NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT 1003-20-4891

April 17, 1959

NBS REPORT 6378

CAPACITY TESTS OF TWO REMOTE AIR-COOLED
SIZE B, CLASS I REFRIGERANT CONDENSERS
MANUFACTURED BY
DUNHAM-BUSH, INC.

by

F. J. J. Drapeau and C. W. Phillips
Air Conditioning, Heating, and Refrigeration Section
Building Technology Division

to

Mechanical Engineering Division
Headquarters,
Quartermaster Research and Engineering Command
Natick, Massachusetts

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Capacity Tests of Two Remote Air-Cooled Size B, Class I Refrigerant Condensers Manufactured By Dunham-Bush, Inc.

by

P. J. J. Drapeau and C. W. Phillips

Introduction

Capacity tests were made of two specimens of remote air-cooled refrigerant condensers of Size B, Class I manufactured by Dunham-Bush, Inc. of West Hartford, Connecticut. These specimens were of identical dimensions and materials and were identified for testing purposes as NBS 135-57 and NBS 155-58.

The tests were made with an apparatus conforming in most details to that described in the proposed ASRE Standard for remote air-cooled condensers, PS 2.4. It provided means for measuring the heat transfer capacity of the specimens by the psychrometric method and by the refrigerant flow method.

Test Procedure

Capacity tests were made at two values of saturation temperature of the refrigerant vapor entering the condenser following the procedure and test conditions set forth in ASRE PS 2.4. At the higher saturation temperature of 130°F, tests were made at three air flow rates; namely, at the free discharge capacity of the fan and at one lower and one higher value, ranging from 2940 cfm to 4090 cfm. In addition, one test was made of each specimen at the high ambient temperature of 110°F established as a standard for QMR&E application.

These tests were a part of a series of tests planned under the Condenser Standardization Project, QMREL-M P. O. 57-26, to determine the possibility of standardizing air-cooled condenser performance on the basis of maximum overall dimensions and minimum air flow rate.

The five capacity tests conducted on specimen NBS 139-57 were the first tests made with the apparatus built for this study. A number of technical problems had to be overcome in the apparatus design, including failure of the immersion electric heating elements installed in the compressor discharge line. The failure of these heating elements produced sludge in the refrigerant circuit which was circulated for a limited time through the condenser specimen. The second specimen of this same condenser, NBS 155-58, was tested at two of the five test conditions for comparison purposes to determine whether or not the heat transfer of the first specimen might have been reduced by interior fouling from sludge, even though the system was thoroughly washed out after the heater failure.

Specimen NBS 139-57 was inspected internally at the end of the tests by removing opposite tube return bends near the condenser inlet. There was a slight sludge accumulation on the aluminum inner fin construction and somewhat less evidence of a deposit on the inside of the tube surface. By spectrochemical analysis the sludge was found to be mainly ferric chloride, probably resulting from the reaction of the refrigerant and the stainless steel sheath of the electric heating elements at high temperature. The appearance of the interior of the specimen suggested that a few tests should be made of a second specimen.

The mechanical bond between the aluminum fins and the copper tube appeared to be better on the second specimen than on the first especially near the tube sheets, and the bellmouth shape appeared to be superior on the second specimen. In addition, the first specimen was damaged slightly by the extensive handling occasioned by the repair and remodeling of the test apparatus during the proving period. This damage consisted principally of flattening of a few fins at the condenser face by accidental blows, and although the fins were straightened before the tests, the heat transfer may have been affected.

The condensers were tested with a Torrington propeller fan with air delivery capacity meeting the minimum requirement of the QMSE purchase description.

Test Results

The results obtained on the two condenser specimens and the dimensional data describing them are attached. Fig. 1 indicates the shape and tube arrangement of the condensers and uses letter symbols to identify the dimensions of the specimen as summarized in Table 1. Table 1 describes the materials and construction of the condensers and lists all the significant dimensions of coil, fins, and complete unit.

Tables 2 and 3 summarize the test data on specimens 139-57 and 155-58, respectively, and the heat rejection capacity ratings and heat transfer coefficients computed therefrom. Fig. 2 is a pressure enthalpy diagram labeled with the symbols used in the proposed ARI Standard [illegible]. This diagram indicates the change in state conditions of the refrigerant occurring between the condenser inlet and outlet.

Comparisons can be made of the heat transfer capacities of the two condenser specimens at two test conditions from the data in Tables 2 and 3. At the "ARI High Saturation Temperature" test conditions with "Free Discharge" air flow rate, the first condenser had 14 percent greater total heat rejection capacity, whereas at the "[illegible] High Ambient Temperature" conditions it had about 6.5 percent greater total heat rejection capacity. These differences are probably attributable in part to the fouling of the internal surfaces of the first condenser by the sludge produced by heater failure, partly to the differences in the bonding of fins and tubes of the two specimens, and partly to the fin damage on the first specimen as a result of extensive handling. The degree to which each of these conditions is responsible for the observed differences in heat transfer cannot be determined from the data.

Further evidence of internal fouling in the first specimen is provided by comparison of the refrigerant flow rates, item 9, and the condenser coil internal pressure drop, item 10, in Table 2 and 3. This comparison is most readily made for the "[illegible] High Ambient Temperature" condition for which the refrigerant flow rate was lower and the pressure drop higher in the first specimen than in the second specimen. This result would be expected if the internal cross section area of the first specimen was somewhat reduced by sludge deposits.

CONDENSER SPECIMEN

MFR. Dunham-Bush, Inc. NBS NO. 139-57, 155-58 SIZE - B CLASS - 1

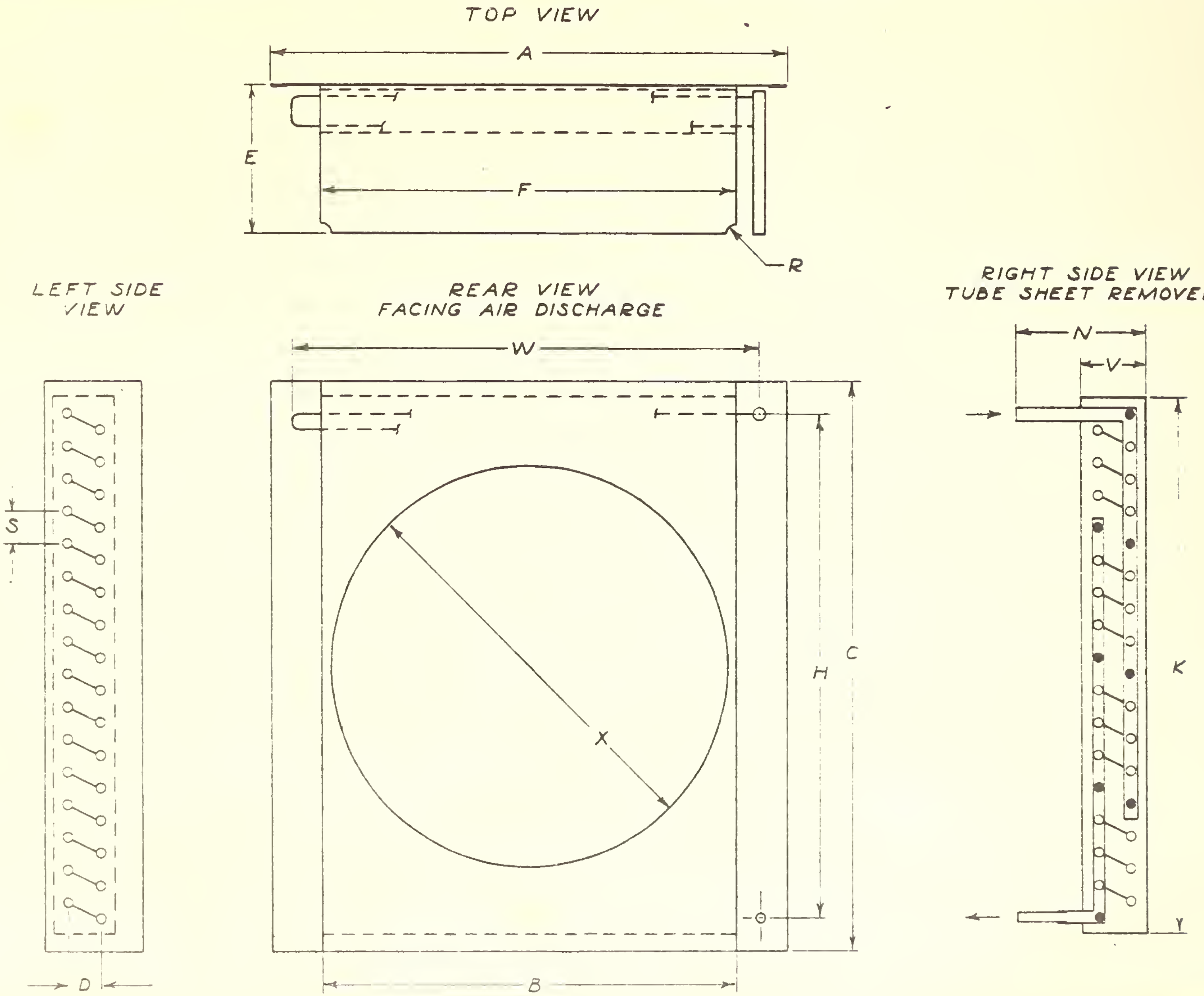
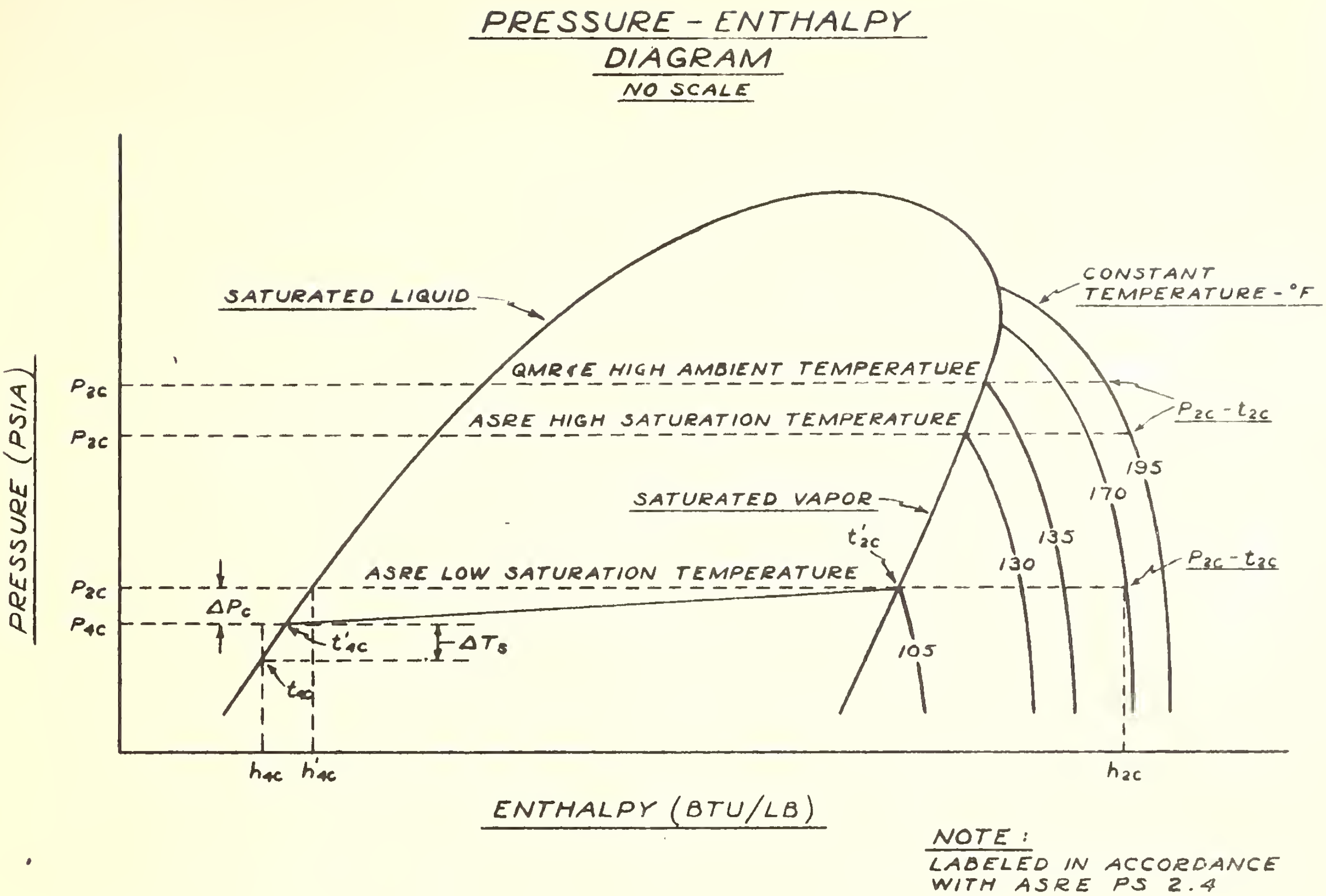
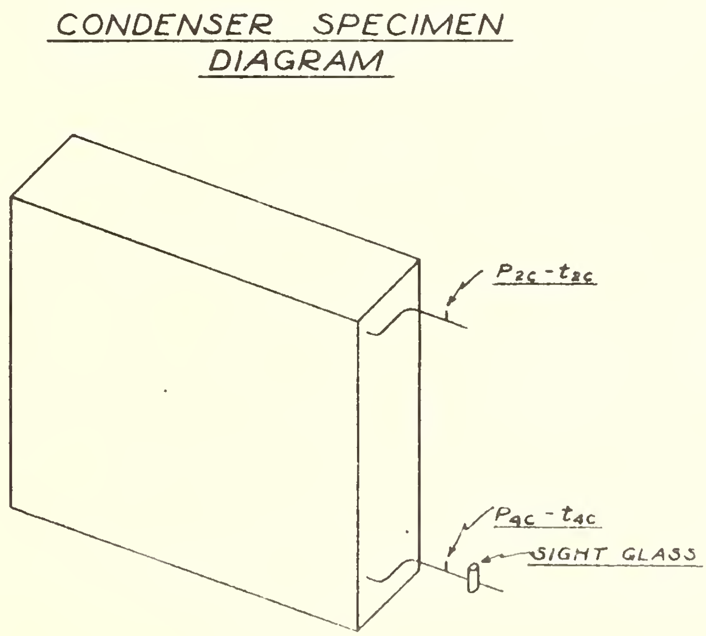


Fig 1



PRESSURE - ENTHALPY
DIAGRAM
NO SCALE
SATURATED LIQUID
CONSTANT
TEMPERATURE - °F
QMR&E HIGH AMBIENT TEMPERATURE
ASRE HIGH SATURATION TEMPERATURE
SATURATED VAPOR
ASRE LOW SATURATION TEMPERATURE
PRESSURE (PSIA)
P2c
P2c
P2c
P4c
ΔPc
ΔTs
t'4c
t4c
t'2c
P2c - t2c
P2c - t2c
195
170
135
130
105
h4c
h'4c
h2c
ENTHALPY (BTU/LB)
NOTE:
LABELED IN ACCORDANCE
WITH ASRE PS 2.4



CONDENSER SPECIMEN
DIAGRAM
P2c - t2c
P4c - t4c
SIGHT GLASS

Fig 2

Table 1

CONDENSER SPECIMEN

MFR. Dunham-Bush, Inc. SIZE - B

NBS NO. 139-57, 155-58 CLASS - 1

ITEM		PROPERTY	REMARKS
			COIL TUBE CHARACTERISTICS
1 MATERIAL		Copper	Type L
2 NUMBER OF ROWS DEEP		2	
3 NUMBER OF TUBES HIGH		32	
4 NUMBER OF CIRCUITS IN PARALLEL		4	
5 NUMBER OF TUBES PER CIRCUIT		8	
6 TUBE DIAMETER, O.D., IN.		5/8	
7 TUBE WALL THICKNESS, IN.		0.042	
8 TUBE RETURN BEND DIAMETER, O.D., IN.		1/2	
9 GAS INLET CONNECTION DIAM., O.D., IN.		7/8	7/8 O.D. inlet manifold
10 LIQUID OUTLET CONN. DIAMETER, O.D., IN.		5/8	3/4 O.D. outlet manifold
11 VERTICAL TUBE SPACING, IN.	S	2.00	
12 PRIMARY SURFACE AREA, SQ. FT.		11.18	
			COIL FIN CHARACTERISTICS
1 MATERIAL		Aluminum	
2 TYPE OF FIN		Embossed	Rolled Collar
3 FIN SPACING, PER INCH		8	202 Fins
4 FIN THICKNESS, IN.		0.010	
5 SECONDARY SURFACE AREA, SQ. FT.		255.6	
			COIL DIMENSIONS
1 FINNED HEIGHT, IN.	K	32.0	Two 16-inch sections
2 FINNED WIDTH, IN.	F	25.5	
3 FINNED DEPTH, IN.	V	3.0	
4 COIL HEIGHT, IN.	H	31.0	
5 COIL WIDTH, IN.	W	29.0	
6 COIL DEPTH, IN.	D	1.5	
7 COIL DEPTH, OVERALL, IN.	N	10.4	
8 FACE AREA, SQ. FT.		5.7	
9 TOTAL SURFACE AREA, SQ. FT.		266.8	
			OVERALL CONDENSER DIMENSIONS
1 WIDTH, OVERALL, IN.	A	32.5	
2 WIDTH, SHROUD, IN.	B	25.8	
3 HEIGHT, IN.	C	34.1	
4 DEPTH, IN.	E	11.0	
5 BELLMOUTH ORIFICE DIAMETER, IN.	X	24.5	
6 BELLMOUTH RADIUS, IN.	R	0.38	Less than specified min.

CONDENSER SPECIMEN

MFR. Dunham-Bush, Inc. NBS NO. 139-57 SIZE - B CLASS - 1

AIR CIRCULATING EQUIPMENT AND REFRIGERANT USED

- FAN MFR. — Torrington
- FAN SERIAL NO. — E-2420-4
- FAN SPEED — 1140
- MOTOR HP RATING — 0.500
- REFRIGERANT — Freon-12

	ITEM			ASRE High Saturation Temperature: Standard Condition	ASRE High Saturation Temperature: Observed Condition, Air Flow Rate CFM: High	Free Disch.	Low	ASRE Low Saturation Temperature: Standard Condition	ASRE Low Saturation Temperature: Observed Condition, Air Flow Rate CFM: Free Discharge	QMR&E High Ambient Temperature: Standard Condition	QMR&E High Ambient Temperature: Observed Condition, Air Flow Rate CFM: Free Discharge
1.	BAROMETRIC PRESSURE	P_{ab}	"Hg	29.921	29.61	29.73	29.92	29.921	29.69	29.921	29.71
2.	DRY BULB TEMPERATURE OF AIR ENTERING COIL	t_{ae}	°F	95	95.0	95.0	94.9	95	94.8	110	110.0
3.	WET BULB TEMPERATURE OF AIR ENTERING COIL	t'_{ae}	°F	75±5	75.2	75.9	77.2	75±5	75.8		75.5
4.	DRY BULB TEMPERATURE OF AMBIENT AIR	t_{ae}	°F	95	95.0	95.0	94.9	95	94.8	110	110.0
5.	SATURATION TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t'_{2c}	°F	130	130.2	129.9	130.1	105	104.7	135	135.2
6.	SUPERHEAT TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t_{2c}	°F	195±10	195.8	197.1	196.1	170±10	169.0		193.0
					AIR FLOW METHOD				AIR FLOW METHOD		
7.	NOZZLE AIR AND WATER VAPOR MIXTURE FLOW RATE	Q_{ad}	CFM		4090	3730	2940		3710		3720
8.	TOTAL HEAT REJECTION CAPACITY	q_{tc}	BTUH		44500	40000	36800		10750		29500
					REFRIGERANT FLOW METHOD				REFRIGERANT FLOW METHOD		
9.	REFRIGERANT FLOW RATE	W_r	lb/min		11.07	9.70	8.88		2.53		8.32
10.	CONDENSER COIL INTERNAL PRESSURE DROP	ΔP_c	PSI		5.95	4.65	4.03		1.04		3.70
11.	SUBCOOLING OF LEAVING REFRIGERANT LIQUID	ΔT_s	°F	10° MAX.	5.7	7.8	7.6	5° MAX.	3.0		2.7
12.	TOTAL HEAT REJECTION CAPACITY	q_{tr}	BTUH		43500	38500	35100		10300		31100
					RATINGS				RATINGS		
13.	TOTAL HEAT REJECTION	q_{tR}	BTUH		43800	39400	35800		10600	35600	30100
14.	CONDENSING HEAT REJECTION	q_{cR}	BTUH		42400	37900	34500		10500		29600
15.	SUBCOOLING HEAT REJECTION	q_{sR}	BTUH		1400	1500	1300		100		500
16.	AIR FLOW RATE	Q_R	CFM		3750	3440	2710		3460		3350
17.	CONDENSER COIL EXTERNAL RESISTANCE	P_{as}	"H_2O		0.24	0.20	0.13		0.20		0.20
18.	FAN MOTOR POWER	P_{fm}	WATTS		457	517	620		514		502
19.	FAN BRAKE HORSEPOWER	P	BHP								
20.	HEAT REJECTION PER UNIT PRIMARY SURFACE AREA	BTUH/SF			3917	3524	3202		948		2692
21.	HEAT REJECTION PER UNIT SECONDARY SURFACE AREA	BTUH/SF			171.4	154.1	140.1		41.5		117.8
22.	HEAT REJECTION PER UNIT TOTAL SURFACE AREA	BTUH/SF			164.2	147.7	134.2		39.7		112.8
23.	HEAT REJECTION PER CFM	BTUH			11.7	11.5	13.2		3.1		9.0

Table 2

CONDENSER SPECIMEN

MFR. Dunham-Bush, Inc. NBS NO. 155-58 SIZE - B CLASS - 1

AIR CIRCULATING EQUIPMENT AND REFRIGERANT USED

- FAN MFR. — Torrington
- FAN SERIAL NO. — E-2420-4
- FAN SPEED — 1140
- MOTOR HP RATING — 0.500
- REFRIGERANT — Freon-12

ITEM			ASRE HIGH SATURATION TEMPERATURE: STANDARD CONDITION	ASRE HIGH SATURATION TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: HIGH	FREE DISCH.	LOW	ASRE LOW SATURATION TEMPERATURE: STANDARD CONDITION	ASRE LOW SATURATION TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCHARGE	QMR&E HIGH AMBIENT TEMPERATURE: STANDARD CONDITION	QMR&E HIGH AMBIENT TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCHARGE
1. BAROMETRIC PRESSURE	P_{ab}	"Hg	29.921		29.66		29.921		29.921	29.03
2. DRY BULB TEMPERATURE OF AIR ENTERING COIL	t_{ae}	°F	95		95.0		95		110	110.0
3. WET BULB TEMPERATURE OF AIR ENTERING COIL	t'_{ae}	°F	75±5		75.2		75±5			74.5
4. DRY BULB TEMPERATURE OF AMBIENT AIR	t_{ae}	°F	95		95.0		95		110	110.0
5. SATURATION TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t'_{2c}	°F	130		130.2		105		135	135.4
6. SUPERHEAT TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t_{2c}	°F	195±10		195.5		170±10			195.7
			AIR FLOW METHOD				AIR FLOW METHOD			
7. NOZZLE AIR AND WATER VAPOR MIXTURE FLOW RATE	Q_{ad}	CFM			3750					3720
8. TOTAL HEAT REJECTION CAPACITY	q_{tc}	BTUH			44700					33100
			REFRIGERANT FLOW METHOD				REFRIGERANT FLOW METHOD			
9. REFRIGERANT FLOW RATE	W_r	lb/min			11.60					8.60
10. CONDENSER COIL INTERNAL PRESSURE DROP	ΔP_c	PSI			5.32					1.95
11. SUBCOOLING OF LEAVING REFRIGERANT LIQUID	ΔT_s	°F	10° MAX.		5.0		5° MAX.			2.5
12. TOTAL HEAT REJECTION CAPACITY	q_{tr}	BTUH			45400					32200
			RATINGS				RATINGS			
13. TOTAL HEAT REJECTION	q_{tR}	BTUH			45000				35600	32100
14. CONDENSING HEAT REJECTION	q_{cR}	BTUH			43750					31700
15. SUBCOOLING HEAT REJECTION	q_{sR}	BTUH			1250					400
16. AIR FLOW RATE	Q_R	CFM			3440					3270
17. CONDENSER COIL EXTERNAL RESISTANCE	P_{as}	"H_2O			0.20					0.19
18. FAN MOTOR POWER	P_{fm}	WATTS			510					496
19. FAN BRAKE HORSEPOWER	P	BHP								
20. HEAT REJECTION PER UNIT PRIMARY SURFACE AREA	BTUH/SF				4025					2871
21. HEAT REJECTION PER UNIT SECONDARY SURFACE AREA	BTUH/SF				176.1					125.6
22. HEAT REJECTION PER UNIT TOTAL SURFACE AREA	BTUH/SF				168.7					120.3
23 HEAT REJECTION PER CFM	BTUH				13.1					9.8

Table 3

It should be noted that neither of the two specimens had a heat rejection capacity as high as the requirement of the ASRE Standard for this size and class of condenser. The capacity of the second specimen was 90 percent of the required value.

It is considered that the results obtained on the second specimen are more representative of the true performance of this model of the Dunham-Bush condensers.