NRL Report 6461

Engineering Observations on an MB-5 Aircraft Fire-Fighting and Rescue Vehicle

H. B. Peterson and R. L. Gipe

Engineering Research Branch
Mechanics Division

October 28, 1966

NAVAL RESEARCH LABORATORY
Washington, D.C.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

CONTENTS

Abstract	ii
Problem Status	ii
Authorization	ii
INTRODUCTION	1
TEST RESULTS	2
Water Feed Rate	2
Foam Output	2
Vehicle Acceleration	2
Foam Pump Operation	2
DISCUSSION	2
Water Feed Rate	2
Foam Output	3
Vehicle Acceleration	3
Foam Pump Operation	4
Pumping Under Heavy Engine Load Conditions	6
Vehicle Inspection	7
Future Procurement	7
Additional Findings	7
CONCLUSIONS	8
RECOMMENDATIONS	9
ACKNOWLEDGMENTS	9
REFERENCES	9
APPENDIX A- Recent Test Results with Improved MB-5 Vehicle	21

ABSTRACT

A production MB-5 aircraft fire-fighting and rescue vehicle was taken from the manufacturer and instrumented to record simultaneously engine speed, road speed, and foam pump speed. The vehicle was then subjected to maximum acceleration runs and simulated fire-fighting operations wherein the vehicle was maneuvered while the foam system was being operated. With the vehicle in its "as-received" condition the fire-fighting system was erratic in performance and completely unsatisfactory. Adjustments by the vehicle manufacturer and the engine manufacturer greatly improved its performance. Operation is still not fully satisfactory because of low water feed rate to the foam pump, hazardous overspeeding of the foam pump, and engine surging while operating on the pumping governor. Numerous other items not in compliance with the purchase specification were found. Improved specifications and inspection procedures are desirable for future procurements.

PROBLEM STATUS

This is an interim report. Work on the problem is continuing.

AUTHORIZATION

NRL Problem C08-15
Project SEQ-621-001/652-1/F012-05-04

Manuscript submitted July 18, 1966.

ENGINEERING OBSERVATIONS ON AN MB-5 AIRCRAFT FIRE-FIGHTING AND RESCUE VEHICLE

INTRODUCTION

By memorandum of 11 March 1965, the Naval Research Laboratory, Code 6220, requested from the Bureau of Naval Weapons* (SEQ) the loan of one of the new MB-5 vehicles then going into production at the plant of American-LaFrance in Elmira, New York. The primary purpose of this request was to obtain one of the new vehicles for test and evaluation because it contained new engineering features, such as a new power train to permit foam system operation while maneuvering the vehicle, hitherto unknown on this unit. It was also desired to compare its performance with the three predecessor versions of the vehicle, all of which had been studied previously by this Laboratory: the Ward-LaFrance straight stick model, the Marmon-Harrington automatic transmission, and the turbine conversion.

SEQ concurred with the request but stated it could not be made available until late June or early July. The subject vehicle actually arrived at this Laboratory on 2 November.

Because the area of greatest interest centered around the main foam system and its drive arrangement, the essential elements consisting of the foam pump, the vehicle engine, and the axle drive shaft were instrumented for simultaneous recording. A gear fitted to the end of the shaft of the foam pump supplied a source of magnetic pulses to a converter which read out in a dc signal proportional to rpm. A similar type transducer was mounted on the propeller shaft of the vehicle, and a third pickup was connected into the drive engine distributor. All output signals were fed into a Honeywell "Visicorder" high-speed oscillograph which was driven by an auxiliary generator carried on the top of the vehicle. After carefully calibrating the newly installed instrumentation, the vehicle was driven through representative fire-fighting operations while recording the speeds of the three components under scrutiny.

The rate of water feed to the foam pump was not included in the original test plan. However, during the routine check out of the water flow preparatory to conducting the foam generation tests, it was discovered that the water flow appeared to be low and this area was investigated more thoroughly.

A complete series of runs was made on the vehicle as it was received directly from the manufacturer. Because of the poor performance found in some operations, additional runs were conducted for the purpose of verifying the initial data. In the process of doing this it was found that not only were the operations very erratic and not capable of duplication, but the general level of performance was also steadily deteriorating. At this stage assistance was sought from the manufacturer to make adjustments to enable continuance of the evaluation. After adjustments had been made by the vehicle manufacturer and the engine manufacturer, reruns of earlier tests were made.

*Now the Naval Air Systems Command.

TESTS RESULTS

Water Feed Rate

The observed water feed rates to the foam pump are plotted in Fig. 1.* These were determined by measuring the rate of drop of the level in the water tank in 20-gal increments against time while pumping and averaging the results from a number of runs. Pump speed was approximately 1350 rpm for all runs from which the data was taken.

Foam Output

With the vehicle in a standing position, the pumping governor was pulled out and the engine allowed to come up to equilibrium speed; shortly thereafter the foam pump was engaged. Foam samples were taken from the ground at six different intervals during the discharge period and analyzed by standard procedures. The stream pattern control was changed each 20 sec from the straight stream setting to the full spray setting and vice versa. The results of this test are plotted and summarized in Fig. 2.

Vehicle Acceleration

All-out acceleration runs were made with the fully loaded vehicle by flooring the accelerator on a level stretch of roadway. Engine and vehicle speeds are plotted against time in Fig. 3.

The effect of the pumping governor, when engaged, on the vehicle's road performance is shown in Fig. 4. The governor was engaged by pulling out the control handle and the vehicle allowed to accelerate freely. The floorboard accelerator was not touched during the run. Acceleration curves before and after adjustments by the field engineer are included.

Foam Pump Operation

Foam pump operation and operating characteristics in the light of the new power train were studied by several approaches. The first was to determine what would happen while pumping foam with the road drive engaged, if the brakes were released by the driver. The results are shown in Fig. 5 for the vehicle as received. A second observation was made on the reaction when the foam pump was engaged while the vehicle was moving. This duplicates the situation wherein foam is applied as the truck approaches the fire after a long run. These relationships are given in Fig. 6. A third observation was made on the foam pump speed variation and governor control when the transmission was engaged and the vehicle moved forward while pumping. These relationships are given in Fig. 7.

A final overall summarizing run was conducted during which a full load of water and foam concentrate were discharged while the vehicle was being intermittently maneuvered in a simulated fire-fighting manner. Records of the results are shown in Fig. 8.

DISCUSSION

Water Feed Rate

The foam pump is of the positive displacement type with the suction open to atmosphere and, therefore, the foam output, and the fire-fighting efficiency of the entire vehicle as well,

*Figures 1-8 appear at the end of the main text preceding the appendix.

are directly dependent on the correct water flow rate to the foam pump and the correct foam pump speed. The current MIL specification (1) governing this truck states that the combined water-foam concentrate flow to the pump shall average 240 gpm. Based on a normal concentration of 6 percent, the water flow alone should then average 225 gpm. Water feeds from its tank to the foam pump inlet by gravity and the flow rate is thus subject to the normal falling head variation. This fact makes it difficult to specify exactly how the flow rate should be determined. In order to minimize this variation, the manufacturer is encouraged to use water tank dimensions and a foam pump location which will minimize flow rate drop-off (para 3.3.15.1, Ref. 1) by keeping the relative liquid head change as low as possible.

The water flow rates as given in Fig. 1 show two characteristics which have not been observed before in the MB series of fire-fighting and rescue vehicles. One is the almost level rate of flow during a large period of tank discharge and the second is the increase in flow rate as the water level nears the bottom of the tank. Neither of these is consistent with the nature of a falling head discharge. The even rate of flow throughout most of the run, of course, is highly desirable but has not heretofore been achieved.

At the start of a run the flow rate surges for about 20 sec before settling down. It can be seen, however, that the overall rate is below the required average water flow 225 gpm by approximately 10 percent. Attention is invited to Ref. 2, wherein low water flow rates were pointed out to the vehicle manufacturer by the foam pump manufacturer because of tank design changes between the prototype vehicle and the production vehicles.

There is no orifice in the water suction line to control the water flow; it is presently full bore. The suction line hose does have a kinked bend in it which might be restricting the flow. The "as-received" water feed rates observed were not affected by any of the adjustments made by the field engineer.

Foam Output

The erratic nature of the performance of the subject vehicle made the evaluation a very frustrating experience. Many times after going to great lengths to collect an accurate set of data, it was found that the truck would not operate in that manner again. The problem centered around the new power train and the uncertain relationship of speeds between engine, vehicle, and foam pump. During the service engineer's check it was found that a slipping clutch in the foam pump drive was allowing variable pump speeds even when the engine speed was constant. In addition, the pumping section of the engine governor was not maintaining adequate control over the engine speed.

After adjustments, the results shown in Fig. 2 were obtained. The foam pump was operating under what is believed to be its "normal" or designed speed, although its speed, of 1360 rpm does not agree with that of 1200 rpm given in the vehicle instruction manual (NAVWEPS 19-25-124) in Sections 1-35 and 3-15.

The 10-sec delay in attaining a stabilized pump speed after clutch engagement was somewhat excessive. Once the pump speed did come to equilibrium, however, the foam-making operation was well controlled and the foam output met the specification requirements. The higher than usual pump speed, combined with the lower than average water flow rate, produces a foam higher in expansion and flow resistance than desired for optimum fire fighting.

Vehicle Acceleration

The acceleration rate of the vehicle reaching 50 mph in 21 sec and 60 mph in 34 sec (Fig. 3a) meets specification requirements. The shift points within the automatic

transmission are clearly evident. The maximum acceleration curves for the four versions of the MB-5 are all given in Fig. 3b to enable the comparison for maximum performance.

The original concept of using the foam pump while simultaneously moving the vehicle embodied a restriction on the vehicle's road speed when the foam pumping governor was engaged in order to forestall unduly hazardous operations at the scene of a fire. It would normally be expected that the pumping governor holding a properly restricted engine speed when engaged would likewise control a maximum road speed.

If the acceleration curve from Fig. 4 for the vehicle as received is compared with the curve of Fig. 3a, it is seen the results are almost the same. This meant that the vehicle acceleration effected by pulling out the control handle to obtain correct foam pump speed was identical to that effected by flooring the accelerator pedal. Because a pumping operation is normal as the driver approaches head-on to a burning aircraft or spill fire, and at only a few feet distant, it created a potentially hazardous situation.

The service engineer found that improper linkage adjustment in the governor control system was not preventing the transmission from upshifting out of third gear, which in turn permitted the high road speed. After adjustments a second acceleration run was made and it is also shown in Fig. 4. By restricting both the top engine speed and the transmission from shifting, the top road speed is held down to a maximum of about 12 mph. This provides a much safer type of operation, but the driver must still be alert and maintain brake pedal pressure to restrict vehicle movement.

Foam Pump Operation

As discussed previously, correct pump speed is as essential to good foam production and good fire-fighting as correct water feed rate. The dangers involved in overspeeding of the foam pump were also considered when an amendment to the basic specification was made requiring a device to prevent engagement of the pump at engine speeds which would result in pump speeds in excess of the manufacturer's maximum allowable speed (3). Further pump protection was provided by further specification revision (4), which not only required prevention of high-speed pump engagement but also any operating pump speeds exceeding the manufacturer's maximum allowable rpm.

By another later change (5) the requirements of Ref. 3 were modified to eliminate the need of a "device" to prevent high engine speed engagement of the pump; however, the requirement for the pump overspeed device still remains through Ref. 4.

The current vehicle is provided with dual speed governors: one to limit maximum road speed and one intended to maintain the proper foam pump speed during fire-fighting operations. The latter governor function is brought into play by pulling out the hand throttle control handle adjacent to the driver's right-hand side. This is normally done prior to engaging the pump and permits the engine to come to the correct pumping speed. This type of operation is illustrated by the data in Fig. 6. The driver may or may not have the vehicle road drive engaged at the time the pump governor is engaged, depending on the fire-fighting situation. In Fig. 5 are shown the data from a run starting with the vehicle stationary road drive engaged and the pump governor control pulled out. At zero time the foam pump was engaged and allowed to come to equilibrium speed of 1400 rpm. At 4 sec the vehicle brake pedal was released and the vehicle began to accelerate rapidly until the driver broke off the run at 35 mph. The foam pump also began to accelerate in speed, together with the vehicle, until it reached a speed of 1830 rpm, at which time it ceased operation of its own accord. This run illustrates two potential dangers inherent in the present power train arrangement when the foam and fire-fighting operations are underway, unless all linkage adjustments are properly maintained. One is the tendency of the vehicle to "run away" unless diligently controlled by the driver, and the second is the lack of control over excessive foam pump speed.

It was found that certain of the above undesirable characteristics could be eliminated by proper adjustment of linkages within the control system. One adjustment made insured a maximum main engine speed of 1800-2000 rpm by regulating a secondary butterfly throttle valve. A second adjustment insured a wide open main butterfly valve, which in turn prevents the transmission from shifting out of third gear and thus holds down the vehicle road speed to about 12 mph. Examination of the "after adjustment" curve in Fig. 4 shows that satisfactory vehicle speed control could be achieved by the system design. Although the foam pump speed is not shown in Fig. 4, the engine speed characteristics are indicative of the proper pump speed.

The vehicle instrument panel is placarded against engaging the foam pump at road speeds in excess of 10 mph and engine speeds of 1700 rpm. (After adjustments by the field engineer, the governor setting holds an engine speed of 1900-2000 rpm, which is in direct conflict with the warning placard.) Because of the location of the pump drive PTO, the vehicle speed has no direct bearing on pump speed. However, engine speed is directly proportional to pump speed, and speeds in excess of 1780 rpm will overspeed the pump. At 1780-rpm engine speed the pump speed will be 1400 rpm, the maximum allowable by the pump manufacturer.

Some method of preventing high-speed engagement of the pump would be desirable for two reasons: first, to prevent overspeeding and damage to the pump from high engine speeds, and second, to forestall blow-back of foam, with resultant blinding of the turret operator and vehicle windshield, from high-vehicle speeds. The turbine conversion MB-5 had a good system for minimizing unsafe operations. It was not possible to engage the foam pump unless the transmission was in neutral or, if it was in gear, unless the brake pedal was being depressed. Also the pump could not be engaged when the engine speed was too high for correct foam generation.

In the case where the foam pump was engaged while the truck was still approaching the fire, Fig. 6, it was found that the performance was satisfactory after the adjustment had been completed. The engine governor maintained good control over the vehicle speed after its engagement. When the foam was called for, the governor brought all elements to proper speeds within a short time period and with a minimum of "hunting."

A variation of the above operation is also frequently encountered in the field, i.e., engagement of the transmission while pumping foam. The curves in Fig. 7 indicate a brief overshoot of engine speed when the pumping governor was engaged and again when the foam pump was engaged. A much more serious condition developed, however, when the transmission was engaged and the load of moving the vehicle was imposed on the engine. The pump speed dropped below the minimum acceptable operating speed for a period of 4 sec and reached a low point of 360 rpm below minimum. This was followed by a surge of engine speed which carried the pump over its maximum allowable for a period of 9 sec and reached a peak of 510 rpm above maximum. The time period of 14 sec for the pump to return to an equilibrium condition accompanied by a pump speed variation of 970 rpm is considered to be excessive for a maneuver of this nature; fire-fighting capability suffers, and the pump is endangered.

For the run of Fig. 8 a simulated speed governed approach to the fire was used. With the vehicle at 10 mph, the pump control throttle was pulled out and at 22 sec the foam pump was engaged. From then on the vehicle pumped and maneuvered intermittently until the agents were exhausted. The speed control during the approach portion of the run was not as good as that illustrated in the previous figure. Equilibrium was never established as the engine kept surging until the brakes were applied and the vehicle brought to a full stop. During these surge periods, the foam pump was operating at speeds above its safe maximum of 1400 rpm for periods of about 5 sec, reaching peaks of 2000 rpm. In addition to these hazardous operating conditions, the foam output was varying widely in nature with the pump going from 2000 to 1000 rpm. Similar surges occurred at several points during the remainder of the run, although they did appear to dampen out fairly well after putting the vehicle into motion either backward or forward.

The pump overspeed and underspeed ranges as designated on Figs. 7 and 8 are based partially on the pump manufacturer's limits and partially on the installation design. The top speed limit of 1400 rpm is the pump manufacturer's maximum for safe pump operation. The bottom speed limit of 1300 rpm in this case represents the limit for allowable speed variation down from a top of 1400 rpm. These speeds are all high in comparison to what would be considered a "normal" pump installation and what has been used on past MB-5's. The pump's rated speed is 1200 rpm and the maximum speed variations permissible during foam making operations is 1200±100 rpm.

The observed variations denoted in Fig. 7, 1350 rpm plus 560 or minus 410, represent 42 percent over and 30 percent under the equilibrium speed as installed. This total variation of over 70 percent in pump speed is much too high for acceptable operation.

It is believed that a potentially hazardous condition exists when it is possible to run the foam pump at speeds of up to 2000 rpm. The pump was not designed for this speed and is in possible danger of disintegration. A failure within the cab, where this pump is located, could endanger the crew. The pump manufacturer puts the top permissible speed at 1400 rpm (6). Reference 6 also cites an occasion where they inspected another vehicle made under the same contract and presently assigned to NAS, Dallas, Texas. Here, pump speeds of 2200 rpm were found. Written approval from the pump manufacturer as to the installation should be sought from the prime contractor.

The poor condition in which the test vehicle was found is cause for concern over the other units delivered under this contract. The experience of NAS Dallas indicates that it is not confined to one vehicle. Steps should be initiated immediately to check all outstanding trucks for proper adjustment of the control system. It is believed that the present instruction manual supplied with the vehicle treats this subject inadequately. Specific and detailed guidance should be given each user and each district fire marshal. This should include:

1. The pump governor control when engaged shall hold an engine speed of 1700-1800 rpm at all times whether pumping foam, moving the vehicle, or a combination of both.

2. The pump governor control when engaged shall prevent the transmission from upshifting out of third gear and shall prevent a forward vehicle speed in excess of 13 mph at all times without brake application.

3. The pump governor control when engaged shall hold a pump speed of 1340-1420 rpm during all foam-making operations. Proper adjustment of the foam pump drive clutch is necessary to prevent dragging and also slipping. (If the pump speed is low with proper engine speeds, suspect clutch slippage.)

The above maintenance checks should be made on a regular basis to insure proper operation. It should be noted that the instruction manual values for engine and pump speed, 1600 and 1260 rpm, respectively, do not agree with the values recommended by the service engineer for the test vehicle.

Pumping Under Heavy Engine Load Conditions

During the current testing program it was not possible to observe the characteristics which occur with the fire-fighting system when the engine is under heavy load induced by operating the vehicle over difficult terrain. These characteristics have not been determined at any time in the approval tests of the vehicle.

The pumping governor, through restricting the engine speed to below 2000 rpm, will severely limit the energy output of the engine while engaged. This output is adequate to drive the pump and move the vehicle slowly over firm ground. However, when the vehicle encounters mud, sand, or other resistance the vehicle horsepower requirements will increase sharply. The distribution of power between vehicle and pump under such conditions has not been determined. In many designs of similar vehicles the drive train is made to always give precedence and full power to the fire-fighting system and to give the vehicle drive only any remaining surplus.

These conditions should be investigated as well as the characteristics operating with the transmission in the first and second gears.

Vehicle Inspection

It is obvious that any faults or shortcomings of the power train and controls should be discovered during the original vehicle inspection. The fact that this was not the case in this instance indicates inadequate inspection. Proper inspection of a complicated piece of machinery of this type requires instrumentation and time, but this usually turns out to be less costly and less time-consuming in the final analysis. Whatever steps are necessary should be taken now to insure adequate inspection in future procurements.

Future Procurement

Additional vehicles of the same type are already under contract with a different manufacturer. Immediate steps should be taken to amend the specifications to include performance requirements which will eliminate the present problems. These should include: a speed control device which will prevent the foam pump from reaching a speed in excess of 1400 rpm; a pumping speed governor which will maintain a pump speed between 1100 and 1300 rpm at all times when the vehicle is stationary or is maneuvering; a device which will prevent the engagement of the foam pump when the vehicle is exceeding 10 mph and/or engine speeds of 1900 rpm; a device that will limit maximum road speed to 10 mph when the foam pump is engaged. Adequate engineering inspection be made on the prototype vehicle to ensure compliance with the above.

Additional Findings

In addition to the above discussed characteristics, the following items were noticed to be at variance with the specification in Ref. 1:

a. Putting the handline into foam operation requires the movement of two control levers, and the direction designation plate mounted adjacent to the controls is ambiguous and confusing. (See para 3.9.3.3. and 3.11.)

b. The piercing bayonet does not conform to USAF drawing 48E6589 in that the tip is not stainless steel and is badly rusting. (See para 3.9.3.5.)

c. There is no provision for stowage of the handline foam nozzle as attached and in the ready position. (See para 3.9.3.5; contractor agreed to provide this in Jan. 1964.)

d. The normal operating pressure of the handline system is not indicated on the instrument panel gage. (See para 3.9.3.4.)

e. Water feed rate to foam pump is below that required. (See para 3.9.6. and 4.2.6.1.)

f. Tank drain valves protrude dangerously beyond side body panels. (See para 3.2.11 and 3.3.1.)

g. Fill caps on battery are inaccessible for checking electrolyte level or adding water. (See para 3.2.14.)

h. Grab handles for rapid ingress to the cab are not available. (See para 3.2.3, 3.3.2 and 3.7.1; contractor agreed to install such handles in Jan. 1964.)

i. Copper tubing fuel lines exposed in left front wheel well. (See para 3.2.13.)

j. The tank level gauges are obscured by the foam concentrate hand pump in its stored position. (See para 3.9.5.3.)

k. Spotlight is not installed on left-hand side where it would be within reach of the driver. (See para 3.8.1.)

l. 150-lb PKP unit never approved by NRL. (Required by Ref. 7.)

m. A valve still exists in the piping which feeds the handline reel. (This valve was stricken through Ref. 7.)

The following items are outside the present specification but should be included in future versions:

a. Outside mounted rear view mirrors inadequate.

b. Handline rewind should be electrically operated. Hose should have quick-disconnect couplings at reel end.

c. The cab heater needs to be capable of more control then "hi" or "lo" for the moderate temperature locations.

d. The instruction manual needs an electrical wiring diagram keyed in the manner of the wiring on the vehicle. Vehicle wiring to be coded also.

e. Better definition of engine governor and foam pump speed functions are needed.

f. More explicit test procedures for the fire-fighting system.

CONCLUSIONS

The fire-fighting performance of the vehicle as received from the manufacturer was completely unsatisfactory because of low water feed rate, inadequate foam pump speed control, lack of control over excessive foam pump overspeeding, and inadequate control of vehicle speed while making foam.

Adjustments by a representative of the vehicle manufacturer and the local representative of the engine manufacturer greatly improved the fire-fighting system operations; however, the conditions of low water feed rate, foam pump overspeeding, and engine surging while operating on the pumping governor still exist at the time of this writing.

Numerous other items have been found which are at variance with the requirements of the governing specification.

RECOMMENDATIONS

Assurance should be sought from the foam pump manufacturer as to whether the installation and control system for the pump are satisfactory to provide safe operation and normal pump life.

The extent of improper operation of other vehicles made under this contract should be determined and such corrective action as necessary be taken by the manufacturer or the Navy.

The basic specification should be modified to insure better definition of performance in the light of problems uncovered in the test program. The current outstanding contract for additional vehicles should be amended immediately to ensure that the desired performance is achieved.

A better prototype inspection procedure should be established to prevent vehicles such as that tested from going into production or ever reaching the field.

ACKNOWLEDGMENTS

The cooperation of Mr. M. H. Sedon of the Naval Air Systems Command (formerly BuWeps) in making the vehicle available for test is appreciated. Thanks are due to Mr. C. S. Butler and Mr. J. W. Porter for their able assistance in conducting the many test.

REFERENCES

1. Military Specification MIL-T; 19753B(WP), "Truck, Fire Fighting, Aircraft Rescue, Water and Foam, 400-gallon Capacity, MB-5, Types I and II," Mar. 10, 1965

2. Enclosure to Cardox letter of Feb. 8, 1966 to U.S. Navy Purchasing Office, Attn: Code P4.1

3. Amendment No. 2 to IFB 40-604-63-2684

4. BuWeps ltr SEQ-44/5842: JLM to Hq. Warner Robbins Air Materiel Area, Attn: WEPF of Dec. 9, 1963

5. BuWeps ltr SEQ-6/8697: TPA to Hq. Warner Robbins Air Materiel Area, Attn: WRPFE of Apr. 22, 1964

6. Cardox ltr to NPO, Attn: Code P4.1, subj: Contract AF40(604)12365 of Feb. 9, 1966

7. BuWeps ltr SEQ-6/5955: TPA to Hq. Warner Robbins Air Materiel Area of Dec. 12, 1963

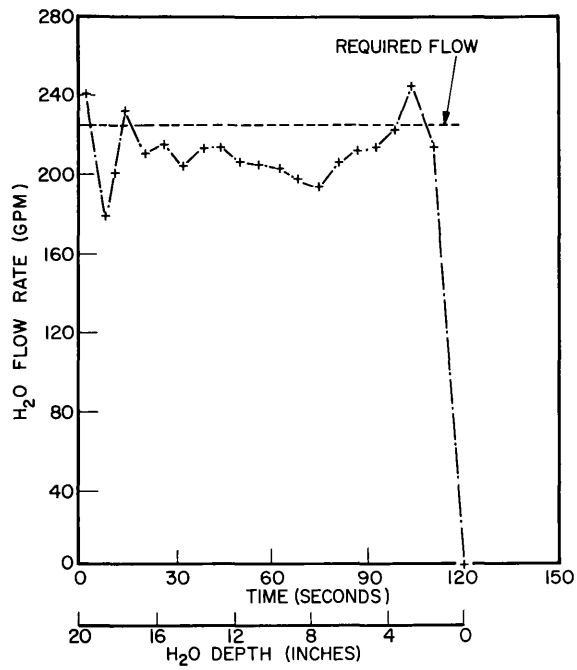

Fig. 1 - Water feed rate to the foam pump

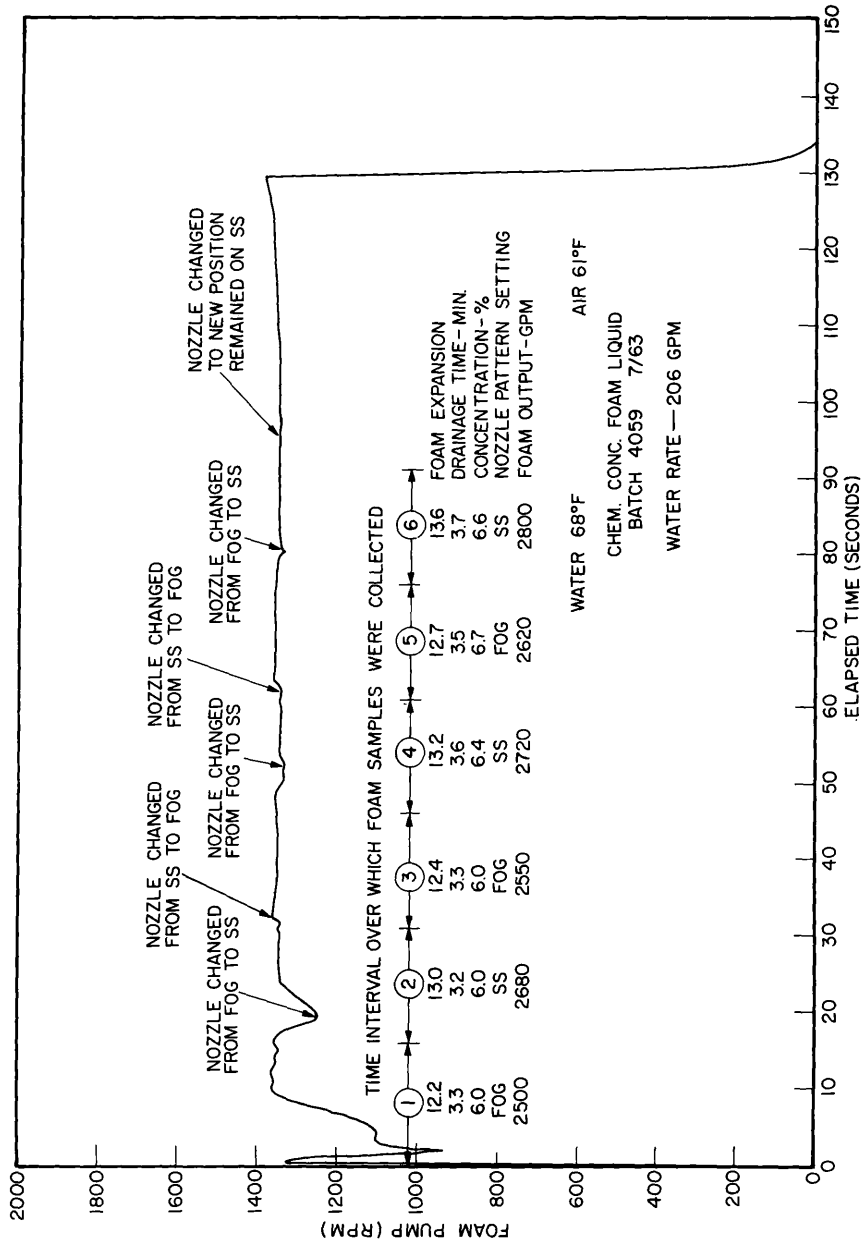

Fig. 2 - Foam analyses and output

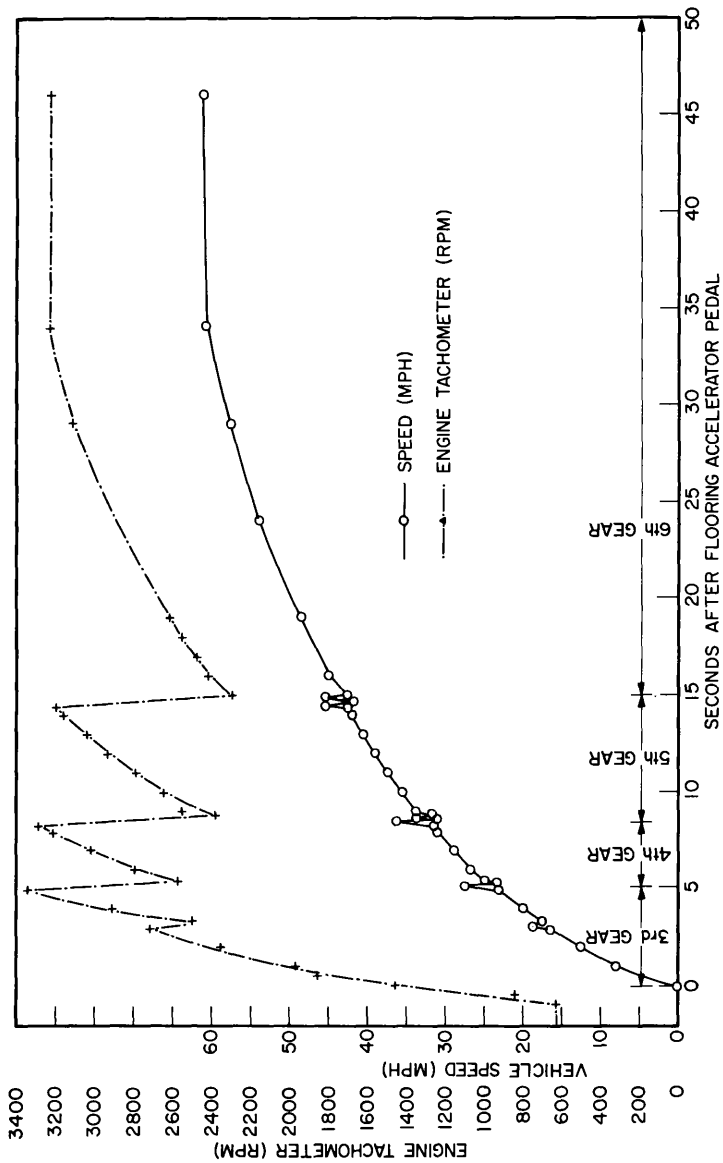

Fig. 3a - Maximum accelerations of MB-5 vehicle

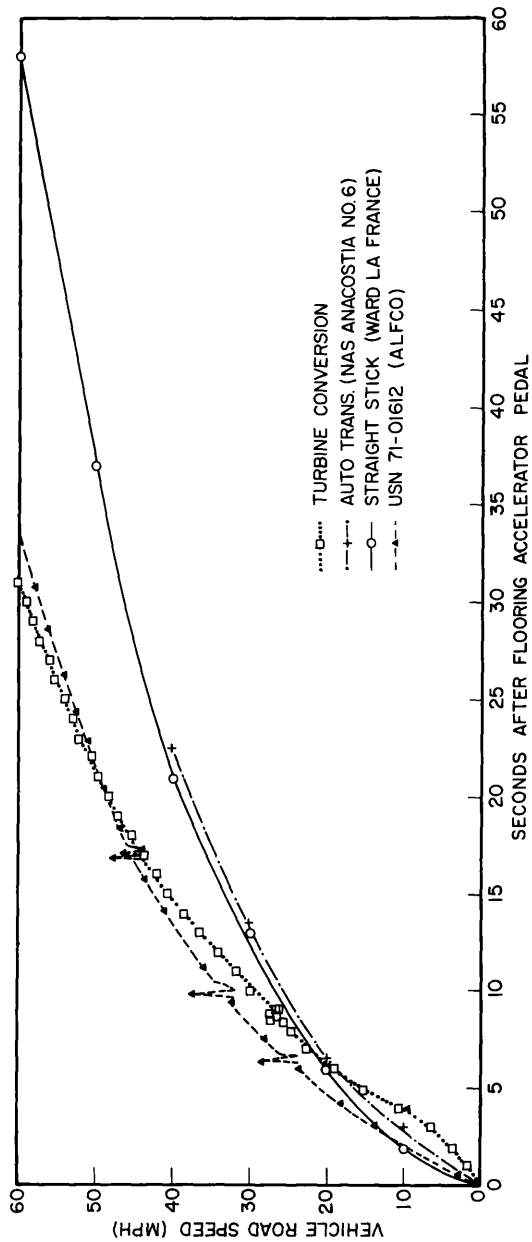

Fig. 3b - MB-5 comparative accelerations

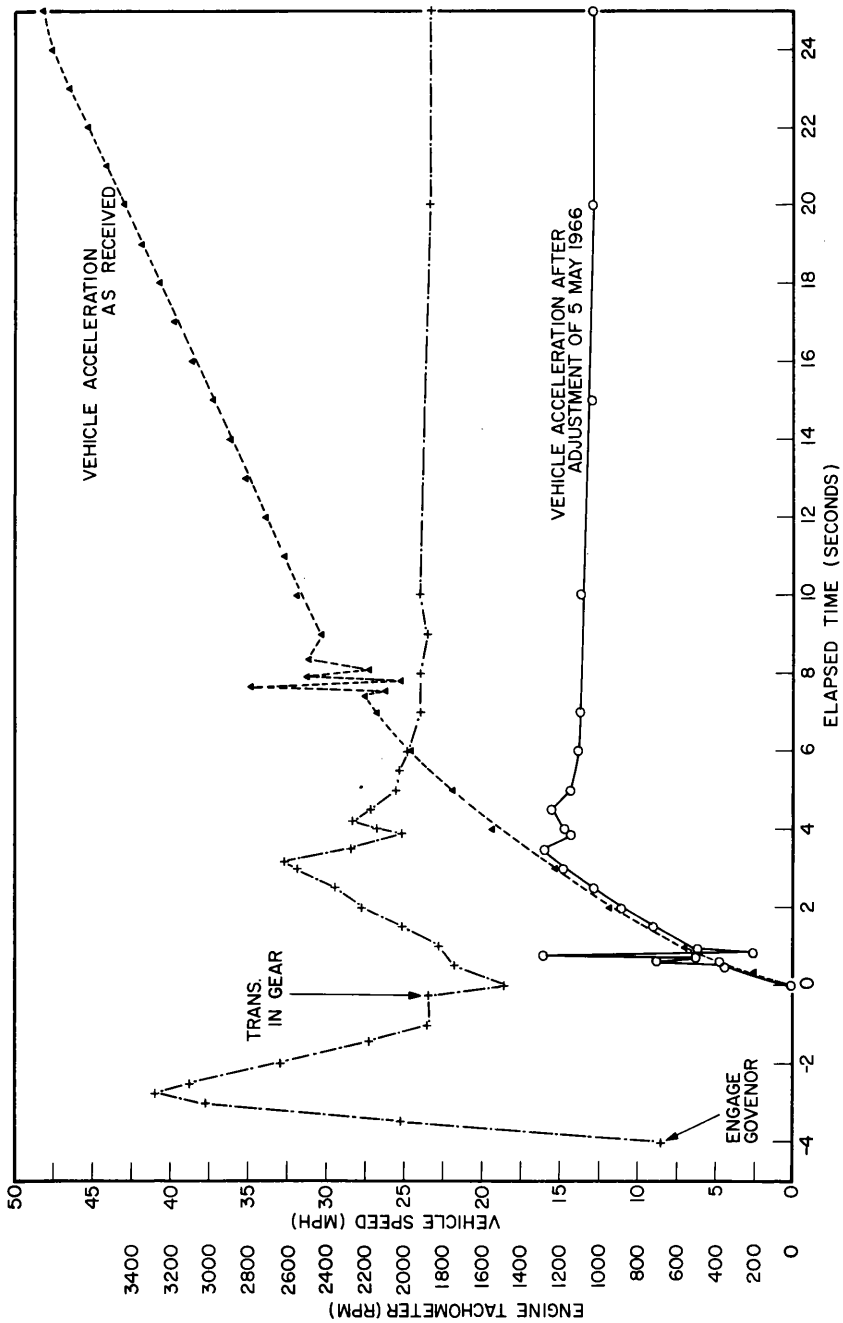

Fig. 4 - Vehicle acceleration with pumping governor engaged

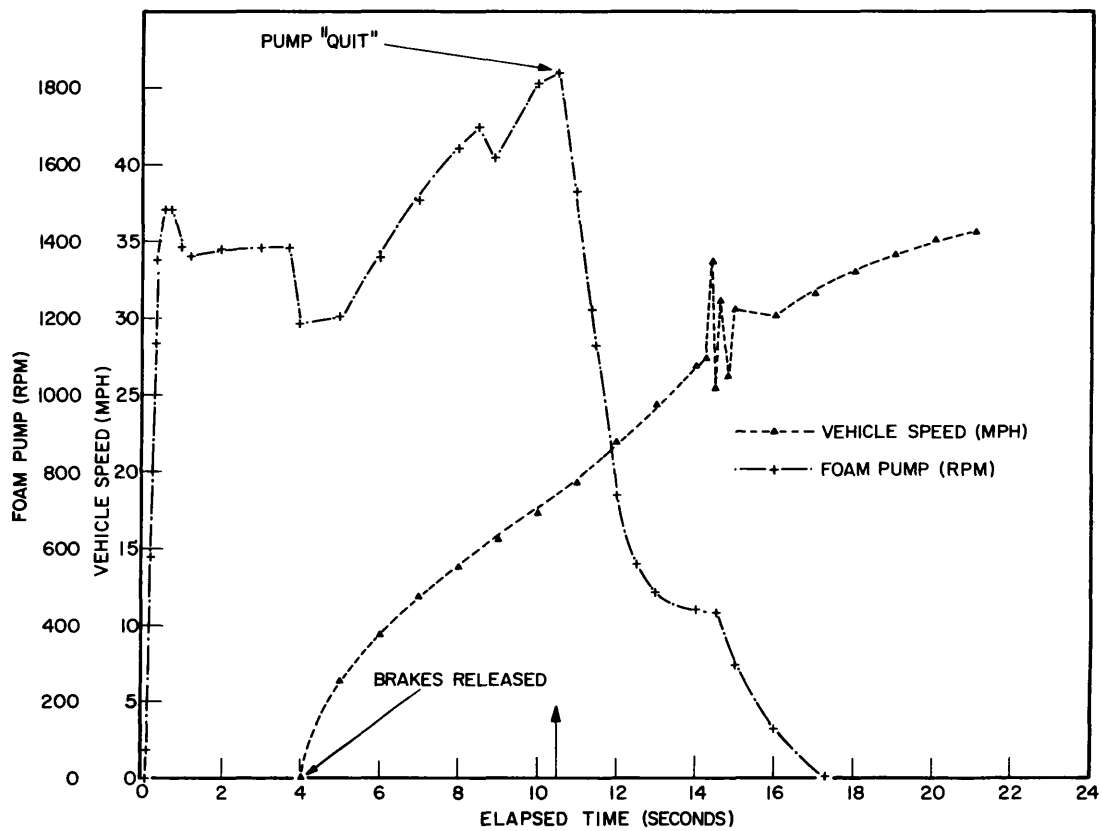

Fig. 5 - Free vehicle speed while pumping (as-received condition)

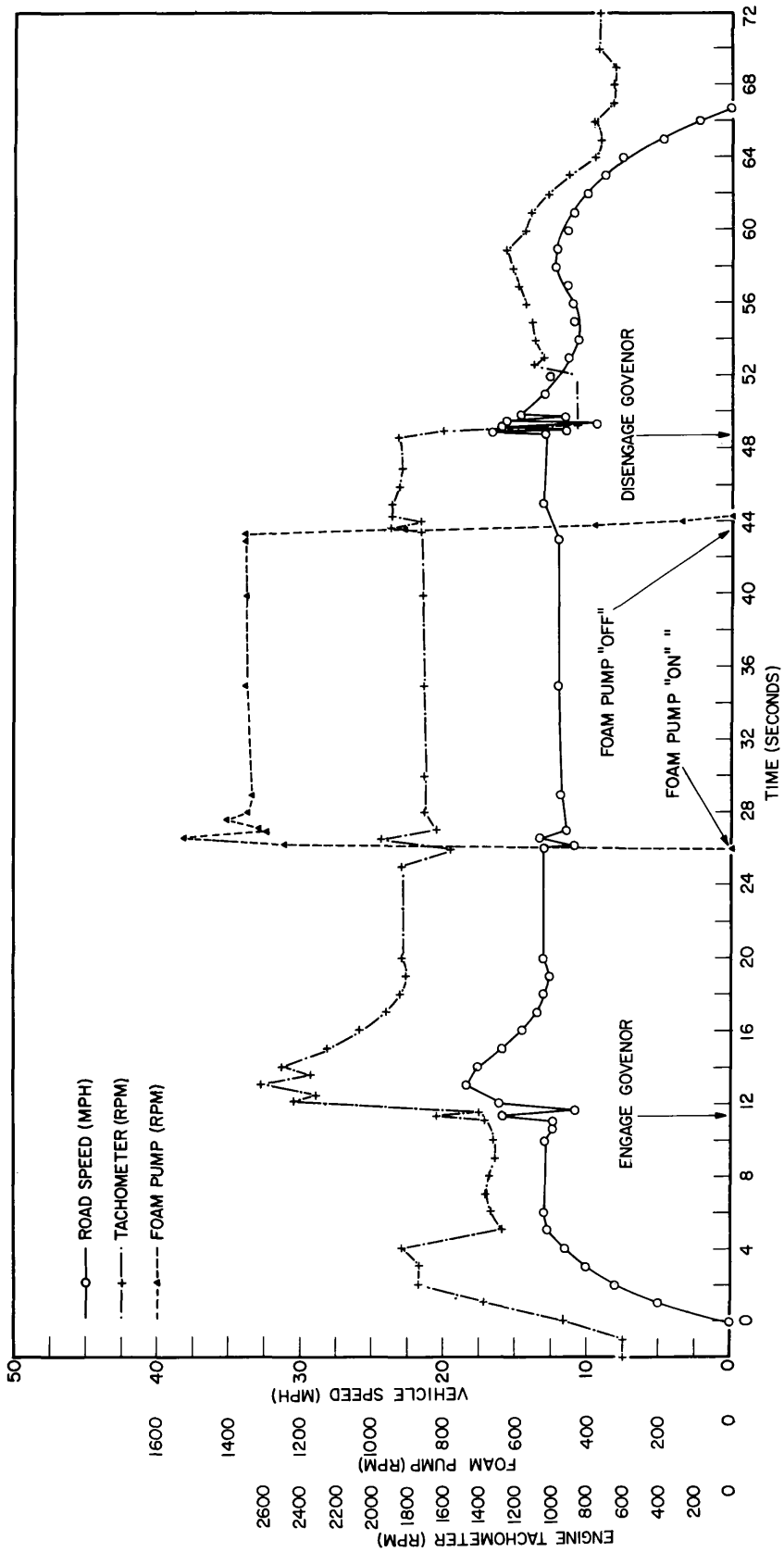

Fig. 6 - Engine, vehicle, and foam pump speeds during engagement of foam pump with vehicle moving

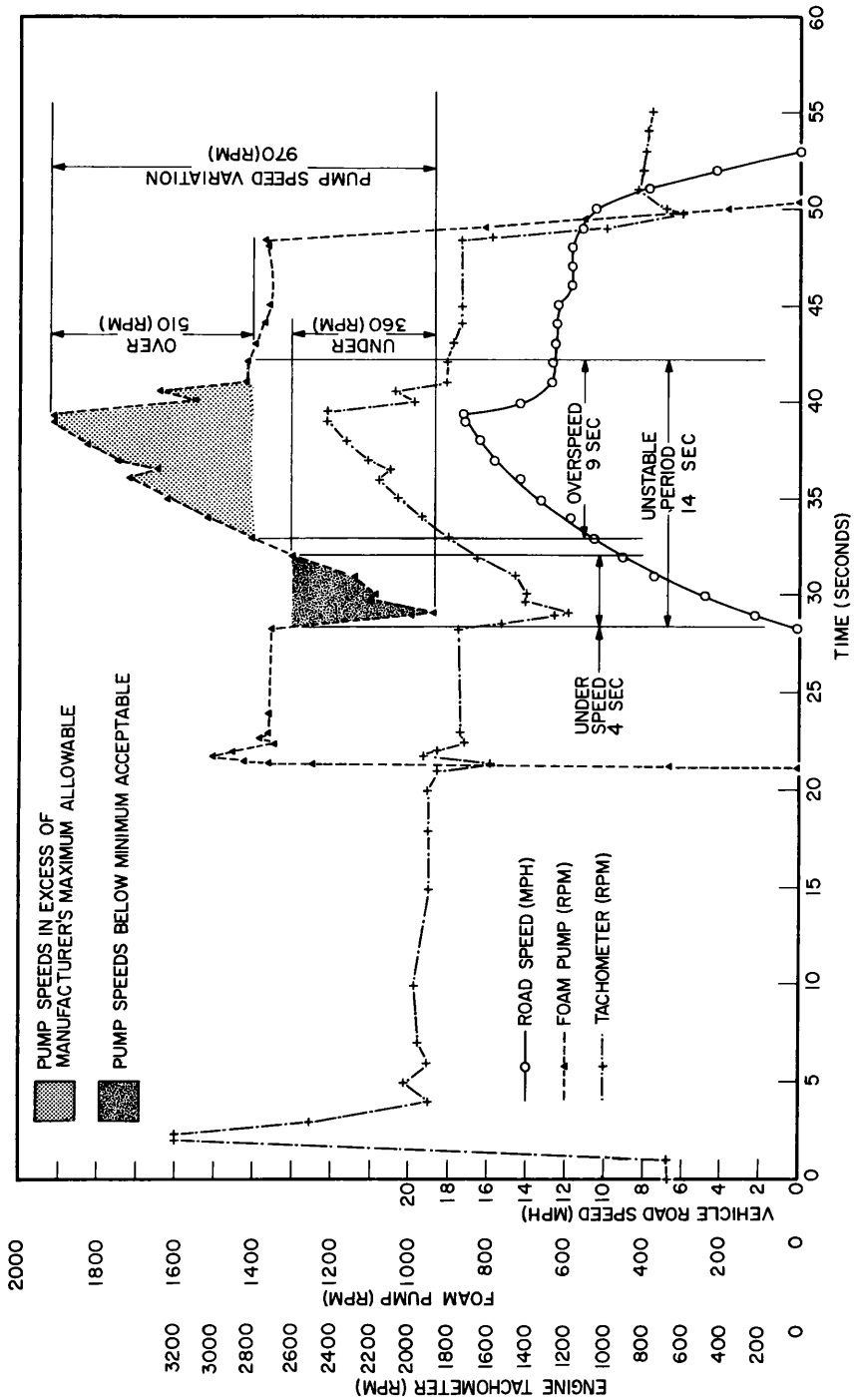

Fig. 7 - Engine, foam pump, and vehicle speeds during engagement of transmission with foam pump operating

This page intentionally left blank.

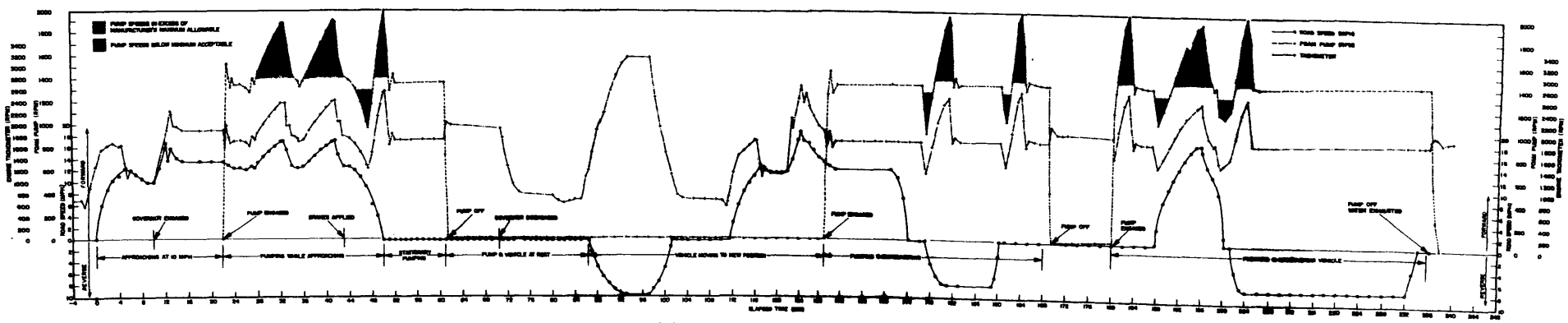

Fig. 8 - Engine, foam pump, and vehicle speeds during a fire-fighting operation

This page intentionally left blank.

Appendix A

RECENT TEST RESULTS WITH IMPROVED MB-5 VEHICLE

Subsequent to the writing of the main text of this report, still further modifications were made on the carburetor-governor arrangement under the direction of the International Harvester engineering department. This change by the engine manufacturer consisted of installation of a vent to the secondary diaphragm on the carburetor. The vent is opened by movement of the cable control engaging the pump governor. It is pictured in Fig. A1. Further performance tests were then conducted on those foam system operations which had been shown to be in need of additional improvement. The purpose of this appendix is to update the material in the report to show the final performance characteristics obtained through 9 months of effort with the prime contractor and the engine subcontractor.

The performance characteristics which have been revised will be considered in the same order as in the main text and the revised figures will be given the same number but preceded by an "A."

A recheck of the water feed rate to the foam pump was made after the final engine adjustments. In Fig. A2 the new rate is shown superimposed over the earlier rate which represented an average of all previous runs (see Fig. 1). It can be seen from the two curves that the new rate is higher and now meets the rate requirements of Ref. 1. The reason for the newly increased rate is not evident. The only difference observed from earlier runs is an increase in the pump speed. However, this should not influence the water rate unless the pump air intake is restrictive enough to allow creation of negative pressure in the feed line. This condition was not investigated. A restricted air inlet would also be reflected by a low foam expansion, but foam output was not reanalyzed after completion of the latest modifications.

As will be shown in subsequent figures, the operation of the engine governor was improved through the modifications to the carburetor. In order to determine if these modifications had in any way restricted the other engine performance, a maximum acceleration run was conducted with the fully loaded vehicle. The results of this run, shown in Fig. A3, when compared with those in Fig. 3, do not indicate any change in acceleration performance.

Figure A4 illustrates the vehicle acceleration rate with the pumping governor engaged. With the vehicle in the original as-received condition, a problem was encountered here by the vehicle moving out at an unrestricted speed as in Fig. 4. This condition was largely corrected in an early adjustment, also shown in Fig. 4, but was improved still further by the latest change evidenced in Fig. A4. The vehicle acceleration was good, but only up to the desired maximum of 13 mph. At that point the engine governor action came smoothly into play without overshoot or surging.

Figure A4 also illustrates the reaction of the engine speed to engagement of the foam pump while the vehicle was already underway. It is seen that the pump response was rapid and achieved a steady-state speed with about 2 sec and with an overshoot of 100 rpm. The equilibrium pump speed has been increased to 1477 rpm from the earlier speed of 1350 rpm in going through all the modifications. Engine governor control upon pump engagement was slightly smoother than the comparable data shown in Fig. 6.

For the run given in Fig. A5 the vehicle drive transmission was engaged while the foam pump was being operated normally. The pump speed curve shows an accompanying dip as the increased load was imposed on the engine. The pump underspeed period existed for 2 sec and full equilibrium was reached in 3 sec. There was no overshoot in pump speed. Minimum pump speed reached during the dip was 1100 rpm. This performance is in contrast to the previous data of Fig. 7. Previously there was an unstable pump speed period of undershoot followed by overshoot which existed for 14 sec. Total pump speed variation was 970 rpm. Thus, the latest governor modification considerably improved performance in this operation.

The speed characteristics shown in Fig. A6 for maneuvering the vehicle while pumping intermittently may be compared to those in Fig. 8. It is immediately evident that the unwanted extent of engine surging has been eliminated through improved governor action. The momentary dips in foam pump speed are acceptable; the pump peak speeds, although reduced, still reached 1680 rpm, a speed higher than recommended.

On the basis of the most recent performance data it is concluded that the fire-fighting system of the subject vehicle is now operating in an acceptable manner. However, final approval by the foam pump manufacturer as to the pump's normal operating speed of 1425 rpm and the peak speed of 1680 rpm have not yet been received.

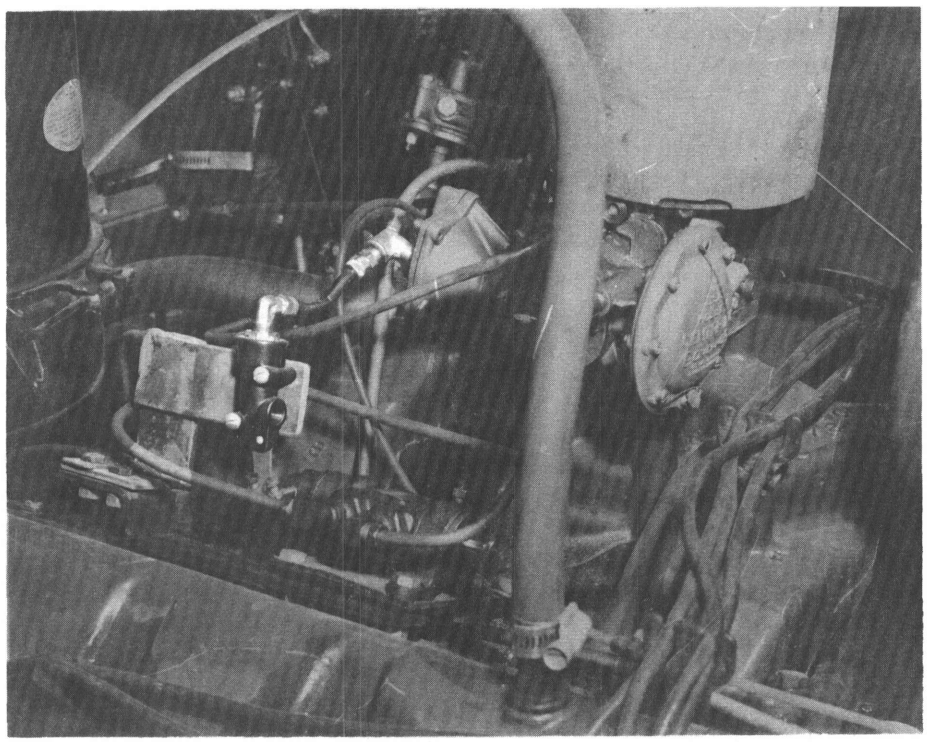

Fig. A1 - Shown here (unshaded) is the vent which was added to the secondary diaphragm on the carburetor to improve the operation of the MB-5 engine governor

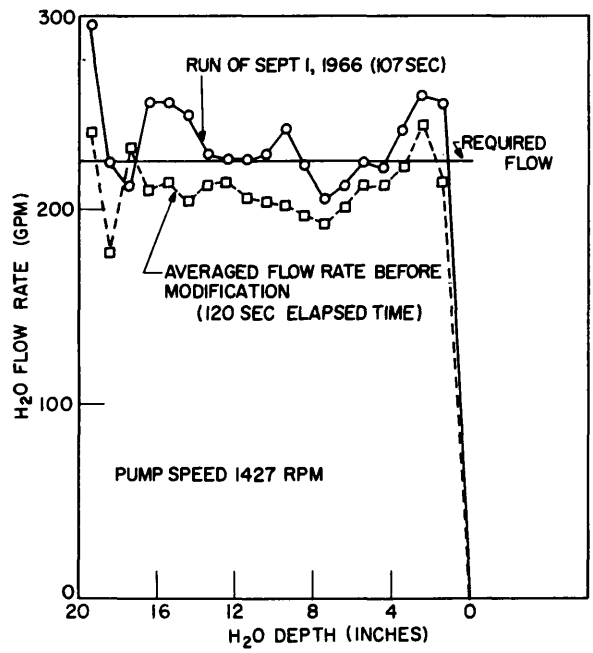

Fig. A2 - Comparison of recent water feed rates with previous rates to the foam pump

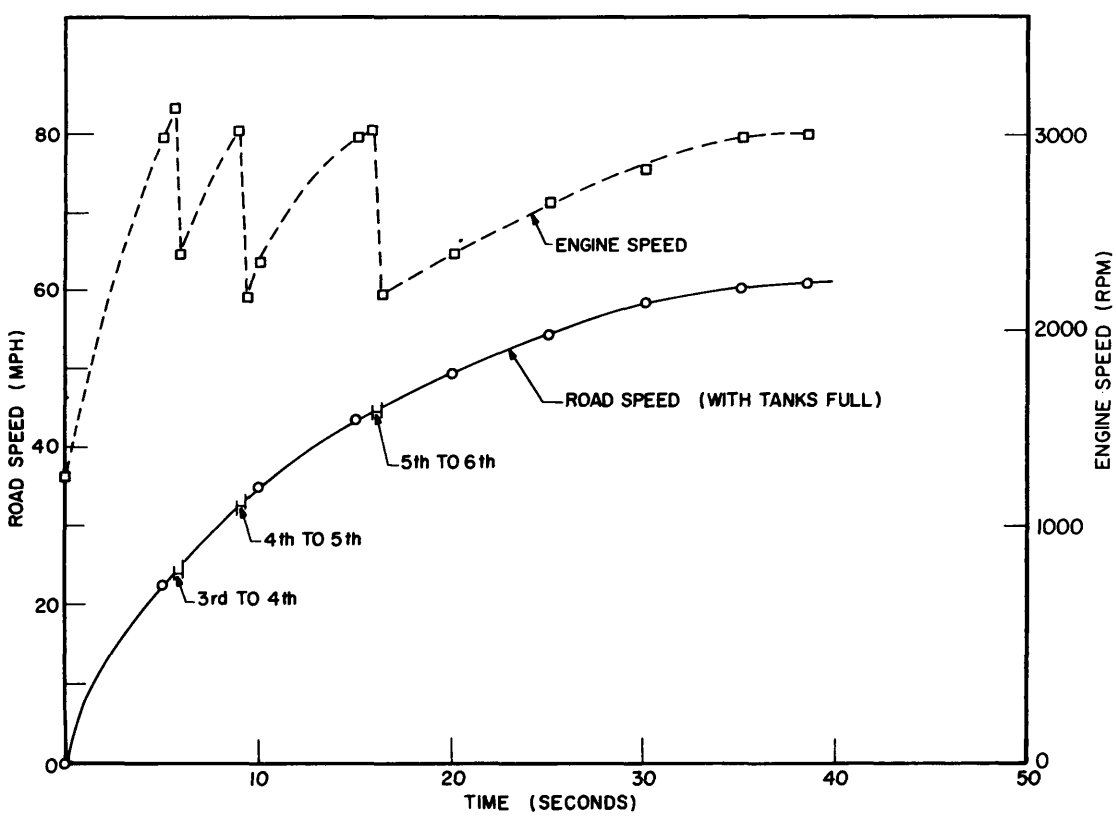

Fig. A3 - Recent results of MB-5 vehicle maximum

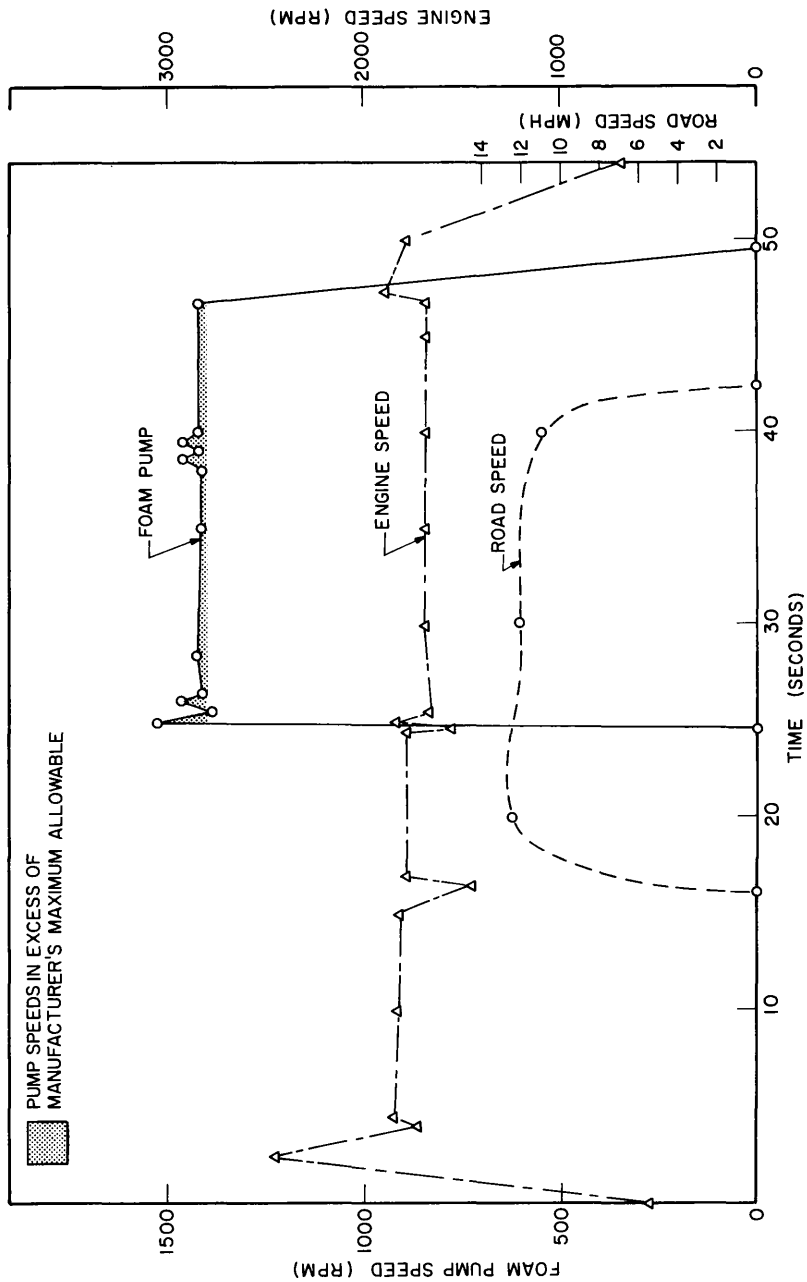

Fig. A4 - Recent measurements of engine, vehicle, and foam pump speeds during engagement of the foam pump with vehicle moving (compare with Fig. 6)

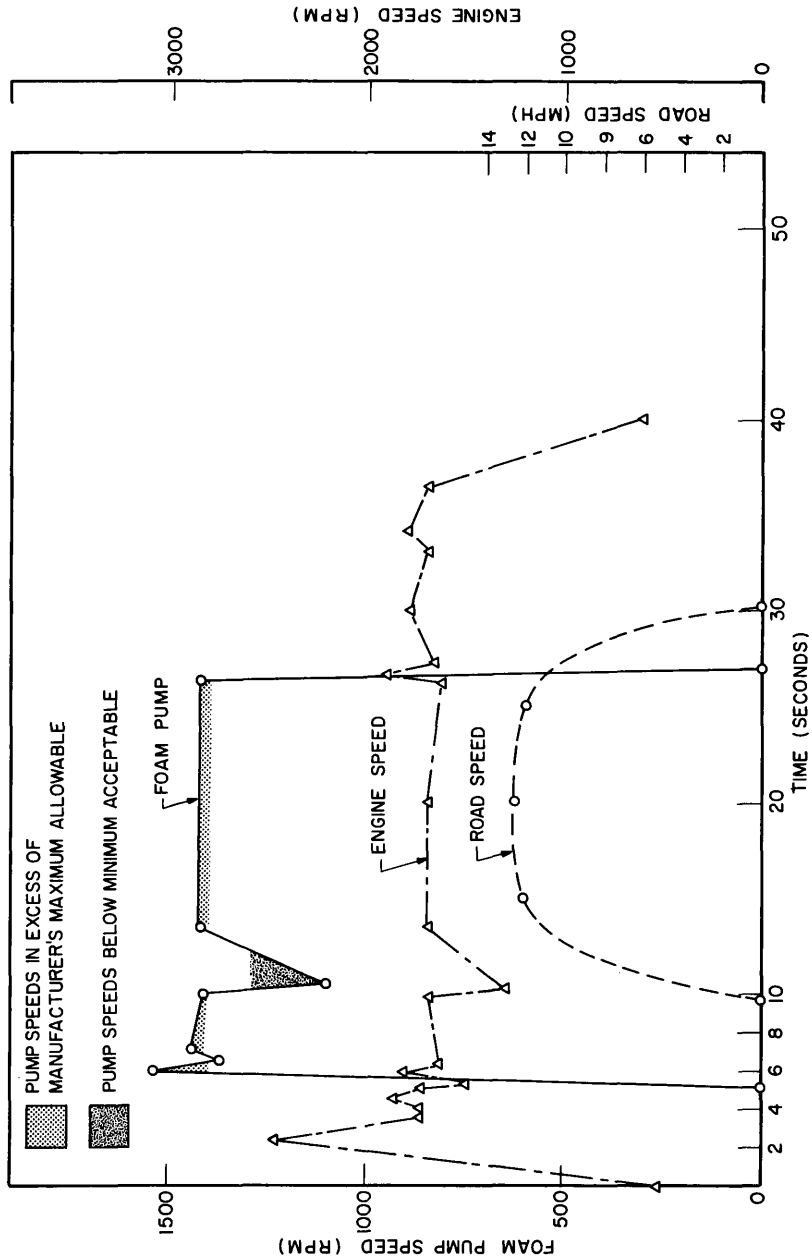

Fig. A5 - Recent measurements of engine, vehicle, and foam pump speeds during engagement of transmission with foam pump operating (compare with Fig. 7)

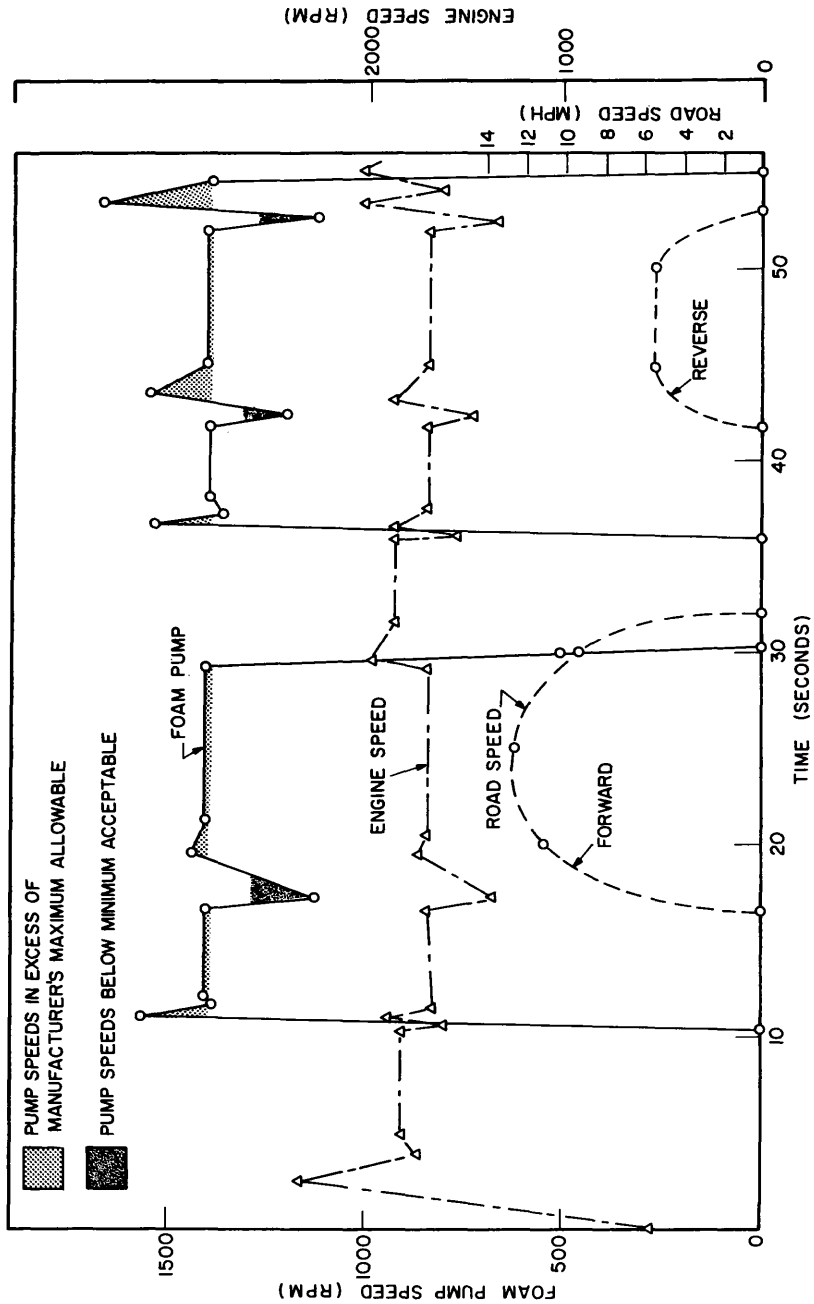

Fig. A6 - Recent measurements of engine, foam pump, and vehicle speeds during a fire-fighting operation (compare with Fig. 8)

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Naval Research Laboratory Washington, D. C. 20390	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

ENGINEERING OBSERVATIONS ON AN MB-5 AIRCRAFT FIRE-FIGHTING AND RESCUE VEHICLE

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

An interim report on one phase of the problem

5. AUTHOR(S) *(Last name, first name, initial)*

Peterson, H. B., and Gipe, R. L.

6. REPORT DATE October 28, 1966	7a. TOTAL NO. OF PAGES 30	7b. NO. OF REFS 7
8a. CONTRACT OR GRANT NO. NRL Problem C08-15 b. PROJECT NO. SEQ-621-001/652-1/F012-05-04 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NRL Report 6461 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* None	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this report is unlimited. Copies available from the Clearinghouse for Scientific and Technical Information (CFSTI), Springfield, Va. 22151

11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY Dept. of the Navy (Naval Air Systems Command)

13. ABSTRACT

A production MB-5 aircraft fire-fighting and rescue vehicle was taken from the manufacturer and instrumented to record simultaneously engine speed, road speed, and foam pump speed. The vehicle was then subjected to maximum acceleration runs and simulated fire-fighting operations wherein the vehicle was maneuvered while the foam system was being operated. With the vehicle in its "as-received" condition the fire-fighting system was erratic in performance and completely unsatisfactory. Adjustments by the vehicle manufacturer and the engine manufacturer greatly improved its performance. Operation is still not fully satisfactory because of low water feed rate to the foam pump, hazardous overspeeding of the foam pump, and engine surging while operating on the pumping governor. Numerous other items not in compliance with the purchase specification were found. Improved specifications and inspection procedures are desirable for future procurements.

DD FORM 1 JAN 64 1473

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Firefighting vehicles Performance (engineering) Pumps Aircraft Fires MB-5 (Aircraft Fire Fighting Truck)						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.