

AD-A072 160 ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND ABERD--ETC F/G 19/3  
SUMMARY OF M60A1 TANK LEAKAGE TESTING.(U)  
JUN 79 J M FERRITER, L J BEESON

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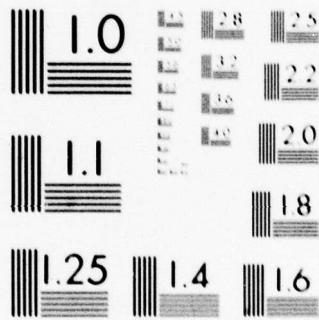
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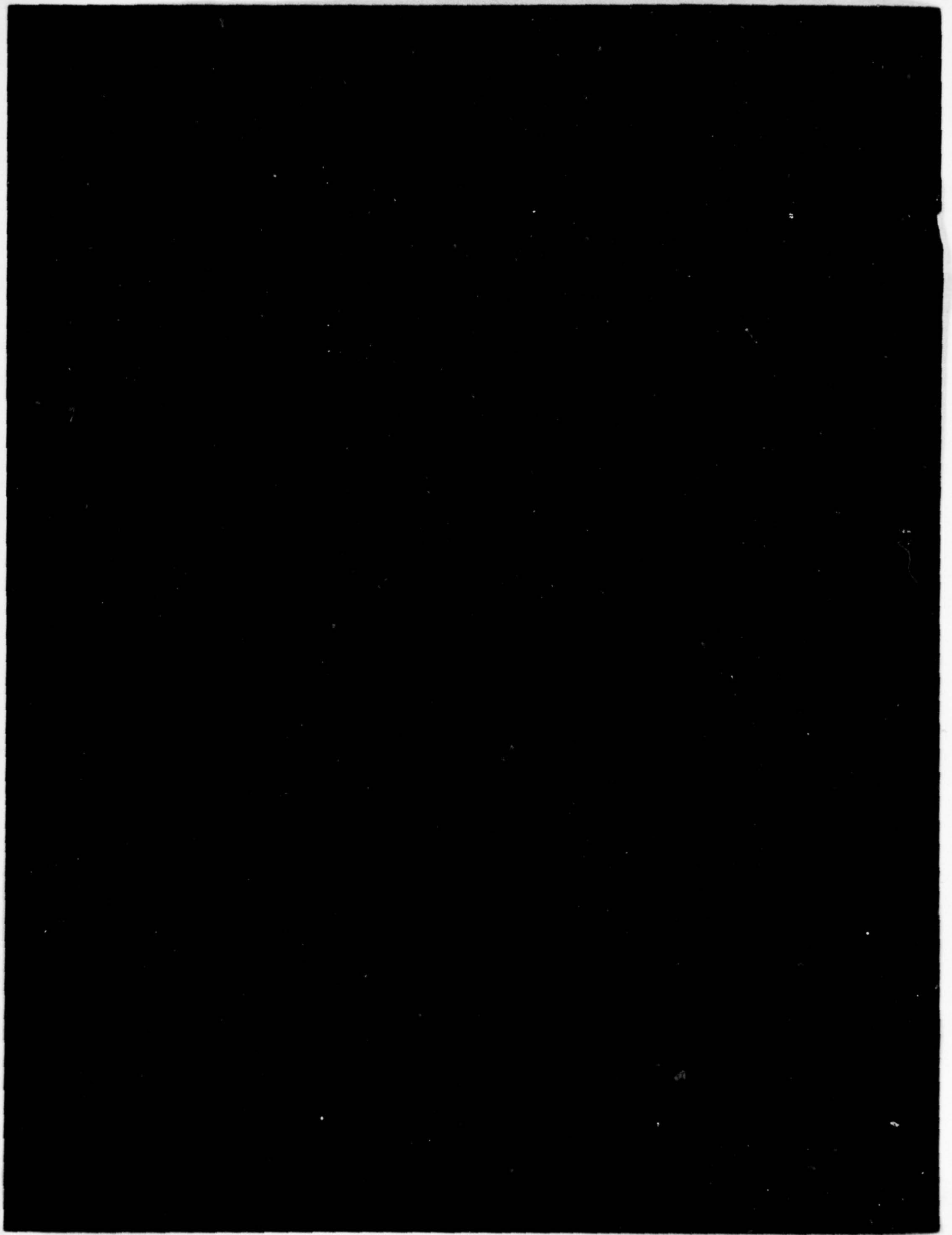


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| 4. TITLE (and Subtitle)<br><br><b>SUMMARY OF M60A1 TANK LEAKAGE TESTING</b>   |                       | 5. TYPE OF REPORT & PERIOD COVERED<br><b>Technical Report<br/>September 1977-July 1978</b>  |
| 7. AUTHOR(s)<br><b>John M. Ferriter<br/>Leonard J. Beeson</b>   |                       | 6. PERFORMING ORG. REPORT NUMBER  |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br><b>Commander/Director, Chemical Systems Laboratory ✓<br/>Attn: DRDAR-CLW-CC<br/>Aberdeen Proving Ground, Maryland 21010</b>  |                       | 8. CONTRACT OR GRANT NUMBER(s)  |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br><b>Commander/Director, Chemical Systems Laboratory<br/>Attn: DRDAR-CLJ-R<br/>Aberdeen Proving Ground, Maryland 21010</b>   |                       | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br><br><b>Task 1M263721D604</b> |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)   |                       | 12. REPORT DATE<br><b>June 1979</b>   |
|   |                       | 13. NUMBER OF PAGES<br><b>30</b>  |
|   |                       | 15. SECURITY CLASS. (of this report)<br><br><b>UNCLASSIFIED</b>                             |
|   |                       | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE<br><b>NA</b>                                     |
| 16. DISTRIBUTION STATEMENT (of this Report)<br><br><b>Approved for public release; distribution unlimited.</b>  |                       |   |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)  |                       |   |
| 18. SUPPLEMENTARY NOTES   |                       |   |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br><br><b>Code tester<br/>Leakage<br/>Anemometer</b>   |                       |   |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br><br>➤ <b>This report summarizes four sets of M60A1 tank leakage data which were acquired from Honeywell, Inc., Aerophysics Co., Chrysler Corporation, and Chemical Systems Laboratory. Testing methodologies are reviewed and a standardized test procedure combining the various methodologies is suggested. Several proposed leak reduction measures are also presented.</b> |                       |   |

PREFACE

The work described in this report was authorized under Project 1M263721D604, NBC Collective Protection Program for Combat Vehicles. Work was carried out from September 1977 to July 1978.

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CONTENTS

|                                      | <u>Page</u> |
|--------------------------------------|-------------|
| I. INTRODUCTION . . . . .            | 7           |
| II. TEST PROCEDURES . . . . .        | 7           |
| III. LEAKAGE DATA RESULTS . . . . .  | 8           |
| IV. DISCUSSION OF RESULTS . . . . .  | 8           |
| V. LEAK REDUCTION MEASURES . . . . . | 12          |
| VI. CONCLUSIONS . . . . .            | 13          |
| VII. RECOMMENDATIONS . . . . .       | 13          |
| SELECTED REFERENCES . . . . .        | 15          |
| APPENDIXES                           |             |
| A. Tables . . . . .                  | 17          |
| B. Total Leakage Values . . . . .    | 25          |
| DISTRIBUTION LIST . . . . .          | 27          |



## SUMMARY OF M60A1 TANK LEAKAGE TESTING

### I. INTRODUCTION.

The current Congressional concern to ensure adequate Nuclear/Biological/Chemical (NBC) protection for armored vehicles has resulted in the establishment of an armored vehicle program managed by Tank Automotive Research and Development Command (TARADCOM). Much of the central effort is at Chemical Systems Laboratory (CSL). Prior to determining armored-vehicle NBC vulnerability and recommending appropriate protective measures, a quantitative data base to include airflow, infiltration, purge, residual hazard and M13A1 filter unit must be generated. One of the first steps is to identify vehicle leakages. Once leak areas are identified, selective leak reduction measures to minimize NBC infiltration may be desirable. The objective of airflow (leakage) evaluation is to identify and quantify the magnitude of each leak area which allows air exchange between the crew compartment and the outside of the armored vehicle. The purpose of this report is threefold: (1) summarize four sets of M60A1 Tank leakage data which have been acquired from Honeywell, Inc., Aerophysics Co., Chrysler Corporation, and CSL, (2) review testing methodologies and select one method for future leakage testing, and (3) prepare preliminary modifications for major leak areas.

### II. TEST PROCEDURES.

CSL supplies air through the commander's hatch with a centrifugal blower, and measures the flow rate with a calibrated-axial-vane anemometer immediately before discharge into the vehicle. The exterior and/or interior of the vehicle is then examined (generally by feel) to locate sources of air leakage which are then sealed with duct seal or tape. Once all accessible leaks are sealed, the unaccounted leakage is measured. Every attempt is made to reduce leakage to zero. Next, each individual leak is unsealed, and the associated leakage measured at several differential static pressures. Each leakage measurement is then repeated. The leak area is resealed prior to measuring the next leak area. Honeywell used the CSL method of leakage measurement.

Aerophysics supplies the air through the loader's hatch using a "code tester" built in accordance with the Joint Air Moving and Conditioning Association, Inc. - American Society of Heating, Refrigerating, and Air Conditioning Engineer's specifications published in April 1975. The "code tester" has the capability to measure airflow up to 6000 ft<sup>3</sup>/min. The air mover is a variable speed centrifugal fan, controlled by a variable voltage-variable frequency "varidyne" electric generator. Initial leak identification is made using an ultrasonic air leak detector. After all accessible leaks are sealed with duct tape, the unaccounted leakage is measured. Next, each leak is unsealed and the associated leakage measured at several differential static pressures.

Chrysler Corporation supplies air through the vehicle ventilation blower inlet with a 2000-ft<sup>3</sup>/min blower. The airflow is measured using a micromanometer while the crew compartment pressure is measured by an inclined-vertical manometer. To aid in leak source identification, an orange smoke flare is placed in the vehicle. Leaks are sealed using duct seal and tape. Beginning with the lowest leakage source, each leak is unsealed and the airflow rate is measured at several differential static pressures.

III. LEAKAGE DATA RESULTS.

The data from the four sources are summarized in the table. CSL and Aerophysics conducted their tests on the same M60A1 vehicles. The Chrysler and Honeywell data are from other M60A1 tanks. The CSL and Honeywell data are projected using a regression analysis.

IV. DISCUSSION OF RESULTS.

Individual leakage points are reported and are compared where applicable. All data are reported in standard cubic feet per minute at 1.5-inch water gage static pressure.

1. Total Vehicle Leakage.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 1028               | 1000   | 1347       | 1461   | 1613            | 1242   | -                |

CSL's figure represents the total vehicle to include vehicle ventilation blower (no leaks sealed) with a round chambered. Aerophysics sealed the vehicle ventilation blower inlet, where Chrysler supplied air through the vehicle ventilation blower inlet. Tanks tested by Aerophysics, Chrysler, and Honeywell had various components (i.e., 7.62-mm coax machine gun, 50-caliber gun, range finders) missing when the vehicles were leak-tested. The vehicle ventilation blower is considered to be an air source, not a leak point and should be excluded from total leakage value. If the above corrections are made (appendix B), the comparative values are as follows:

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 947                | 971    | 871        | 995    | 1361            | 1058   | -                |

2. Ejection Port, 50-Caliber.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 491                | 431    | 469        | 457    | 324             | 443    | 779              |

3. Turret Ventilation Blower

| <u>Aerophysics</u> |  | <u>CSL</u> |        | <u>Chrysler</u> |  | <u>Honeywell</u> |
|--------------------|--|------------|--------|-----------------|--|------------------|
| -                  |  | SN8753     | SN8946 | -               |  | SN2967           |
|                    |  | 476        | 466    |                 |  | 662              |

Table. M60A1 RISE Leakage - Comparison of Results  
(standard ft.<sup>3</sup>/min at 1.5-in water gage pressure)

| Leak location         | CSL*<br>SN8753 | CSL*<br>SN8946 | Aerophysics<br>SN8753 | Aerophysics<br>SN8946 | Chrysler<br>SN4285 | Chrysler<br>SN8050 | Honeywell*<br>SN2967 |
|-----------------------|----------------|----------------|-----------------------|-----------------------|--------------------|--------------------|----------------------|
| As received           | 1347**         | 1461**         | 1028                  | 1000                  | 1613               | 1242               |                      |
| 50-cal. ejection port | 469            | 457            | 491                   | 431                   | 324                | 443                | 779                  |
| Turret blower         | 476            | 466            |                       |                       |                    |                    | 662                  |
| Range finders (both)  | 138            | 143            | 146                   | 145                   | 138                | 130                | 326                  |
| 7.62-mm gun port      | 83             | 94             | 143                   | 144                   | 136                | 123                |                      |
| Cupola race           | 78             | 63             |                       |                       | 125                | 26                 | 73                   |
| 50-cal. access        | 71             | 93             |                       |                       |                    |                    |                      |
| Unaccounted leakage   | 23             | 23             | 51                    | 45                    | 170                | 108                |                      |
| Heater                | 18             | 17             | 15                    | 12                    | 17                 | 17                 |                      |
| Main turret race      | 15             | 11             |                       |                       | 99                 | <17                | 3                    |
| Gunner's sight        | 6              | 12             | 7                     | 7                     |                    |                    |                      |
| Bilge pump            | 2              | 2              |                       |                       |                    |                    |                      |
| Cupola                |                |                | 146                   | 165                   |                    |                    |                      |
| Driver vision plate   |                |                | 43                    | 29                    | 46                 | 27                 | 65                   |
| Commander hatch       |                |                |                       |                       | 117                |                    | 65                   |
| Cupola rotor          |                |                |                       |                       | 40                 |                    |                      |
| Main gun intersection |                |                |                       |                       | <56                | 17                 |                      |
| Hatches, scopes, etc. |                |                |                       |                       |                    |                    |                      |

\* Data projected from regression analysis.

\*\* Round in breach

The 50-caliber ejection port and the turret ventilation blower are the largest leakage areas.

4. Main Gun Leakage, Breech Closed.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 369                | 372    | 374        | 368    | -               | -      | -                |

TRADOC states that a round will normally be chambered when enemy contact is anticipated. Therefore, this leak area is not considered significant.

5. Port, 7.62-mm Machine Gun.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | -                |
| 143                | 144    | 83         | 94     | 136             | 123    | -                |

Aerophysics and Chrysler were measuring the port without a machine gun. CSL measured the leak with a demilitarized machine gun installed. The data indicate that on the average the leakage decreases by 37% when a gun is installed.

6. Range Finders (Both).

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8496 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 146                | 145    | 138        | 143    | 138             | 130    | 326              |

Good agreement is obtained among Aerophysics, CSL, and Chrysler. Honeywell's measurement was without the range finders installed. The leakage through this port is 130% higher than with the range finders installed.

7. Cupola Race.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| -                  | -      | 78         | 63     | 125             | 26     | 73               |

Data show vehicle-to-vehicle variation. The average of all values is 73 ft<sup>3</sup>/min.

8. Access Cover, 50-Caliber Machine Gun.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| -                  | -      | 71         | 93     | -               | -      | -                |

9. Unaccounted for Leakage.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 51                 | 45     | 23         | 23     | 170             | 108    | -                |

This baseline leakage value depends on the effort made to identify individual leaks.

10. Driver's Vision Block Cover.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 43                 | 0      | -          | -      | 46              | 17     | 65               |

If vision block was installed, the leakage is zero as indicated by SN8946, above.

11. Gunner's Sight.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 7                  | 7      | 6          | 12     | -               | -      | -                |

12. Personnel Heater Outlet.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 15                 | 12     | 18         | 17     | 17              | 17     | -                |

13. Main Turret Race.

| <u>Aerospace</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753           | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| -                | -      | 15         | 11     | 99              | -      | 3                |

Aerophysics measured the leakage with the turret ring seal inflated and determined that leakage is essentially zero.

14. Commander's Hatch.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| -                  | 29     | -          | -      | -               | -      | 65               |

The difference between the two hatches could be due to the gasket or metal warpage.

15. Hull Drains.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| 27                 | 0      | -          | -      | -               | -      | -                |

The hull drains have no measurable leakage when closed.

16. Main Gun Intersection.

| <u>Aerophysics</u> |        | <u>CSL</u> |        | <u>Chrysler</u> |        | <u>Honeywell</u> |
|--------------------|--------|------------|--------|-----------------|--------|------------------|
| SN8753             | SN8946 | SN8753     | SN8946 | SN4285          | SN8050 | SN2967           |
| -                  | 250    | -          | -      | 40              | -      | -                |

The band sealing the mantlet to the main gun tube was loose on SN8946 when received. This was due to firing the main gun. The mantlet on SN4285 and SN2967 was deteriorated from age and could not hold air. A plastic covering was placed over the mantlet.

V. LEAK REDUCTION MEASURES.

Proposed leakage reduction modifications were suggested by Donaldson Corp., Aerophysics, and CSL (after review of Chrysler leakage data). Definitive suggestions were presented by Donaldson Corp. encompassing those of Aerophysics and CSL. Therefore, only Donaldson's Corp. suggestions are presented:

1. For the 50-caliber ejection port, use a spring-loaded door covering the opening which would open after a given weight buildup and dump the brass.

2. The range finders generally leak through the pivot mechanism. Sealing washers could form an effective seal where the mechanism passes through the inside turret wall.

3. Felt gasketing around the edges of the 50-caliber access cover would reduce leakage and eliminate modification to the mantlet.

4. The cupola race may be more involved to reduce leakage; however, a grease seal or a felt or "bristle pad" seal could be used.

5. For the 7.62-mm machine gun port, an asbestos or silicone plug could be fit to seal the gap between the barrel extension and the port.

6. The gunner's sight is a small leak, but sealing should be easily accomplished with washers or gaskets between the sight and the turret.

7. The main gun-to-mantlet seal has been found to work loose when the gun is fired. A longer sealing neck with a molded lip and a wider band would help prevent this. The mantlet has also been found to deteriorate with age. Periodic inspections should be made and the mantlet replaced as required.

## VI. CONCLUSIONS.

1. CSL, Chrysler, Aerophysics and Honeywell have similar approaches to leakage measurement.

2. M60A1 leakage data indicate the possibility for leak reduction. Modifications to the 50-caliber ejection port, range finder, 7.62-mm coaxial gun port, cupola race, 50-caliber access cover, gunner's sight and main gun-to-mantlet seal appear feasible.

3. A single method for future leakage testing can be established by a combination of CSL and Aerophysics test procedures and equipment.

4. The average leakage value using all data of the M60A1 as received with a round chambered is 1035 ft<sup>3</sup>/min at 1.5-inches water gage. NOTE: Vehicle ventilation blower is not included in leakage value.

5. CSL and Honeywell data are projected using a regression analysis of actual measured data.

## VII. RECOMMENDATIONS.

1. The test procedure should be standardized and followed for all vehicle leakage testing.

2. Standardized test equipment should be procured incorporating features of the Aerophysics' code tester, the CSL PR III (axial van anemometer) flow measurement device or other accurate airflow measurement instruments.

3. The seven above-mentioned "fixable leak points" should be examined for leakage reduction.

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3. Krisko, W. J., and Camplin, H. R. Donaldson Co., Inc. Final Report. Contract DAAK11-78-C0020. Investigative Study of Positive Pressure Collective Protection for Combat/Armored Vehicles. August 1978.
4. Jackson, W. P., Foshag, W. F., and Boehler, G. B. Aerophysics Company. Contract DAAK11-78-M-0013. Report 78-76-1. Static Air Leakage Assessment on Two M60 Tanks. 30 July 1978.
5. 1979 Honeywell Inc. Independent Research and Development Brochure.

**APPENDIX A**

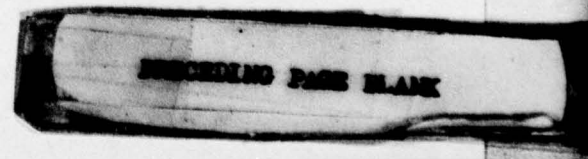
**LEAKAGE DATA TABLES**

**Table A-1. Chrysler Corporation Leakage Data - Vehicle M60A1 (SN4285)**

| Leakage point                 | Air leakage at 1.5-inches static-pressure water gage |
|-------------------------------|--|
|                               | ft <sup>3</sup> /min                                 |
| Main gun intersection         | 40   |
| Driver's vision block covers  | 46   |
| Cupola race                   | 125  |
| Cupola rotor                  | 117  |
| Main gun tube                 | 119  |
| 7.62-mm gun port              | 136  |
| Rangefinder ports             | 138  |
| .50-Cal. gun intersection     | 226  |
| .50-Cal. ejection port        | 324  |
| Personnel heater exhaust port | 17   |
| Driver's escape hatch         | -  |
| Front drain valve             | -  |
| Driver's IR scope             | -  |
| Loader's scope                | 56   |
| Loader's hatch                | -  |
| Commander's hatch             | -  |
| Telescope port                | -  |
| Driver's hatch                | -  |
| Turret race                   | 99   |
| Residual leakage              | 170  |
| Total                         | 1613   |

**NOTES:**

1. Turret vent blower port used as pressurization port.
2. Leakage through the turret ring was measured as a separate item because of the leak-down rate of the ring seal in the test vehicle.
3. Floor access plates required sealing. RTV Sealant was used to seal around broken bolts.
4. Leakage at the personnel heater exhaust port was zero due to fuel trapped in the exhaust pipe.
5. The entire gun intersection was covered with plastic and tape for this test because of the deteriorated condition of the mantlet cover.



**Table A-2. Chrysler Corporation Leakage Data - Vehicle M60A1  
(SN8050)**

| Leakage point                    | Air leakage at 1.5-inches static-pressure water gage |
|----------------------------------|--|
|                                  | ft <sup>3</sup> /min                                 |
| Residual leak after sealing tank | 108  |
| Driver's escape hatch            | -  |
| Front drain valve                | -  |
| Main gun intersection            | -  |
| Driver's IR scope                | -  |
| Loader's scope                   | -  |
| Loader's hatch                   | 17   |
| Turret ring seal                 | -  |
| Commander's hatch                | -  |
| Telescope                        | -  |
| Driver's hatch                   | -  |
| Personnel heater exhaust port    | 17   |
| Driver's vision block covers     | 27   |
| Cupola race                      | 26   |
| Cupola rotor                     | 51   |
| Main gun tube                    | 118  |
| 7.62-mm gun intersection         | 123  |
| Rangefinder ports                | 130  |
| 50-mm gun intersection           | 182  |
| 50-mm ejection port              | 443  |
| <b>Total</b>                     | <b>1242</b>  |

NOTE: Turret vent blower port used as pressurization port.

Table A-3. Honeywell Inc. Leakage Data - Vehicle M60A1  
(SN2967)

| Test point | Configuration           | Flow rate                           |             |             |             | Slope       | Total area      | Delta area |
|------------|-------------------------|-------------------------------------|-------------|-------------|-------------|-------------|-----------------|------------|
|            |                         | Static pressure (inches water gage) |             |             |             |             |                 |            |
|            |                         | ft <sup>3</sup> /min                |             |             |             |             | ft <sup>2</sup> |            |
| 1          | Base                    | 0.35<br>52                          | 0.80<br>92  | 1.00<br>108 | 1.30<br>129 | 1.65<br>152 | 0.0269          | -          |
| 2          | Heater outlet           | 0.35<br>67                          | 0.80<br>112 | 1.00<br>130 | 1.30<br>157 | 1.65<br>174 | 0.324           | 0.0055     |
| 3          | Tank commander's hatch  | 0.35<br>77                          | 0.80<br>134 | 1.00<br>154 | 1.30<br>177 | 1.55<br>198 | 0.0379          | 0.0110     |
| 4          | Driver's hatch          | 0.35<br>75                          | 0.80<br>125 | 1.00<br>145 | 1.30<br>173 | 1.55<br>190 | 0.0362          | 0.0093     |
| 5          | Base                    | 0.40<br>64                          | 0.80<br>95  | 1.00<br>115 | 1.30<br>133 | 1.65<br>154 | 0.0281          | -          |
| 6          | Driver's periscope      | 0.25<br>76                          | 0.80<br>137 | 1.00<br>160 | 1.30<br>183 | 1.55<br>195 | 0.0392          | 0.0111     |
| 7          | Turret thru fittings    | 0.40<br>64                          | 0.80<br>103 | 1.00<br>121 | 1.30<br>149 | 1.60<br>160 | 0.0300          | 0.0019     |
| 8          | Base                    | 0.40<br>58                          | 0.80<br>92  | 1.00<br>108 | 1.30<br>128 | 1.65<br>145 | 0.0266          | -          |
| 9          | Left range finder dome  | 0.25<br>79                          | 0.80<br>162 | 1.00<br>188 | 1.30<br>210 | 1.55<br>233 | 0.0456          | 0.0190     |
| 10         | Right range finder dome | 0.23<br>74                          | 0.80<br>165 | 1.00<br>192 | 1.30<br>215 | 1.50<br>225 | 0.0460          | 0.0194     |

Table A-3. (Contd)

| Test point | Configuration                                   | Flow rate                           |      |      |      |      | Slope  | Total area | Delta area      |
|------------|---|-------------------------------------|------|------|------|------|--------|------------|-----------------|
|            |   | Static pressure (inches water gage) |      |      |      |      |        |            |                 |
|            |   | 0.10                                | 0.20 | 0.40 | 0.60 | 0.80 |        |            |                 |
|            |   | 132                                 | 287  | 414  | 555  |      |        |            | ft <sup>2</sup> |
| 11         | Empty gunner's IR periscope                     | 0.10                                | 0.20 | 0.40 | 0.65 | 0.80 | 0.747  | 0.2047     | 0.1781          |
| 12         | Turret vent blower                              | 0.10                                | 0.20 | 0.40 | 0.60 | 0.85 | 0.580  | 0.1358     | 0.1092          |
| 13         | Commander's machine-gun cartridge-ejection slot | 0.10                                | 0.20 | 0.40 | 0.60 | 0.75 | 0.5754 | 0.1493     | 0.1227          |
| 14         | Base  | 0.65                                | 0.80 | 1.00 | 1.30 | 1.70 | 0.6884 | 0.0235     | -               |
| 15         | Base - engine 550 rpm                           | 0.30                                | 0.80 | 1.00 | 1.30 | 1.55 | 0.1665 | 0.0548     | 0.0313          |
| 16         | Base - engine 1250 rpm                          | 0.30                                | 0.80 | 1.00 | 1.30 | 1.50 | 0.1742 | 0.0548     | 0.0313          |
| 17         | Base - engine 1800 rpm                          | 0.30                                | 0.80 | 1.00 | 1.30 | 1.45 | 0.1360 | 0.0564     | 0.0329          |
| 18         | Base  | 0.43                                | 0.80 | 1.00 | 1.30 | 1.60 | 0.6757 | 0.0258     |                 |
| 19         | Machine gun evaluation slot                     | 0.25                                | 0.80 | 1.00 | 1.30 | 1.50 | 0.7676 | 0.0452     | 0.0194          |
| 20         | Commander turret ring                           | 0.20                                | 0.80 | 1.00 | 1.30 | 1.60 | 0.6606 | 0.0397     | 0.0139          |
| 21         | Gun boot  | 0.20                                | 0.80 | 1.00 | 1.30 | 1.45 | 0.576  | 0.0562     | 0.0304          |
| 22         | Main turret ring                                | 0.50                                | 0.80 | 1.00 | 1.30 | 1.70 | 0.651  | 0.0263     | 0.0005          |

**Table A-4. CSL Leakage Data\***  
(Vehicle M60A1 - SN8753)

| Leakage point                 | Flow rate                           |      |      |      |      |      |
|-------------------------------|-------------------------------------|------|------|------|------|------|
|                               | Static pressure (inches water gage) |      |      |      |      |      |
|                               | 0.5                                 | 1.0  | 1.5  | 2.0  | 3.0  | 6.0  |
|                               | ft <sup>3</sup> /min                |      |      |      |      |      |
| As received round in breech** | 773                                 | 1097 | 1347 | 1558 | 1912 | 2714 |
| 50-Cal. ejection port         | 252                                 | 373  | 469  | 551  | 692  | 1023 |
| Turret ventilation blower     | 233                                 | 366  | 476  | 575  | 749  | 1177 |
| Main gun breech open          | 173                                 | 254  | 319  | 374  | 470  | 691  |
| Range finders (both)          | 73                                  | 109  | 138  | 163  | 206  | 309  |
| Main gun breech closed        | 67                                  | 99   | 124  | 146  | 184  | 272  |
| 7.62-mm machine-gun port      | 43                                  | 65   | 83   | 98   | 125  | 190  |
| Cupola race                   | 38                                  | 60   | 78   | 95   | 124  | 196  |
| 50-Cal. access cover          | 35                                  | 55   | 71   | 85   | 111  | 173  |
| Unaccounted for leakage       | 9                                   | 16   | 23   | 29   | 41   | 73   |
| Personnel heater outlet       | 9                                   | 14   | 18   | 22   | 29   | 48   |
| Main turret race              | 6                                   | 10   | 15   | 19   | 28   | 54   |
| Gunner's sight                | 3                                   | 5    | 6    | 8    | 11   | 19   |
| Bilge pump outlet             | 1                                   | 2    | 2    | 3    | 4    | 7    |

**NOTES:**

\* Data projected using a regression analysis of five points between 0.5 - 2.5 in static pressure water gage.

\*\* Sum of individual components will not provide satisfying results when compared to total measure value because of cumulative error for each leak point and error for unaccounted leak.

**Table A-5. CSL Leakage Data\***  
(Vehicle M60A1 - SN8946)

| Leakage point                 | Flow rate                           |      |      |      |      |      |
|-------------------------------|-------------------------------------|------|------|------|------|------|
|                               | Static pressure (inches water gage) |      |      |      |      |      |
|                               | 0.5                                 | 1.0  | 1.5  | 2.0  | 3.0  | 6.0  |
|                               | ft <sup>3</sup> /min                |      |      |      |      |      |
| As received round in breech** | 744                                 | 1139 | 1461 | 1743 | 2236 | 3422 |
| 50-Cal. ejection port         | 248                                 | 364  | 457  | 536  | 672  | 987  |
| Turret ventilation blower     | 235                                 | 362  | 466  | 557  | 717  | 1104 |
| Main gun breech open          | 167                                 | 248  | 313  | 368  | 464  | 689  |
| Range finders (both)          | 76                                  | 114  | 143  | 169  | 214  | 318  |
| Main gun breech closed        | 68                                  | 100  | 126  | 149  | 187  | 277  |
| 7.62-mm machine-gun port      | 49                                  | 73   | 94   | 111  | 141  | 212  |
| Cupola race                   | 30                                  | 47   | 63   | 76   | 100  | 160  |
| 50-Cal. access cover          | 48                                  | 72   | 93   | 111  | 142  | 217  |
| Unaccounted for leakage       | 9                                   | 16   | 23   | 29   | 40   | 71   |
| Personnel heater outlet       | 8                                   | 13   | 17   | 21   | 27   | 44   |
| Main turret race              | 4                                   | 8    | 11   | 14   | 21   | 39   |
| Gunner's sight                | 5                                   | 9    | 12   | 14   | 19   | 33   |
| Bilge pump outlet             | 1                                   | 1    | 2    | 2    | 3    | 5    |

**NOTES:**

- \* Data projected using a regression analysis of five points between 0.5 - 2.5 in static pressure water gage.
- \*\* Sum of individual components will not provide satisfying results when compared to total measured value because of cumulative error for each leak point and error for unaccounted leaks.

**Table A-6. Aerophysics Co. Leakage Data - Vehicle M60A1  
(SN8753)**

| Leakage point                              | Flow rate                           |     |      |      |      |      |
|--|-------------------------------------|-----|------|------|------|------|
|  | Static pressure (inches water gage) |     |      |      |      |      |
|  | 0.5                                 | 1.0 | 1.5  | 2.0  | 2.5  | 3.0  |
|  | ft <sup>3</sup> /min                |     |      |      |      |      |
| <b>Total leakage, measured</b>             | 573                                 | 826 | 1028 | 1193 | 1338 | 1471 |
| <b>50-Cal. ejection port*</b>              | 288                                 | 397 | 491  | 573  | 636  | 701  |
| <b>Main gun breech open</b>                | 184                                 | 252 | 316  | 369  | 413  | 457  |
| <b>7.62-mm machine gun port</b>            | 82                                  | 118 | 143  | 164  | 183  | 198  |
| <b>Range finders (both)*</b>               | 82                                  | 119 | 146  | 170  | 189  | 207  |
| <b>Cupola*</b>                             | 77                                  | 122 | 146  | 168  | 191  | 209  |
| <b>Main gun breech closed*</b>             | 72                                  | 104 | 127  | 145  | 160  | 175  |
| <b>Driver's vision block cover plates*</b> | 25                                  | 36  | 43   | 49   | 55   | 59   |
| <b>Unaccounted for leakage*</b>            | 22                                  | 36  | 51   | 67   | 83   | 100  |
| <b>Personnel heater outlet*</b>            | 9                                   | 13  | 15   | 17   | 17   | 18   |
| <b>Gunner's sight*</b>                     | 4                                   | 6   | 7    | 7    | 8    | 8    |
| <b>Hull drains open (both)</b>             | 14                                  | 20  | 26   | 27   | 30   | 32   |

\* Items included in total leakage value.

**Table A-7. Aerophysics Co. Leakage Data - Vehicle M60A1  
(SN8946)**

| Leakage point                      | Flow rate                           |     |      |      |      |      |
|------------------------------------|-------------------------------------|-----|------|------|------|------|
|                                    | Static pressure (inches water gage) |     |      |      |      |      |
|                                    | 0.5                                 | 1.0 | 1.5  | 2.0  | 2.5  | 3.0  |
|                                    | ft <sup>3</sup> /min                |     |      |      |      |      |
| Total leakage, measured            | 554                                 | 810 | 1000 | 1178 | 1300 | 1425 |
| 50-Cal. ejection port*             | 247                                 | 351 | 431  | 499  | 569  | 609  |
| Main gun breech open               | 179                                 | 259 | 320  | 372  | 415  | 455  |
| 7.62-mm machine gun port           | 84                                  | 118 | 144  | 166  | 183  | 201  |
| Range finders (both)*              | 82                                  | 118 | 145  | 168  | 188  | 205  |
| Cupola*                            | 109                                 | 133 | 165  | 193  | 219  | 242  |
| Main gun breech closed*            | 68                                  | 97  | 118  | 138  | 152  | 164  |
| Unaccounted for leakage*           | 19                                  | 32  | 45   | 60   | 77   | 97   |
| Personnel heater outlet*           | 7                                   | 11  | 12   | 14   | 16   | 16   |
| Gunner's sight*                    | 4                                   | 7   | 7    | 8    | 9    | 9    |
| Main-Gun-to-Mantlet Seal Loose     | 123                                 | 175 | 223  | 250  | 285  | 310  |
| Commander's hatch*                 | 18                                  | 25  | 29   | 37   | 41   | 51   |
| 50-Cal. access cover partly opened | 109                                 | 155 | 190  | 219  | 246  | 271  |

\* Items included in total leakage value.

**APPENDIX B**

**TOTAL LEAKAGE VALUES**

1. **Chrysler data**

**SN4285**

1613 - mantlet - driver vision block - main gun tube - (7.62-mm-installed)

1613 - 40 - 46 - 119 - 47 = 1361 ft<sup>3</sup>/min

**SN8050**

1242 - driver's vision block - (7.62-mm-installed) - main gun tube

1242 - 27 - 39 - 118 = 1058 ft<sup>3</sup>/min

2. **Aerophysics data**

**SN8753**

1028 + (7.62-mm-installed) - main gun tube - driver periscope lids

1028 + 89 - 127 - 43 = 947 ft<sup>3</sup>/min

**SN8946**

1000 - main gun tube + (7.62-mm-installed)

1000 - 118 + 89 = 971 ft<sup>3</sup>/min

3. **CSL data**

**SN8753**

1347 - vehicle ventilation blower

1347 - 476 = 871 ft<sup>3</sup>/min

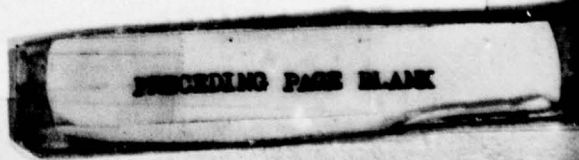
**SN8946**

1461 - vehicle ventilation blower

1461 - 466 = 995 ft<sup>3</sup>/min

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