

Submitted for recognition as an American National Standard

**LABORATORY TESTING OF VEHICLE AND INDUSTRIAL HEAT EXCHANGERS
FOR HEAT TRANSFER PERFORMANCE**

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board format.

1. Scope—This SAE Recommended Practice is applicable to all heat exchangers used in vehicle and industrial cooling systems. This document outlines the tests to determine the heat transfer performance under specified conditions.

1.1 Purpose—This document is to provide a test guideline for determining the heat transfer performance of a heat exchanger under specified design conditions.

1.2 Objective—To determine and document the heat transfer characteristics of a heat exchanger. This document describes a system to flow fluids through the heat exchanger at specified rates and temperatures, and describes and recommends a procedure for documenting the results. The procedure may be varied to match existing equipment and methods.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale PA 15096-0001.

SAE J1393—On-Highway Truck Cooling Test Code

SAE Paper 890227—Prediction of Heat Transfer Performance of a Heat Exchanger

3. Facility Requirement—The facility should provide the following as required:

3.1 Source capable of delivering the fluids to the test unit at a specified temperature, pressure, and flow.

3.2 Means of moving these fluids to and from the test unit in a specified manner.

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3.3 A test system adequate to contain the test unit and control the flow and temperatures of the fluids as specified. It may include, but not be limited to, the following:

- a. Air flow rate instrumentation
- b. Automatic data logging equipment
- c. Fluid flow rate meters
- d. Heater and controls
- e. Humidity measuring equipment
- f. Pressure measuring instrumentation
- g. Pump and motor with controls
- h. Reservoir
- i. Safety features as specified by regulatory codes and common practices
- j. Temperature indicators
- k. Thermocouples
- l. Valves as required
- m. Various ducting, piping, hoses, and fittings

4. Testing (not necessarily in the following order)

4.1 Install test unit as specified.

4.2 Start heaters and heat fluids to specified temperature.

4.3 Start pumps and adjust flows and pressures as specified.

4.4 Insure conditions are stable before recording data.

4.5 Read and record inlet and outlet temperatures and mass flow rates for fluids. Calculate the differences in temperature, multiply the differences by the mass flow rates (taking into account corrections for relative humidity if necessary), and specific heats of each to obtain heat transfer capacity. For heat exchangers involving phase change, see Appendix A.

4.6 If the heat transfer capacity of the fluids are within 3% of each other, record the data and continue. (This may be difficult to obtain when one fluid has a small temperature change.)

4.7 Read and record pressure drop of each fluid.

4.8 Change test parameters and repeat steps 4.5, 4.6, and 4.7 as specified.

5. Test Procedures (see Appendix A for specific procedures)

5.1 Liquid-to-Gas (e.g., radiator) (See Figures A1.A and A1.B.)

5.2 Liquid-to-Liquid (e.g., shell/tube) (See Figures A2.A and A2.B.)

5.3 Gas-to-Liquid (e.g., jacket water aftercooler) (See Figures A3.A and A3.B.)

5.4 Gas-to-Gas (e.g., air-to-air aftercooler) (See Figures A4.A and A4.B.)

5.5 Phase Change Heat Exchanger (e.g., condenser) (See Figures A5.A, A5.B, and A5.C.)

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6. This document is valid for laboratory performance testing and comparison.

It is recommended that a full-size heat exchanger be tested, if possible. If this is not possible, then it is recommended that the test results from the test heat exchanger be extrapolated to the full-size heat exchanger as recommended in SAE Paper 890227 and the results be reported for the full size.

Any correlation to field results must be developed on an individual basis (see SAE J1393 for details of field testing).

PREPARED BY THE SAE COOLING SYSTEMS COMMITTEE

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APPENDIX A

Customer Part Number:
 Manufacturer Part Number:

Test Date:
 Tested By:
 Test Number:

Core Type:
 Core Size:
 Core Construction:

TEST DATA

ITEM	CRITERIA	UNITS	1	2	3	4	5
MEASURED VALUES							
A	Hot Liquid Flow Rate	kg/min (lb/min)					
B	Hot Liquid Inlet Temperature	°C (°F)					
C	Hot Liquid Outlet Temperature	°C (°F)					
D	Hot Liquid Inlet Pressure	kPa (psia)					
E	Hot Liquid Outlet Pressure	kPa (psia)					
F	Cooling Gas Flow Rate	kg/min (lb/min)					
G	Cooling Gas Inlet Temperature	°C (°F)					
H	Cooling Gas Outlet Temperature	°C (°F)					
I	Cooling Gas Inlet Pressure (static)	kPa (psia)					
J	Cooling Gas Outlet Pressure (static)	kPa (psia)					
K	Barometric Pressure	kPa (inches Hg)					
CALCULATED VALUES							
L	Hot Liquid Temperature Differential	(B-C)					
M	Hot Liquid Pressure Differential	(D-E)					
N	Cooling Gas Temperature Differential	(H-G)					
O	Cooling Gas Pressure Differential	(I-J)					
P	Heat Exchanger Effectiveness (Hot Side)	(L/X)					
Q	Average Hot Liquid Temperature						
R	Average Hot Liquid Specific Heat						
		kJ/kg°K (Btu/lb°R)					
S	Average Cooling Gas Temperature						
T	Average Cooling Gas Specific Heat						
		kJ/kg°K (Btu/lb°R)					
U	Hot Side Heat Transfer	(A x R x L)					
V	Cooling Side Heat Transfer	(F x T x N)					
W	Heat Transfer Balance	(V/U) x 100					
X	Inlet Temperature Differential	(B-G)					
Y	Average Heat Transfer Per °ITD	((V+U)/2)/X					
Z	Heat Transfer Per Average Temperature	((V+U)/2) / (Q-G)					
AA	Cooling Air Density	kg/m ³ (lb/ft ³)					
BB	Face Velocity (at standard conditions)						

FIGURE A1.A—LIQUID-TO-GAS HEAT EXCHANGER TEST DATA (REFERENCE 5.1)

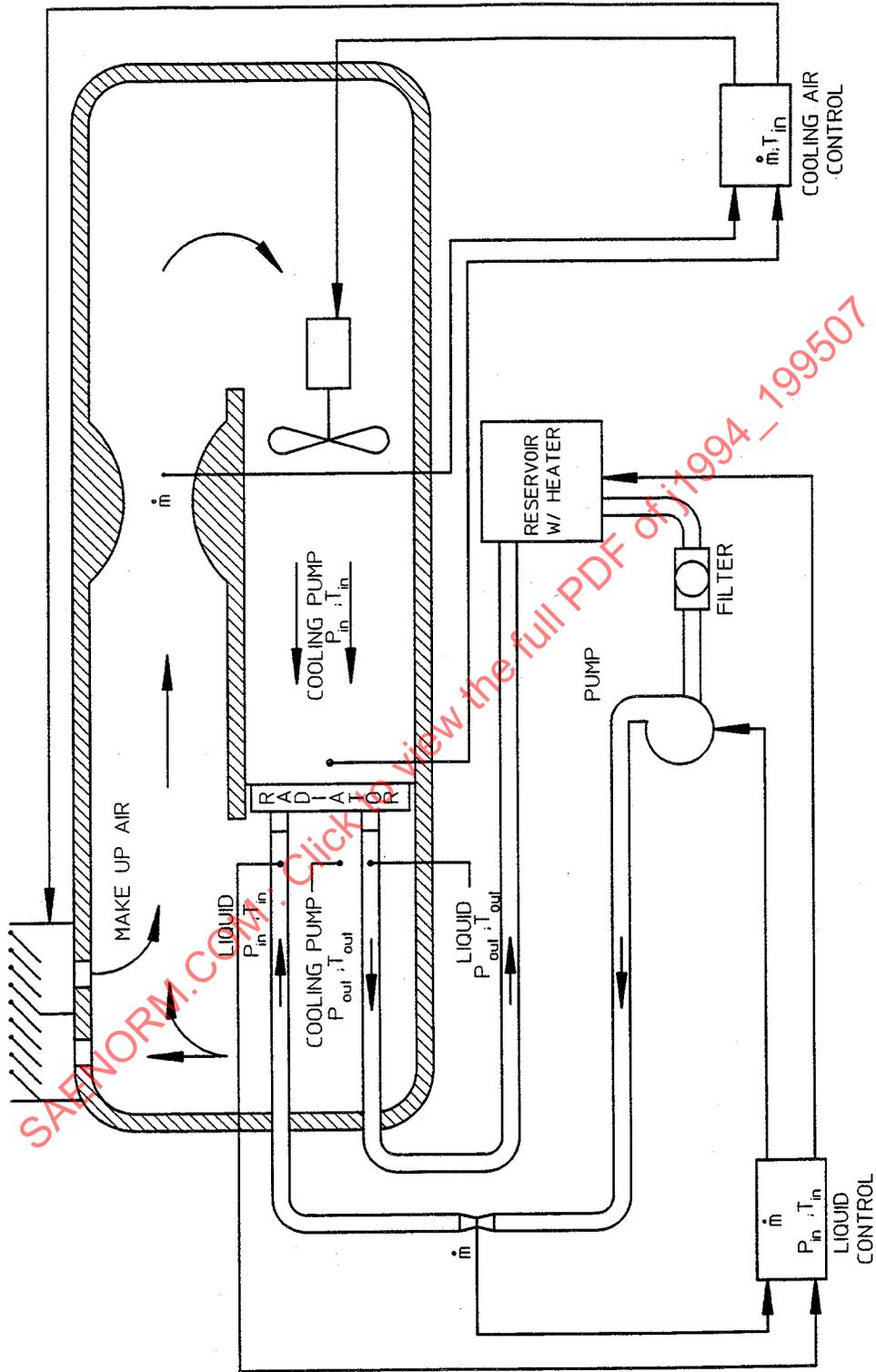


FIGURE A1.B—LIQUID-TO-GAS (E.G., RADIATOR) HEAT TRANSFER TEST LOOP (REFERENCE 5.1)

Customer Part Number:
 Manufacturer Part Number:

Test Date:
 Tested By:
 Test Number:

Core Type:
 Core Size:
 Core Construction:

TEST DATA

ITEM	CRITERIA	UNITS	1	2	3	4	5
MEASURED VALUES							
A	Hot Liquid Flow Rate	kg/min (lb/min)					
B	Hot Liquid Inlet Temperature	°C (°F)					
C	Hot Liquid Outlet Temperature	°C (°F)					
D	Hot Liquid Inlet Pressure	kPa (psia)					
E	Hot Liquid Outlet Pressure	kPa (psia)					
F	Cooling Liquid Flow Rate	kg/min (lb/min)					
G	Cooling Liquid Inlet Temperature	°C (°F)					
H	Cooling Liquid Outlet Temperature	°C (°F)					
I	Cooling Liquid Inlet Pressure	kPa (psia)					
J	Cooling Liquid Outlet Pressure	kPa (psia)					
CALCULATED VALUES							
K	Hot Liquid Temperature Differential	(B-C)					
L	Hot Liquid Pressure Differential	(D-E)					
M	Cooling Liquid Temperature Differential	(H-G)					
N	Cooling Liquid Pressure Differential	(I-J)					
O	Heat Exchanger Effectiveness (Hot Side)	(K/W)					
P	Average Hot Liquid Temperature						
Q	Average Hot Liquid Specific Heat						
R	Average Cooling Liquid Temperature						
S	Average Cooling Liquid Specific Heat						
T	Hot Side Heat Transfer	(A x Q x K)					
U	Cooling Side Heat Transfer	(F x S x M)					
V	Heat Transfer Balance	(U/T) x 100					
W	Inlet Temperature Differential	(B-G)					
X	Average Heat Transfer Per °ITD	((U+T)/2)/W					
Z	Heat Transfer Per Average Temperature	((U+T)/2) / (P-G)					

FIGURE A2.A—LIQUID-TO-LIQUID HEAT EXCHANGER TEST DATA (REFERENCE 5.2)

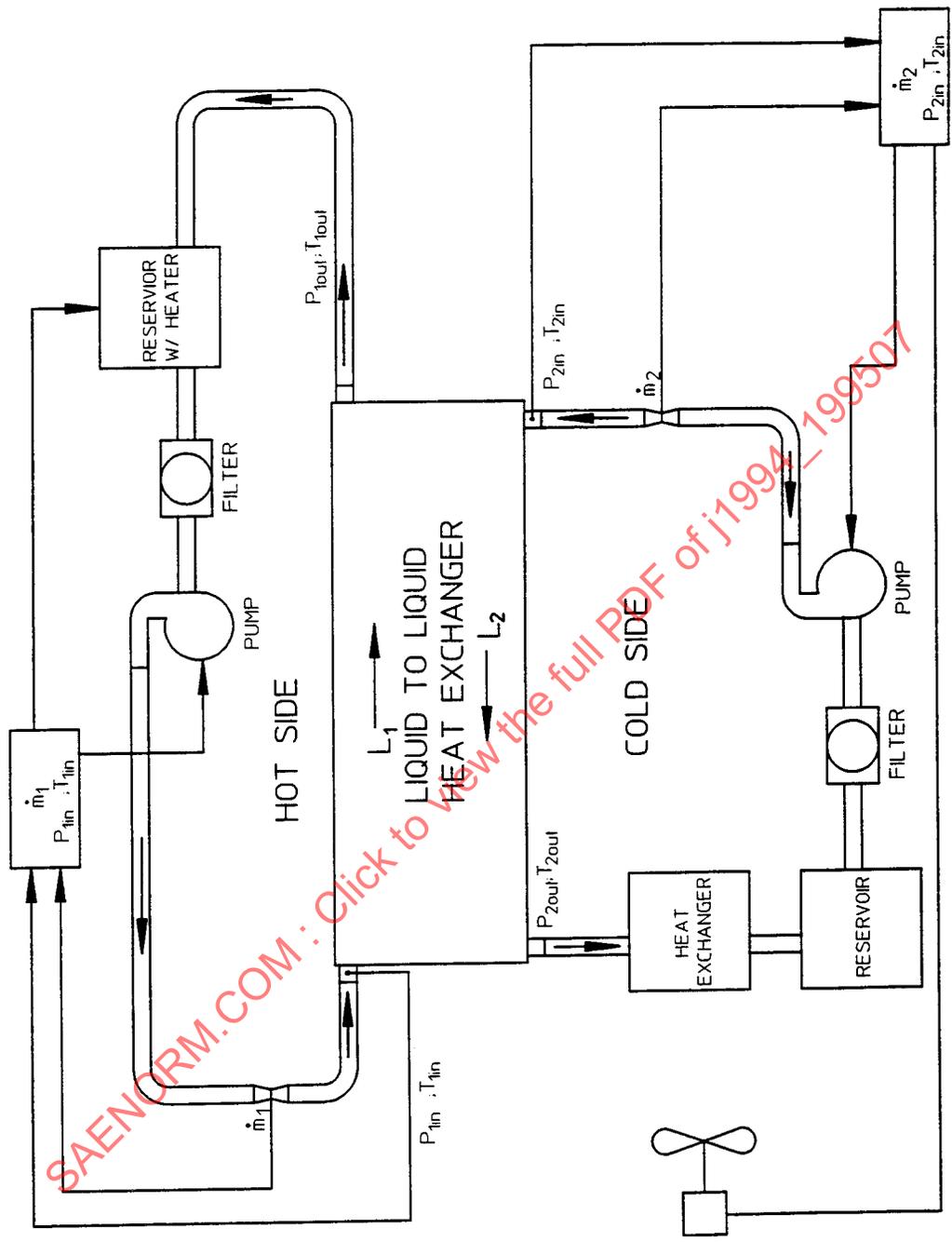


FIGURE A2.B—LIQUID-TO-LIQUID (E.G., SHELL/TUBE) HEAT TRANSFER TEST LOOP (REFERENCE 5.2)

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Customer Part Number:
 Manufacturer Part Number:

Test Date:
 Tested By:
 Test Number:

Core Type:
 Core Size:
 Core Construction:

ITEM	CRITERIA	UNITS	TEST DATA				
			1	2	3	4	5
MEASURED VALUES							
A	Hot Gas Flow Rate	kg/min (lb/min)					
B	Hot Gas Inlet Temperature	°C (°F)					
C	Hot Gas Outlet Temperature	°C (°F)					
D	Hot Gas Inlet Pressure (static)	kPa (psia)					
E	Hot Gas Outlet Pressure (static)	kPa (psia)					
F	Cooling Liquid Flow Rate	kg/min (lb/min)					
G	Cooling Liquid Inlet Temperature	°C (°F)					
H	Cooling Liquid Outlet Temperature	°C (°F)					
I	Cooling Liquid Inlet Pressure	kPa (psia)					
J	Cooling Liquid Outlet Pressure	kPa (psia)					
CALCULATED VALUES							
K	Hot Gas Temperature Differential	(B-C)					
L	Hot Gas Pressure Differential	(D-E)					
M	Cooling Liquid Temperature Differential	(H-G)					
N	Cooling Liquid Pressure Differential	(I-J)					
O	Heat Exchanger Effectiveness (Hot Side)	(K/U)					
P	Average Hot Gas Specific Heat kJ/kg°K (Btu/lb°R)						
Q	Average Coolant Specific Heat kJ/kg°K (Btu/lb°R)						
R	Hot Side Heat Transfer	(A x P x K)					
S	Cooling Side Heat Transfer	(F x Q x M)					
T	Gas Density Recovery Efficiency ((D-L)/D) x (G/C)						
U	NOTE—D, G, and C are all absolute terms Inlet Temperature Differential	(B-G)					

FIGURE A3.A—GAS-TO-LIQUID HEAT EXCHANGER TEST DATA (REFERENCE 5.3)

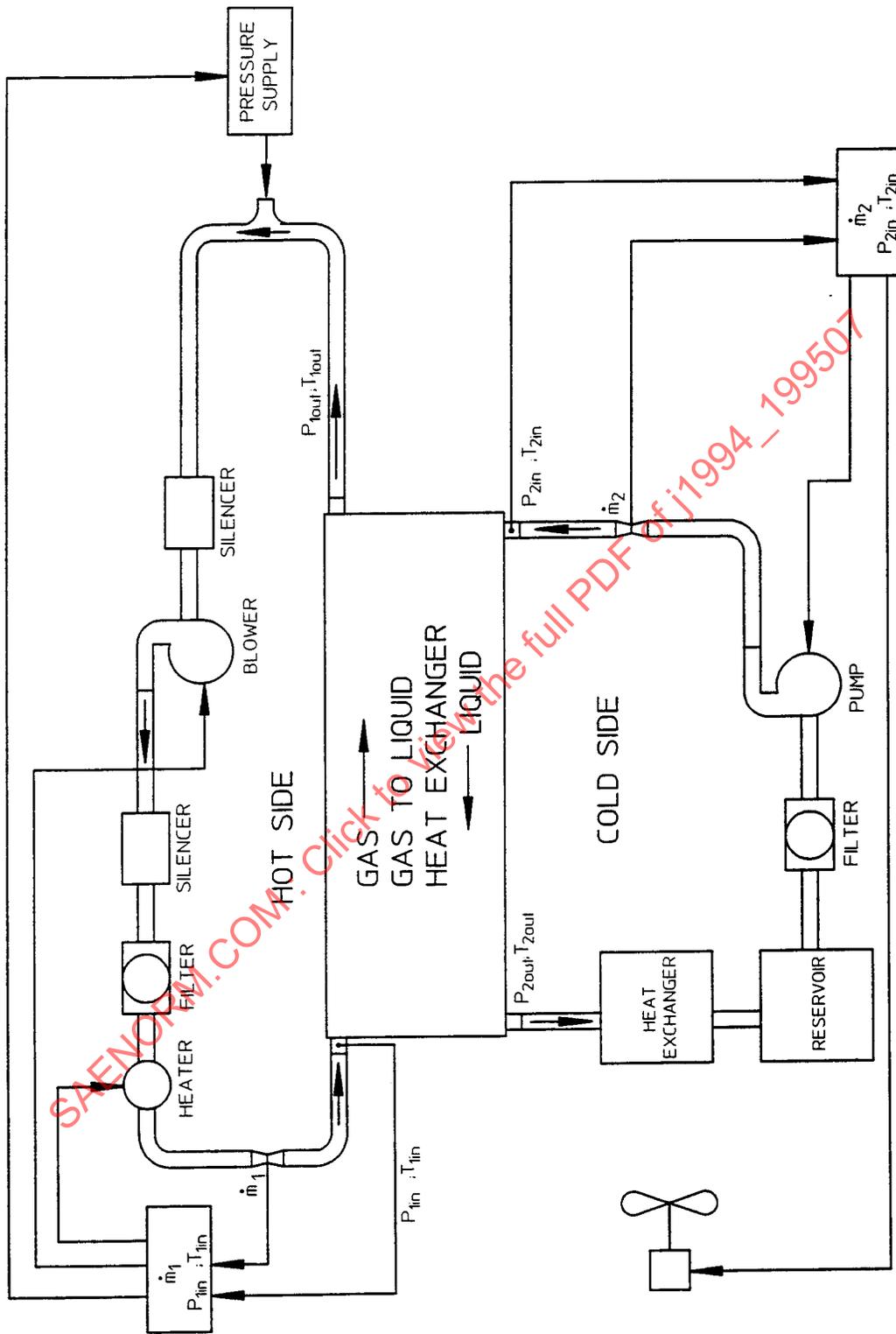


FIGURE A3.B—GAS-TO-LIQUID (E.G., JWAC) HEAT TRANSFER TEST LOOP (REFERENCE 5.3)

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Customer Part Number:
 Manufacturer Part Number:

Test Date:
 Tested By:
 Test Number:

Core Type:
 Core Size:
 Core Construction:

TEST DATA

ITEM	CRITERIA	UNITS	1	2	3	4	5
MEASURED VALUES							
A	Hot Gas Flow Rate	kg/min (lb/min)					
B	Hot Gas Inlet Temperature	°C (°F)					
C	Hot Gas Outlet Temperature	°C (°F)					
D	Hot Gas Inlet Pressure	kPa (psia)					
E	Hot Gas Outlet Pressure	kPa (psia)					
F	Cooling Gas Flow Rate	kg/min (lb/min)					
G	Cooling Gas Inlet Temperature	°C (°F)					
H	Cooling Gas Outlet Temperature	°C (°F)					
I	Cooling Gas Inlet Pressure	kPa (psia)					
J	Cooling Gas Outlet Pressure	kPa (psia)					
CALCULATED VALUES							
L	Hot Gas Temperature Differential	(B-C)					
M	Hot Gas Pressure Differential	(D-E)					
N	Cooling Gas Temperature Differential	(H-G)					
O	Cooling Gas Pressure Differential	(I-J)					
P	Heat Exchanger Effectiveness (Hot Side)	(L/V)					
Q	Average Hot Gas Specific Heat						
		kJ/kg°K (Btu/lb°R)					
R	Average Coolant Specific Heat						
		kJ/kg°K (Btu/lb°R)					
S	Hot Side Heat Transfer	(A x Q x L)					
T	Cooling Side Heat Transfer	(F x R x N)					
U	Gas Density Recovery Efficiency	((D-M)/D) x (G/C)					
	NOTE—D, G, and C are all absolute terms						
V	Inlet Temperature Differential	(B-G)					

FIGURE A4.A—GAS-TO-GAS HEAT EXCHANGER TEST DATA (REFERENCE 5.4)

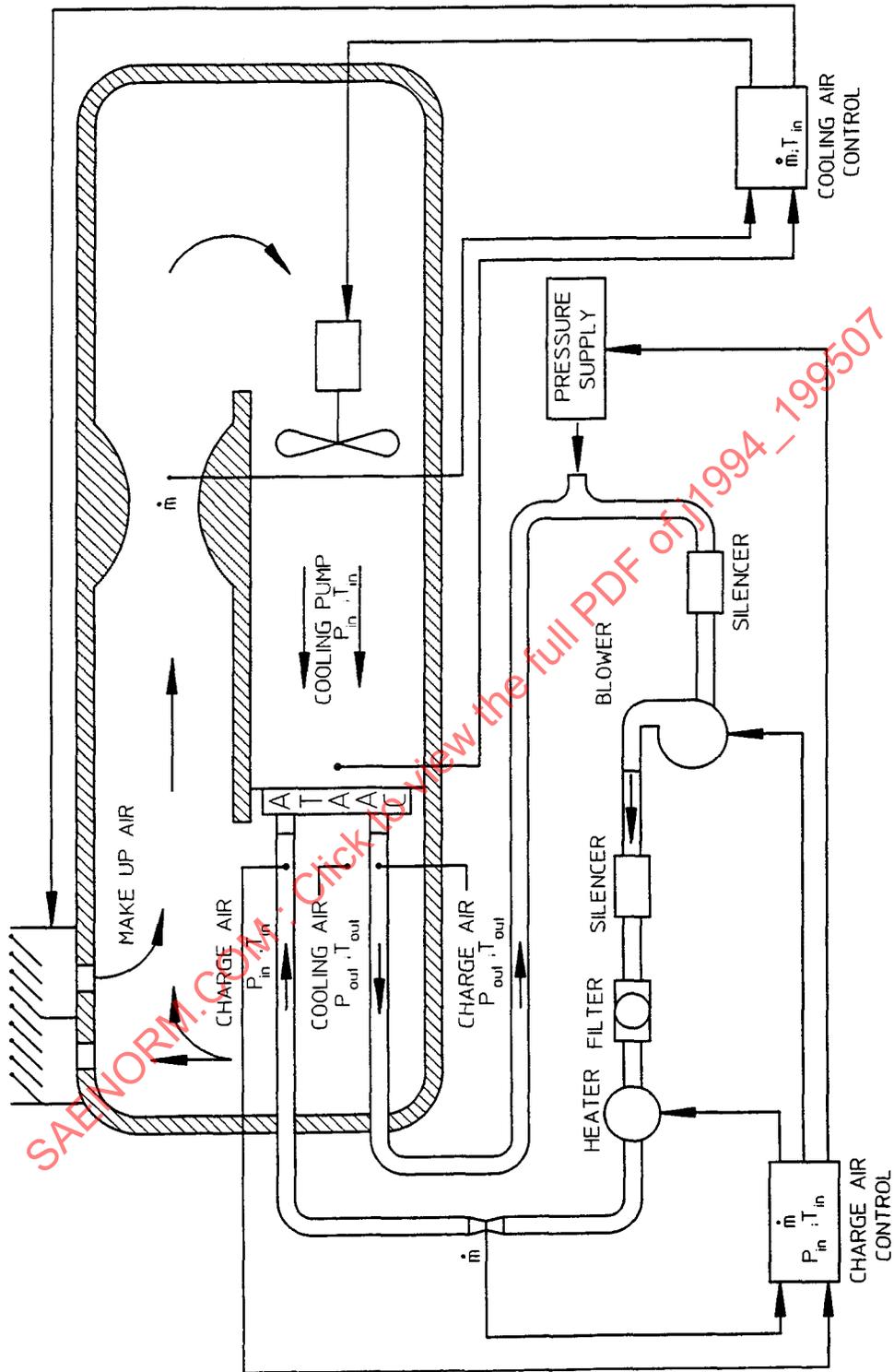


FIGURE A4.B—GAS-TO-GAS (E.G., ATAC) HEAT TRANSFER TEST LOOP (REFERENCE 5.4)

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Customer Part Number:
 Manufacturer Part Number:

Test Date:
 Tested By:
 Test Number:

Core Type:
 Core Size:
 Core Construction:

TEST DATA

ITEM	CRITERIA	UNITS	1	2	3	4	5
MEASURED VALUES							
A	Barometric Pressure, Inlet	kPa (in Hg)					
B	Barometric Pressure, Outlet	kPa (in Hg)					
C	Nozzle Pressure Drop	kPa (in H ₂ O)					
D	Frontal Area	m ² (ft ²)					
E	Air Inlet Dry Bulb Temperature	°C (°F)					
F	Air Inlet Wet Bulb Temperature	°C (°F)					
G	Air Outlet Dry Bulb Temperature	°C (°F)					
H	Air Outlet Wet Bulb Temperature	°C (°F)					
I	Test Coil Air Pressure Drop	kPa (in H ₂ O)					
CALCULATED VALUES							
J	Corrected Inlet Barometric Pressure	kPa (in Hg)					
K	Corrected Outlet Barometric Pressure	kPa (in Hg)					
L	Corrected Outlet Dry Bulb	°C (°F)					
M	Corrected Outlet Wet Bulb	°C (°F)					
N	Cooling Air Face Velocity	m/min (ft/min)					
P	Inlet Volumetric Flow Rate	(N x D)					
Q	Inlet Specific Volume	m ³ /kg (ft ³ /lb)					
R	Inlet Mass Flow Rate	(P/Q)					
S	Inlet Specific Heat	kJ/kg°C (Btu/lb°F)					
T	Outlet Volumetric Flow Rate	(N x D)					
U	Outlet Specific Volume	m ³ /kg (ft ³ /lb)					
V	Outlet Mass Flow Rate	(T/U)					
W	Outlet Specific Heat	kJ/kg°C (Btu/lb°F)					
X	Inlet Heat Transfer	(R x S x (L - E))					
Y	Outlet Heat Transfer	(V x W x (L - E))					
Z	Total Capacity Heat Transfer	(X - Y)					

FIGURE A5.A—EVAPORATOR/CONDENSER HEAT EXCHANGER—TEST AIR DATA (REFERENCE 5.5)