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Project Manager, M60 Tanks

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M60 CLEAN AIR WINTER TEST

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Final Report

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Dust Detector
Clean Air

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This is a final test report of a comparison test of two M60 Tank Air Induction Systems conducted in falling snow and cold temperatures at the Keweenaw Research Center, Houghton, MI. One tank was equipped with the proposed "Clean Air" improvements including a vehicle exhaust dust ejector system and a dust detector. The comparison tank was equipped with current production hardware.

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ABSTRACT

Two air induction systems on the M60 series tank were evaluated in falling snow. One tank used the standard air cleaner blower motor system (ACBM) while the other tank incorporated the Vehicle Exhaust Dust Ejector System (VEDES). None of the air filter elements on either tank became clogged with snow during the test. The check valves froze shut on the VEDES tank, while the ACBM became frozen with slush. The precleaner plugs on both tanks became packed with snow often.

The tests were performed by personnel at the Keweenaw Research Center (KRC) in cooperation with personnel from General Dynamics Land Systems Division (GDLSD). The Keweenaw Research Center is a research agency of Michigan Technological University. It operates from the Keweenaw Field Station located on the Keweenaw Peninsula about 500 miles northwest of Detroit, Michigan. The field station offers a unique combination of terrain features, vegetation, lakes, access to an airport, and climatic variations. The long snow season also facilitates access to arctic-like conditions that can be reached easily from almost any part of the country.

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I. INTRODUCTION

The objective of these tests was to compare the "clean air" Vehicle Exhaust Dust Ejector System (VEDES) to the standard Air Cleaner Blow Motor (ACBM) system on the M60 series tank. There were two basic areas investigated during these tests. One was to check the air filter elements for clogging of snow, which would prevent normal operation of the air induction system. The second area of investigation was to determine if overnight cold soaking of the VEDES tank would cause freezing of the check valves.

II. CLEAN AIR TEST SET-UP

Test Course

A test course was first devised as shown in Figure 1. The course was designed to be run at different speeds in various sections of the course. This is so the vehicles would not be operated at a constant high or low speed for an extended period of time, which may favor one system over the other. The course was 2.1 miles long with one lap taking approximately nine to ten minutes to complete. The testing periods consisted of a number of two-hour cycles. Each two-hour cycle consisted of: five laps forward (45-50 minutes), followed by a reverse operation for 5 minutes; a 15-minute idling period; and finally another five to six forward laps. This would be approximately 21 to 23 miles of operation per two-hour cycle. When weather conditions permitted, the two-hour cycle would be repeated until either poor weather conditions (i.e., no snowfall) existed, or it became too dark outside to read the pressure gauges.

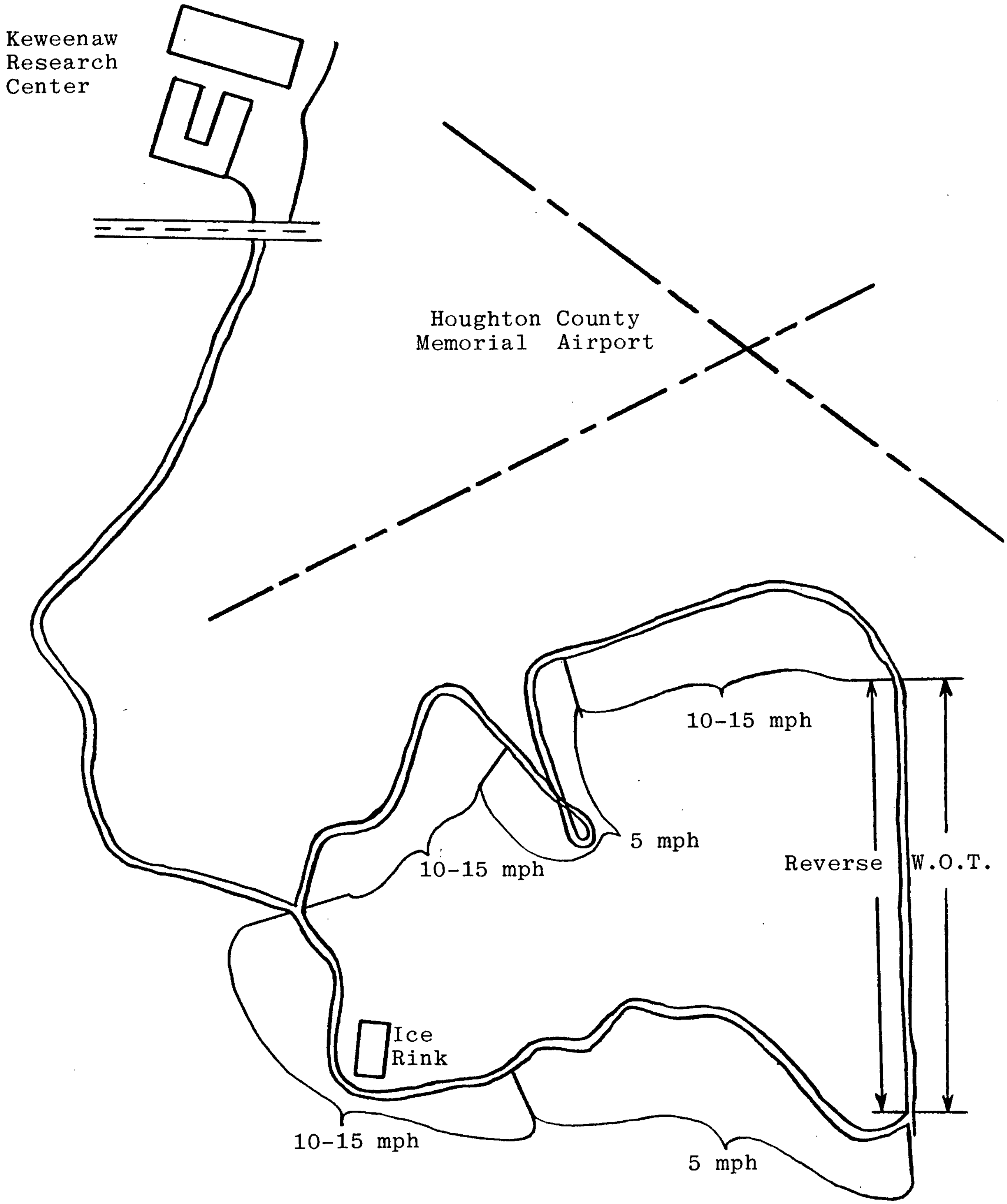


Figure 1. Test course map for Clean Air Tests, February-March 1983.

Vehicle Description and Instrumentation

Two M60 tanks were used during the clean air tests. One tank was an Annison rebuild, which is kept at the Keweenaw Research Center (KRC) for other vehicle testing. The other tank was sent to KRC from General Dynamics Land Systems Division (GDLSD). This tank arrived at KRC on 16 February 1983. The tank at KRC utilized the standard ACBM system, while the GDLSD tank incorporated the VEDES clean air system. In order to compare results on an equal basis, both tanks were operated at the same time.

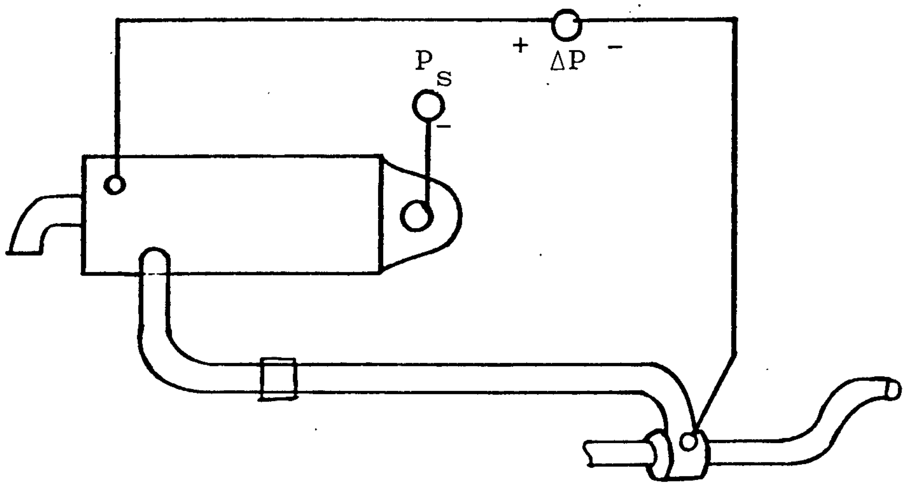
On the standard vehicle, both air cleaners were instrumented to obtain the pressure at the restriction indicator on the outlet elbow. The gauges required to measure these pressures were installed within view of the driver.

On the "clean air" vehicle both air cleaners were instrumented exactly the same as the standard vehicle. In addition, instrumentation was added to measure the pressure differential between the top scavenge cleanout plug and the VEDES nozzle. A diagram showing the instrumentation location is presented in Figure 2.

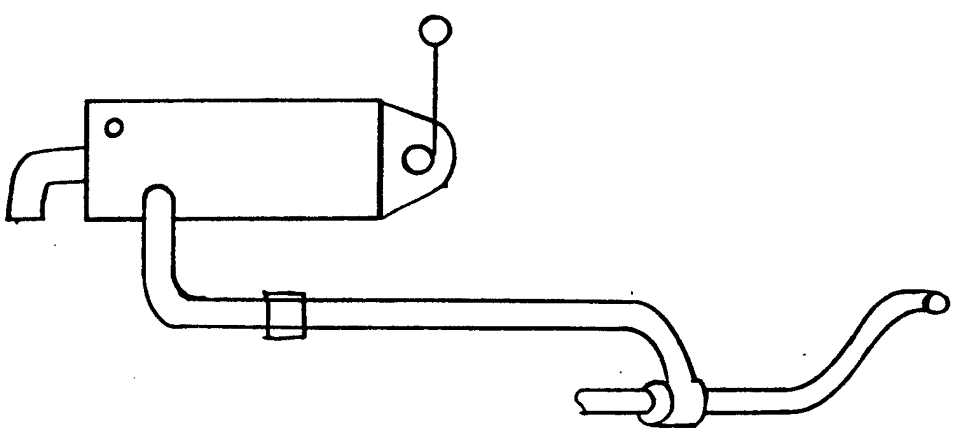
A pressure reading of 30 inches H_2O or greater at wide open throttle, at the air cleaner elbow restriction, would indicate a plugged air cleaner filter element. A pressure reading of 8 inches H_2O or greater during the high speed stall test, at the scavenge tube location, would indicate a clogged scavenge tube or frozen check valve.

Recording of Test Data

A sample data sheet is shown in Figure 3. Prior to running each two-hour cycle, pre-operational checks were performed on both tanks at idle and stall speeds to insure



Clean air tank configuration



Standard tank configuration

Figure 2. Vehicle pressure gauge instrumentation.

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HOUGHTON, MICHIGAN 49931

DATA WORKING SHEET
CLEAN AIR WINTER TEST 1983

DAY/
DATE:____________ TIME:____________ TEMP:____________

SNOW CONDITIONS: Quanity/Description & Wind Speed

CYCLE PREOP CHECKS:		STANDARD		CLEAN AIR	
P_1 GAUGE	IDLE:	R:______	L:______	R:______	L:______
AIR FILTER	STALL:	R:______	L:______	R:______	L:______
Δ P VEDES	IDLE:	------N/A------		R:______	L:______
	STALL:	------N/A------		R:______	L:______
ACBM OPR CK'D		R:______	L:______	------N/A------	

PERFORMANCE :

(A) CYCLE BEGINNING
(B) CYCLE ENDING

ENGINE	(A)	(B)	(A)	(B)
NO LOAD MAX RPM	______	______	______	______
STALL RPM	______	______	______	______
ODOMETER	______	______	______	______
ENGINE HOUR	______	______	______	______
BEGIN CYCLE TIME	______	______	______	______
1ST LAP TIME	______		______	
2ND LAP TIME	______		______	
DRIVER TO SUPPLY TOP SPEED	______MPH		______MPH	
HI SPEED RUN AIR FILTER RESTRICTION	R:______ L:______	R:______ L:______	R:______ L:______	R:______ L:______

CYCLE POST OP CHECK					
P_1 GAUGE	IDLE:	R:______	L:______	R:______	L:______
AIR FILTER RESTRICTION	STALL:	R:______	L:______	R:______	L:______
Δ P VEDES	IDLE:	------N/A------		R:______	L:______
	STALL:	------N/A------		R:______	L:______
ACBM OPR CK'D		R:______	L:______	------N/A------	

(OVER)

Figure 3. Sample data sheet for 1983 Clean Air Winter Tests.

NUMBER OF LAPS TO REVERSE OPERATION:

TIME OF IDLE

AIR CLEANER RESTRICTION OBTAINED AT ______________

/_7 LEFT /_7 RIGHT /_7 STANDARD TANK /_7 CLEAN AIR TANK

ODOMETER	________	________
ENGINE HOUR	________	________
INDICATED AIR CLEANER RESTRICTION READING	R:_____ L:_____	R:_____ L:_____
PRECLEANER RESTRICTION INDICATED (TCM REQD)	R:_____ L:_____	R:_____ L:_____

FILTER REMOVED
ORIGINAL INSTALLED WEIGHT ______________

CLOGGED WEIGHT ______________

REMARKS:

VEDES CHECK VALVE RESTRICTION NOTED ON /_7 LEFT /_7 RIGHT
TIME: ____________________

IDLE ENGINE FIVE MINUTES THEN PERFORM ENGINE STALL TO CONFIRM FROZEN VALVE/VERIFY RELEASE

RELEASED BY______________

AFTER____________FIVE MINUTE IDLE CYCLE

WALKAROUND INSPECTION NOTES:

that all pressure gauges and the ACBMs were operating adequately.

Performance checks were made at the beginning and end of each cycle. These checks were to insure that both tanks were comparatively operational. The performance checks were: no load at maximum engine speed; stall engine speed; and vehicle top speed. During the top speed run, the air filter restrictions on both sides of each tank were recorded to check for filter element clogging.

At the end of each cycle, post-operational checks were made on each vehicle at idle and stall speeds to insure adequate operation of all instrumentation. These checks were identical to the pre-operational checks described above.

III. M60 CLEAN AIR TEST SUMMARY

On 24 February 1983, the vehicles were operated for 27 miles in very light snowfall. None of the air cleaner filter elements became clogged with snow. The ACBM on the standard vehicle was noted to be not working after about four miles of operation. The ACBM was removed, found to be incrusted with ice and snow, thawed out and reinstalled. It should also be noted that the air filter restriction during the high speed run was higher for the standard tank (18-20 inches H_2O) as compared to the clean air tank (12 inches H_2O). Because the snowfall was so light and only four miles had been accumulated on the vehicle, this problem did not seem to be caused during this test period, and may have been frozen before starting the day's testing. This same ACBM had been restricted during other winter testing at KRC, prior to the clean air tests. After about eight miles of operation, the lower inspection plug for the precleaner compartment on the standard tank was pulled and 1/2 to 3/4 inches of snow was found. This is the outboard plate of the precleaner box and probing indicated snow was present against the outside plate only. No packed snow could be seen through limited inspection within the rest of the precleaner box. A plugged precleaner is shown in Figure 4. The snow was melted with a mobile heating unit against the outside of the plate until all precleaner interior snow was melted. The next morning, the precleaners were pulled before operation and found to have about the same amount of snow packed against the outside plate in both boxes. This snow was again melted before testing on 25 February 1983.

On 25 February 1983, 28 more miles were accumulated on both tanks in light snowfall with no noticeable filter element clogging or precleaner plug restriction. At the end of the day's operation (55 total course miles), during the post operational checks, it was noted that the right outboard ACBM had restricted output. This unit was replaced on 28 February 1983. During replacement of this ACBM it was also noted that there was approximately four ounces of water in the bottom of both blower motor housing compartments, as shown in Figure 5.

On 1 March 1983, there were 17 more test course miles accumulated on the tanks in light sleet and snow. There was no air filter element clogging or precleaner plug restruction noted on 1 March.

On 9 March, both tanks were operated for about 5 hours (58 miles) during a heavy, blowing snowfall. The temperatures ranged from 17-19°F, but the snow did not accumulate on the tanks. The snow was not the large, fluffy flake type, but rather the smaller, graupel type. The filter restrictions remained basically the same throughout the period of operation. The VEDES ΔP readings remained basically the

Figure 4. Plugged precleaner holes from testing in snow.

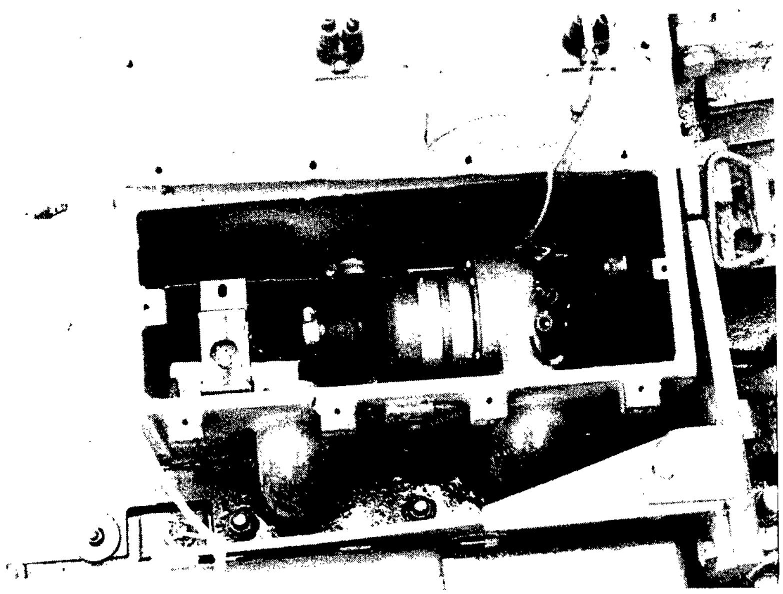

Figure 5. Water in bottom of blower motor housing compartments on 28 February 1983.

same throughout the period of operation, but the check valves were frozen shut the following morning. The ACBM exhaust elbows built up with freezing slush during this period of operation. The slush build-up progressively restricted blower output and by the end of the day there were two restricted ACBM elbows with one more being restricted to the point of being clogged. The other ACBM exhaust elbow was unrestricted during this testing period. The next morning the ACBM system failed to operate.

The ACBMs were removed on 10 March 1983, after they were found to be inoperable, and brought inside a heated building to melt the ice. After reinstalling the dried out motors, they operated normally. The air cleaner box exhaust elbows were cleared of the slush ice build-up by using a propane torch immediately after the ACBMs had been removed.

On 10 March, the VEDES check valves were found to be frozen shut per instrumentation gauge readings. Following the test plan procedures, the vehicle was idled for five minutes and then a stall test was performed to verify if the check valves had or had not broken loose, by observing the instrumentation gauge readings. This procedure was repeated 13 times without results. It was then decided to lift the grill doors to gain access to the check valve cages and hit these cages to break the valves free. After a number of hits both check valves were broken free. In the afternoon, the vehicle was operated for over three hours, primarily parked and idling, but it was also driven 13 miles during this time period. The vehicle did not travel through any snow fields, nor was any snow falling, but was operated within packed snow or clear areas. The following morning, with overnight temperatures below freezing, the VEDES operation was checked and found to be fully operational by observing the instrument gauge readings.

Immediately before beginning operation on 9 March 1983, clean air filter elements were installed in both tanks. The following morning, 10 March, the air box filter covers were lifted and photographs of the "as installed" condition in both vehicles were taken. These are shown in Figures 6 through 9. The filters were then carefully removed, taking care not to disturb any clinging snow, and placed into plastic bags. Next, the filters were weighed within the plastic bags for a gross weight measurement. In all cases, if packed snow was seen, it was packed only at the outlet side. The filter and accumulated snow weights are presented in Table 1.

The results of the precleaner inspection are presented in Table 2. The observations were made through the lower blowout hole and the probe was a standard wooden, lead pencil shoved into the inspection hole in order to gauge the depth of packed snow in the precleaner.

When the tanks are stored outside while it is snowing and they are not running, snow accumulates on the air intake grill doors as shown in Figure 10. Then, when the tanks are started, the snow is sucked into the air filter element compartments as shown by the reduced amount of snow on the grill doors in Figure 11. This fact may have a significant influence in the clogging of the air filter elements with snow.

The snowfall on each day the tanks were operated is shown in Table 3.

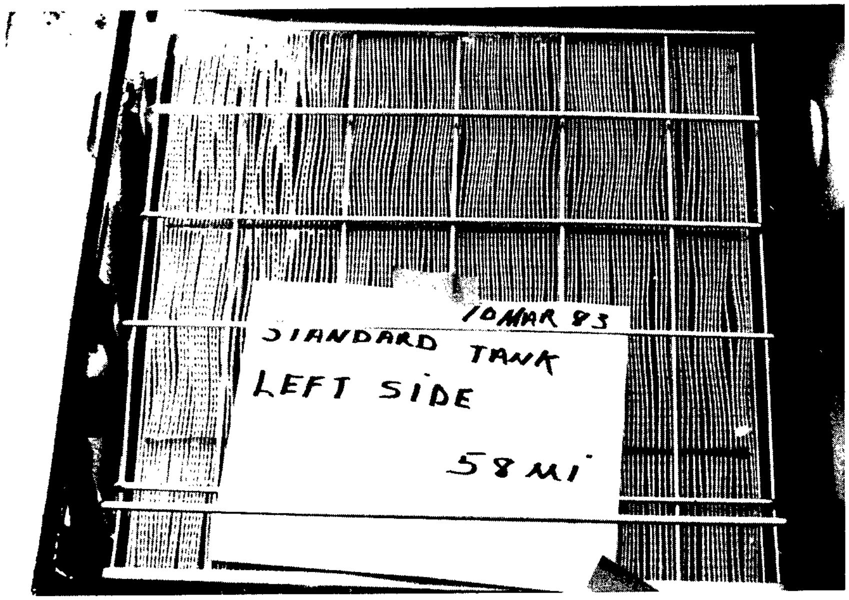

Figure 6. Standard Tank. Left Side Air Filter Element, After Testing 9 March 1983, on Morning of 10 March.

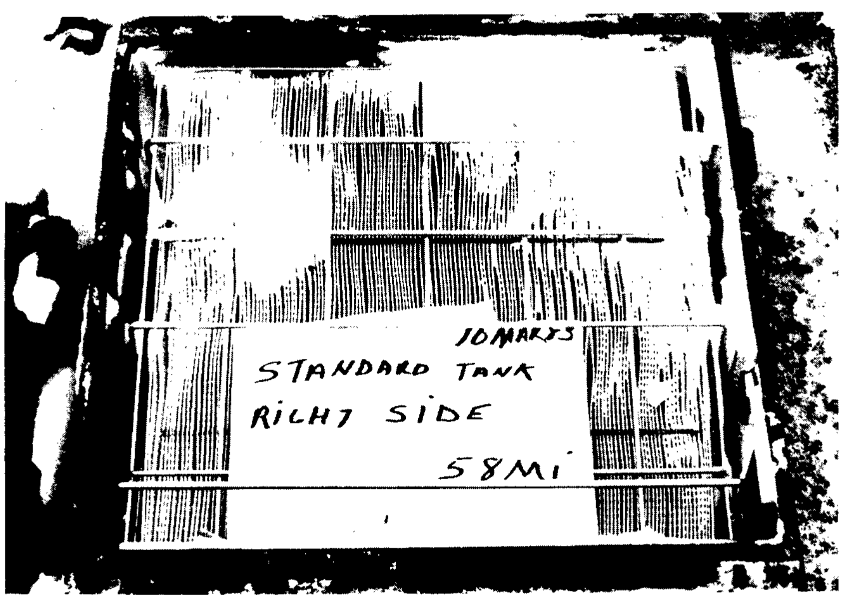

Figure 7. Standard Tank, Right Side Air Filter Element, After Testing 9 March 1983, on Morning of 10 March.

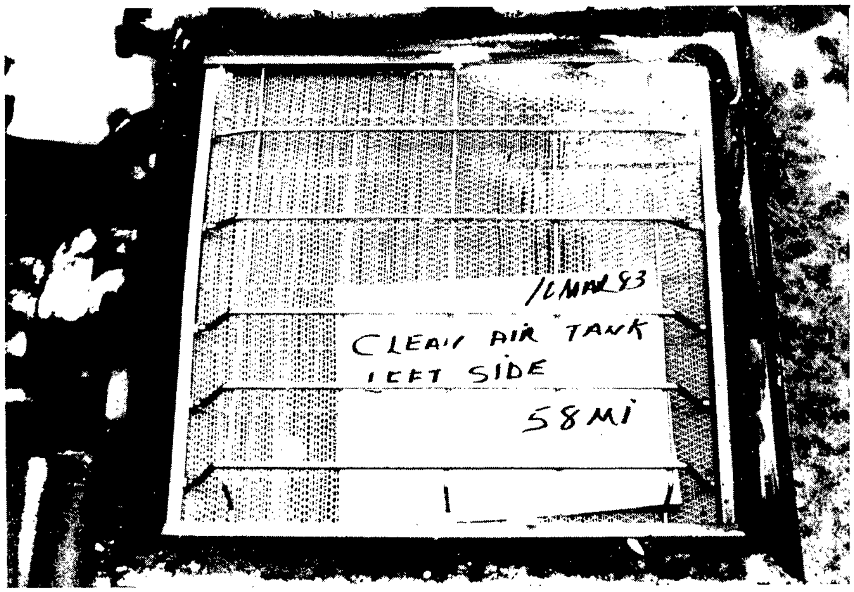

Figure 8. Clean Air Tank, Left Side Air Filter Element, After Testing 9 March 1983, on Morning of 10 March.

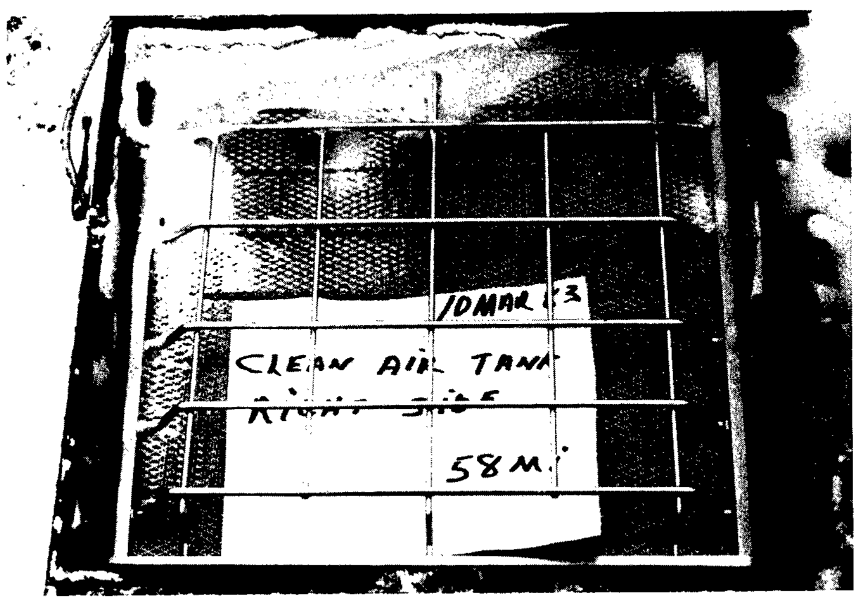

Figure 9. Clean Air Tank, Right Side Air Filter Element, After Testing 9 March 1983, on Morning of 10 March.

Table 1. Air cleaner filter element weights after testing 9 March 1983

	Standard (ACBM)		Clean Air (VEDES)	
	Left	Right	Left	Right
Gross	24 lb 14-1/8 oz	22 lb 14-1/4 oz	32 lb 14-3/8 oz	31 lb 12-15/16 oz
Tare	2-3/4	2-3/4	2-3/4	2-3/4
Net	24 lb 11-3/8 oz	22 lb 11-1/2 oz	32 lb 11-3/5 oz	31 lb 10-3/16 oz
Orig Weight	21 lb 14-15/16 oz	21 lb 15-1/8 oz	30 lb 5.0 oz	30 lb 13-3/16 oz
Diff	2 lb 12-7/16 oz	12-3/8 oz	2 ob 6-5/8 oz	13.0 oz

Snow packed in filter box (approximate measurements)

2-1/2 cups	3.0 cups	3-3/4 cups	1-1/2 cups

Table 2. Precleaner inspection results after testing 9 March 1983

	Standard (ACBM)		Clean Air (VEDES)	
	11:45 AM	5:45 PM	11:45 AM	5:45 PM
Left Side	2-3"	1-1/2"	None	Some snow apparent
Right Side	6"+	6"+	6"+	6"+

Examination through lower blowout hole, the "probe was a standard wooden lead pencil shoved into inspection hole to gauge depth.

Figure 10. Photograph of Snow on Intake Grill Doors Before Starting Tank.

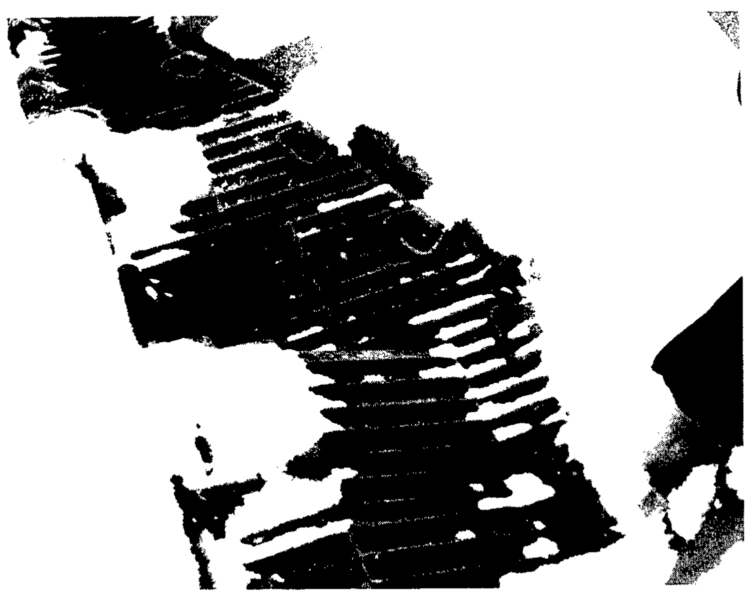

Figure 11. Photograph of Intake Grill Doors After Starting Tank

Table 3. Recap of snowfall during testing periods.

DATE	TIME	AMOUNT OF SNOWFALL	COURSE MILES
24/02/83	7 AM - 1 PM	.3"	6
	1 PM - 7 PM	T	21
25/02/83	7 AM - 1 PM	T	28
01/03/83	6 AM - NOON	T	
	NOON - 6 PM	1.5"	17
09/03/83	7 AM - 1 PM	2.5"	23
	1 PM - 7 PM	4.5"	35
10/03/83	7 AM - 1 PM	.2"	13

Officially recorded snowfall at the Houghton County Memorial Airport, FAA Weather Station.

IV. CONCLUSIONS

A total of 143 miles were accumulated on both M60 tanks in various types of snow conditions, during the test period, which ran from 16 February to 21 March 1983. None of the air filter elements became restricted to the point of being clogged (i.e., 30 inches H_2O pressure reading at maximum speed) during the 143-mile test period. The maximum air filter element restriction on the standard ACBM tank was 20 inches H_2O and 18 inches H_2O on the clean air tank. It must be remembered that at no time during the test period were the weather conditions ideal; ideal conditions being light, fluffy snowflakes producing a heavy snowfall. The snow was typically a wet snow or graupel type snow. When the snow fell on the vehicles during operation, it would melt or become slushy. Therefore, no definite conclusions can be made as to which vehicle's air filter elements will clog or clog faster.

On the standard vehicle, the ACBMs tend to freeze and the exhaust elbows will build up with packed snow or freezing slush, thereby restricting blower output.

On the clean air vehicle the VEDES check valves will freeze shut. The valves require a method other than operation of the tank to unfreeze and resume normal operation.

The precleaners on both vehicles tend to become packed with snow. In order to unplug the precleaners, some form of heat must be applied to melt the accumulated snow.