AIR LEAKAGE IN REFRIGERATED VANS

MASTERREPORT OF CONFIRMATION TESTS
CONDUCTED WITH THE PROTOTYPE AIR LEAKAGE
TEST SET

B. A. BODENHEIMER & CO., INC.

Stamford, CT 06905

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OCTOBER 1978

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EP
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FOREWORD

In conducting this study, B. A. Bodenheimer & Co., Inc. has been fortunate in receiving the extensive cooperation of several manufacturers and users of equipment. These companies have made available both test equipment and trailers or containers for the conduct of the tests covered by this report, and we express our appreciation for their cooperation in this regard and for their willingness to absorb related expenses. We have also received valuable counsel from their personnel.

At the request of these companies, there is no specific identification made in this report as to ownership of either test equipment or vehicles. It is our shared belief that in this way maximum benefit will be derived from the study.

FRONT VIEW

PROTOTYPE AIR LEAKAGE TEST SET

B. A. BODENHEIMER & CO., INC.

TABLE OF CONTENTS

	<u>Page</u>
1. OBJECTIVE	1
2. CONCLUSIONS	2
3. DISCUSSION	4
3.1 General	4
3.2 Principal Characteristics of the Test Equipment	4
3.3 Use of the Prototype Test Set	4
3.4 Test Method	10
3.5 Flow Meter Corrections	12
3.6 Results of Test A	14
3.7 Results of Test B	20
3.8 Results of Test C	26
3.9 Summary	27

~~1.~~ OBJECTIVE

To evaluate the utility of the Prototype Air Leakage Test Set constructed for the United States Department of Energy under this contract, and to compare the air leakage data obtained by use of the Test Set to that obtained by use of three different, existing test equipments at three manufacturers of trailer and containers.

2. CONCLUSIONS

2.1 Comparison of the air leakage measurements obtained by use of the Prototype Air Leakage Test Set constructed under this contract with the measurements obtained by use of existing units at three different manufacturers shows that the manufacturer's units do not yield accurate values of air leakage.

2.2 Manufacturer's units do not have sufficient instrumentation to correct the flow meter readings for pressure at the flow meter. Thus readings may be higher or lower than the correct value, depending on the choice of calibration pressure for the flow meter and the pressure drop in the air delivery connection to the test body.

2.3 The Truck Trailer Manufacturers Association Practice # 38-73 should be amended to specify the air leakage tests more precisely. This may be accomplished either by specifying equipment in detail or by requiring a pressure gage at the flow meter to correct readings taken.

2.4 When the manufacturer's data is corrected for the actual test conditions, the results agree with data taken by the Prototype Test Set within 5 percent.

2.5 When air leakage data is plotted on log-log graph paper, the resulting graph is a straight line, since

$$Q = bp^n$$

Where Q is the air leakage
 b is a constant

p is the pressure
 n is a constant

and

$$\log Q = \log b + n \log p$$

The slope of the line, n , has been assumed to be an index of the type of leakage in the test body. However, the slope of the line for uncorrected data is not identical to the slope of the line for corrected data; therefore the slope of the lines for uncorrected data obtained by the Prototype Test Set is not accurate and cannot be used for judging the character of the leakage paths.

2.6 Since the data obtained by manufacturer's existing equipment is incorrect, conclusions about the character of air leakage paths based on published values of the slope of the line, n , are also incorrect.

2.7 The Prototype Test Set functioned as designed except for the vehicle overpressure protection device. This device cannot be used because of the pressure relationships in the delivery connection leading from the test set to the vehicle under test. The tests were performed without the use of this device and it has been established that it can be deleted without affecting safety of operation.

2.8 The instructions contained in the Manual for Use, Operation, Calibration and Maintenance were followed in detail. Minor problems were encountered and resolved, and only minor changes to the Manual are required.

2.9 Set up time for the test set in the field is approximately 30 minutes, and installation of the delivery connection and manometer tubing consumes about 15 minutes additional time per vehicle tested.

3. DISCUSSION

3.1 General

Three separate tests were performed to compare the results obtained by use of the Prototype Air Leakage Test Set to the results obtained by use of similar equipment at three manufacturers' plants. Two of the manufacturers' test sets, designated A and B, are used for acceptance testing of trailers and containers; the third, designated C, is used to measure air leakage of equipment prior to introducing a modified atmosphere into the equipment.

Each of the three manufacturers' units has been assembled for a specific purpose, and the acceptance criteria of each user appear to be based on the unique results obtained with his test equipment. This must be kept clearly in mind, since the purpose of this series of tests was not to question the current criteria used by the various parties, but rather, to establish whether or not the equipment used by them yields comparable results, and to establish whether or not the Prototype Test Set results are equivalent to data now being published .

3.2 Principal Characteristics of the Test Equipment

The major differences in instrumentation in the four units is shown in Table 1.

3.3 Use of Prototype Test Set

3.3.1 The testing was performed in accordance with the instructions contained in the Manual for Use, Operation, Calibration and Maintenance of Prototype Air Leakage Test Set, dated July 1978. No major problems were

TABLE I

PRINCIPAL CHARACTERISTICS OF AIR LEAKAGE TEST SETS

	Prototype Test Set	Test Set A	Test Set B	Test Set C
Flow Meter Calibrated for	Air	Air	Air	Nitrogen
Flow Meter Calibration Temperature	70 ⁰ F	70 ⁰ F	70 ⁰ F	70 ⁰ F
Flow Meter Calibration Pressure	24.7 psia	54.7 psia	14.7 psia	34.7 psia
Provision for Flow Meter Pressure Correction	Yes	No	No	No
Provision for Flow Meter Temperature Correction	Yes	No	No	No
Regulated Line Pressure of Air Supply during Test	Variable	54.7 psia	64.7 psia	59.7 psia

encountered in the use of the equipment, except that the vehicle overpressure protection device originally designed to protect the equipment being tested against excessive pressure was found both difficult to use and unnecessary in actual practice.

Figure 1, a schematic of the Prototype Test Set, is helpful to illustrate the reason why this device did not work as expected. The pressure in the test body is typically one-half to one inch of water (125 to 250 Pa); at the exit of the flow meter the pressure typically ranges from 1 to 15 psig (6.9 to 103 kPa) depending on the length of the delivery connection, the air flow in the tube, and the possible crimping of the tube at the entry to the test body. Obviously, the closer the device is located to the end of the delivery connection the more predictable is the expected pressure. The original position of the overpressure device was thus set at 5 feet (1.5 m) from the entry to the test body. However, even at this short distance from the end of the connection, pressures were found to be too variable to allow use of such a device.

When the entry to the test body is through a door, the air delivery tube may be pinched or deformed by the door seal. This actually occurred during Test A; as a result the pressure was so high that all of the water in the overpressure protection assembly was immediately blown out very forcefully. This prevented pressure build-up in the test body.

Figure 2 is a plot of the flow meter readings vs. secondary pressure, derived from 60 separate test points using the Prototype Test Set. It illustrates the variation of the pressure with flow. The plot is,

FIGURE 1

TEST SYSTEM SCHEMATIC

FIGURE 2
AIR FLOW IN SYSTEM vs. SECONDARY PRESSURE

as expected, linear on log-log graph paper, since the pressure loss in a given piping system is defined by the equation

$$(1) \quad Q = b p^n$$

where Q = the air flow

b = a constant

p = pressure drop

The fifteen fold pressure increase from minimum flow to maximum, as measured at the outlet of the flow meter, is also reflected in a similar ratio at any point along the delivery connection. Therefore, at any point where the overpressure device could be located it is not possible to predict an overpressure limit that can be pre-set.

Since the pressure in the test body can be regulated safely and comfortably by the operator without danger of overpressure as demonstrated by over 60 tests performed to date, the device is not deemed necessary and has not been used.

3.3.2 In addition, two other, and minor, problems with the Prototype Test Set were found; these were corrected after completion of Test A.

a. During Test A, the container was located outside the plant building, on an unimproved and very uneven surface. The weather was heavy rain. The exit door from the plant was at some distance from the container and to avoid the terrain and rain, the test set was located immediately inside the door. Thus the 25ft (7.6m) delivery tubing and the 25ft (7.6m) manometer tube were both considered marginal. Additional tubing,

of a more flexible material, was procured for both the delivery connection and manometer. Both tubes were extended to 50 feet (15.2 m), and this was found to be satisfactory.

b. Since there were no drain holes in the container during Test A, attachment of the manometer tube was made by disassembly of the liquid nitrogen connection on the front of the container. The delivery connection was slipped between the door and the door frame, and the close fit in this area collapsed the plastic tubing completely. A 6" long piece of copper tubing was added to the end of the plastic tubing; although there was some deformation of the copper tube due to door closing, the tube did not collapse. Approximately 2 hours were consumed in making the initial installation, about 80% of which was in locating components. A more adequate supply of copper tubing, hose clamps and small fittings were procured for further tests, and this reduced set up time to approximately 15 minutes per test.

3.4 Test Method

Tests for air leakage in refrigerated vehicles are generally performed at manufacturer's plants after construction of a vehicle is completed. These tests may be performed for the purpose of internal quality control, or for showing compliance with purchaser's specifications.

The ISO Standard for Thermal Containers (DIS 1496/II) and the ANSI draft Standard MH5 1 2 specify that the air leakage test measurements be made at 1.0 inch water pressure. The Truck Trailer Manufacturers Association Recommended Practice #38-73 specifies that the tests be

conducted at 1/2" overpressure. Both standards require that the pressure be maintained +4% during the test. Various user's criteria are stated at still other values of overpressure, e.g., 100 CFH at 1/4 inch water column.

Experience has shown that to maintain the overpressure within +4% is difficult, since the flow rate must be adjusted with great care, and even minor temperature variations will cause fluctuations. Therefore, an alternate method of testing was used. At least three tests were made using first the Prototype Test Set and then at least three tests using the manufacturer's equipment. For each test a different overpressure was used and the corresponding flow meter reading was observed and recorded. If the tests are performed properly, then a plot of the air leakage rate versus overpressure, on log-log paper, will yield a straight line, since from (1)

$$(2) \quad \frac{L_1}{L_2} = \left\{ \frac{P_1}{P_2} \right\}^n$$

The slope of the line defines the exponent n . This exponent has an "expected" value of 0.65, since holes and other large orifices tend to exhibit a value $n = 0.5$, whereas long narrow slits exhibit values of n approaching 1.0.

If the three points do not define a straight line on log-log graph paper, it is indicative of a phenomenon that requires further evaluation. For example, failure to plot a straight line may be due to:

a. Measurement or Set Up Error - This should be assumed to be the cause, and the tests should be repeated to verify that the data taken is accurate.

b. Condensation of Moisture in the Air Supply to the Test Vehicle --

The correction factors supplied as an integral part of the Test Set Manual should correct for this phenomenon, which is exhibited whenever the interior vehicle temperature is below the dew point temperature of the air supply.

c. Construction -- If the construction includes seals which may change shape or sealing characteristics due to overpressure, the nature of the openings through which air escapes may change with varying overpressure.

If the three points do define a straight line, the graphical solution may then be used to extrapolate or interpolate to the overpressure called for by a specific standard. For purposes of evaluating the results obtained by the different test equipments, the graphs then allow comparison at any desired overpressure.

3.5 Flow Meter Corrections

Flow meters based on the variable area principle (Rotameters) are calibrated with a specific fluid at a set temperature and downstream pressure. When the flow meter is used with a different fluid, at a temperature and pressure different from those used in calibration, a correction factor must be applied to the scale reading. The equation is

$$\text{SCFH}_{\text{equivalent}} = \text{SCFH}_{\text{scale reading}} \times \sqrt{\frac{\text{SG}_1 \text{ } T_1 \text{ } P_2}{\text{SG}_2 \text{ } T_2 \text{ } P_1}}$$

where SG is the specific gravity

T is the absolute temperature, $^{\circ}\text{K} = ^{\circ}\text{F} + 460$

P is the absolute pressure, $p_a = p_{\text{gage}} + 14.7$

Subscript 1 is the calibration condition

Subscript 2 is the condition at which the measurement is made.

In order to calculate the correction factor, it is obvious that the temperature, the humidity and the pressure at the flow meter must all be known.

In order to control the flow of air into the test body, a flow control valve was provided in the Prototype Test Set. This was located at the entry to the flow meter, similar to the existing manufacturer's units. In actual practice it was found more convenient to control the flow by use of the pressure regulator only. Increasing pressure increases the flow throughout the system, and since the Prototype Test Set is equipped with a pressure gage at the flow meter (see Figure 1) the proper correction can be made regardless of how the flow is controlled.

Manufacturer's test sets are not equipped with such gages. One of two possible assumptions has been made by the manufacturer's- albeit erroneously. The first is that if the input pressure at the regulator is set equal to the pressure at which the flow meter has been calibrated, the readings obtained at the flow meter are correct. This does not account for the pressure drop in the flow control valve, which is a variable depending on flow. This is true even if the flow control valve is located downstream of the flow meter since the flow control valves used

are not of the pressure regulating kind.

The second assumption that is often made is that the pressure at the flow meter is atmospheric, since the test body is pressurized to only a few inches of water column. This assumption ignores the pressure drop in the piping and air delivery connection to the test body - all downstream of the flow meter. As shown by Figure 2, even 50 feet (15.2m) of $\frac{1}{2}$ inch (13 mm) diameter tubing results in substantial pressure drops depending on the quantity of air flowing.

3.6 Results of Test A

Figure 3 shows the data obtained during Test A. The test body, a container, was equipped with an internal overpressure protection device, which limited the overpressure used to less than one half inch of water (125 Pa).

Three runs were made using the Prototype Test Set. (runs 1-3, Figure 3). Each run took about five minutes to complete; in all cases the uncorrected data was plotted on log-log graph paper immediately after taking the data to assure that the three points defined a straight line. The uncorrected data taken resulted in a line with slope equal to 0.58 (Figure 4). After applying the correction factors for the Regulated Line Temperature and Humidity, and for the Secondary Pressure, a straight line of slope equal to 0.66 was obtained by graph.(Figure 4).

After completion of these three runs the manufacturer's test set was used (Runs 4-9, Figure 3). Several items of interest were noted.

AIR LEAKAGE TEST DATA SHEET

4 Aug 73
Date

TRAILER
OR VAN

CODE T

Make

2/77

Year

20' CTR

Size

Model #

01956

Serial #

76030167

Registration #

CODE C

Owner

NY

Address

TEST SPEC: 40 PSIG INLET
1" H₂O OVERPRESSURE

INSULATION
THICKNESS
AND TYPE

FRP PANELS
W/FOAM
Walls

STYRENE
PADS + FOAM
Floor

PANEL
Roof

STYRENE
PADS + FOAM
Doors

REFRIGERATION NONE
UNIT Make & Model #

DOOR LOCATIONS
INDICATE BY

CTR. EQPD. W/RELIEF VALVE FOR 0.5" H₂O

DOOR VENTS
IF ANY

NONE
Front

NONE
Rear

OBSERVATIONS AND CORRECTED RESULTS

CORRECTED AIR FLOW = FLOW METER READING x Correction Factor 1 x Correction Factor 2

TEST	AMBIENT TEMP °F	REGULATED LINE		MANO- METER "H ₂ O	TEST BODY TEMP °F	SECOND. PRESS psig.	FLOW METER SCFH	CORRECTION FACTOR		CORRECTED AIR FLOW SCFH	CORRECTION FACTOR 3	ACTUAL AIR LEAKGE CFH
		TEMP °F	HUM. %					1	2			
1	72	70	35	.12	-	1	350	1.0	.797	279		
2	72	70	35	.282	-	2 3/4	575	1.0	.834	480		
3	72	70	35	.47	-	5	773	1.0	.893	690		
* 4	74	/	/	.26	-	EST 2 1/2	830	EST 1.0	.561	465		
* 5	74			.45	-	EST 4 3/4	1070	EST 1.0	.596	638		
* 6	74			.27	-	EST 2.6	850	EST 1.0	.562	478		
* 7	74			.372	-	EST 3 3/4	990	EST 1.0	.581	575	SOME WATER IN TUBE	
* 8	74			.43	-	-	720	EST 1.0	-	-	HEAVY OIL & H ₂ O	
* 9	74			.13	-	-	790	EST 1.0	-	-	" " " "	

* USING MFGRS EQPT @ 40 PSIG INLET PRESSURE, FLOW METER CALIBRATED AT 40 PSIG

CORRECTION FACTOR 1 - Corrects Air Flow Meter reading for the Regulated Line Temperature and Humidity - USE TABLE I

CORRECTION FACTOR 2 - Corrects Flow Meter reading for Secondary Pressure - USE TABLE II

CORRECTION FACTOR 3 - Corrects measurement for test body temperatures other than 70°F - USE TABLE III

FIGURE 3 - DATA TAKEN DURING TEST A

FIGURE 4
TEST A - AIR LEAKAGE vs. OVERPRESSURE (Pressure Difference)

- a. The flow meter tube had apparently been broken some time in the past, and a new float and tube had been installed. Although the meter scale is marked " 100 x SCFM", we were informed that the same scale now reads "100 x SCFH" with the new float and tube.
- b. Many of the fittings on the test set were loose, although none on the outlet side of the flow meter.
- c. The acceptance test for which the manufacturer's equipment is used is to test at 40 psig inlet pressure (274.6 kPa) at one inch (250 Pa) water column in the container. The flow meter is calibrated at 40 psig (274.6 kPa). There is no instrumentation to measure the pressure at the flow meter.
- d. The air filter is not of the coalescing type. As a result, after a short period of operation the walls of the flow meter tube and the float were coated with oil and water. The manufacturer's personnel indicated that this was a common occurrence, and that they had to disassemble and clean the flow meter periodically.

In order to make a correction for the actual pressure at the flow meter when using the manufacturer's equipment it was necessary to make a fairly accurate estimate of the pressure. Thus it was considered helpful to use the identical hose and tubing set up as with the Prototype Test Set, since the pressure drop is a function of the flow, and this had been measured during the test with the Prototype Test Set.

The delivery connection was carefully removed from the Prototype Test Set at the test set end and then re-attached to the manufacturer's set without disturbing the container end of the tubing. The manometer tube was left connected to the Prototype Test Set to limit possible sources of error to that portion of the manufacturer's equipment consisting of filter, regulator and flow meter.

Six separate runs were made using this test set up (Runs 4-9, Figure 3). At run # 7, some water was visible in the meter tube; during runs 8 and 9 the flow meter tube and float were liberally covered with oil and water. The inlet pressure was controlled at 40 psig (274.6 kPa) throughout the test.

When the four data points during which oil and water were not visible in the flow meter tube were plotted on log-log graph paper, a straight line of slope equal to 0.46 resulted. All air leakage values obtained were considerably higher than the uncorrected data taken with the Prototype Test Set.

Since at a given overpressure in the test body the air leakage rate should be constant, this was assumed and estimated correction values for pressure at the flow meter were calculated for the manufacturer's equipment. This is valid since neither the delivery connection or the manometer tube had been disturbed. Manometer Reading vs. Secondary Pressure froms runs 1 through 3 were plotted, and values of secondary pressure for the manufacturer's equipment, based on corresponding manometer readings, were interpolated from the graph (Figure 5). These are indicated as "estimated" on the data sheet. Correction factors for

FIGURE 5

pressure were calculated based on the flow meter correction formula presented in paragraph 3.5.

When plotted on the same graph as the corrected data from runs 1 through 3 (Figure 4), the corrected values obtained by use of the manufacturer's equipment yields the same result as the corrected data when using the Prototype Test Set. The largest single error is approximately 5 percent.

3.7 Results of Test B

Figure 6 shows the data obtained during Test B. The test body was a 42 foot (12.8 m) long trailer.

The manufacturer's test equipment is built to meet the Truck Trailer Manufacturers Association (TTMA) Recommended Practice 38-73 (See Appendix A), except that a Dwyer Magnahelic pressure gage is used in lieu of a manometer.

Three runs were first made using this equipment (Runs 1-3, Figure 6). The data was plotted on log-log graph paper and resulted in a straight line with slope equal to 0.59 (see Figure 7). Three tests were then made using the Prototype Test Set (Runs 4-6, Figure 6). The slope of the line joining the test points when plotted on log-log graph paper for the uncorrected data is 0.59; for the corrected data 0.75 (See Figure 7).

As in Test A, a substantial discrepancy was found between the raw data obtained by the manufacturer's test set and the raw and corrected data obtained by use of the Prototype Test Set. After

AIR LEAKAGE TEST DATA SHEET

Date 9/24/78

TRAILER
OR VAN

CODE U

Make

8/76

Year

42'

Size

93100

Model #

Serial #

Registration #

CODE U

Owner

Address

INSULATION
THICKNESS

AND TYPE

Walls

Floor

Roof

Doors

REFRIGERATION

UNIT

Make & Model #

DOOR LOCATIONS
INDICATE BY

DOOR VENTS
IF ANY

Front

Rear

OBSERVATIONS AND CORRECTED RESULTS

CORRECTED AIR FLOW = FLOW METER READING x Correction Factor 1 x Correction Factor 2

TEST	AMBIENT TEMP °F	REGULATED LINE		MANO- METER "H ₂ O	TEST BODY TEMP °F	SECOND. PRESS psig.	FLOW METER SCFH	CORRECTION FACTOR		CORRECTED AIR FLOW SCFH	CORRECTION FACTOR 3	ACTUAL AIR LEAKGE CFH
		TEMP °F	HUM. %					1	2			
1	?	--	--	.5	—	NONE	705					
2	?	--	--	.25	—	"	465					
3	?	--	--	.85	—	"	960					
4	81	81	32	.82		8	1130	.99	.959	1073		
5	81	81	32	.64		6	970	.99	.915	879		
6	81	81	32	.235		2	535	.99	.822	435		
7	84	--	--	.56		2	768		1.069	821		
8	84	--	--	.82		3 1/2	972		1.112	1081		
9	84	--	--	.26		.6	450		1.02	459		

* MFGS. EQUIPT. ; ** MFGS EQUIPT. W/ SECOND. PRESS. GAUGE INSTALLED

CORRECTION FACTOR 1 - Corrects Air Flow Meter reading for the Regulated Line Temperature and Humidity - USE TABLE I

CORRECTION FACTOR 2 - Corrects Flow Meter reading for Secondary Pressure - USE TABLE II

CORRECTION FACTOR 3 - Corrects measurement for test body temperatures other than 70°F - USE TABLE III

FIGURE 6 - DATA TAKEN DURING TEST B

FIGURE 7

TEST B - AIR LEAKAGE vs. OVERPRESSURE (Pressure Difference)

discussion with plant personnel it was decided to modify the manufacturer's equipment by addition of a pressure gage immediately downstream of the flowmeter. This was accomplished very quickly, although the pressure gage available was not calibrated and had relatively poor resolution due to its small size and large range. Runs 7-9, Figure 6 show the data obtained with the modified equipment. A correction for pressure was then made in accordance with the formula of paragraph 3.5. As in Test A, the results obtained by the two pieces of test equipment are identical within 3 percent when the corrections are properly made.

Figure 7 shows the relationship between corrected and uncorrected data for all of Test B. It is interesting to compare the results that would have been reported if both manufacturer A and B had tested the same trailer using their own equipment and standard procedures. At one half inch water column (125 Pa) overpressure, the results would be as follows:

	AIR LEAKAGE RATE	SLOPE OF LINE
TEST SET A	1193 SCFH	0.46
TEST SET B	680 SCFH	0.59
PROTOTYPE TEST SET	745 SCFH	0.75

To demonstrate the possibility of inadvertent or deliberate manipulation of the results when using the equipment shown in TTMA Practice # 38-73 (Figure 8), the tests were repeated using the flow control valves downstream of the flowmeters, rather than the lower valves ("A" on Figure 8) normally used, but not specified to be used, for flow control. Figure 9 shows the uncorrected data as well as the corrected data taken with the

FIGURE 8
TTMA RECOMMENDED TEST SET-UP FOR AIR
LEAKAGE TESTING.

AIR LEAKAGE TEST

INCLINED
MANOMETER

CONTROL
VALVES

HOUSE AIR
90-110 PSI

DRYER

PRESSURE
REGULATOR

10-50
SCFM

0-30
SCFM

0-5
SCFM

VARIABLE AREA
FLOWMETER

A

AIR LEAKAGE TEST DATA SHEET

9/25/78
Date

TRAILER
OR VAN

CODE U

Make

8/76

Year

42'

Size

93100

Model #

Serial #

Registration #

CODE U

Owner

Address

INSULATION
THICKNESS
AND TYPE

Walls

Floor

Roof

Doors

REFRIGERATION
UNIT

Make & Model #

DOOR LOCATIONS
INDICATE BY

DOOR VENTS
IF ANY

Front

Rear

OBSERVATIONS AND CORRECTED RESULTS

CORRECTED AIR FLOW = FLOW METER READING x Correction Factor 1 x Correction Factor 2

TEST	AMBIENT TEMP °F	REGULATED LINE		MANO- METER "H ₂ O	TEST BODY TEMP °F	SECOND. PRESS psig.	FLOW METER SCFH	CORRECTION FACTOR		CORRECTED AIR FLOW SCFH	CORRECTION FACTOR 3	ACTUAL AIR LEAKGE CFH
		TEMP °F	HUM. %					1	2			
1	84	-	-	.56		2.1	768		1.069	821		
2	84	-	-	.82		3 1/2	972		1.112	1081		
3	84	-	-	.26		.6	450		1.02	459		
4	84	-	-	.54		6.9	660		1.212	800		
5	84	-	-	.55		7.0	666		1.215	809		
6	84	-	-	.95		7.7	930		1.234	1148		
7	84	-	-	.26		13	306		1.373	420		
8												
9												

* MFG'S EQUIPT. w/ SECOND. PRESS. GAUGE INSTALLED USING LOWER VALVE

CORRECTION FACTOR 1 - Corrects Air Flow Meter reading for the Regulated Line Temperature and Humidity - USE TABLE I

CORRECTION FACTOR 2 - Corrects Flow Meter reading for Secondary Pressure - USE TABLE II

CORRECTION FACTOR 3 - Corrects measurement for test body temperatures other than 70°F - USE TABLE III

* MFG'S EQUIPT. w/ SECOND. PRESS. GAUGE INSTALLED USING UPPER VALVE

FIGURE 9 - DATA TAKEN DURING TEST B

manufacturer's equipment after installation of the pressure gage at the flow meter. Allowing for the poor resolution of the pressure gage at the pressures encountered, the plot of the corrected data (Figure 10) when using the upper or lower valve coincide. There is a substantial difference in raw data however, approximately 16 percent at $\frac{1}{2}$ inch water column (125 Pa) and over 45 percent at $\frac{1}{4}$ inch water column (68 Pa). Inadvertant use of the upper valves (as shown in the TTMA instructions as the flow control valves, but not actually used in this manner) give results that appear to be better than use of the lower valves.

3.8 Results of Test C

Figure 11 shows the data obtained in Test C. The test body was a forty foot (12.2 m) long trailer.

The manufacturer's test equipment is built for a limited range (240 SCFH) and is calibrated for nitrogen. The flow control valves are located downstream of the flow meter, and the input pressure was maintained at 45 psig (310 kPa). The delivery tubing was very short, less than 8 feet (2.4 m) and of large diameter ($\frac{3}{4}$ inch (19 mm)). The trailer used was very "leaky", i.e., it was difficult to maintain any significant pressure in the test body. The manufacturer's equipment also uses a Magnahelic gage in lieu of a manometer. This instrument has a range of zero to one inch water column (0 to 250 Pa) with fairly close graduations of the scale; each graduation is 0.02 inches of water (5 Pa). Thus both zeroing of the gage, and measurements at low pressures (less than 0.1 inches of water (25 Pa) mandated by the "leaky" trailer

FIGURE 10
TEST B - AIR LEAKAGE vs. OVERPRESSURE(Pressure Difference)

AIR LEAKAGE TEST DATA SHEET

9/26/78
Date

TRAILER
OR VAN

CODE U

Make

Year

40' TRAILER

Size

Model #

Serial #

78574097

Registration #

* MISSING NAMEPLATE

CODE B

Owner

Address

INSULATION
THICKNESS

AND TYPE

** USING MFR EQUIPT. (CODE S): NITROGEN METER CALIBRATED @ 20 PSIG & 70°F
W/ 3/4" HOSE ABOUT 8 FT. LONG, INLET PRESS. 45 PSI, DOWNSTREAM
CONTROL

Walls

Floor

Roof

Doors

REFRIGERATION

UNIT

Make & Model #

DOOR LOCATIONS
INDICATE BY

DOOR VENTS
IF ANY

Front

Rear

OBSERVATIONS AND CORRECTED RESULTS

CORRECTED AIR FLOW = FLOW METER READING x Correction Factor 1 x Correction Factor 2

TEST	AMBIENT TEMP °F	REGULATED LINE		MANO- METER "H ₂ O	TEST BODY TEMP °F	SECOND. PRESS psig.	FLOW METER SCFH	CORRECTION FACTOR		CORRECTED AIR FLOW SCFH	CORRECTION FACTOR 3	ACTUAL AIR LEAKGE CFH
		TEMP °F	HUM. %					1	2			
1	83	85	39	.195	36	5	905	.99	.893	800		
2	83	84	37	.105	36	3	680	.99	.847	570		
3	83	84	34	.01	36	1/2	225	.99	.784	175		
4	84	-	-	.03/.04	36	-	240	EST 1.0	1.256	301		
5	84	-	-	.02	36	-	180	EST 1.0	1.256	226		
6												
7												
8												
9												

CORRECTION FACTOR 1 - Corrects Air Flow Meter reading for the Regulated Line Temperature and Humidity - USE TABLE I

CORRECTION FACTOR 2 - Corrects Flow Meter reading for Secondary Pressure - USE TABLE II

CORRECTION FACTOR 3 - Corrects measurement for test body temperatures other than 70°F - USE TABLE III

FIGURE 11 - DATA TAKEN DURING TEST C

are subject to a potentially large percentage error.

Figure 12 shows the plots of uncorrected and corrected data obtained by use of the Prototype Test Set. Also shown is the plot of the two points obtained by use of the manufacturer's equipment. The correction factor used for the data obtained by the manufacturer's test equipment is based on assumed values believed to be reasonable, but which could not be verified since no pressure gage was available. The flow meter is calibrated for dry nitrogen at 70°F. At this condition nitrogen has a density of 0.0724 lbs/ft³ (1.1598 kg/m³). The density of the air at 85°F and 40 % RH (assumed from runs 1-3, Figure 10) is 0.07235 lbs/ft³ (1.1590 kg/m³). The correction factor is then

$$\sqrt{\frac{D_{\text{calibration}}}{D_{\text{use}}}} = \sqrt{\frac{0.0724}{0.7235}} = 1$$

With the flow control valves located downstream of the flow meter, and inlet pressure maintained at 45 psig (310 kPa), a reasonable assumption of pressure at the flow meter is 40 psig (274.6 kPa) since there was very little flow through short and large diameter hose. The correction factor, calculated in accordance with the formula given in paragraph 3.5 is then 1.256.

When the lines established by the data points plotted on log-log graph paper are extended to the ½ inch water column (125 Pa) point, an error of 6.9 percent results between the corrected data obtained by the Prototype Test Set and the manufacturer's set. It must be recognized

FIGURE 12

TEST C - AIR LEAKAGE vs. OVERPRESSURE (Pressure Difference)

however that this extrapolation is tenuous, since small errors in reading of the Magnahelic gage could have occurred and this would drastically change the slope of the plotted lines.

Compared to tests A and B, where the results are clear cut, test C only confirms the general trend. It does, however, clearly show the inability to compare test results obtained with existing test sets. Further, it clearly demonstrates the change in slope of the lines plotted to establish the exponent "n" between uncorrected and corrected data.

3.8 Summary

The results of the three tests, performed with three sets of manufacturer's equipment, all differing in construction, are of major significance in the further study and evaluation of air leakage phenomena in trailers and containers.

3.8.1 It has been shown, first of all, that the data published by various manufacturers and test stations is not comparably based, that indeed, "apples and oranges" are being compared. While any given piece of test equipment may be suited to a user in terms of acceptance criteria based on his own experience and the use of his specific equipment, the TTMA Recommended Practice # 38-73 cannot be realistically applied. Either the test set configuration must be further defined in terms of calibration of flow meter, tubing diameters and lengths, or the use of a pressure gage at the flow meter and correction factors must be mandated.

The information developed during the tests has been forwarded to industry personnel responsible for the TTMA Recommended Practice # 38-73 and they have personally observed one of the tests. Assurance has been given that the Practice will be reviewed and amended as required.

3.8.2 When air leakage tests are performed the slope of the line obtained by joining the test points, when plotted on log-log graph paper, has been taken as an indication of the character of the air leakage openings. It has now been shown that the slope of the line is very sensitive to systematic errors caused by use of the uncorrected flow measurements. Thus, many of the conclusions formed in the past about the nature of the air leakage phenomena in specific vehicles, based on such uncorrected values of air flow, must be considered suspect.

T T M A

RP#38-73

July 10, 1973

Recommended Practice

TRUCK TRAILER
MANUFACTURERS ASSOCIATION

2430 Pennsylvania Ave. N.W.
Washington, D.C. 20037
Tel. (202) 785-5833

CHARLES J. CALVIN
MANAGING DIRECTOR

SUBJECT   METHOD FOR RATING HEAT TRANSMISSION OF
REFRIGERATED VEHICLES

1.0 PURPOSE:

To establish a test method for determining rates of heat transmission and air leakage of refrigerated trailers and containers* which can readily be conducted within the plant facility of a manufacturer.

2.0 SCOPE:

- (a) The basic method of rating a vehicle is without the refrigeration unit in place. However, the test methods described herein are equally applicable to vehicles with or without a refrigeration unit in place.
- (b) This recommended practice is applicable to all refrigerated vehicles except those which employ certain materials where the elevated interior temperatures permitted in the tests may cause damage.
- (c) This test procedure not only applies to new equipment but also may be used to determine overall heat transmission rates for vehicles at any time during their useful life to evaluate changes in performance.
- (d) The equation used for correcting the overall heat transmission rate with mean wall temperatures**higher than 50°F. is presently limited to polyurethane insulation with densities of 1.5 to 2.5 lb/ft³ and also limited to structures that have uprights with non-metallic furring.

---

* - Some test parameters described in this test method are not in accord with the ANSI and ISO drafts. These test parameter differences are listed in Appendix E. These test parameters are to be appropriately adjusted for testing containers that are built to ISO specifications for certification & constructed for intermodal operations.

** - Mean Wall Temperature = Avg. Temp. of Interior Probes + Avg. Temp. of Exterior Probes

July 10, 1973

- (e) This test method determines heat transmission rates for vehicle in a static condition. It is beyond the scope of this document to simulate operational conditions such as vehicle motion, wind direction, solar radiation, door openings, etc.

3.0 TEST VEHICLE:

The vehicle may be tested with or without a refrigeration unit installed. If an opening is provided for a refrigeration unit, this opening must be carefully plugged with an airtight plug, similar to the front wall in type of insulation, quality and thickness.

Published ratings, unless qualified by a statement to the contrary, shall indicate the test results performed without the refrigeration unit. If the test was performed with the unit in place, then the make and model number of the unit shall be stated.

All floor drains or other such air leak conduits must be sealed during the air leakage test and must be left in their normal manner during the thermal test. All vents, doors, etc. must be closed in the normal manner prior to the air leakage and thermal tests.

4.0 AIR LEAKAGE TEST:

See pp 4-23 - 4-25

A schedule of air leakage rates for various vehicle lengths is included in 6.0 of this practice. It is recommended that the air leakage test be conducted prior to thermal testing to determine whether the heat transmission rate (defined in 5.0) is subject to a correction, or whether the vehicle being tested has a leak rate that would preclude its being tested and rated according to this recommended practice.

4.1 Test Method:

Air is introduced into the vehicle until a predetermined positive pressure is reached, and is maintained for a period of time to establish equilibrium. The amount of air required to maintain the positive interior pressure is recorded. An acceptable technique for conducting the air leakage test is illustrated schematically in Appendix A, Part 1. Other techniques may be substituted so long as the accuracy requirements described in the succeeding paragraphs are met.

4.2 Standard Rating Conditions for Air Leakage Test:

4.2.1 Allowable Temperature Ranges

- (1) Vehicle interior and exterior temperatures are to be within a range of.....70°F. to 90°F.
- (2) Maximum difference of vehicle interior-exterior temperatures should not exceed.....5°F.

- (3) Air temperature in flow meter to be within a range of.....70°F. to 90°F.
- (4) Vehicle interior pressure to be held at 0.5 inches W. C. during leak rate determination.

4.2.2 Steady State Conditions

Vehicle interior pressure to be held constant within ± 0.04 "W.C. for a period of not less than 3 minutes during leak rate determination.

4.3 Instrumentation

All instruments used for obtaining data for interior-exterior pressure differences and air leak rate shall meet the accuracy requirements stated in the following:

- (1) pressure measurement..... $\pm 5\%$ of the reading
- (2) flow rate measurement..... $\pm 2\%$ of the quantity measured within the temperature ranges stated above.
- (3) the smallest scale division of the pressure measuring device shall not exceed.....0.02" W.C.

4.4 Data to be Recorded

<u>Item</u>	<u>Unit</u>
(1) Vehicle interior temperature	°F.
(2) Vehicle exterior temperature	°F.
(3) Interior-exterior pressure difference	Inches W. C.
(4) Air flow rate	CFH
(5) Period for which data taken	Minutes

5.0 THERMAL TEST:

5.1 Test Method

5.1.1 Description

Test shall be conducted by using heating devices inside a trailer and measuring the energy required to maintain a trailer interior-exterior temperature difference. The trailer interior temperature shall be increased through the use of heaters, and the test room temperature is to be controlled within the

limits of this section. An acceptable technique, including test apparatus, schematic, and procedure is given in Appendix A, Part II. Other internal heating techniques may be substituted so long as the accuracy requirements described in the succeeding paragraphs are met.

5.1.2 Temperature Probe Locations

- A. The inside air temperature shall be measured 4" to 6" from the inner walls at the following 12 points: Refer to Appendix B, Fig. IV.
- (a) The eight inside corners of the vehicle.
  - (b) At the center of the length of the vehicle, at the center of the side walls, floor and ceiling.
- B. The outside air temperature shall be measured 4" to 6" from the outer walls at the following 12 points: Refer to Appendix B, Figure V.
- (a) The eight outside corners of the vehicle.
  - (b) At the center of the length of the vehicle, at the center of the side walls, underside, and roof.

5.1.3 Electrical Power Dissipation Control

Proper heater size and control must be maintained to minimize a "pumping effect" which produces erroneously high heat transmission rates. A guideline to achieve this is described in Appendix A, paragraph 2.2(2)

5.2 Standard Rating Conditions

5.2.1 Allowable Temperature Ranges

- (1) maximum vehicle interior temperature.....140°F.
- (2) minimum vehicle exterior temperature..... 40°F.
- (3) minimum vehicle interior-exterior temperature difference..... 50°F.

5.2.2 Steady State Conditions

Test data for determining the heat transmission rate of the vehicle must be taken for a continuous period of not less than 8 hours during which the following conditions must be satisfied:

- (1) Maximum temperature difference between any two vehicle interior probes.....5.4°F.
(See Appendix B, Figure No. 1)

- (2) Maximum temperature difference between any two vehicle exterior probes.....5.4°F.
(See Appendix B, Figure No. 1)
- (3) Maximum difference between any two average* interior temperatures.....2.7°F.
(See Appendix B, Figure No. II)
- (4) Maximum difference between any two average* exterior temperatures.....2.7°F.
(See Appendix B, Figure No. II)
- (5) Maximum percentage difference between any two power dissipation watt-hr values is not to exceed 3% of the lowest figure.   hr.
(See Appendix B, Figure No. III)
- (6) All readings shall be recorded at not more than 30 minute intervals.
- (7) All temperature measuring instruments placed inside and outside the vehicle shall be so designed to render the effect of radiation negligible.

5.3 Instrumentation

All instruments used for obtaining data for the heat transmission rate shall be calibrated periodically. In the case of air temperature measurement, checks will be made before each test by means of an ice bath.** Measurement system shall meet the following accuracy requirements:

- (1) temperature measurement system..... $\pm 2.0^{\circ}\text{F.}$
- (2) power measurement system of the quantity measured***..... $\pm 2\%$

---

* - "Average" shall be taken to mean the arithmetic sum of all interior or exterior probe temperatures divided by number of probes.

** - Ice bath may be substituted with any other suitable known temperature bath.

*** - Includes error due to voltage fluctuations in voltage supply and error due to inaccuracy of the measurement system.

- (3) the smallest scale division of the temperature measuring devices shall not exceed 2°F.
- (4) the smallest scale division of the power measuring device shall not exceed one (1) watt-hour.
- (5) ice bath thermometer is to have a certified accuracy of..... $\pm 0.20^\circ\text{F}$.
(ASTM or equivalent, certification required)

5.4 Data to be Recorded

<u>ITEM</u>	<u>UNIT</u>
(1) Date and Time of Test.	
(2) Average Vehicle Interior Temperature.....	°F.
(3) Average Vehicle Exterior Temperature.....	°F.
(4) Mean Wall Temperature*.....	°F.
(5) Ice Bath Temperature (Temp. Probe).....	°F.
(6) Ice Bath Temperature (Thermometer).....	°F.
(7) Total Power Dissipation During Steady State.	Watt-hr.
(8) Period of Steady State.....	Hours
(9) Interior-Exterior Pressure Differences During Steady State.....	Inches of Water Column

---

* - Mean Wall Temperature = $\frac{\text{Avg. Temp. of Interior Probes} + \text{Avg. Temp. of Exterior Probe}}{2}$

5.5 Calculation of Overall Heat Transmission Rate:

5.5.1

If temperature readings of a temperature probe (connected to temperature measuring system) and thermometer in ice bath* are not the same, a correction to average temperatures must be made by the following procedure.

$$T_{ic} = T_{ia} + (T_t - T_p)$$

and

$$T_{ec} = T_{ea} + (T_t - T_p)$$

Where: T_{ic} = corrected average interior temp., °F.

T_{ia} = average interior temp., °F.

T_t = ice bath temperature from thermometer, °F.

T_p = ice bath temperature from temp. probe, °F.

T_{ec} = corrected average exterior temp., °F.

T_{ea} = average exterior temp., °F.

EXAMPLES

Positive Correction

$$T_{ia} = 130^{\circ}\text{F.}$$

$$T_t = 32.0^{\circ}\text{F.}$$

$$T_p = 31.0^{\circ}\text{F.}$$

$$T_{ic} = 130^{\circ}\text{F} + 1.0^{\circ}\text{F.} = 131.0^{\circ}\text{F.}$$

Negative Correction

$$T_{ia} = 140^{\circ}\text{F.}$$

$$T_t = 32.0^{\circ}\text{F.}$$

$$T_p = 33.0^{\circ}\text{F.}$$

$$T_{ic} = 140^{\circ}\text{F.} - 1.0^{\circ}\text{F} = 139.0^{\circ}\text{F.}$$

---

* - Ice bath may be substituted with any other suitable known temperature bath.

5.5.2

The overall heat transmission rate of the vehicle shall be determined by the following formula:

$$U_{a2} = \frac{3.413P}{t \times \Delta T}$$

where: U_{a2} = overall heat transmission rate at test mean wall temperature

P = total power dissipation during steady state period, watt-hr.
(1 watt-hr = 3.413 Btu)

t = period of steady state, hrs.

$$\Delta T = T_i - T_e, \text{ } ^\circ\text{F.}$$

T_i = average value of T_{ic} during steady state conditions, $^\circ\text{F.}$

T_e = average value of T_{ec} during steady state conditions, $^\circ\text{F.}$

5.5.3

The overall heat transmission rate of a vehicle having polyurethane insulation (with densities of 1.5 to 2.5 lb/ft³ and uprights with nonmetallic furring) shall be corrected to 50°F mean wall temperature using the following empirical equation:

$$\begin{aligned} U_{a1} &= \frac{T_1 + 275}{T_2 + 275} \times U_{a2} + U_c \\ &= C \times U_{a2} + U_c \end{aligned}$$

where:

U_{a1} = Heat transmission rate at 50°F mean wall temperature

U_{a2} = Heat transmission rate at test mean wall temperature T_2

$C = \frac{T_1 + 275}{T_2 + 275}$ correction factor for mean wall temperature.

This correction factor is plotted against test mean wall temperature in Figure VI, Appendix B. The plot may be used in place of the correction factor formula.

$$T_1 = 50^\circ\text{F.}$$

T_2 = Test mean wall temperature

$$= \frac{T_i + T_e}{2}, \text{ } ^\circ\text{F.}$$

U_c = thermal correction for vehicle air leakage rate, if applicable, from Table in 6.0

6.0 THERMAL CORRECTIONS FOR AIR LEAKAGE:

Referring to the following table, if vehicle air leakage rate does not exceed the CFH value in Column (a) for its length as shown in Column (d), no correction factor has to be applied to the formula in 5.5.3. If the air leakage rate exceeds the value in Column (a), but is less than the value in Column (b), the heat transmission (U_{a1}) determined from 5.5.3 has to be increased by a correction factor (U_c) as shown in Column (c). If the air leakage rate is greater than the value in Column (b), the vehicle is not to be certified by this recommended practice.

Leakage @ 0.50" W. C.		Correction Factor U_c	Nominal Body Length Of Trailer or Container (L)
Basic Allowance	Correction Required		
Column (a)	Column (b)	Column (c)	Column (d)
<u>CFH</u>	<u>CFH</u>	Btu/hr. - $^\circ\text{F.}$	<u>Feet*</u>
720	1,440	5.01	$45 \leq L < 50$
675	1,350	4.58	$40 \leq L < 45$
517	1,034	3.51	$30 \leq L < 40$
382	764	2.59	$20 \leq L < 30$
203	406	1.37	$10 \leq L < 20$

* - Length of test vehicle shall be rounded to the nearest whole foot.

NOTE: An explanation of the derivation of the corrections stated above is included in Appendix D.

July 10, 1973

7.0 PUBLISHED RATINGS:(a) Air Leakage Test

When air leakage rate is to be expressed, it is to be stated in cubic feet per hour at a pressure head differential of 0.5 inches Water Column.

(b) Thermal Test

Results from the thermal test shall consist of the heat transmission rate at a mean wall temperature of 50°F. expressed in $\frac{\text{Btu}}{\text{hr } ^\circ\text{F.}}$ and include

(if applicable) the appropriate correction stated in 6.0.

8.0 RATING PLATE:

Where a rating plate is to be affixed to show certified initial thermal performance, the format illustrated in Appendix C should be used. The format shown is self-explanatory with the exception of the percentage tolerance shown in conjunction with the heat transmission rate. It is left to the discretion of the manufacturer to state this tolerance based upon his own experience to represent the heat transmission rate of vehicles not uniquely tested. The tolerance need not be stated if the particular unit exhibiting certification was tested.

TTMA
PKW/em
Encls:

APPENDIX A

PART I - Air Leakage Test

PART II - Thermal Test

APPENDIX B

- FIG. I - Illustration of Permissible Range of Individual Temp. Readings
- FIG. II - Illustration of Permissible Variation of Average of Readings
- FIG. III - Illustration of Tolerance of Electrical Power Consumption
- FIG. IV - Schematic of Location of Interior Probes
- FIG. V - Schematic of Location of Exterior Probes
- FIG. VI - Plot of mean wall temperature correction factor vs. Test Mean Wall Temperature.

APPENDIX C - Sample Recommended Rating Plate to Show TTMA Test Results

APPENDIX D

Derivation of air leakage rates and heat transmission corrections.

APPENDIX E

List of main test parameters of the ISO and ANSI drafts which are different from the TTMA recommended practice - RP#38.

PART I1.0 AIR LEAKAGE TEST:1.1 Test Apparatus: (For schematic arrangement, See Page A-2)

1. A manometer is used to measure the pressure within the trailer. An inclined manometer is preferred due to the relatively small pressures to be read. This instrument is calibrated in inches of water with a range of at least 0.0 to 0.50" W. C. and be capable of measuring a pressure difference of ± 0.02 " W. C.
2. Air for this test can be provided by a blower or from a pressurized system capable of supplying approximately 30 cubic feet of air per minute.
3. The air flow may be measured by an orifice, volumetric displacement gas meter, rotameter, or a flow meter and stop watch, capable of measuring air flow within an accuracy of $\pm 2\%$ of the flow rate measured.

1.2 Test Conditions:

As stated in 4.2 of this TTMA Recommended Practice.

1.3 Test Procedure:

1. The trailer is placed in the test room with its doors open to allow temperatures to stabilize.
2. The hoses for air supply and pressure measurement are installed as shown in the schematic and sealed to prevent leakage around the hoses.
3. All other openings are sealed such as gutter drains, etc. and vents and doors are closed.
4. Using the air supply, positive pressure of 0.5" W. C. is maintained within the trailer and is held for at least three minutes.
5. At constant pressure, mentioned above, the flow rate is recorded in cubic feet per minute.

7/10/73

AIR LEAKAGE TEST

2.0 THERMAL TEST - INTERNAL HEATING: *Sept 4-19-4-22*

PART II

2.1 Test Apparatus: (For schematic arrangement, See Page A-5)

1. The test room is to be of sufficient size to accommodate the vehicle being tested and capable of controlling temperature as set forth in paragraph 5.2.2 of this recommended practice.
2. Eight 125 watt heaters equipped with 125 cfm fans are required. These heaters are to be connected to operate continuously and are positioned above the vehicle floor and directed to blow vertically. For location of these units, see Item "A" in the schematic.
3. Two 125 watt cfm fans and two 250 watt heaters with 250 cfm fans are also required. These heaters are to be connected to a thermostat set to maintain the desired interior temperature, and are positioned as mentioned above. For location of these units, see item "B" in the schematic.
4. A booster heater is required to minimize initial interior temperature rise time. This unit is to be approximately a 5,600 watt heater and is to be controlled manually.
5. A watt-hour meter is required to measure energy input. This device is to have a sweep hand register calibrated in watt hours and cumulative registering capability to accommodate total testing time (approximately 1,000 kilowatt hours).

2.2 Test Conditions:

1. As stated in 5.2 of this TTMA Recommended Practice.
2. The hourly power consumption watt-hr during steady state conditions should not be less than 80% of the total capacity of the heaters used during test and/or the interior-exterior pressure differences during steady state conditions shall not exceed ± 0.05 " W. C.

NOTES:

1. Maximum temperature differential obtainable with heater sizes and quantities mentioned above for a typical 40' trailer is approximately 65°F.
2. For testing a typical 20' unit the capacities of both systems (continuous and intermittent) must both be reduced by approximately 35%.

2.3 Test Procedure:

1. The vehicle is placed in the test room and temperature sensing devices are attached.
2. All heaters are placed in the trailer as shown in the schematic and drains are sealed.
3. The booster heater is turned on to achieve required trailer interior temperature.
4. After achieving required trailer interior and exterior temperatures the booster heater is turned off, and the smaller heaters are activated to maintain interior temperature.
5. After steady state conditions are reached (as defined in paragraph 5.2.2 of this recommended practice), temperatures and watt-hour readings are recorded.

7/10/73

- (A) CONTINUOUSLY
OPERATING
8-125 WATTS
- (B) THERMOSTATICALLY
CONTROLLED
2-125 WATTS
2-250 WATTS
- (C) BOOSTER HEATER
5,600 WATTS

INTERNAL HEATING

FIG. I - ILLUSTRATION OF PERMISSIBLE RANGE OF INDIVIDUAL TEMPERATURE READINGS

FIG. I - ILLUSTRATION OF PERMISSIBLE RANGE OF INDIVIDUAL TEMPERATURE READINGS

FIG. III - ILLUSTRATION OF TOLERANCE ON ELECTRICAL POWER CONSUMPTION

Figure IV - Schematic of Locations of Interior Temperature Probes

7/10/73

Figure V - Schematic of Locations of Exterior Temperature Probes.

B-4

FIGURE VI - PLOT OF MEAN WALL TEMPERATURE CORRECTION FACTOR VERSUS TEST MEAN WALL TEMPERATURE AS DEFINED IN 5.5.3

(MANUFACTURER'S NAME)

**TTMA
THERMAL RATING**

This structure is certified by the manufacturer to meet the following initial thermal performance at 50°F mean wall temperature when tested in accordance with Truck Trailer Manufacturers Association Recommended Practice No. 38-73:

Heat Transmission Rate _____ $\frac{\text{Btu}}{\text{hr. °F.}} \pm \text{ } \%$

Certification based on manufacturing test series no. _____

and rated _____ with _____ without refrigeration unit in place

Refrigeration Unit: Make _____ Model No. _____

Serial No. of Trailer _____

Date of Manufacture _____

Rating Plate Format

1.0 DERIVATION OF VEHICLE AIR LEAKAGE RATES (Table in 6.0)

A survey was taken by soliciting trailer manufacturers for air leakage rates of typical units currently being manufactured. It was found that leak rates varied considerably with specification i. e., vent doors, side doors, etc. From the data received, a plot was developed that isolated the effects of side doors, vent doors, vehicle length, and refrigeration unit installation. This plot appears on Page (11-7) of TTMA Research Report entitled, "THERMAL TESTING OF COMMERCIAL TRANSPORT EQUIPMENT."

The values appearing in paragraph 6.0 of this recommended practice were taken from that chart including typical specifications for a particular vehicle length at 0.50" W. C. pressure difference.

The values in Column (a) of the Table, if not exceeded, are those amounts which when related to actual operating conditions of less than ± 0.05 " W. C. interior-exterior pressure difference will result in an additional heat gain due to air leakage of less than 5% of the total heat transmission rate of a typical vehicle of that length.

If air leakage rates exceed values stated in Column (a) but are less than values stated in Column (b), the additional heat gain due to air leakage is considered to be significant and the Btu/hr-°F. values in Column (c) are to be added to the heat transmission rate determined by thermal testing.

Vehicles exhibiting air leakage rates in excess of Column (b) are considered to be too greatly affected by additional heat gain due to air leakage and therefore cannot be certified by this practice.

2.0 DERIVATION OF THERMAL CORRECTIONS (Column (c)):

The flow rates appearing in Column (a) at 0.50" W. C. pressure difference (std. air leakage test pressure difference) were extended to a pressure difference of ± 0.05 " W. C. This pressure was found to be quite representative of operational conditions of 100°F. exterior and 0°F. interior. The sensible and latent heat loads of 100°F. 50% relative humidity air entering a 0°F. vehicle interior at this reduced flow rate were calculated in a similar manner as described in 5.8.0 of the TTMA Research Report and stated in Column (c).

List of Main Test Parameters of the ISO and ANSI Drafts which are different from the
TTMA Recommended Practice - RP#38-73.

The listing below has been included to assure awareness of the major differences between certification requirements for vehicles versus intermodal containers. It is recommended for certification of intermodal containers that the below list not be used in place of the latest ISO and ANSI drafts.

THERMAL TEST

	TTMA	ISO(6/1/72) and ANSI(1/29/73)
1. Mean Wall temperature range	Not specified	68°F. to 90°F.
2. Minimum Temperature Diff.	50°F.	36°F.
3. Maximum Temp. permitted	140°F.	122°F.
4. Minimum Temp. permitted	40°F.	32°F+
5. Is refrigeration unit in place (normal position) during test?	Either way - normal position without refrigeration unit. If refrigeration unit is removed, opening must be closed with an air tight plug similar to the front wall construction in type, quality and thickness of insulation.	Yes - except for "clip-on" type units in which case closures shall be shut.
6. Correction of test results	$U_{a1} = \frac{T_1 + 275}{T_2 + 275} U_{a2}$	Not recognized, but rating is identified at the actual mean wall temp. during test.

AIR LEAKAGE

1. Test Pressure	0.5" W. C.	1.0" W. C.
2. Test Temp. Range	70°F. to 90°F.	59°F. to 77°F. *
3. Upper air leakage rate limit for where no correction for latent heat and sensible heat is required for a 40' unit.	675 CFH @ 0.5" W. C.	1059 CFH @ 1.0" W. C.
4. Upper air leakage rate limit beyond if exceeded a 40' unit cannot be rated and below (but not less than 3 above) if a correction for latent and sensible heat applies.	1350 CFH @	2119 CFH @ 1.0" W. C.

* - If this test is carried out as a production line test, the temperature limits specified do not necessarily apply.

List of Main Test Parameters - continued

Test Parameters which are more specific and/or more conservative in the TTMA Recommended Practice as compared to the ISO and ANSI drafts are not included in the above listing.

The listing is included in order to aid in the selection of proper test equipment and to assure a properly designed Thermal Laboratory which is dependent upon the requirements of compliance one might have to meet with different certifying agencies.

The above listing was prepared from the ISO draft proposal ISO TC 104/SC 2/WG 1 (Sec. 8.7) 47 of June 1, 1972 on Thermal Containers and the ANSI draft MH5.1.2 - Requirements for Thermal Containers dated January 29, 1973.

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