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VENTILATION FLOW PATTERNS IN THE M-47 MEDIUM TANK

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Project 2167

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FOREWORD

The study of ventilation flow patterns presented here was completed at the Aircraft Propulsion Laboratory as part of an overall project to determine the feasibility of ventilating, heating, and cooling a combat tank in order to obtain increased crew comfort and efficiency.

ABSTRACT

Measurements were made of air flow direction by means of smoke puffs, and of air velocity by use of a thermo-anemometer at numerous points within the crew compartment of an M-47 medium tank. The results of these measurements are shown on a series of horizontal plane charts drawn at specific vertical distances from a reference point within the compartment. The measurements were taken under two sets of conditions, the first being concerned with the turret ventilator fan and the second being concerned with the compartment combustion heater.

The subjective reactions of the investigators while they were making measurements are discussed and conclusions concerning the flow patterns themselves, on the basis of the accompanying charts, are presented.

OBJECTIVE

The objective of this project was to determine the feasibility of ventilating and heating, or ventilating and cooling, the crew compartment of a medium combat tank in environments characterized by extreme temperatures. The upper limit of environmental temperature anticipated by the project is 120°F and the lower limit is -30°F. The possibility of controlling temperatures in the main engine compartment was also to be studied, and an estimate was to be made of the practicability of attaining all the above objectives through the design of a universal package system which could be fitted to all tanks without the necessity for redesign.

I. INTRODUCTION

It is believed that the ventilation flow pattern achieved in a tank crew compartment would have a large effect on the amount of refrigeration or heat required to increase crew comfort to the point where efficiency is enhanced. The M-47 medium tank ventilation and heating systems, as presently designed, contain only enough duct work to bring air from the ventilator and heater fans into the compartment. Proper distribution within the compartment depends mainly on the geometry of the compartment itself and the turbulence of the air to convey the effects of these components to all positions. Crew members in the field have complained that the ventilation and heating effects of the present system become inadequate as atmospheric temperatures deviate from annual average temperatures. Because of the belief that distribution, rather than production of ventilation and heat, may be primarily at fault, the measurements resulting in this report were made.

Conclusions reached as a result of the measurements will be presented at the end of the discussion in this report. Recommendations are omitted, however, since it is felt that any suggestions made should be based on all phases of the project. Such recommendations, therefore, will be withheld for inclusion in the final report of the project.

II. PLAN OF INVESTIGATION

There were two sets of conditions under which the measurements were made, one set dealing with the effects of the turret ventilation fan and the other set dealing with the effects of the combustion heater, with respect to air distribution only. In both cases all hatches were kept closed, the main engine was shut down, the turret was facing forward, five crew members (some simulated) were at combat positions, and most items of equipment were not in position. When the ventilation fan was running, the auxiliary engine was also kept running for part of the time in order to determine whether its exhaust gases were being drawn into the compartment. When the heater was running the auxiliary engine was always shut down. No tests were made with turret ventilator and combustion heat in simultaneous operation. In the cases where any of the hatches were open or the main engine was running, it was found that the air took the most direct route to either the nearest open hatch or to the air cleaners. Consequently no detailed measurements were made in these cases.

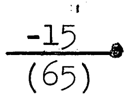
Directional measurements of the air flow at a given point were made by using an M.S.A. ventilation smoke tube assembly, manufactured by the Mine Safety Appliances Company, Pittsburgh, Pennsylvania and listed under their catalog number BH-5607. This consists simply of a chemical-filled tube to which a rubber bulb is attached. When the rubber bulb is squeezed, a dense puff of white smoke is emitted from the tip of the tube. Since the smoke emitted has acid characteristics, care must be taken not to inject too high a concentration into the air current.

Air velocities at a given point were measured by using an "Alnor" double range type 8500 thermo-anemometer, manufactured by the Illinois Testing Laboratories, Inc., of Chicago, Illinois. The low range scale can measure velocities between 10 and 300 feet per minute, and the high range scale extends from 150 to 2000 feet per minute.

The general procedure was to measure air direction and velocity at a given point, using these two instruments; the information obtained was recorded on charts which had been prepared for the purpose. The charts are plan views of horizontal planes which were figuratively cut through the vehicle crew-compartment space at fixed vertical distances from some reference point in the compartment. Directional arrows on such charts can, of course, show only the horizontal components of flow. In order to represent the direction of flow relative to the horizontal plane, an ordinary draftsman's protractor was used to obtain an approximate measurement of the angle above or below the horizontal at which the air was flowing. These approximate angles are presented as positive or negative numbers beside the directional arrows on the charts. Velocities are shown in parentheses on the same charts beside the arrows. The approximate location of a measurement point is given by the dot from which an arrow originates. Any variation in the length of the arrows shown has no significance; that is, they are not to be considered in the sense of vectors.

The charts, shown as Planes 1 through 9, are drawn so that the area occupied by an obstruction in a given plane is shaded. This has been done in the case of approximate areas occupied by human occupants at battle positions, as well as in the case of compartment contour or major pieces of equipment.

An example of the reading of an arrow on the chart follows:



For purposes of clarity, arrowheads are not drawn in. This arrow signifies that a measurement was taken at the approximate point represented by the dot at the tail end of the arrow. The horizontal components of air flow direction at that point are shown by the arrow itself. The figures indicate further that the flow was in a direction approximately 15 degrees below the horizontal and at an approximate velocity of 65 fpm. In those cases where an area is marked "diffuse", a definite and constant direction of air flow could not be measured. Velocities in these areas generally were in the range from less that 10 fpm up to about 80 fpm.

It is hoped that this method of presentation may enable a reader to mentally associate the charts in an overall sense and, thus, to visualize a qualitative picture of the flow patterns in the compartment. At least, it should be possible to pick isolated points in the compartment and be able to decide from the charts whether the air currents at these points are unsatisfactory.

III. DISCUSSION

The charts presented here should be regarded as showing air flow characteristics only in the qualitative sense, in spite of the fact that numerical values are reported. This precaution stems from the fact that the directions and velocities shown are estimated mean values. Turbulence of flow resulted in variations of both over short periods of time, in many cases as small as a fraction of a second. At some points, where velocity was generally high, the velocity fluctuations were as high as ± 100 fpm, and the higher the velocity the smaller seemed the time period of velocity fluctuation. An exception to this statement is that at the duct exit from the ventilation fan the flow was constant in direction and velocity; at these points the velocity was about 1000 fpm. Directional fluctuations were of smaller magnitudes at the higher velocities and the time periods of direction fluctuations were greater. Directionally, the fluctuations were large at the lower velocities, varying at some points, as much as sixty degrees in any direction. This situation held true especially in those areas marked "diffuse". In the gross sense, though, the directions and velocities shown on the charts can be qualitatively regarded as giving the predominant flow characteristics for the conditions applied.

During the periods of the measurements notes were made on the subjective reactions of the occupants of the tank. The taking of sufficient measurements to supply the information necessary for filling the planar charts required from one-half hour to two hours per chart for completion, depending upon the plane being worked. In those cases where the ventilation fan and the auxiliary engine were running at the same time, there seemed to be no noticeably disagreeable odor. Nevertheless, after a period of about one hour in the compartment under these conditions, the occupants experienced a feeling of "heaviness" around the eyes, dryness of the mouth and throat, and headache. Several hours later stomach cramps and slight nausea were experienced in addition to the original symptoms. In other cases where the ventilation fan was running but the auxiliary engine was shut down, these symptoms did not occur. There seem to be three possible explanations for the above experiences. One explanation is that exhaust fumes were being drawn into the compartment from the auxiliary engine. A second explanation is that the measurements with the auxiliary engine running were the first to be taken, and at that time the investigators were inexperienced in the use of the smoke tube assembly. Consequently, they may have injected too high a concentration of the acid smoke into the tank atmosphere. A third possibility, although a relatively remote one, is the psychological factor involved; that is, the investigators, having decided to run the auxiliary engine in order to check for noxious fumes, may have been unconsciously biased in their judgment. This could happen to the extent where the discomforts described could be induced by imagination.

In those cases where the ventilation fan was running, with or without auxiliary engine, the occupant of the commander's seat complained of pains around the left waist some time after a measuring period was ended. This man, at the time measurements were taken, was rather lightly clothed, (light underwear, trousers, T-shirt, light sweater, socks, and shoes) and the ambient temperature outside the tank varied from about 60° to 70°F.

In all cases with the ventilation fan running, the turret occupants were conscious in varying degrees of the air currents around their bodies. On the other hand, the occupants of the driver's and bow gunner's compartment were not conscious of any air currents whatever.

In those cases where the heater was running and the ventilation fan was shut down, the air currents were definitely evident in the lower compartment (driver and bow gunner) and the compartment was rapidly heated. In the turret compartment, air currents were not very noticeable. Here the turret did become heated, but at a slower rate than did the lower compartment. The ambient temperatures during these measurements were also between 60° and 70°F.

It was noted during measurements that the flow pattern in a given area was quite sensitive to variation in posture of a man at that position. For example, if the tank commander in his position sat so he was facing sidewise the flow pattern was somewhat different in his general area than if he sat facing forward, all of this in the case where the ventilation fan was running. Movement by the loader on his side affected flow patterns there to a lesser extent and a similar situation existed in the gunner's position. In the lower compartment, movement by the occupants did not alter flow patterns, because they were not in the flow path. An extension of the situations would seem to indicate that equipment would also alter flow patterns and that these might be substantially different from those presented in this report, because the vehicle here was incompletely equipped (ammunition, etc.) during the measurements. Because of the sensitivity of the local flow to the posture of the occupant at a position, attempts were made to standardize this posture to the extent that an occupant was required to sit facing as nearly forward as he could. This rule could not be rigidly adhered to, however, because the occupant of a position was usually the one making measurements in his own vicinity.

Remarks pertaining to the flow patterns themselves, as evidenced in the accompanying charts, are presented as conclusions in the following section of this report.

IV. CONCLUSIONS

1. Air distribution in the turret is not accomplished in the most effective manner when the turret ventilator fan is running. The gunner receives a good general distribution of air over all parts of his body, and the commander and loader get good distribution on their upper bodies.

2. The driver and bow gunner get negligible benefit from the turret ventilator. At the level of their heads, as can be seen on Plane 7 (ventilator fan running), the air enters their compartment near the center line of the vehicle. It then proceeds to the front of the compartment, diverges along the front wall toward either side, then along the side walls toward the rear. The heads of the two crew members in the lower compartment are positioned in the relatively stagnant vortex of the whirlpool thus created.

3. Practically all the air drawn in by the ventilator fan leaves through the turret ring without circulating to any great extent in the tank. This is seen quite well by comparing Planes 5, 6, and 7 (ventilation fan running). Plane 5 is the one in which the duct exit from the fan lies, and here of course, are located the extremely high velocities—over 1000 fpm at the duct exit. Plane 6 lies just below the points where the air would escape through the turret ring, and except for the center of diagram it can be seen that many points already have low air velocities. In Plane 7, which passes about ten inches below the turret ring, the highest velocity measured anywhere is 140 fpm, with more typical values being 50 to 100 fpm.

4. When any of the hatches were open, the great majority of the air flow passed to the nearest one by the most direct route; when the main

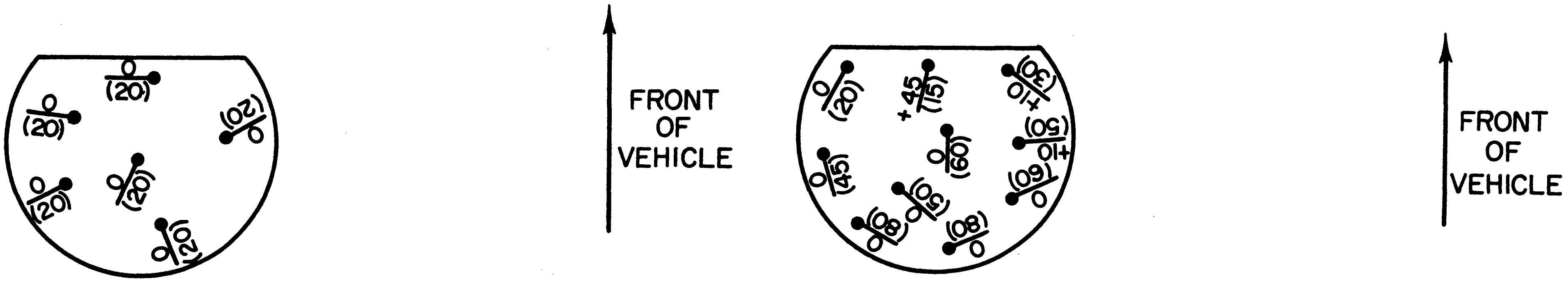
engine was running, it went directly to the air cleaners. Although an observation was not made with the breech of the 90-mm gun open, it seems reasonable on the basis of the above that the air flow would proceed directly out the gun barrel. This would be especially true with hatches closed and main engine shut down.

5. Air distribution from the heater was better than from the ventilator fan. While the actual volume capacity of the heater is much less than that of the ventilator, it does not have its intake from the outside atmosphere. Because of the fact that it recirculates the air in the tank, there is only small loss of air through the turret ring. Some air does leak through the ring and faulty hatch seals, but the majority of it travels back to the intake of the heater as quickly as possible. This is shown especially well in Planes 6, 7, and 8 (combustion heater running) where it is shown that the flow travels toward the rear on the bow gunner's side of the vehicle (starboard side), circles through the lower front portion of the turret, and moves forward on the driver's side to the heater intake.

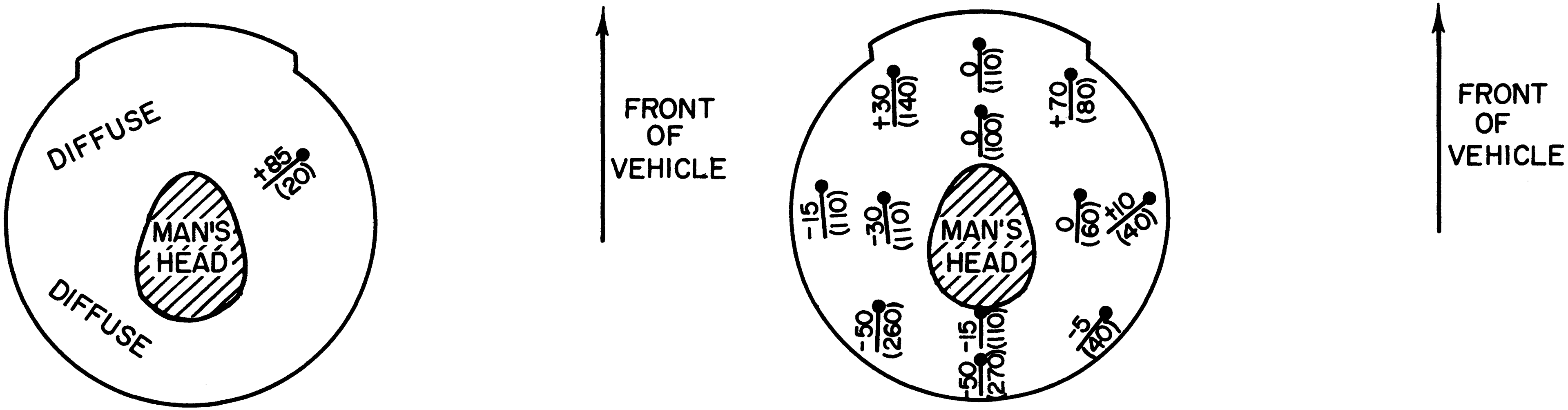
6. The chief beneficiary of the effects of the combustion heater is the bow gunner, with the driver also getting good effect, although to a lesser extent. Circulation to the personnel positions in the turret is slow and diffuse.

7. At atmospheric temperatures cool enough to require heat, but not extremely cold, the use of the heater might provide comfort for the turret personnel while making the lower compartment personnel uncomfortably hot. At very cold atmospheric temperatures, the lower compartment might be pleasantly warm while the turret is uncomfortably cold. It would seem that the needs of both sections would be simultaneously satisfied only over an extremely narrow range of atmospheric temperatures.

8. Equitable distribution of ventilation and of heat can be accomplished only by the use of a well-designed duct system. Disregarding air requirements of the main engine, a good duct system will make the use of a smaller ventilator fan practicable. By the same reasoning, it may be that the heater capacity presently available in the crew compartment would be easily sufficient for all crew members if the heated air was carried through well-insulated ducts to reasonable distribution points.

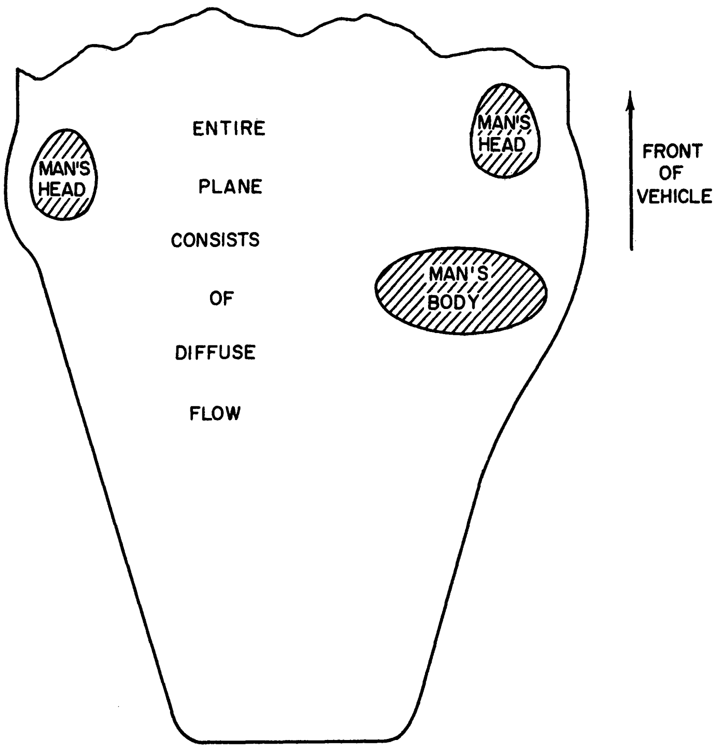


Plane 1. One inch below inside of commander hatch cover.
Left, combustion heater running; right, ventilator fan running

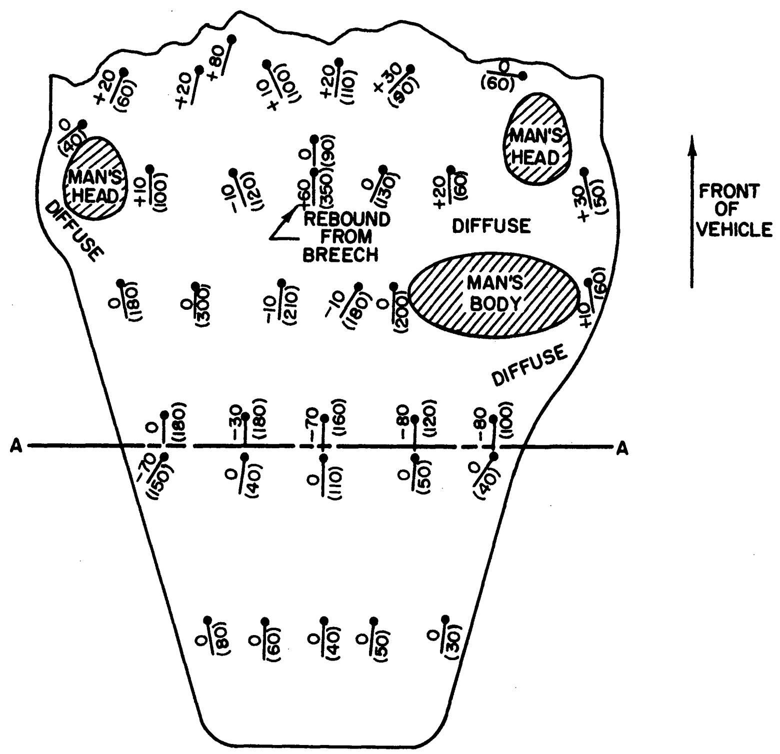


Plane 2. Bottom edge of view windows in commander hatch.
Left, combustion heater running; right, ventilator fan running

COMBUSTION HEATER RUNNING



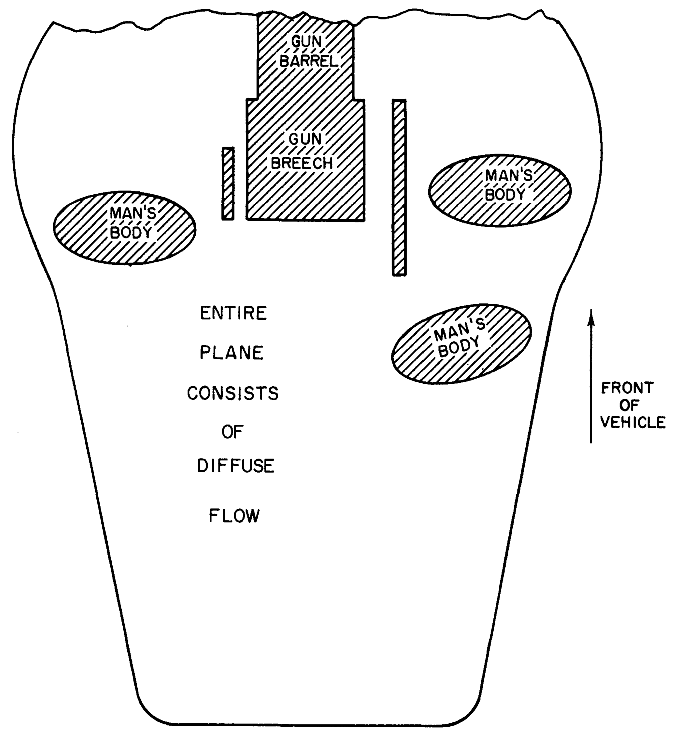
VENTILATOR FAN RUNNING



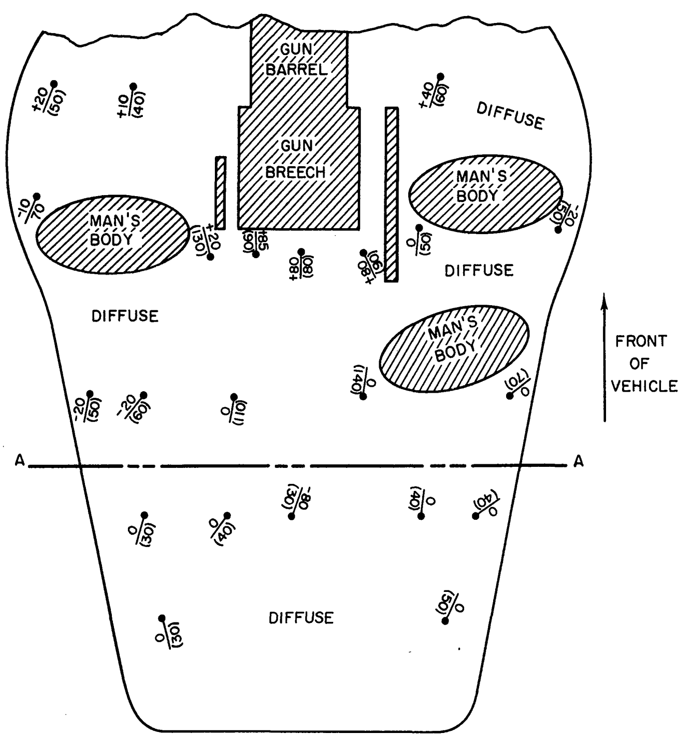
Note: Point marked "rebound from breech" is just above and to rear of gun breech. Points forward of line AA are above and forward of ventilator duct exit.

Plane 3. 15 inches below inside of commander hatch cover

COMBUSTION HEATER RUNNING



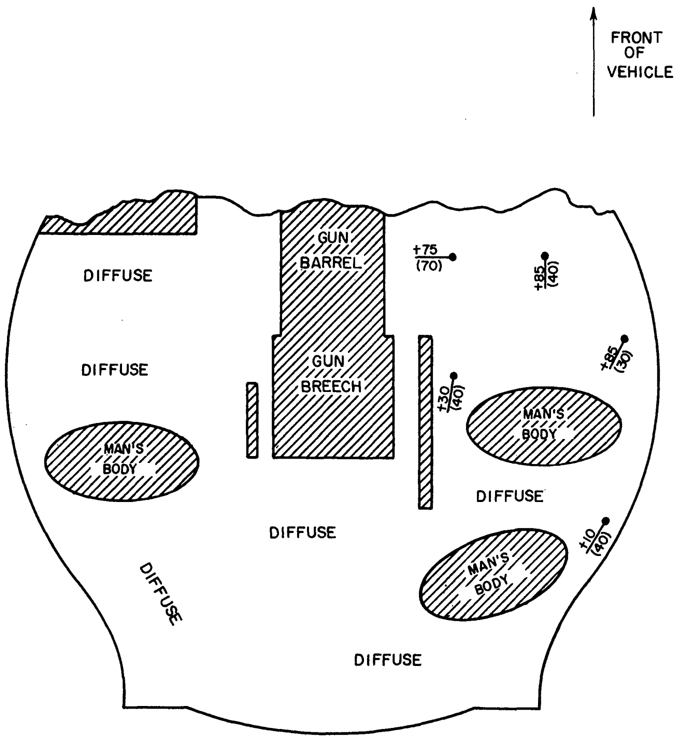
VENTILATOR FAN RUNNING



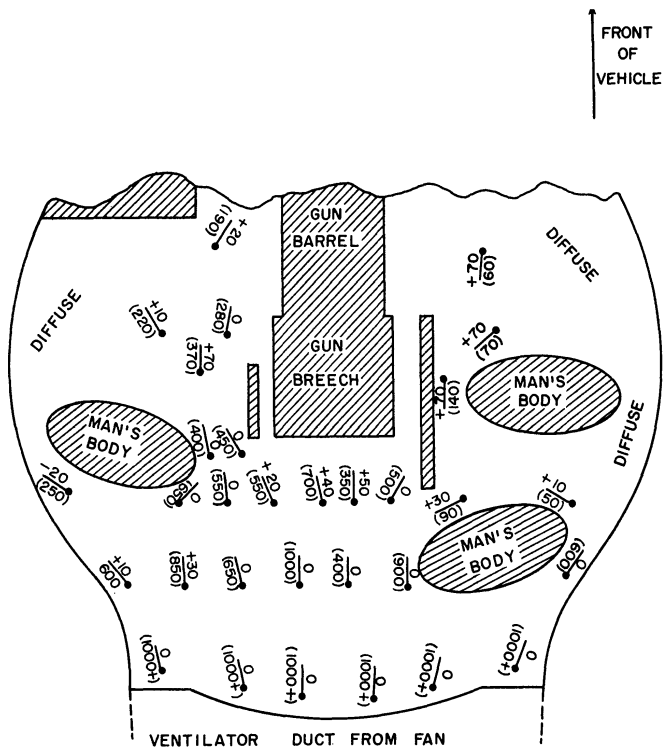
Note: Points forward of line AA are above and forward of ventilator duct exit.

Plane 4. 27 inches below inside of commander hatch cover

COMBUSTION HEATER RUNNING



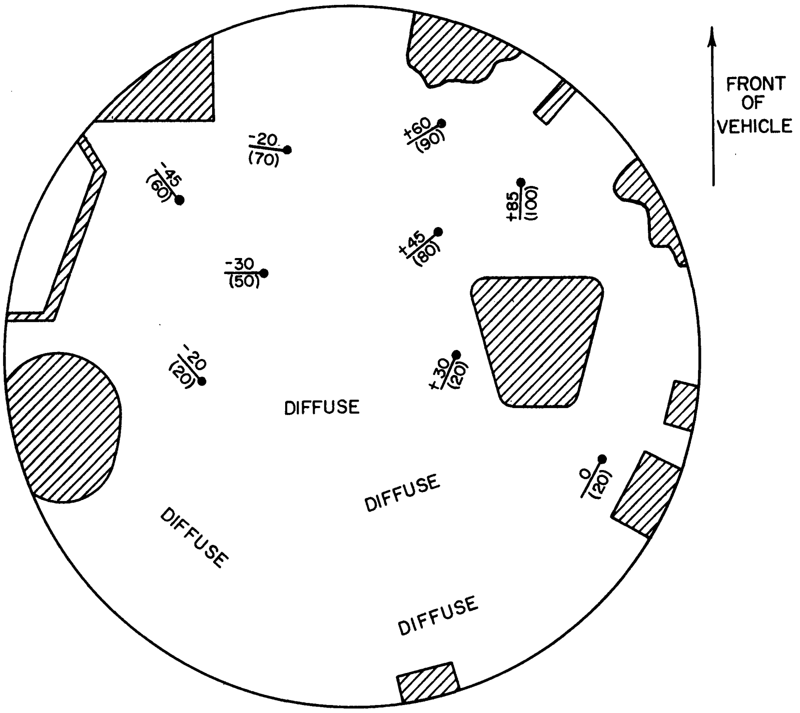
VENTILATOR FAN RUNNING



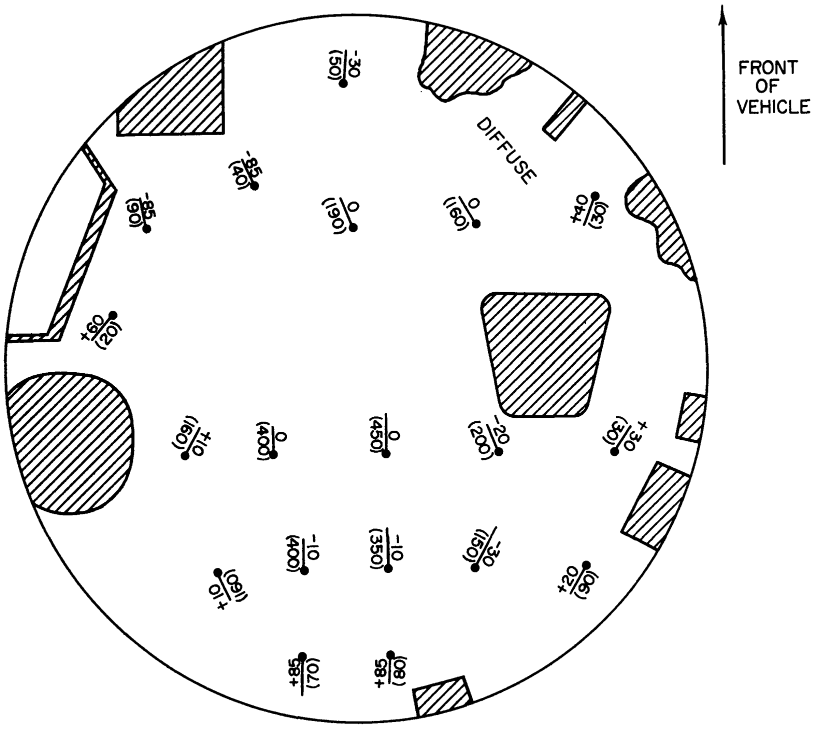
Note: Ventilator duct exit lies in this plane.

Plane 5. 35 inches below inside of commander hatch cover

COMBUSTION HEATER RUNNING

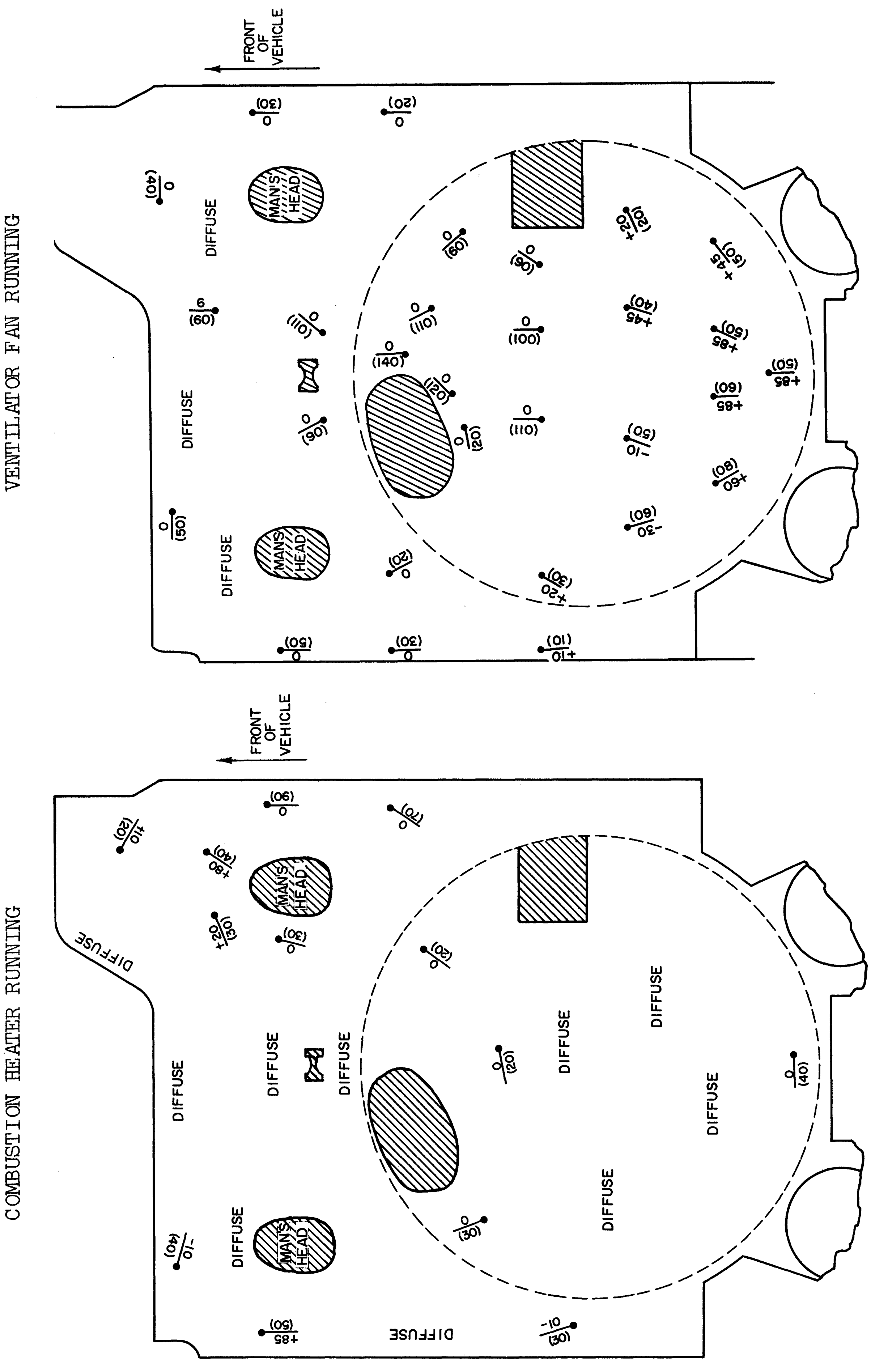


VENTILATOR FAN RUNNING



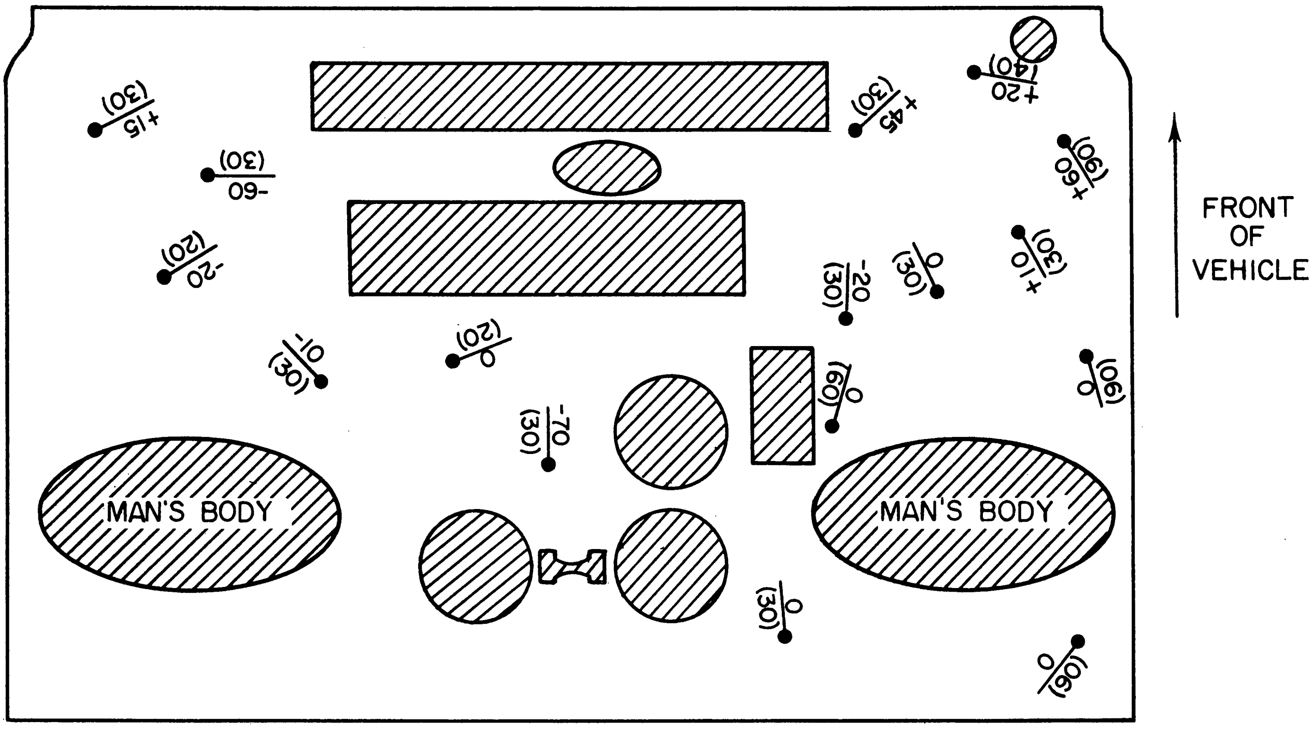
Note: Not shown on this diagram are flow lines to designate air flow out the circumference (through the turret ring). Leakage occurred through all parts of the turret ring and velocity varied at the different points, being as high as 600 ft/min at some points. Turret ring lies in this plane.

Plane 6. 45-1/2 inches below inside of commander hatch cover

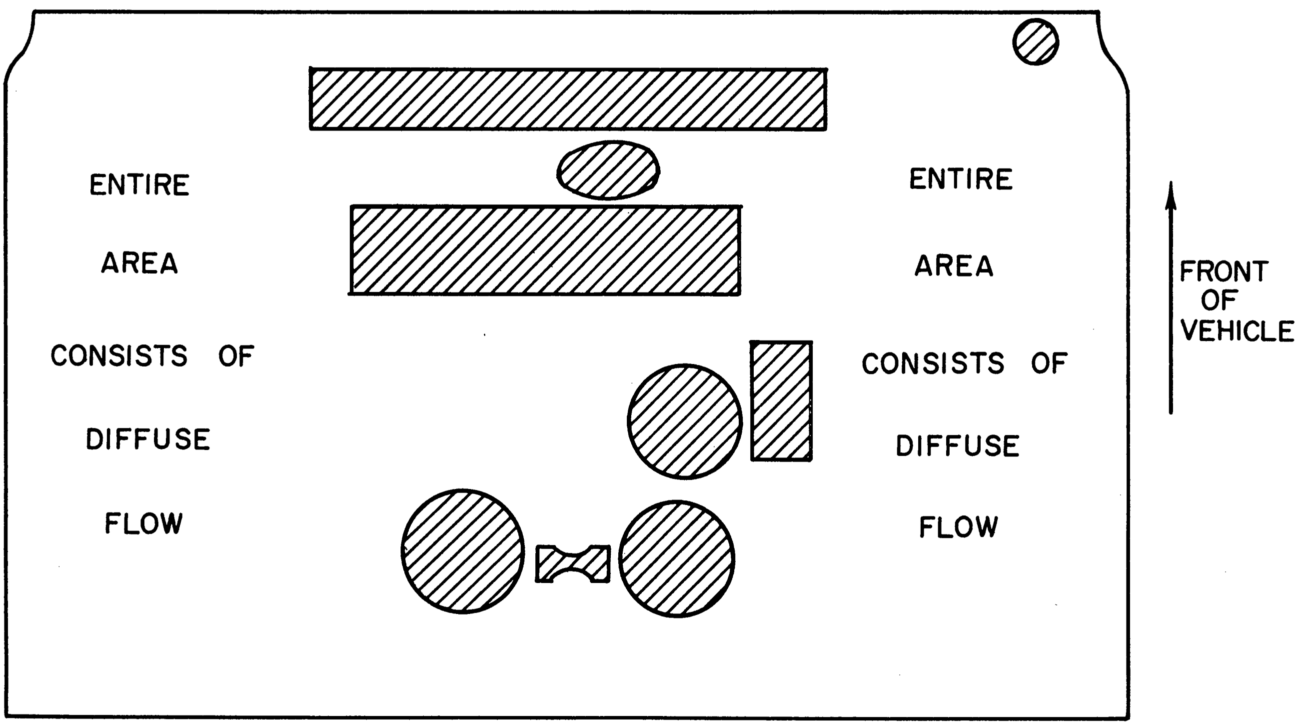


Plane 7. 55 inches below inside of commander hatch cover, includes turret and hull compartment. (Note: Dashed lines indicate approximate location of turret basket.)

COMBUSTION HEATER RUNNING

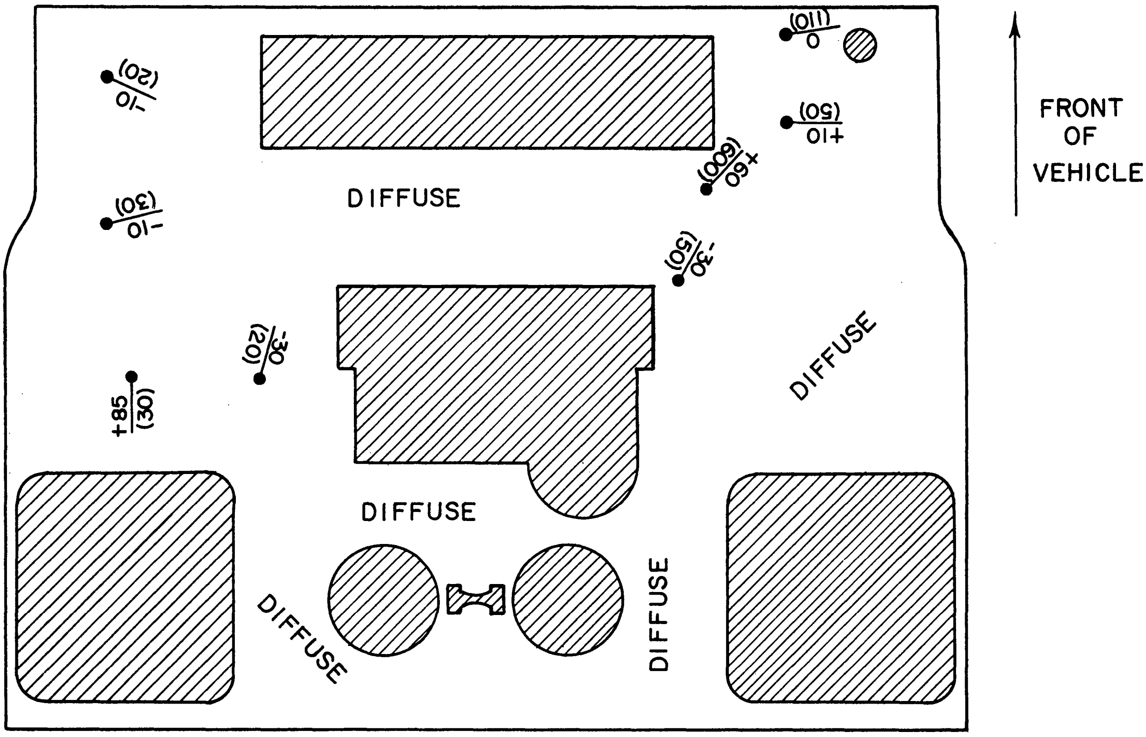


VENTILATOR FAN RUNNING

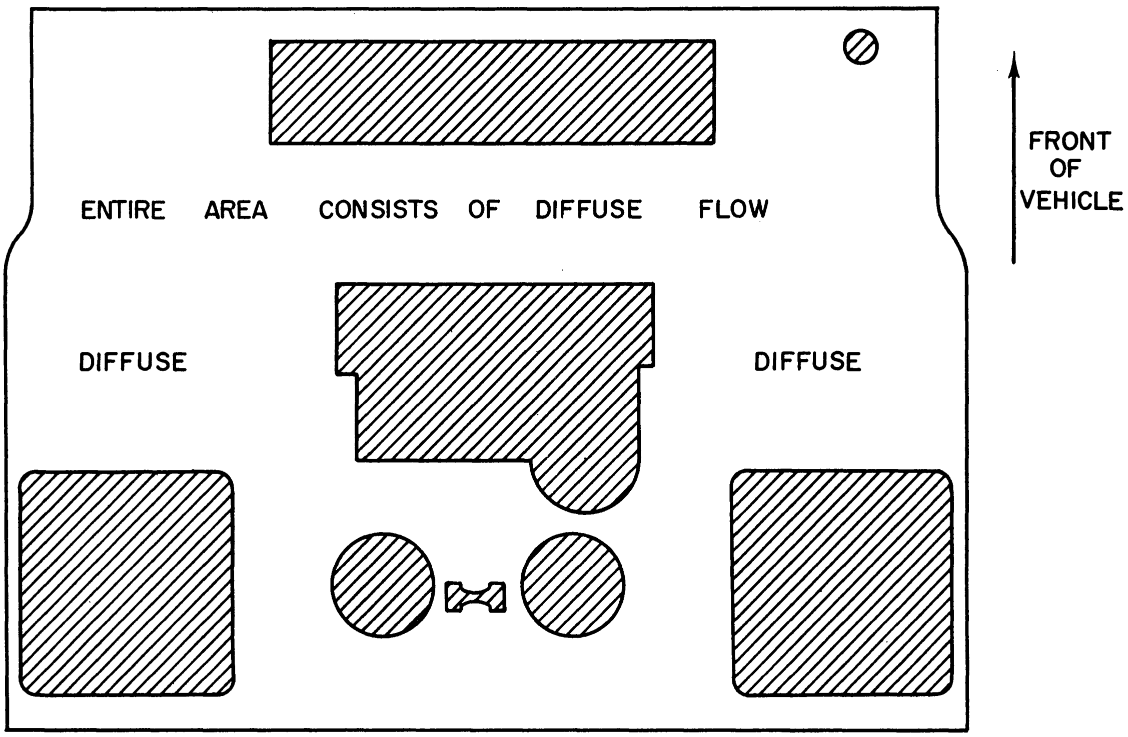


Plane 8. 70 inches below inside of commander hatch cover
(hull compartment)

COMBUSTION HEATER RUNNING



VENTILATOR FAN RUNNING



Plane 9. 78 inches below inside of commander hatch cover
(hull compartment near floor)