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ARMORED MEDICAL RESEARCH LABORATORY  
Fort Knox, Kentucky

Project No. T-14  
SPMEA 724.9

22 October 1945

1. PROJECT NO. T-14 - Discussion of Ventilation Requirements of Armored Vehicles.

a. Authority: Reported for record. Analysis of tank ventilation reports, studies, and field investigations.

b. Purpose: To outline the requirements for crew compartment ventilation in tanks and indicate certain desired future lines of investigation and development.

2. DISCUSSION:

a. Because of the more direct and obvious importance of other requirements the problems of crew compartment ventilation have not received primary consideration in tank design. Treatment of ventilation as a secondary matter after the basic design was fixed required the employment of compromise ventilation measures which were incapable of the required performance.

b. Laboratory and field tests, design experience, and particularly combat conditions have largely indicated the essential requirements of tank ventilation which should be considered in future design and development. These are summarized in the Appendix.

3. CONCLUSIONS:

a. Adequate crew compartment ventilation is essential for the maintenance of combat efficiency of the tank and its crew. Ventilation requirements must be considered along with other basic requirements in the initial consideration of tank design.

b. The present system of turret exhaust ventilation in the M4 series tanks is not adequate to control the gun fume released during high rates of fire of the main tank weapon.

c. The present system of crew compartment ventilation in the M4 series tanks is not adequate to control the heat and humidity in closed tanks operating in hot and humid climates.

d. Further improvement in ventilation is needed for the maintenance of reasonable comfort in cold weather operations.

4. RECOMMENDATIONS:

a. That, in future tank design and development, basic requirements for design and operation of the crew compartment ventilating system be considered with other fundamental requirements in the initial plans.

b. That crew compartment ventilation operate independently of the main tank engine and be capable of continuous operation for several hours.

c. That, in the design of the crew compartment ventilation system, provisions be made for:

- (1) Control of gun fumes at the maximum rate of fire to be encountered in combat.
- (2) Maintenance of the atmosphere in closed tanks within tolerable limits of heat and humidity during intense combat of long duration in tropical climates.
- (3) Maintenance of reasonable crew comfort in tank operation at low temperature.
- (4) Elimination of the dust nuisance in closed tanks.

NOTE: The recommendations as set forth in this project have been concurred in by Colonel Louis V. Hightower, President, Army Ground Forces Board No. 2.

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1 Incl. (Appendix)

## APPENDIX

### Tank Ventilation

Combat experience has demonstrated the importance of adequate crew compartment ventilation in tanks. Failure of the ventilating system to maintain proper atmospheric conditions in the fighting compartment has required the removal of tanks from combat just as mechanical failure and damage from enemy action have caused the loss of tanks in battle. This point is emphasized so that in future tank design the requirements of ventilation will receive early consideration along with other basic requirements and thus make possible the adoption of a sound system of ventilation rather than the forced acceptance of an unsatisfactory compromise after other design features have been fixed. Crew compartment ventilation must be independent of the main tank engine and be capable of operation for prolonged periods when the tank is stationary and the tank engine off.

The objectives of crew compartment ventilation are:

- a. Control of the toxic and irritating fumes given off in firing the tank weapons.
- b. Maintain a tolerable condition with respect to heat and humidity.
- c. Provide a reasonable amount of heat for the crew in cold weather operations.
- d. Reduce the dustiness of the ventilating air to a minimum.

#### CONTROL OF GUN FUMES

The gases produced by the tank weapons contain carbon monoxide (approximately one-third of the volume of fumes produced) and ammonia. The first is a well-known respiratory poison, causing loss of mental alertness and even disorientation and collapse. Ammonia is highly irritating and produces an immediate effect upon the eyes. The presence of these gases in excessive concentration have reduced the effectiveness of tank crews and have even caused collapse and unconsciousness in battle. It is obvious that concentrations of such toxic agents should not be permitted to build up in the crew compartment beyond their tolerable limits.

The problem was acute in the M4 series tanks because the negative-pressure ventilation system, provided for the crew compartment, depends on and varies directly with the speed of the main tank engine. Because of the negative pressure within the crew compartment, the entire volume of fumes contained in the gun barrel is drawn inside with the opening of the breech and ejection of the shell casing. Thus, approximately four liters of carbon monoxide (1/3 volume of gun barrel) is contributed to the crew compartment atmosphere with the

firing of each round of 75 mm ammunition. Since firing generally occurs when the tank engine is idling or dead, minimal or perhaps no ventilation is provided to dilute or remove the contamination. Opening the turret hatches may reduce the hazard but does not eliminate it. To provide a degree of control, on the recommendation of the Armored Medical Research Laboratory, an exhaust fan was installed in the turret roof with its inlet over the breech of the main weapon. Owing to the limited space and power available and the restricted discharge opening in the turret roof, a fan of small capacity had to be employed. Under average combat conditions the rate of firing is within the design capacity of this fan (average of one round per minute, fired in bursts of five at ten second intervals every five minutes) and adequate control is provided. Combat in the Pacific theatre, however, has required rates of fire greatly in excess of of this test rate, and the exhaust fan has failed with serious consequences. Sustained rates of fire as high as an average of four rounds per minute have been employed; under these conditions the entire tank crew has been affected by the fumes, with the loader frequently "knocked out". It is evident that the problem of gun fume control requires reconsideration and further study.

A turret exhaust fan of sufficient capacity to control fumes generated at such high rate of fire can hardly be installed, owing to the limited space, moreover it is certain that the required air flow could not be handled through the present turret roof ventilator without excessive power consumption and noise. Another method of control is therefore indicated. One scheme is to provide an independent system of positive-pressure ventilation for the crew compartment which, when the tank is completely closed, maintains an outward flow of air and thus forces the gun fumes to the outside when the breech opens. The small volume of fumes carried in with the shell casings is diluted and removed with the ventilating air. Since there is no pressure when hatches are open, a sufficient rate of air flow must be provided to dilute and remove the fumes through the open turret hatch. This method has the advantage of maintaining adequate control in the closed tank at all rates of fire. Furthermore, the independent positive-pressure system of ventilation is desired to meet other ventilation requirements. It has the disadvantage of failing to provide positive removal of fumes when the tank is not closed. Entire dependence must then be placed on a sufficient rate of air flow and proper distribution and mixing to insure prompt dilution and removal without accumulation of fumes in pockets. Under this circumstance, the method is not independent of rate of fire and the design must be determined for the maximum rate to be encountered. In the M26 tank, a positive-pressure system of 1000 cfm capacity, developing a static pressure of 1.4 inches water gage, gave superior control in the closed tank, and maintained acceptable condition when the turret hatches were open.

A third method of control, commonly employed in naval gun turrets and adopted in the latest German tanks, makes use of a high-pressure blast of air directed down the gun barrel immediately after the shell casing is ejected which blows the fumes outside. In the German practice, a separately ventilated collecting box for ejected casings was also provided thus insuring complete and independent control of gun fumes from the main weapon without reference to other ventilation requirements. Problems of supplying the compressed air and the design of a synchronized valve mechanism which operates automatically during

firing present certain difficulties. Furthermore, the capacity of the compressed air supply must be sufficient to provide for the maximum rate of fire. The apparent complications of this system of control make it appear less desirable than positive-pressure ventilation. As a possible alternate method, however, investigation and development should be pursued.

#### HEAT IN TANKS

The atmosphere inside tanks operating in hot climates is generally hotter and more humid than outside and under certain circumstances may reach and even exceed the limit of human tolerance. Such situation developed in M4 tanks in combat in the Pacific theatre, definitely reducing the combat efficiency of the tank and its crew. The conditions leading to such difficulties, were, perhaps, unique to the theatre and to the local requirements of operation, but were frequent enough to warrant the statement that further improvement with respect to crew compartment ventilation and toward elimination of correctable heat sources is necessary. The following measures are indicated:

- a. Employ heat-reflecting paint on the outside of the tank. Paints having the desired visual color but with high reflectivity in the invisible infra-red region are now available and improved paints may be anticipated in the future. The gains from the use of such a paint are not large but are justified since the only measure involved is a change in the paint.
- b. Provide an insulation blanket over the transmission and final drive assembly of all front-drive tanks. A few of the blankets developed for the M4 tank were employed in the Pacific theatre and were found to improve the conditions in the bow markedly. Insulation of the turret roof and bow deck should also be considered.
- c. Insulate the bulkhead between the engine and crew compartments to minimize the forward flow of engine heat when the tank stops.
- d. Provide a system of positive-pressure ventilation for the crew compartment operating independently of the engine and capable of continuous operation for several hours when the main tank engine is dead. The distribution of air must be planned with regard to the requirements of both bow and turret crew members. Laboratory tests and field studies at Camp Polk, Louisiana\* indicate that a rate of ventilation of 1000 cfm is required to prevent the tank atmosphere from becoming too humid and hot. The wet bulb temperature in the fighting compartment should not exceed 88°F during closed combat operation.
- e. Every effort must be made to reduce the work effort required of the loader through improved ammunition stowage and handling. This member of the crew has the highest work rate and is most likely to be affected by the heat.

\* AMRL Report No. 35 - Determination of the Optimum Method for Protection of Tank Crews Against Chemical Warfare Agents, dated 13 September 1944.

## TANK HEATING AT LOW TEMPERATURES

No successful method has been developed for crew compartment heating in cold weather. A sufficient quantity of heat is available from engine cooling but means for utilizing this waste heat have not been developed. The practice of passing air from the engine compartment into the crew compartment cannot be recommended because of the danger from carbon monoxide poisoning. With liquid-cooled engines, means should be provided for passing the ventilating air over the radiators or over special heat-transfer units located in the crew compartment and connected to the liquid-cooling system. For most effective use of the heated air, distribution with respect to the various crew positions must be carefully planned. Further gains will come from the insulation wherever possible, of all metal parts with which the crew members come in contact—seats, pedals, control handles, foot rests, etc. Wind shield canopies for open driving are essential. Frost formation on the cold walls of a warmed tank may be a source of trouble and must be guarded against through adequate capacity and distribution of ventilation.

The minimum desired temperature in tanks cannot be definitely fixed because of the intimate relationship with the amount of clothing worn. A temperature between freezing and 50°F is probably desirable.

## DUST CONTROL

The heavy dust concentration to which tank crew members are at times exposed presents no likely hazard from the standpoint of lung injury. The dust does, however, cause temporary eye and throat irritation and is a nuisance. With the employment of positive-pressure ventilation it becomes possible to consider the installation of a cleaner for the ventilating air. Because of the space requirements and power consumption, it is recognized that a highly efficient device comparable to an industrial air cleaner probably cannot be employed. It may be remembered, however, in judging performance, that only elimination of a nuisance is desired and that moderately high dust concentrations are tolerated provided the coarser dust particles, say above 5 microns in diameter, are removed. Further investigation and development are desirable.

Dust skirts over the tracks have not found wide favor among tank crews because they are easily damaged. Skirts are, however, of great value in reducing the dust raised around the tank and, for this reason, should be retained and improved. Much can also be gained by the proper location of the ventilating system intake since the dust concentration varies greatly around the outside of the moving tank. The optimum intake location with regard to minimal dust intake may not be the best from the standpoint of inside arrangements, space available, etc; therefore a carefully considered compromise may be necessary.

## MECHANICAL FEATURES OF VENTILATING SYSTEM

a. The advantage of the system of negative-pressure ventilation in the M4 series tanks is that it requires no extra power supply, being merely a by-product of the engine cooling system. The positive-pressure system in the M26 tank was objected to because of the high power consumption made necessary, in part, by the compact installation required and the restricted inlet available. In original

design the installation of a fan of adequate dimensions to permit lower fan speed and less power consumption should be considered. A better choice of inlet location will permit the use of a larger and less restricted opening.

b. Installation of the positive-pressure fan in the M26 tank after tank design was fixed did not permit optimal air distribution in relation to crew position. The high air blast directly upon the bow crew members is objectionable and in addition no special provisions are made for the turret. The reverse situation applies to a lesser degree when the fan is installed in the turret bulge. Again, the solution of the problem lies in early consideration of ventilation requirements before tank design has been fixed.

c. Tank noise has received little consideration. Although it is generally recognized as undesirable, noise is not regarded as a hazard. In combat, however, the tank engine and even the turret exhaust fan have been shut off because of the need for the best possible communication and understanding of outside activities. In view of this, it is evident that the noise created by the present M26 fan would be wholly unacceptable and even the turret exhaust fan is too noisy. Adequate ventilation with minimum sound requires a low-speed fan which, in turn, requires an unrestricted inlet, adequate space for the larger fan, and distribution ducts of generous dimensions.

d. Because of the prolonged operations of the tank ventilating system, the fan, motor and accessory equipment need to be of first quality. The present turret exhaust fan has given trouble in this respect, some combat crews stating that the fan had required more frequent repair and service than any other single item of tank equipment.