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THE DEVELOPMENT OF A COMBINATION RUNWAY FOAMING-TANKER VEHICLE FOR AUGMENTING NAVAL AIR STATION FIRE FIGHTING OPERATIONS

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ABSTRACT

A vehicle to combine the functions of foaming runways for emergency aircraft landing and serving as a "nurse" truck to resupply water and foam concentrate to aircraft fire fighting vehicles has been constructed. This vehicle is to serve as a prototype to illustrate and define some of the features deemed critical for successful operations. Certain elements are left flexible so that conversions can be made from different large capacity tank vehicles.

Minimum requirements are (a) 3000-gallon water capacity, (b) 600 gpm at 100-psi water pumping capacity and 750 gpm at 15 psi, (c) 200-gallon foam concentrate capacity, (d) 45-gpm foam concentrate pumping capacity, (e) 10-expansion, 8-minute drainage time foam characteristics, (f) a foam laying boom, and (g) a vehicle engine speed tachometer.

A 24-ft-wide foldable boom is used to apply the foam gently on the runway in a readily controlled manner with a minimum of wind interference. A series of graduated hole sizes and baffles in the boom were found necessary to achieve proper distribution over the entire pattern width.

The prototype vehicle carries 3000 gallons of water and pumps at a rate of 600 gpm of foam solution. A strip of foam 24 ft wide can be laid down at a rate of 250 fpm (2.8 mph) for a total distance of 1250 ft, per each waterload. Final foam depth was 1.6 inches. Foam expansion as laid on the runway surface was 10.7 and the drainage time 9.3 minutes.

PROBLEM STATUS

This is a final report on the runway foaming project. Work on other phases of aircraft fire fighting is continuing.

AUTHORIZATION

NRL Problem C08-15
BuWeps SEQ12-001/652-1/F012-05-04

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THE DEVELOPMENT OF A COMBINATION RUNWAY FOAMING-TANKER VEHICLE FOR AUGMENTING NAVAL AIR STATION FIRE FIGHTING OPERATIONS

INTRODUCTION

Background

The spreading of foam on airport runways in preparation for the landing of an aircraft with landing gear difficulties has been the subject of much discussion in the past. The investigation conducted by this Laboratory in 1960 (1) was directed toward finding the fire-prevention capabilities of foam and how it could be used most effectively.

It was concluded that foam could be of value in the suppression of ignition caused by friction-generated metal sparks (1). It was also pointed out that the foam must be of good quality in sufficient depth and without gaps in order to achieve good results. Because of the difficulty in accomplishing this operation with the standard aircraft fire fighting and rescue vehicles, it has not been set down as a standard operating procedure at naval air activities. Specialized vehicles for this purpose have not been generally available except as fabricated on a local basis according to local design.

Since publication of Ref. 1 on foam-covered runways, 73 reports concerning emergency landings because of wheel malfunctions have been examined. Despite the lack of proper foaming equipment, foam was applied to the runway in some manner in all except 23 of the landings and some of these were inadvertent cases with no prior warning time. In the 50 instances when foam was used, only one minor fire occurred and this where the foaming operation was incomplete. In contrast, within the 23 no-foam landings there were 13 fires. Although most of them were not of a serious magnitude, it is believed significant that an ignition did take place. These additional statistics give added impetus toward providing runway foaming capability on naval air stations.

The fire-fighting-agent carrying capacity of aircraft fire fighting and rescue vehicles has always been severely limited because of the need for vehicle performance both in acceleration and off-highway operation. One common attempt at solving this problem has been the use of auxiliary trucks which have greater capacities and which serve to replenish the faster, first-response vehicles at the scene of a fire. The nature of this operation has led to the popular name of "nurse" truck. Here again, as with the runway foaming vehicles, the ingenuity and initiative of many local fire departments have been demonstrated. They have fabricated such trucks locally and in most cases from surplus or salvaged material.

Runway foaming vehicles and auxiliary tank vehicles have two important features in common: the carrying of copious amounts of water and foam concentrate and a means of pumping both at high flow rates. These features make it possible and desirable to combine them both into one vehicle as both functions are not required simultaneously.

The capacity of the vehicle is not fixed by any rule, but it should be capable of carrying at least 3000 gallons of water and 200 gallons of foam concentrate. This is equivalent to three loads of the largest primary vehicle, the MB-1, and can provide the MB-1 with 8 minutes of continuous foam application at a rate of 6000 gpm or a total of 48,000 gallons

of expansion 12 foam. Of course, it is necessary that the nurse truck be capable of transferring both liquids in excess of the output rate of the MB-1, which is 530 gpm water and 30-gpm foam concentrate. Allowing some time for delayed arrival and making the necessary hose connections, the nurse vehicle should have a minimum output of 750 gpm of water at 15 psi and 45 gpm of foam concentrate.

A minimum pumping rate of 600 gpm at 100 psi will also expedite runway foaming operations as rate of area coverage depends directly on the rate of water discharge and foam production. On the basis of 0.1 gallon of water per square foot required to cover the runway surface adequately, a total of 30,000 square feet can be covered by one load of 3000 gallons of water in 5 minutes.

Operational Problems

Many factors other than applying the foam itself must be considered. These have been discussed in other writings (1,2) and are concerned with such things as subfreezing temperatures, other aircraft movements, and availability of foam concentrate. It is generally accepted that plans for foaming a runway should never include use of the primary aircraft fire fighting and rescue vehicles. Full fire fighting capabilities for use after the aircraft has touched down must not be compromised in any way. The flight plans of an aircraft under emergency conditions are usually subject to sudden change and this may lead to being caught with empty or partially filled vehicles should the plane come in ahead of schedule. Therefore, only vehicles over and above the normal required complement should be used for runway foaming.

It can be readily appreciated that a foamed runway and a possible disabled aircraft on its belly on the runway will present a problem in conducting normal flight operations. Even the presence of foam alone creates a delay while it is being cleaned off. The mission and location of the activity play a role in how critical this will be and the emergency foaming concept should be based on a Navy-wide organization. In some areas where a complex of landing fields exists, it would be desirable to designate one field which could handle all runway foaming operations with a minimum of interference to its normal missions. Planes from surrounding fields could be diverted to the emergency field at time of need. It would be even more desirable to organize such a procedure on a military-wide basis to achieve the same objectives - a minimum of interruption to flight operations. Present emergency procedures in civil flying are not well defined at this time. With the exception of a few of the largest metropolitan airports, most pilots feel that military air fields are better equipped to handle emergencies than civil airports and for this reason often try to reach a military field in case of emergency. Here again it would be best to preplan for these occurrences and have a clear-cut, specific instruction as to which military fields may be used when necessary and which military fields should be avoided except for the most dire emergency. Everything possible must be done for an aircraft in distress, but a large jetliner stranded in the middle of a strategic air base duty runway could create another serious crisis.

EXISTING APPARATUS

"MB" Vehicles

The MB-2 and MB-5 vehicles are both completely unsatisfactory as runway foaming apparatus because their foam generating pumps are driven by power takeoffs which preclude moving and discharging foam simultaneously. A towing procedure was utilized during test work (1) but this could not be considered as a recommended field practice.

The MB-1 with its two independently driven foam generating systems is better adapted toward the runway foaming operation. However, its use has three disadvantages: it is part of the primary aircraft fire and rescue force, it is too difficult to apply the foam properly from a turret, and its water-carrying capacity is too low.

From the appearance of the foam discharge pattern of the turrets as shown in Fig. 1, the problem of handling in wind while moving down a runway will be evident. Only one turret turned at 90 degrees to the direction of travel can be utilized. At best, only a spotty, irregular foam covering may be obtained. As a interim measure a system using pouring tubes attached to the turrets was designed (1). A scraper on the rear of the vehicle was used to even any irregularities and hold the foam to a precise depth of 2 inches. Figure 2 illustrates the operation of the modified unit. It has never been adopted for air station use.

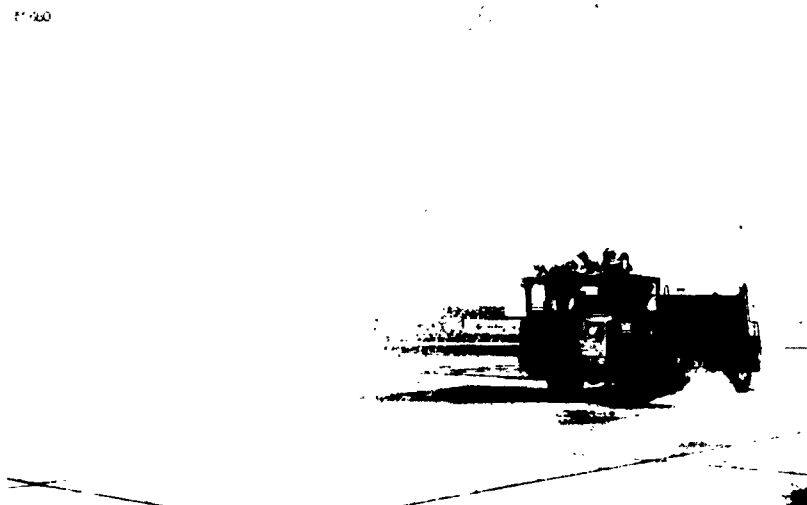


Fig. 1 - A typical spray pattern of foam from turret nozzles of an "MB" series vehicle

Other Vehicles

Figure 3 illustrates a vehicle designed by fire fighting personnel of NAS Alameda, Calif. Foam is discharged from a low-mounted nozzle as shown. The foam is of good quality, but the output volume is low and the ground pattern difficult to control. Figure 4 shows a unit designed by NAS, North Island, Calif. Foam is discharged rearward from two fog-foam-type nozzles mounted at bumper height. The total water-carrying capacity is excellent, the pumping rate fair, and foam quality fair. Figure 5 is the truck designed by NAS, Corpus Christi, Texas. Its total capacity is excellent, ground pattern width very good, pumping rate low, and the foam quality fair. The outrigger booms as used on this version provide a good method of laying the foam down where it is wanted and with a minimum of wind influence.



Fig. 2 - An experimental device for diverting foam from the turrets to a gentle application on the runway surface



Fig. 3 - A tank truck for runway foaming modified by and used by the fire department of NAS, Alameda, California



Fig. 4 - A semitrailer tank truck converted for runway foaming by fire department personnel of NAS, North Island, California

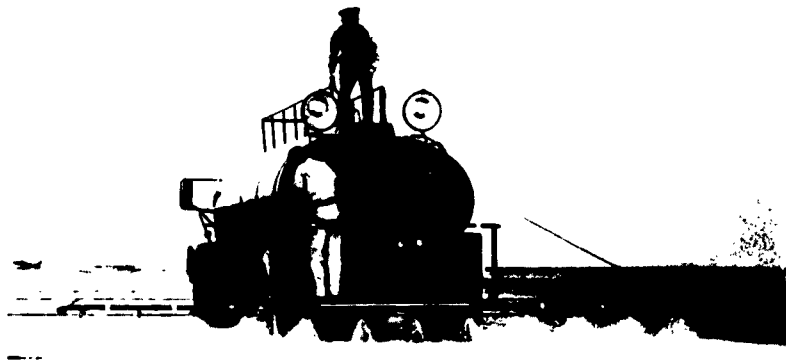


Fig. 5 - Another converted semitrailer tanker. This one was designed and built by fire department personnel at NAS, Corpus Christi, Texas.

CONSTRUCTION OF PROTOTYPE VEHICLE

Because of the aforementioned limitations in existing vehicles for the purpose of foaming runways, construction of a pilot vehicle to illustrate most of the desired features was undertaken. The integration of this unit into the field service is not known and, thus, it was planned to design something which could be supplied as a kit to install on surplus tank vehicles at individual activities. A 3000-gallon-capacity refueler truck was made available by the Bureau of Naval Weapons for the pilot conversion project. All piping and equipment were removed with the exception of the power-takeoff-driven pump which was retained to serve as the foam concentrate transfer pump.

Removal of the existing fuel filters on the back of the vehicle frame left sufficient space to install a skid-mounted engine-pump combination rated at 500 gpm at a 120-psi discharge and a foam concentrate storage tank of 110-gallon capacity (Fig. 6). Proportioning of the foam concentrate into the water at a rate of six percent was accomplished through the use of around-the-pump-type devices. A portion of the pump's output is drawn off and passed through a venturi which serves to induct the foam concentrate into the low-pressure region of the pump suction line. Two venturi units were required to obtain the proper proportioning with the maximum flow rates desired. Individual shutoff valves permit the discharge of clear water or of a six-percent foam solution.



Fig. 6 - Installation of foam concentrate tank and 500-gpm pumper on the rear of aircraft refueler. This area formerly housed the fuel filter system.

The two 2-1/2-inch discharge outlets from the pump were joined together into a single 4-inch manifold which served to supply the aspirating foam-making nozzles arranged across the rear of the vehicle. Two 2-1/2-inch hose outlets and a 4-inch block

valve in this line serve to divert the water flow from the foam makers when it is desired to serve as a nurse truck to other primary aircraft fire fighting and rescue trucks. Details of this piping arrangement are shown in Figs. 7 and 8.



Fig. 7 - Foam concentrate proportioning system and water system piping as installed on prototype vehicle

The power-takeoff-driven pump for foam concentrate has a capacity of 80 gpm. A suction line was provided from the foam concentrate tank and a 2-1/2-inch discharge line terminated at the side of the vehicle as shown in Fig. 9. This permits replenishment of foam concentrate to other vehicles at the same time water is being transferred by the water pump.

UNSATISFACTORY FOAM SPRAY APPLICATION

The first foam application method investigated was the use of aspirating foam nozzles (Rockwood Sprinkler Corp., Model S6610) from a fan-shaped mounting arrangement to cover a path to the rear of the vehicle. It was selected because of the high-expansion and high-drainage-time foam the nozzle was capable of generating and because its output

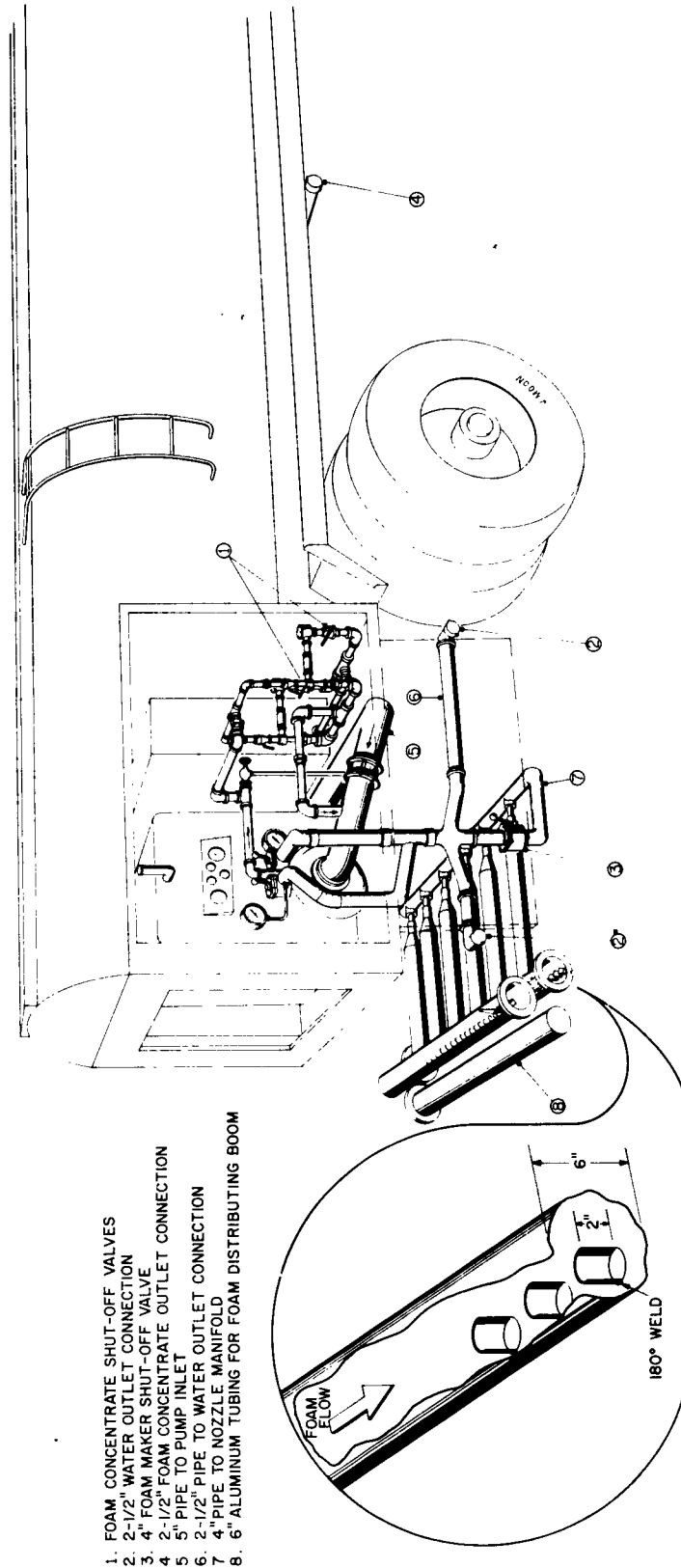


Fig. 8 - Schematic diagram of the complete piping system for the handling of water, foam solution, and foam concentrate as used in the prototype. Inset is a detail of inner baffle construction which deflects the foam straight downward.

pattern could be adjusted to a flat spray stream. The typical ground pattern from a stationary nozzle is shown in Fig. 10 by means of a contour presentation which shows the distribution of foam with the outline area.

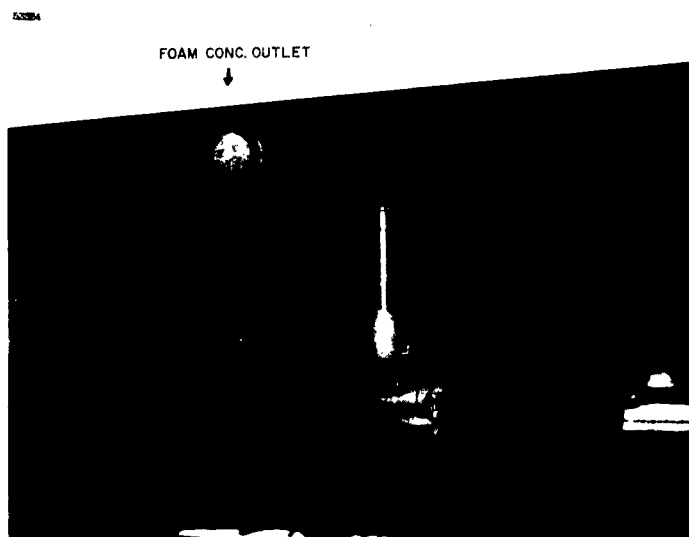


Fig. 9 - Installation of the power-takeoff-driven foam concentrate pump and outlet for hose connection for supplying fire fighting vehicles. This is used only in nurse truck operations.

At this time work was conducted at a 300-gpm-discharge rate to expedite testing. Half the final desired water rate of 600 gpm was used and directed to one side of the centerline of the vehicle with the assumption that it could be duplicated on the other side. One combination of three 100-gpm-capacity nozzles was used to form a strip pattern to one side of the vehicle as it moved down the runway. Figure 11 illustrates the mounting of the nozzles on the vehicle to produce a one-half-width pattern to the port side of the truck. By trial the three nozzles were directed to obtain the best pattern from the vehicle centerline outward to a distance of 24 ft. At a truck forward speed of 200 fpm, the average foam depth should have been one inch based on the nozzles output of expansion-10 foam.

Figure 12 shows the measured values obtained as to foam spread and depth. The overlaid patterns show what the resultant ground patterns should have been for a non-moving, no-wind condition. At the time of the run there was a direct head wind of 900 fpm (10 mph) while the vehicle moved forward at 200 fpm (2 mph). The result of this 12-mph effective head wind was that the pattern was narrowed from 24 ft to 18 ft. This is indicated as "wind effect" in Fig. 12. Above the horizontal pattern plan is shown a profile of the foam depth for the full pattern width. It is seen that the depth distribution was not very uniform, there being a gradual slope from 1/2 inch at the center up to 2 inches at the outside edge. For the pattern width actually obtained the average depth calculated out to be 1.3 inches. This performance was not considered acceptable. It is possible that the further adjusting of the nozzles under the conditions could have improved the distribution; however, it was appreciated how susceptible the patterns were to the vagaries of the winds.

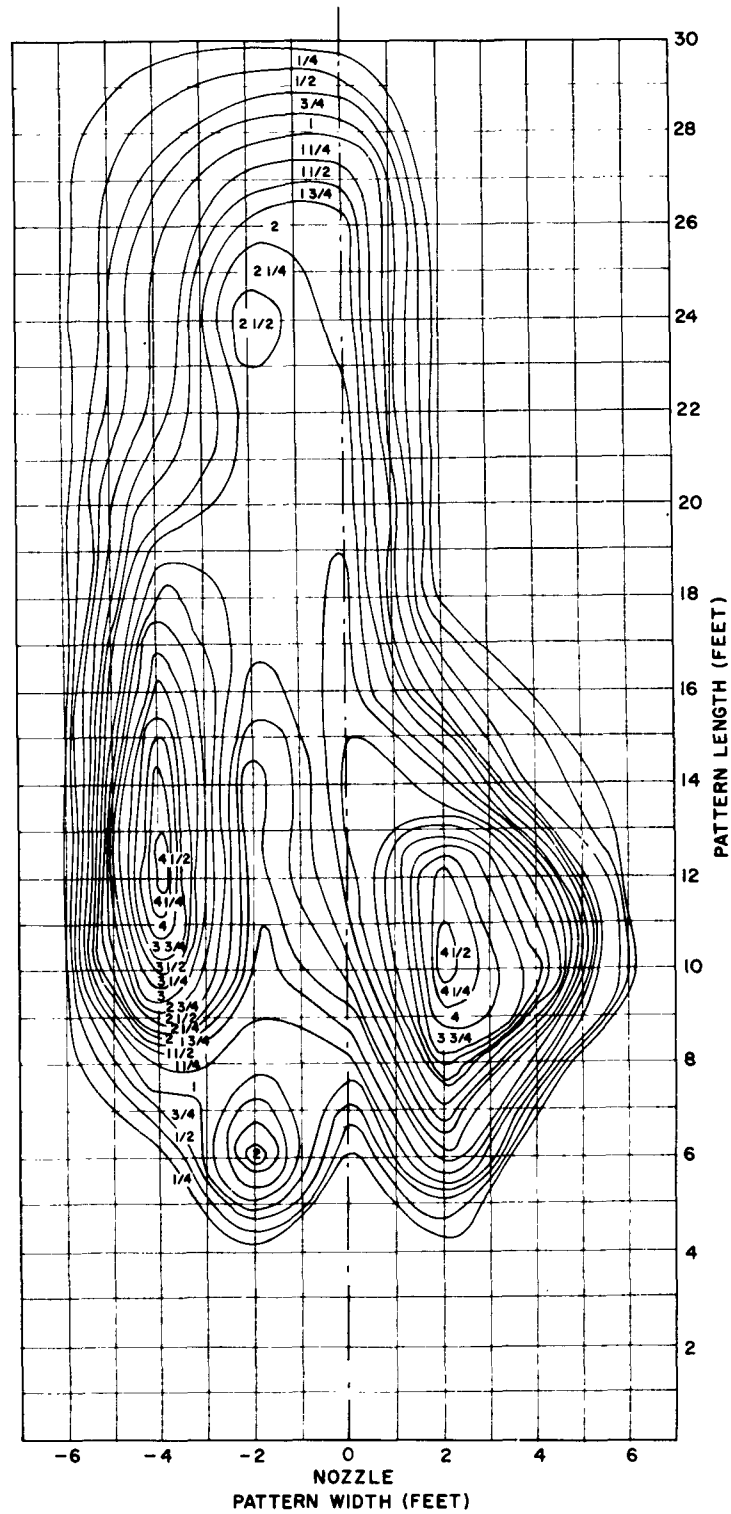


Fig. 10 - A contour pattern of the S6610 nozzle when discharging in a fixed horizontal position from a height of 18 inches and set for full spray. The figures indicate the depth of foam in inches produced in 30 seconds.

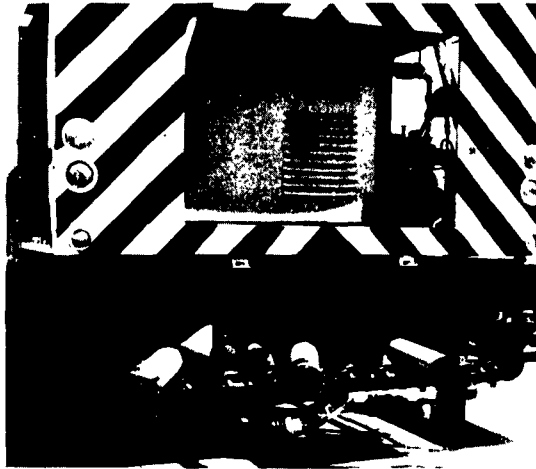


Fig. 11 - Three aspirating nozzles were mounted to discharge a pattern to the rear of the truck during one test trial

A modified version of the three-nozzle system was tried by using five 60-gpm foam makers in an attempt to achieve a more uniform foam strip. The results of this arrangement are given in Fig. 13. Some improvement was found in evenness of distribution but it was still taken to be unacceptable.

FINAL DESIGN USING A BOOM APPLICATOR

The outrigger boom method wherein the foam is gently applied from a low height appeared to offer the best technique for forming the desired foam strip. An extremely short-length foam maker was required when installed vertically because of the limited clearance between the boom and the ground. However, the "zero length" foam nozzles (Fig. 5) are extremely inefficient in generating good stable foams with no barrel to produce proper intermixing of air and foam solution. For example, the Rockwood TF-57 nozzle produces a form of expansion 5 and drainage time of less than two minutes in contrast to the expansion 11 and eight-minutes drainage time of the foam from the S6610 unit. Therefore, it was desired to retain the barreled-type foam maker when using a boom-type applicator. The nozzles were relocated in a horizontal position underneath the truck frame and the outlets were connected directly into an 8-ft-long section of header mounted crosswise at the rear of the truck 12 inches above the ground. In order to permit the laying of a 24-ft-wide foam strip, an 8-ft extension was attached to each end of the header through a swing joint so they could be retracted for normal vehicle side clearance. Figure 14 shows the boom, made from aluminum tubing having 1/16-inch walls, in both the folded and the extended positions.

The asymmetrical location of the five foam makers in relation to the length of the boom and outlet holes made it necessary to equalize the output of foam along the boom. In the first trials, the outlet holes along the bottom of the boom were graduated in three sizes, with the largest diameter at the outer ends. Foam runs showed, however, that this was not sufficient to produce a uniform coverage. The foam velocity through the 6-inch line reached 12 to 15 fps and imparted an appreciable horizontal component to the foam stream as it emerged rather than the straight vertical direction needed for proper distribution. In order to counteract this characteristic, it was found necessary to insert a semicircular baffle on the upstream edge of each hole in the outer portions of the boom. The layout of holes in the boom is given in Fig. 15 and the details of the baffle construction in Fig. 8.

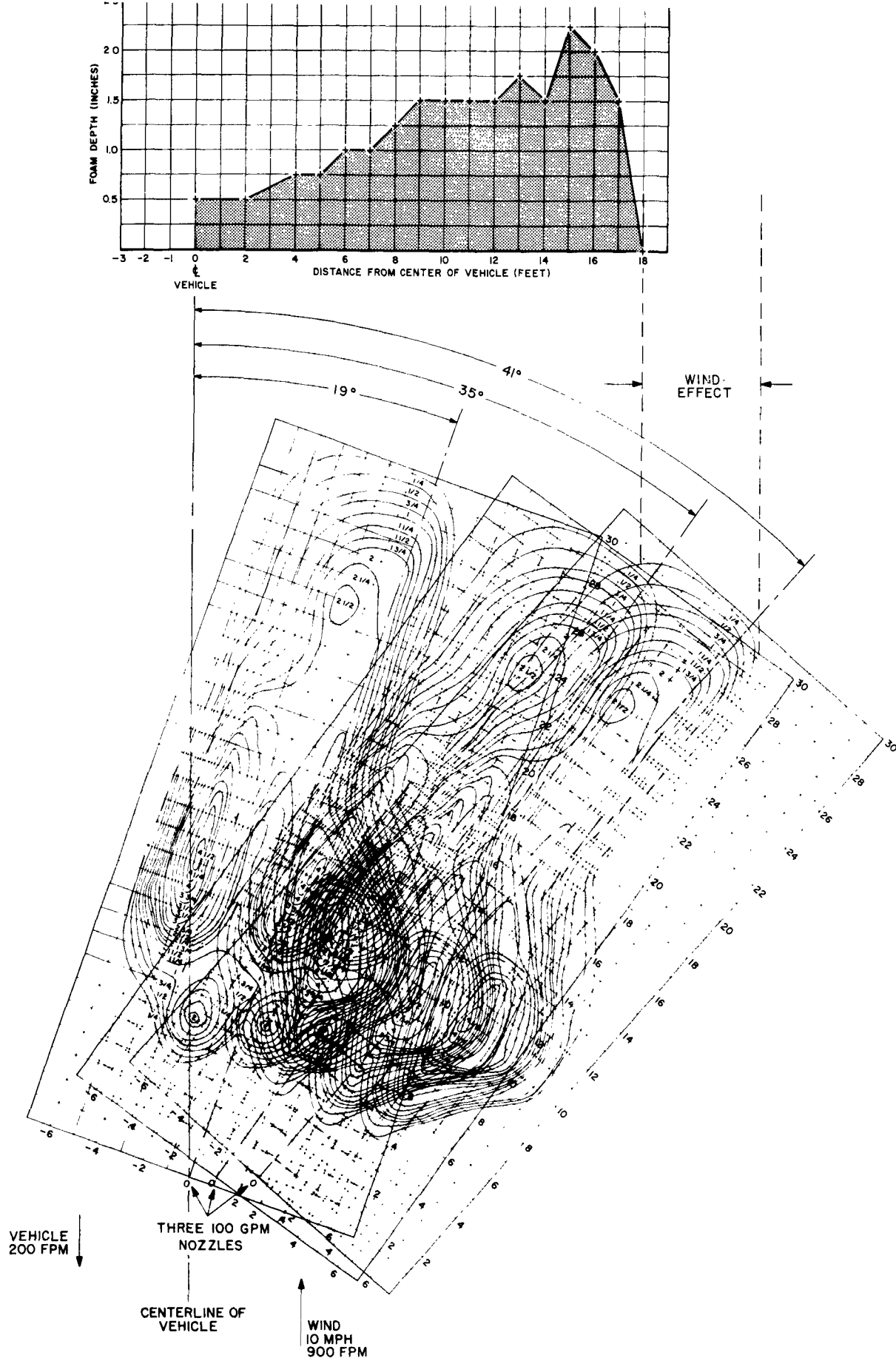


Fig. 12 - Three S6610 nozzle patterns superimposed on one another to give the best foam coverage behind the vehicle. At the top a typical cross section of the foam strip is shown as produced by the vehicle moving forward at 200 fpm into a 900 fpm headwind.

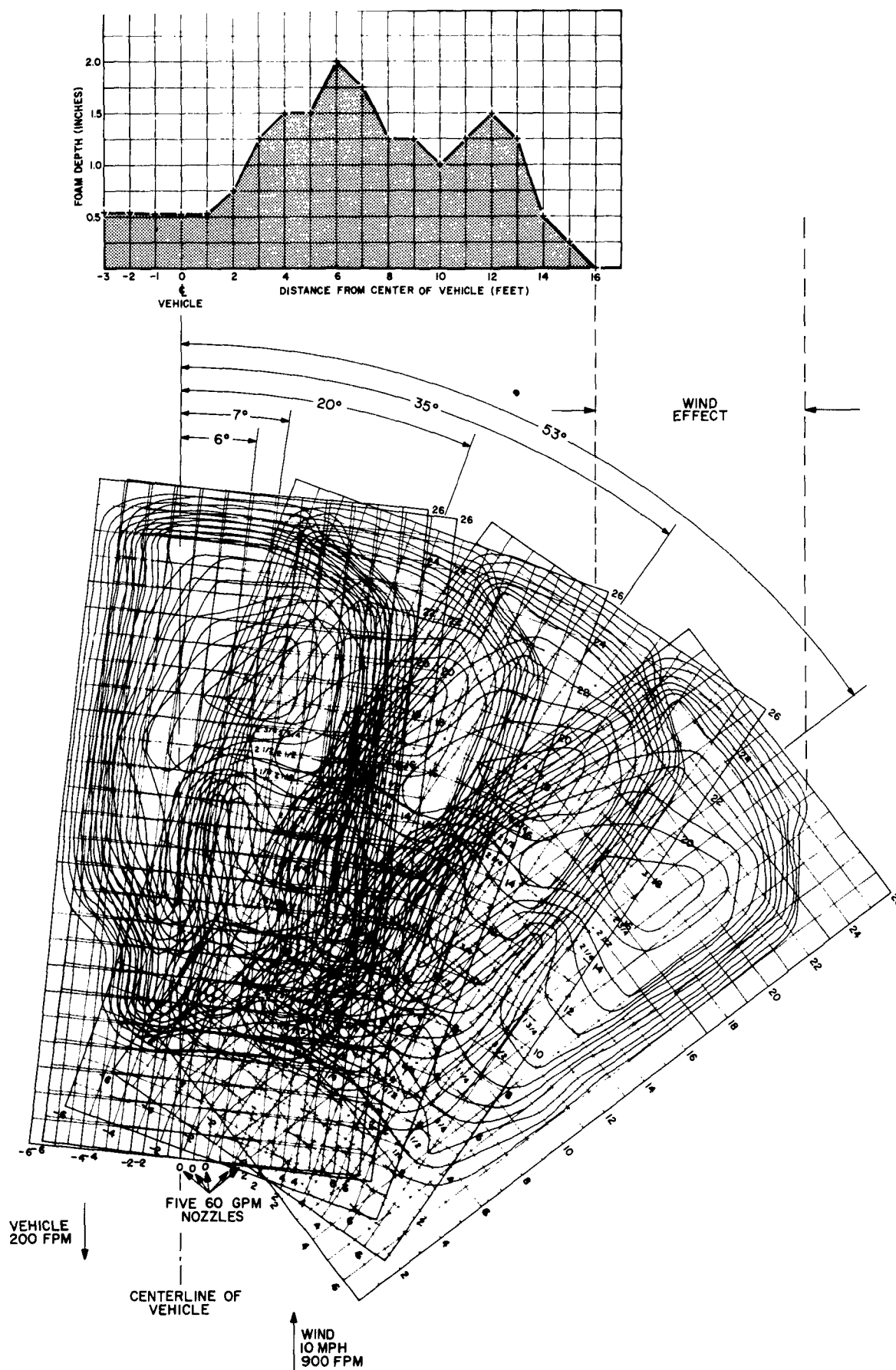
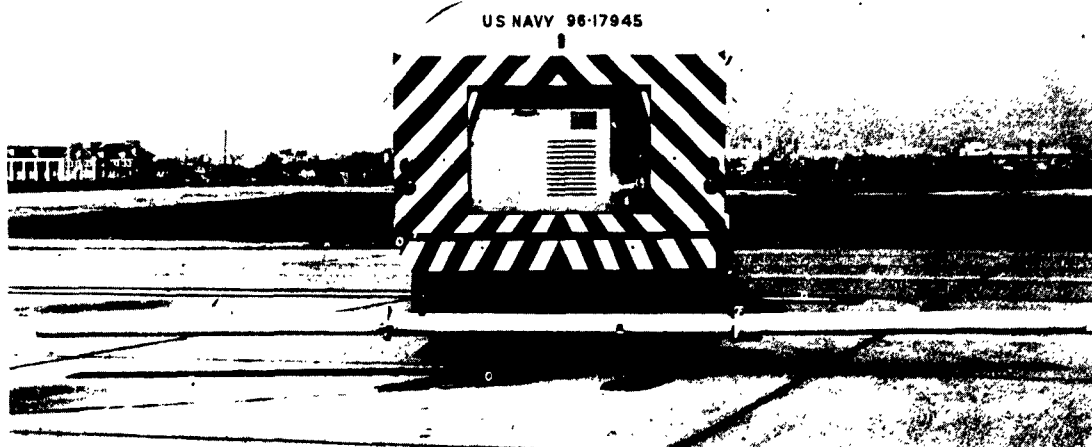


Fig. 13 - Overlapping nozzle patterns and foam strip profile using five 60-gpm nozzles in a fan-shaped array. Vehicle speed 200 fpm into headwind of 900 fpm.

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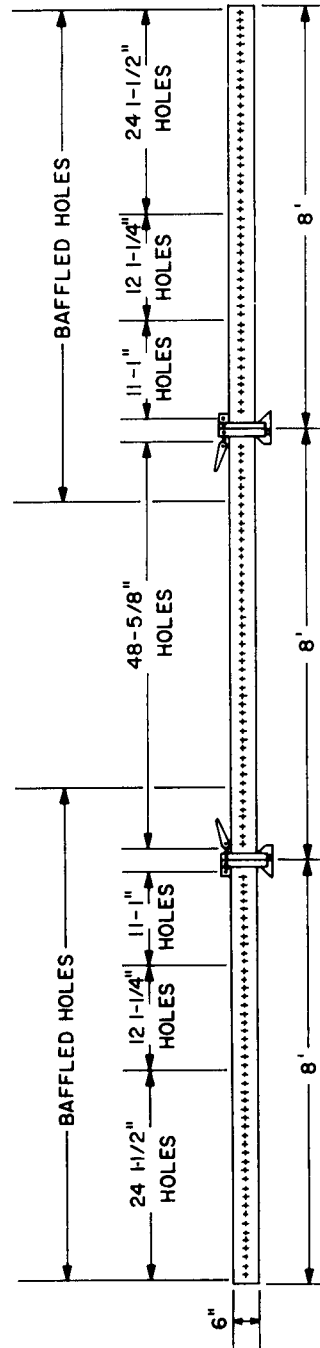


(a)



(b)

Fig. 14 - Final configuration of 24-ft-wide boom in both the folded storage position and the foam laying position



NOTE:

ALL HOLES ON 2" CENTERS

Fig. 15 - Detailed layout of boom showing the dimensions of the graduated hole diameters and locations of baffles in reference to the foam producing nozzles

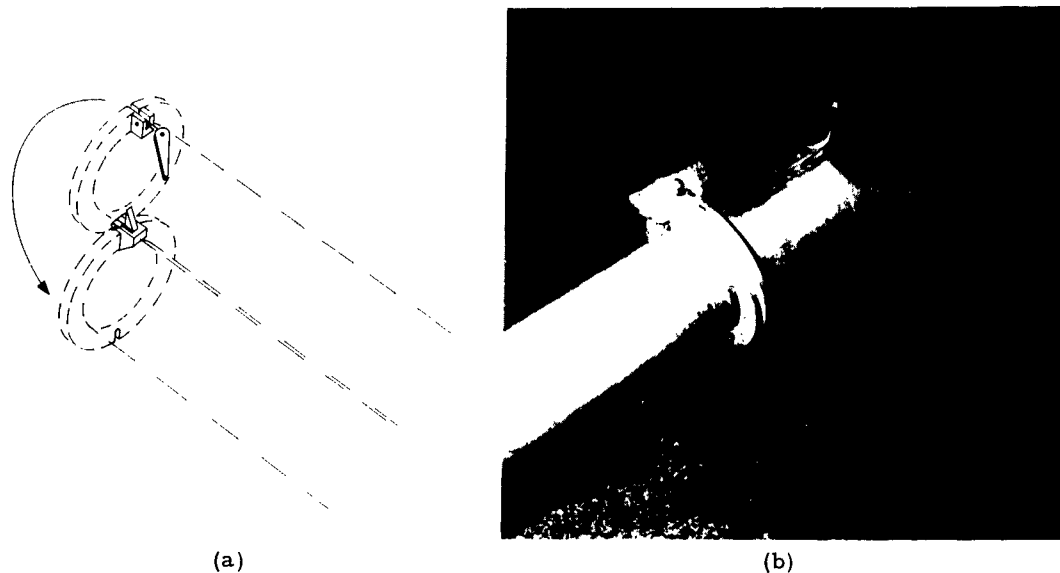


Fig. 16 - Hinge detail which allows the boom to be folded and carried within the vehicle's side clearances

The method of attaching the boom extensions as used is only one of several that could be satisfactory. The objectives were to have something simple and rapid to place in operation. Figure 16 illustrates the details of the hinged flange arrangement finally adopted.

A tachometer was installed in the cab as a guide to the driver for holding the correct speed of the vehicle. For each particular truck and transmission gear ratio, the vehicle's forward speed in fpm can be calibrated against the tachometer reading of engine rpm. This affords a positive means of control of the foam application rate. It will likewise serve as a means of accurately checking the pumping rate of foam concentrate when it is being pumped into other vehicles.

PERFORMANCE OF THE PROTOTYPE VEHICLE

Foaming the Runway

Immediately upon receipt of instructions to foam a runway, the pump engine should be started and allowed to warm up as the truck proceeds to the runway. After arrival at the scene where the foam is to be laid, the booms should be unfolded and secured in the open position. One pump operator and one vehicle driver will normally be used as the crew. The pump operator rides on a platform at the rear where he has ready access to the pump throttle, water valves, and foam concentrate valves. When the appropriate point is reached and the vehicle is operating at the desired speed, he opens the pump discharge valves, opens the pump throttle to hold 100 psi at the foam nozzle inlets, and then turns on the foam concentrate supply. At the end of the desired length of foam strip he shuts down foam production in the reverse order. In some instances it may be desired to form a wider path of foam, in which case the vehicle will turn around and come back while abutting the second strip to the first strip.

The water pumping rate of the prototype vehicle is 600 gpm at 100 psi and the total water capacity is 3000 gallons. Water should be applied in the form of foam to the amount of 0.1 gal per square foot of runway surface. The foam expansion with this equipment is approximately 10, so the volume of foam applied will be 1.0 gal per square foot. Thus, the runway can be foamed at a rate of $600/0.1 = 6000$ sq ft per min and the total coverage per tank load will be $3000/0.1 = 30,000$ sq ft which will take 5 minutes. The full boom will apply a strip 24 feet wide. The forward rate of the vehicle will be $6000/24 = 250$ fpm. This means a strip 24 feet wide will be $30,000/24 = 1250$ feet long per tank load. The average depth of foam over the entire area will be 1.6 inches.

Foam samples taken from the nozzle under its normal operating conditions discharging onto the ground in the pattern shown in Fig. 10 showed the expansion to be 9.7 and the drainage time 8.0 minutes. Foam samples taken from the runway surface of foam discharged through the boom showed the expansion to be 10.7 and the drainage time 9.3 minutes. This indicates that the additional restriction of the piping and orifices on the nozzle outlet actually improved the foam characteristics and output volume. The foam was lower in both expansion and drainage time than that generated by the foam pump in the MB series vehicles. According to the work done under Ref. 1, this present foam should be well suited for the application. It is stable enough to have good resistance to aging and destructive conditions and yet fast enough in drainage time to eliminate any aging time after it has been laid down.

Figure 17 is the profile of the cross section of the foam blanket as laid down with a forward vehicle speed of 250 fpm. This profile should be compared with that of the nozzle applications shown in Figs. 12 and 13.

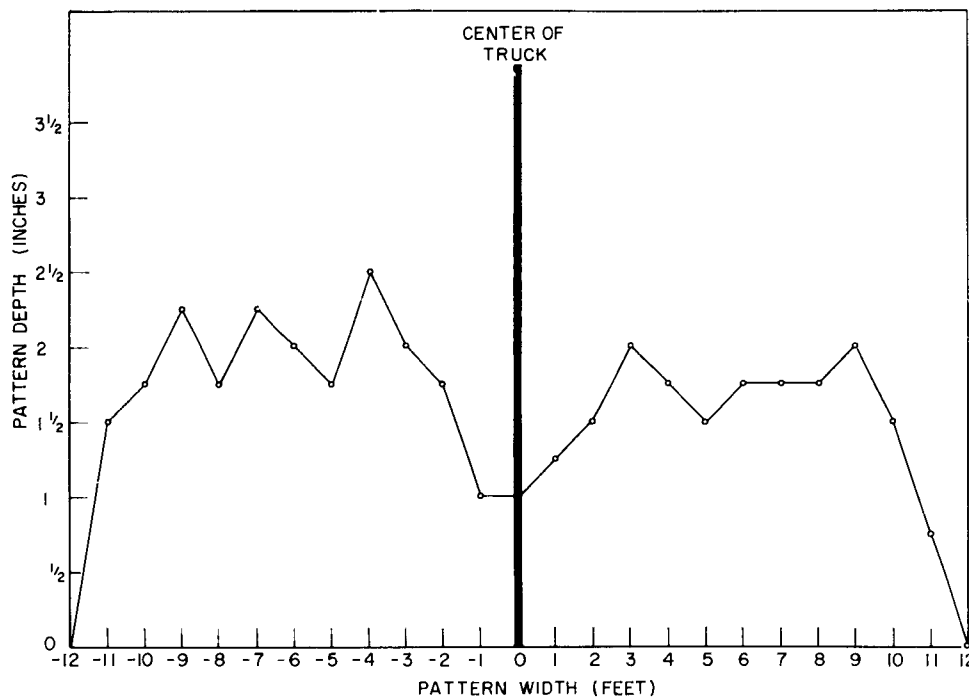


Fig. 17 - Profile of the foam pattern as laid down with the boom. Foam output 6000 gpm, vehicle speed 250 fpm. Compare with profiles in Figs. 12 and 13.

Water and Foam Concentrate Transfer (Nursing Operation)

Two 2-1/2-inch water outlets are provided on the prototype for the connection of hoses to supply other first line fire fighting vehicles at the scene of major fires where the original contents of the trucks may not be sufficient. The MB-1 and MB-5 vehicles have 2-1/2-inch siamese fittings on their fill lines, or supply lines could be led directly into the tank-fill hatches on top of the truck. Since the pump output head required is very low, being only the friction loss in the hose, no difficulty should be encountered in obtaining a flow of 750 gpm. The maximum water consumption rate of the MB-1 is about 530 gpm and, thus, the use of the nurse vehicle is capable of extending the full output period of the MB-1 to 8 minutes to produce a total of 48,000 gallons of foam at an expansion 12 from its 1000 gallons of water plus the nurse truck's 3000 gallons.

The maximum water consumption rate of the MB-5 is 265 gpm so the nurse vehicle could provide a 16-minute-long continuous operation. Alternatively, if desired, it could resupply two MB-5's with water simultaneously.

The foam concentrate consumption rates are 30 gpm and 15 gpm with the MB-1 and MB-5 respectively. The prototype's pumping capacity of 80 gpm is more than adequate to meet the requirements.

DISCUSSION

The experimentation has firmly established that the only feasible method of applying foam is by pumping it through a distributing boom directly over the runway. Applications from turrets or nozzles have been found to be too haphazard and incapable of producing the carefully controlled, continuous pattern needed. A minimum of skill and training is needed when using a boom type spreader. After flow has been started by opening four quarter-turn valves, it is only necessary for the driver to watch the tachometer, and an almost perfect pattern will result irrespective of any but the most severe wind conditions.

The vehicle construction described in this report was accomplished on a surplus unit which was conveniently available. Other trucks may do just as well or may possess advantages not now realized. The main objective of this project was to demonstrate the important principles and to serve as a guide for others to fabricate vehicles for the same purposes. Unusual local conditions may also influence the final design. In order to produce a vehicle acceptable as a first-rate runway foaming and nurse truck the following criteria should be met:

1. 3000-gallon water capacity
2. 600 gpm at 100 psi and 750 gpm at 15 psi water pumping capacity
3. 200-gallon foam concentrate capacity
4. 45-gpm foam concentrate pumping capacity
5. 10-expansion, 8-minute, drainage time foam characteristics
6. A foam laying boom in accordance with this report
7. A vehicle engine speed tachometer

In most cases it will be desirable to subdivide a portion of the water tank with a bulkhead to form the foam concentrate tank of adequate capacity. This compartment should be fitted with the necessary drains, valves, and piping to permit draining the foam concentrate, flushing the tank, etc. Some type of foam can opener and device to minimize frothing during filling should be employed. A small water line connected into the foam-concentrate-pump suction line just downstream from the shutoff valve would be helpful in flushing the pump after use without having to drain the tank.

If the final vehicle's pumping rates are appreciably different from those in the prototype, then the proper vehicle speed should be computed. The proper rate of application of water is to be 0.1 gal/sq ft. For expansion-10 foam output the foam rate will be 1.0 gal/sq ft, and foam depth 1.6 inches. If the carrying capacity of the tanks is different from the prototype, the values for area of coverage must also be recomputed. Coverage is based on 0.1 gallon of water (applied as foam) per square foot.

Foam can be readily washed off the runway using the same vehicle. By discharging only clear water through the foam nozzles and out the boom the foam is floated away to the edges of the runway. The vehicle should move down the same path as when it was laying the foam and at about the same speed.

CONCLUSIONS

A combination runway foaming and nurse unit for the support of fire fighting and fire prevention operations at naval air stations can be conveniently constructed as a single vehicle. The liquid capacity requirements and pumping rates are compatible for both purposes.

A boom for gentle application of foam over the full width of the pattern is the most satisfactory method of applying a uniform, continuous pattern with a minimum of skill and influence from wind.

RECOMMENDATIONS

It is recommended that the Bureau of Naval Weapons establish a standard policy on the use of foam on runways and that the field activities be instructed accordingly.

It is further recommended that the Bureau of Naval Weapons establish an allowance for a combination runway foaming and nurse truck for each naval air station. Each vehicle should meet the requirements and general configuration of the prototype described in this report. Where surplus tank vehicles are available, kits could be furnished for installation on a local basis.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Mr. J. W. Porter for his valuable contributions in the construction and testing of the prototype. The sheet metal and plumbing shops of the Laboratory provided a great amount of assistance in the design and fabrication of the final vehicle.

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Minimum requirements are (a) 3000-gallon water capacity, (b) 600 gpm at 100 psi water pumping capacity and 750 gpm at 15 psi, (c) 200-gallon foam concentrate capacity, (d) 45-gpm foam concentrate pumping capacity, (e) 10-expansion, 8-minute drainage time foam characteristics, (f) a foam laying boom, and (g) a vehicle engine speed tachometer.

A 24-ft-wide foldable boom is used to apply the foam gently on the runway in a readily controlled manner with a minimum of wind interference. A series of graduated hole sizes and baffles in the boom were found necessary to achieve proper distribution over the entire pattern width.

The prototype vehicle carries 3000 gallons of water and pumps at a rate of 600 gpm of foam solution. A strip of foam 24 ft wide can be laid down at a rate of 250 fpm (2.8 mph) for a total distance of 1250 ft per each water load. Final foam depth was 1.6 inches. Foam expansion as laid on the runway surface was 10.7 and the drainage time 9.3 minutes.

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