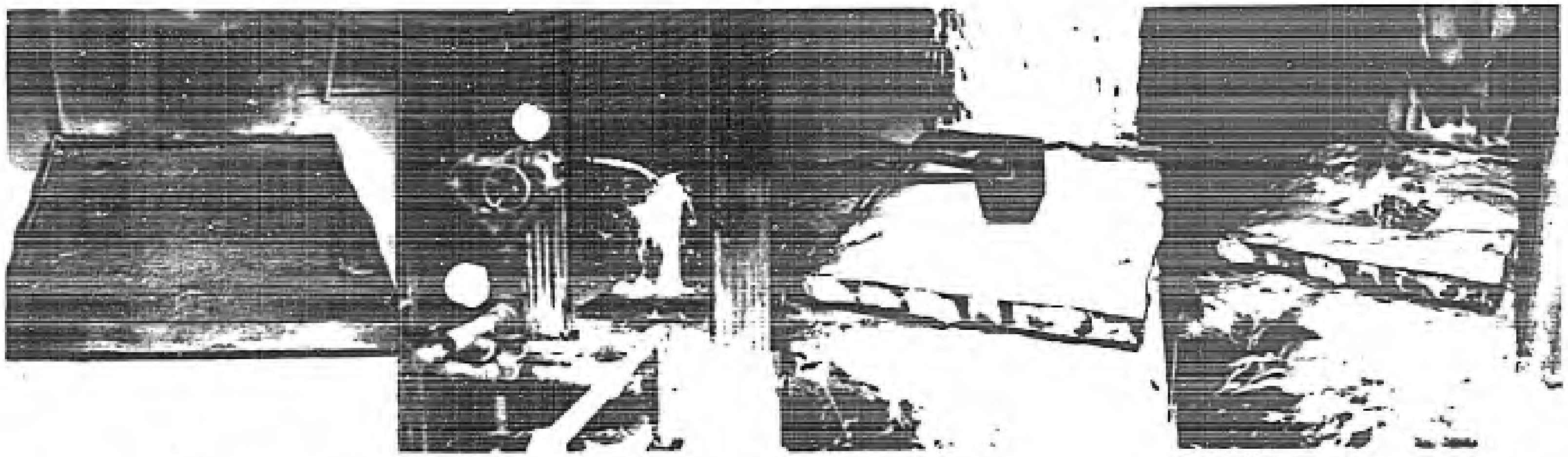
5 DRY POWDER APPLICATION — 6 — 7 SEALABILITY DETERMINATION

PHOTO L-19920-2

FIGURE 2-NASL INDOOR COMPATIBILITY TEST-SEALABILITY METHOD



1. TEST TANK WITH MAT
2. FUELING TANK
3. FUEL IGNITION
4. DRY POWDER APPLICATION



5. MAT COVERED WITH DRY POWDER
6. FOAM APPLICATION
7. CUTTING 6"×6" OPENING
8. BURN-BACK FIRE

PHOTO L-19920-3

FIGURE 3-NASL FIELD 3'×3' COMPATIBILITY TEST

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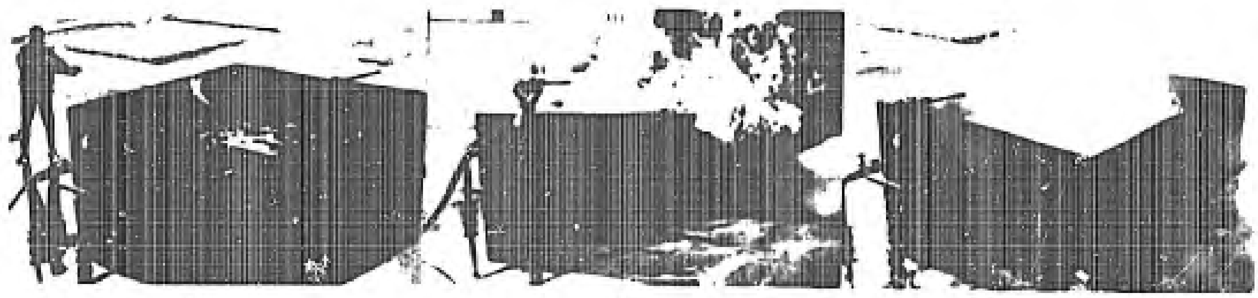
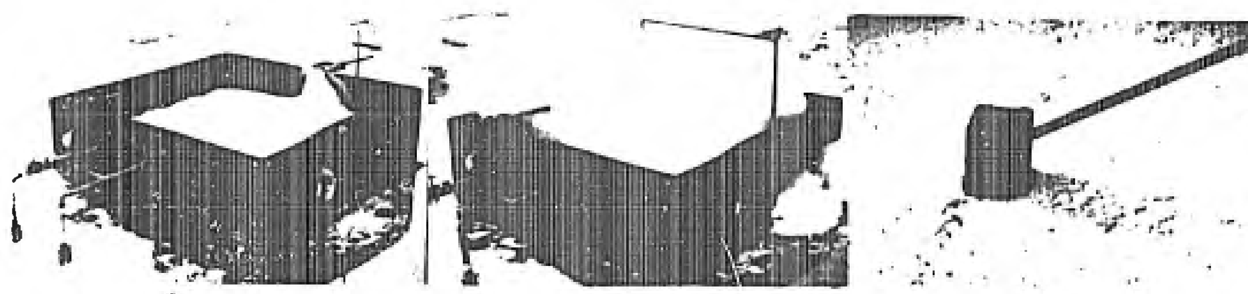
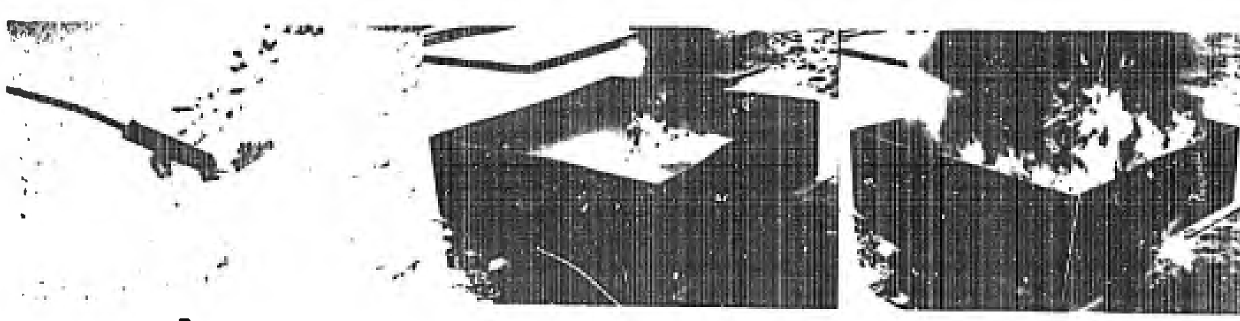


1. FUEL IGNITION
2. FOAM APPLICATION
3. FIRE EXTINGUISHED



4. DRY POWDER SET-UP
5. DRY POWDER APPLICATION
6. CUTTING 6"X6" OPENING

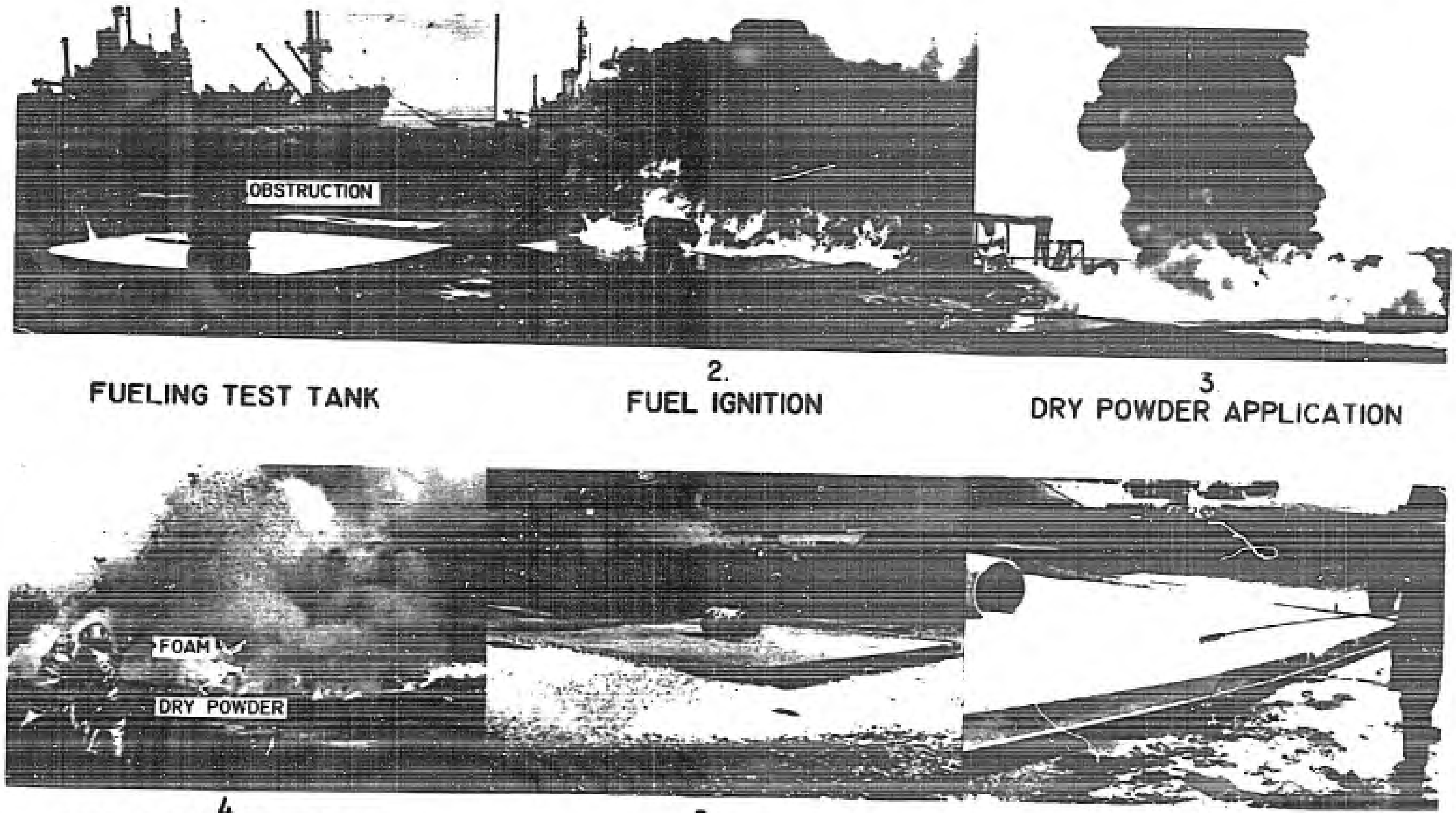


7. IGNITION OF 6"X6" AREA

8. 9. PROGRESSION OF BURN-BACK AREA FOR TYPICAL CONVENTIONAL FOAM

PHOTO L-19920-4

FIGURE 4-NASL FIELD 10'X10' COMPATIBILITY TEST



FUELING TEST TANK

2. FUEL IGNITION

3. DRY POWDER APPLICATION

4. DUAL AGENT APPLICATION

5. FIRE EXTINGUISHED

6. SEALABILITY DETERMINATION

PHOTO L-19920-5

FIGURE 5- NASL FIELD 20'X20' COMPATIBILITY TEST

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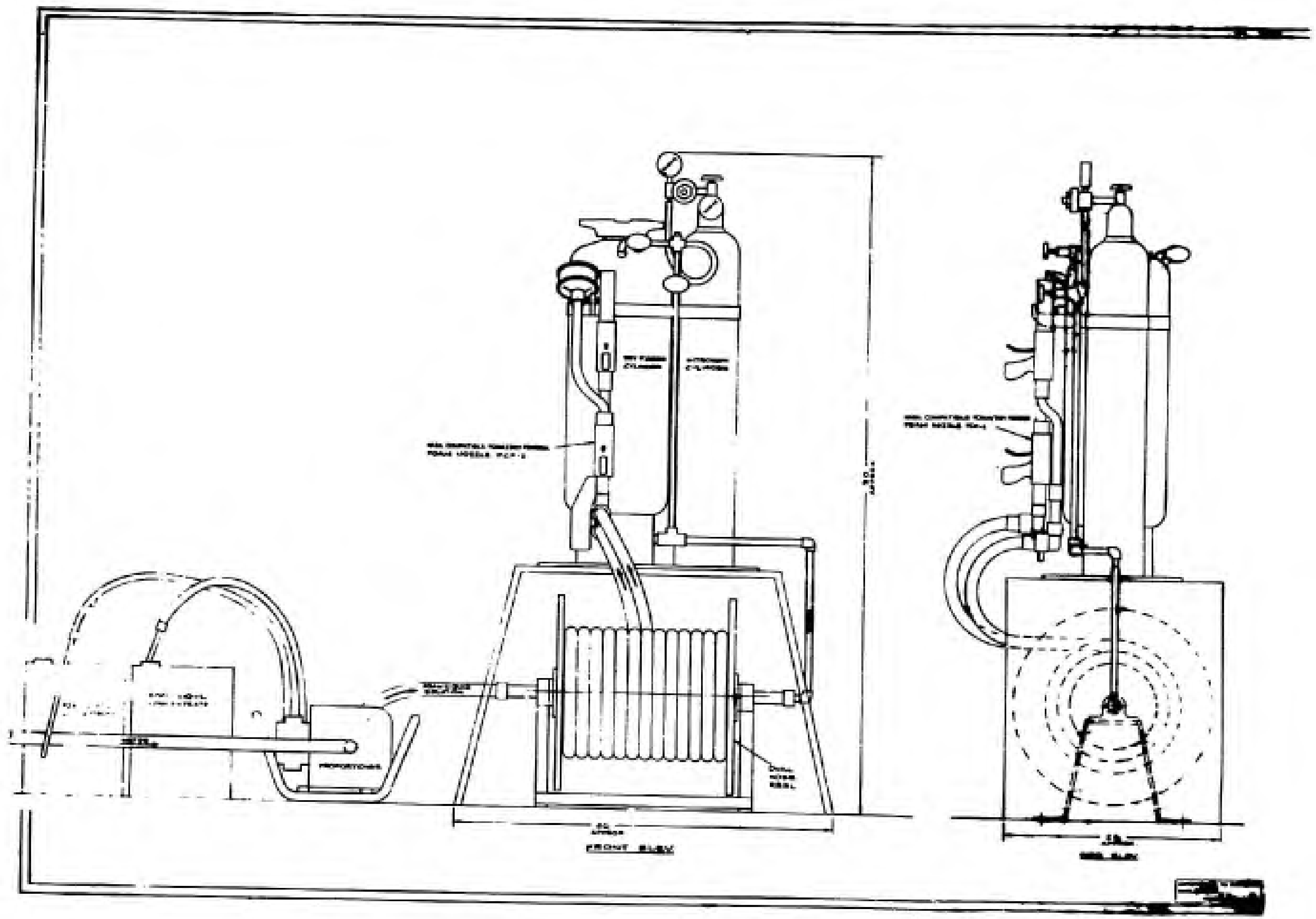

PHOTO L-19920-6

FIGURE 6-NASL COMPATIBLE FOAM/DRY POWDER SYSTEM
ARRANGEMENT I - NASL DWG. SKN-2026

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TABLE 2

NASL-INDOOR "FOAM/DRY POWDER COMPATIBILITY TESTS"

		Burn-Back Method: Time for complete foam destruction, min				Sealability Method: Time for sustained ignition, min			
			$NaHCO_3$	Purple K Powder			$NaHCO_3$	Purple K Powder	
Experimental Liquids Manufacturer	Formulation No.	Control	Powder "A"	"B"	"C"	Control	Powder "A"	"B"	"C"
	XL-6	9.0	8.5	6.1	5.9	13.5	12.2	7.6	7.8
	C110-15	8.3	8.2	5.8	5.9	13.3	11.6	6.8	6.5
	C110-16	8.2	8.2	5.7	5.4	14.9	12.1	6.0	6.1
National Foam System, Inc.	C110-17	8.6	6.9	3.3	3.4	12.9	7.2	3.5	3.8
	C110-18	9.7	4.5	3.0	2.6	12.7	5.0	3.0	3.0
	C110-19	8.6	4.4	2.7	3.0	13.2	5.2	3.6	3.3
	C110-20	9.6	4.2	2.4	2.6	16.1	5.0	1.6	1.6
Conventional Liquids Manufacturer									
D		9.7	4.1	1.9	2.0	10.6	5.3	1.2	1.0
E		9.5	5.7	2.2	2.2	10.3	5.8	0.9	1.2
F		8.4	4.9	1.8	1.9	9.0	6.1	0.9	0.8
G		8.8	4.8	1.9	2.1	10.1	5.0	0.8	0.9
H		8.5	4.0	2.5	2.2	9.8	5.2	1.2	0.8

TABLE 3

NASL-FIELD "FOAM/DRY POWDER COMPATIBILITY TESTS"

		3' x 3' Test				10' x 10' Test			20' x 20' Test	
		5-min burn-back area, ft^2				5-min burn-back area, ft^2			Extinguishment time, min	
Experimental Liquids			$NaHCO_3$	Purple K Powder			Purple K Powder		Control	Foam and Purple K
Manufacturer	Formulation No.	Control	Powder "A"	"B"	"C"	Control	"B"	"C"	(Foam Alone)	Powder "B"
	XL-6	0.6	0.7	0.9	1.0	0.7	0.9	0.8	0.8 (1)	0.45 (1)
National Foam	C110-15	0.6	0.8	1.1	1.0	0.8	1.0	1.1	0.9 (1)	0.5 (1)
Systems, Inc.	C110-16	0.8	1.0	1.2	1.1	0.8	1.1	0.9	1.0 (1)	0.5 (1)
Conventional Liquids										
Manufacturer										
D		0.8	1.4	9.0	9.0	1.1	100	100	1.0 (1)	Not extinguished in 80% of the tests. (2)
E		0.9	1.5	9.0	9.0	1.0	100	100	1.1 (1)	Not extinguished in 80% of the tests. (2)
F		1.0	1.6	9.0	9.0	0.9	100	100	1.2 (1)	Not extinguished in 80% of the tests. (2)
G		0.7	1.6	9.0	9.0	0.7	100	100	Not tested	Not tested
H		0.8	1.4	9.0	9.0	0.8	100	100	Not tested	Not tested

Notes: (1) A satisfactory vapor sealing blanket was provided by the foam.
(2) In the tests wherein extinguishment was effected, no satisfactory vapor sealing blanket was provided by the foam.

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TABLE 4

SUMMARY OF NASL - "FOAM/DRY POWDER COMPATIBILITY TESTS"

	Indoor Tests										
	Burn-back Method			Sealability Method			3' x 3'			10'	
	Time for complete foam destruction, min			Time for sustained ignition, min			5-min burn-back area, ft^2			5-mi[n burn-] back [a...]	
Foam-Liquids	Con-trol	$NaHCO_3$ Powder	Purple K Powder	Con-trol	$NaHCO_3$ Powder	Purple K Powder	Con-trol	$NaHCO_3$ Powder	Purple K Powder	Con-trol	
Compatible (XL-6) Formulation	9.0	8.5	6.0	13.5	12.2	7.7	0.6	0.7	1.0	0.7	
Conventional Liquids	9.0	4.7	2.1	10.0	5.5	1.0	0.8	1.5	9.0	0.9	

Notes: (1) A satisfactory vapor sealing blanket was provided by the foam.
(2) In the tests wherein extinguishment <u>was</u> effected, <u>no</u> satisfactory vapor sealing

A.

TABLE 4

- "FOAM/DRY POWDER COMPATIBILITY TESTS"

...lity Method ...r sustained ...ion, min		Field Tests 3' x 3' 5-min burn-back area, ft^2			10' x 10' 5-min burn-back area, ft^2		20' x 20' Extinguishment time, min	
...CO_3 ...der	Purple K Powder	Control	$NaHCO_3$ Powder	Purple K Powder	Control	Purple K Powder	Control (Foam Alone)	Foam and Purple K Powder
.2	7.7	0.6	0.7	1.0	0.7	0.9	0.8 Note (1)	0.45 Note (1)
.5	1.0	0.8	1.5	9.0	0.9	100	1.1 Note (1)	Not extinguished in 80% of the tests. Note (2)

...t was provided by the foam.
...was effected, no satisfactory vapor sealing blanket was provided by the foam.

B.

TABLE 5

FOAM-LIQUID SPECIFICATION TESTS ON XL-6

	Specified, reference (d)	Value found for XL-6 by NASL
Specific Gravity at 60°F/60°F	1.12 min	1.149
Viscosity, centistokes at 68°F	15 min	27.2
at 32°F	110 max	83.3
pH - concentrate	6.0-7.5	7.1
pH - 6% solution in sea water	6.0-7.5	7.0
Pour Point	14 max	9
Sedimentation, %	0.1 max	<0.05
Precipitation - distilled water, %	0.05 max	none
Precipitation - sea water, %	0.05 max	none
Low Temperature Stability, sedimentation, %	0.2 max	0.1
High Temperature Stability (Note (1)), sedimentation, %	0.2 max	0.1
Iron Content, %	para 3.11	0.37
Drainage Factor	17.5-26.0	24.0
Expansion at 68°F	7.5 min	7.8
Expansion at 41°F	6.5 min	7.2
Fire Tests	para 3.13	satisfactory
Corrosion to Steel, $mg/dm^2/day$	30 max	6.5
Corrosion to Aluminum (Note (2)), $mg/dm^2/day$	15 max	1.5

Notes: (1) The values for specific gravity, viscosity, pH, pour point, precipitation, iron content, drainage factor, expansion and fire performance were found to be unaffected by this test.

(2) Although this test is not part of the current foam-liquid specification, it is understood that it will be incorporated at the time of the next specification revision.