

FINAL REPORT

OPERATION OF A LOW TEMPERATURE ABSORPTION CHILLER AT
RATING POINT AND AT REDUCED EVAPORATOR TEMPERATURE

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1.0 PROGRAM OBJECTIVE

The work done under this contract was prompted by the availability of a fifteen ton Solar Absorption Machine (SAM 015) which had been in operation for two cooling seasons in Tyler, Texas, as a component of a solar cooling packaging experiment. While five chillers of this design have been placed in field installations under DOE contracts, this is the only one which is not still in service on an occupied building, having been removed to make space for a plant expansion. This machine, therefore, presented a unique opportunity to evaluate any deterioration or other problems which might arise in this design after a few years of service.

The agreed work statement sought to accomplish three objectives, as follow:

1.1 Inspection and Test

The returned SAM 015 chiller was given a cursory visual inspection, some obvious problems were remedied, and then it was placed on a test stand to get a measure of "dirty" performance. It was then given a standard acid clean, the water side of the tubes was brushed clean, and then the machine was retested. The "before" and "after" cleaning data were compared to equivalent data taken before the machine was shipped.

1.2 Operation as Refrigeration Machine

There appears, from market studies made by Carrier and other information, to be a significant social utility for a heat-operated chiller capable of chilling food, pharmaceuticals and other perishable materials in storage. Calculations indicated that the SAM series absorption machines, particularly if charged with "Carrol" (lithium bromide with an additional anti-crystallization additive) would fill this need.

The second part of our work statement was to experimentally demonstrate the technical feasibility of operating the chiller at evaporator temperatures below 0°C (32°F) and identify any operational problems.

1.3 Mexican-American Liaison

A third objective was to carry out this program in such a manner that a staff member from the National University of Mexico could be technically updated in absorption technology by sharing the experience gathered by the Carrier group over eight years of participation in DOE programs.

Mr. Roberto Best, who is a co-author of this report, was nominated by his university to be this contact person.

2.0 "AS RECEIVED" SAM 015 CHILLER

Externally the returned SAM chiller was clean, showed no serious corrosion and still had a good vacuum after nearly a year of non-use. When the chiller was connected into the test loop it was found that the hot water flow could not reach design. Pulling off the water box covers showed that serious corrosion had occurred on the divider plates of the generator water boxes. Corrosion products had built up to the point that partial blockage of the tubes was present, explaining the low flows being experienced. Some perforations had taken place, causing partial bypass of circuits.

The divider plates in the other water boxes were also seriously corroded but, because of the lower temperatures, much less badly than the generator plates.

All the corroded dividers were replaced before further testing.

2.1 Test Stand Data

Several runs near the standard rating point of 7.2°C (45°F) evaporator/29.4°C (85°F) condenser/82°C (180°F) generator were taken and were reasonably self-consistent. Figure 2.1A shows the test data taken in a typical run compared to the "new machine" numbers contained in adjacent parentheses. The analysis of the data is shown in Figure 2.1B, and a schematic drawing of the machine in Figure 2.1C. In general, the performance is similar and, perhaps, a bit better than a new machine.

15 TON SAM
TEST DATA

- 3 -

TEST CONDITIONS SAM 015 (Machine #2) "As received," from Tyler

RUN # 3
DATE 8/5/83
BY Reimann

<u>TEMPERATURES (°C)</u>		<u>DIFFERENTIALS</u>		<u>mV</u>	<u>°C</u>
1. REF. CONDENSATE (T2)	<u>32.8 (34.5)</u>	1. GEN. WATER (DTG)	<u>0.926 (1.110)</u>		
2. ENT. ABS., ST. PLUS RECYCLE (TRC)	<u>48.2 (49.2)</u>	2. COND. WATER (DTCA)			
3. WK. SOL. OUT ABS. (T4)	<u>37.2 (37.6)</u>	3. ABS. WATER (DTAB)			
4. ABS./EVAP. DEW PT. (TAS)	<u>6.7 (7.1)</u>	4. EVAP. WATER (DTCW)	<u>0.610 (0.900)</u>		
5. ENT. GEN., WK. SOLN. (T5)	<u>64.0 (59.8)</u>	<u>FLOWS</u>		<u>in Hg</u>	<u>GPM</u>
6. GEN. OUT, ST. SOLN. (T6)	<u>76.6 (76.4)</u>	1. GEN. WATER (MGW)			<u>50.1 (50.0)</u>
7. COND./GEN. DEW PT. (TGS)	<u>33.2 (34.7)</u>	2. COND. WATER (MCA)			<u>47.0 (47.0)</u>
8. ST. SOLN. OUT HX (T7)	<u>48.8 (48.3)</u>	3. ABS. WATER (MAB)			<u>58.0 (58.0)</u>
9. REF. ENT. EVAP. SPRAY HDR. (T2A)	<u>6.5 (6.9)</u>	4. EVAP. WATER (MCW)			<u>38.6 (36.0)</u>
10. EVAP. WATER IN (TCW1)	<u>10.9 (11.8)</u>	5. WK. SOLN. (MWK)			<u>3.6</u>
11. EVAP. WATER OUT (TCW2)	<u>6.8 (7.2)</u>	<u>CONCENTRATIONS</u>			
12. COND. WATER IN (TCA1)	<u>28.7 (29.3)</u>		<u>°C</u>	<u>SP. GR.</u>	<u>X %</u>
13. COND. WATER OUT (TCA2)	<u>32.1 (33.9)</u>	1. WEAK (XWK)		<u>56.89</u>	<u>(55.96)</u>
14. GEN. WATER IN (TG1)	<u>82.7 (82.3)</u>	2. STRONG (XST)		<u>59.50</u>	<u>(58.57)</u>
15. GEN. WATER OUT (TG2)	<u>77.5 (77.8)</u>	3. AFTER RECIRC. (XRC)		<u>59.5</u>	<u>(58.6)</u>
16. ABS. WATER IN (TAB1)	<u>28.7 (29.3)</u>	<u>PRESSURES</u>			
17. ABS. WATER OUT (TAB2)	<u>31.6 (33.2)</u>			<u>mm Hg</u>	
18. ST. SOLN. IN HX (T6A)	<u>76.6 (76.4)</u>	1. ABSORBER-EVAPORATOR		<u>7.2</u>	
19. AMBIENT	<u>21.0</u> —	2. GENERATOR-CONDENSER		<u>38.2</u>	
20. ICE BATH	<u>0.0</u> —				

NOTES Strong solution dew point entering absorber = 9.7°C
Subcooling = 9.7 - 6.7 = 3.0°C

FIGURE 2.1.A - COMPARISON OF OPERATING CONDITIONS OF SAM 015 BEFORE AND AFTER FIELD SERVICE

ESD H2O COOLED 15 TON ABSORPTION UNIT DATA REDUCTION PROGRAM

INPUT T2,TRC,T4,TAS,T5,T6,TGS,T7,T2A

INPUT TCW1,TCW2,TCA1,TCA2,TG1,TG2,TAB1,TAB2,TAMB,TIR

INPUT DTG,DTCA,DTAB,DTCW,MGW,MCA,MAB,MCW,MWK,XWK,XSTXRC,PAB,PG

INPUT MONTH,DAY,YEAR,USER CODE,RUN NUMBER

LIBR CYCLE CALCULATION

RUN: 0 DATE: 9/17/1983

CONDITIONS: 6.8/ 28.7/ 82.7C 44.2/ 83.7/180.9F

**** ULTRASONIC MEASUREMENT FOR MWK ****

USER: REIMANN

CYCLE STATE POINTS:

NO.	TEMP. C	CONC. %	W KG/KG	MASS FL. KG/S	ENTHALPY KJ/KG	SP.HEAT J/KG.K	DUH C	DWPT C	MS C
1	76.09	0.0	1.00	0.02080	2643.17	1893.58			
2	32.80	0.0	1.00	0.02080	137.48				
2A	6.50								
3	6.39	0.0	1.00	0.02080	2513.22	1881.04			
4	37.20	56.89	17.79	0.3700	93.75	2018.68	4.16	6.39	
4S	39.76	56.89	17.79	0.3700	93.75	2018.68	6.39		
5	64.00	56.89	17.79	0.3700	147.85	2018.68	27.49	33.19	
5A	70.10	56.89	17.79	0.3700	160.17	2018.68			
6	76.60	59.50	16.79	0.3492	182.85	1945.46	33.63	33.19	
6S	76.09	59.50	16.79	0.3492	181.87	1945.46	33.19		
6A	76.60	59.50	16.79	0.3492	182.85	1945.46			
7	48.80	59.50	16.79	0.3492	128.77	1945.46	9.75	6.39	
RC	48.20	59.50		0.3613	127.61		9.23	6.39	
F	45.17			0.3613	127.61				

AMB 21.00

IB 0.0

UNIT CAPACITY, TONS

EVAPORATOR COPREFRIG 0.771 COPWATER 0.750 R 0.033

HEAT EXCHANGER PERFORMANCE:

HTEXT KW	HTEXTWK KW	HX EFFY -	NTUHX -	UHX W/M2C	LMTDHX C
18.89	20.02	0.706	2.368	512.81	12.093

EVAPORATOR PERFORMANCE:

EVAPR KW	EVAPW KW	EV EFFY -	NTUEV -	UTEV W/M2C	LMTDEV C
49.40	49.40	0.909	2.264	5259.48	1.712

HI 5484.31 W/M2C
 HO 86395.44 W/M2C
 QW/AO 2640.90 W/M2
 VFLW 38.60 GPM

FIGURE 2.1.B

REDUCED DATA FOR SAM 015 BEFORE CLEANING

CONDENSER PERFORMANCE:

CONDNR	CONDA	CD FFFY	NTUCD	UICD	LMTDCD
KW	KW	-	-	W/M2C	C
52.11	41.97	0.829	1.756	5348.41	2.404
HI	HO	RW/AO	VFLW		
W/M2C	W/M2C	W/M2	GPM		
6712.14	25521.62	9390.95	47.00		

OVERALL GENERATOR PERFORMANCE:

GTOTR	GTOTW	SURCL	UGI	LMTDGO
KW	KW	C	W/M2C	C
64.12	65.86	-0.5	966.47	9.315
HI	HO	RW/AO	VFLW	
W/M2C	W/M2C	W/M2	GPM	
11964.52	309.82	2640.14	50.10	

GENERATOR SENSIBLE SECTION PERFORMANCE:

GSENR	GSENW	GS FFFY	NTUGS	UAGS	LMTDGS
KW	KW	-	-	W/C	C
4.56	4.56	0.440	0.588	439.70	10.365

GENERATOR LATENT SECTION PERFORMANCE:

GLATR	GLATW	GL FFFY	NTUGL	UAGL	LMTDGL
KW	KW	-	-	W/C	C
59.56	62.39	0.516	0.943	9047.82	6.896

ABSORBER PERFORMANCE:

ARSR	ARSA	SUBCL	SUPHT	UIA	LMTDAB
KW	KW	C	C	W/M2C	C
62.14	44.18	2.559	3.909	855.85	10.839
HI	HO	RW/AO	VFLW		
W/M2C	W/M2C	W/M2	GPM		
6563.75	894.45	5980.43	58.00		

PURGE: 0.0 KW

HEAT BALANCE:

HR	HRW		
-0.01	0.25		
32.8000031	48.1999969	37.1999969	6.69999981
64.0000000	76.6000061	33.1999969	48.8000031
6.50000000	10.8999996	6.80000019	28.6999969
32.1000061	82.6999969	77.5000000	28.6999969
31.6000061	76.6000061	21.0000000	.0
.925999999	.0	.0	.610000014
50.1000061	47.0000000	58.0000000	38.6000061
3.60000038	56.8899994	59.5000000	59.5000000
7.19999981	38.1999969	9.00000000	1.00000000
1983.00000	1.00000000		

FIGURE 2.1.B - Continued

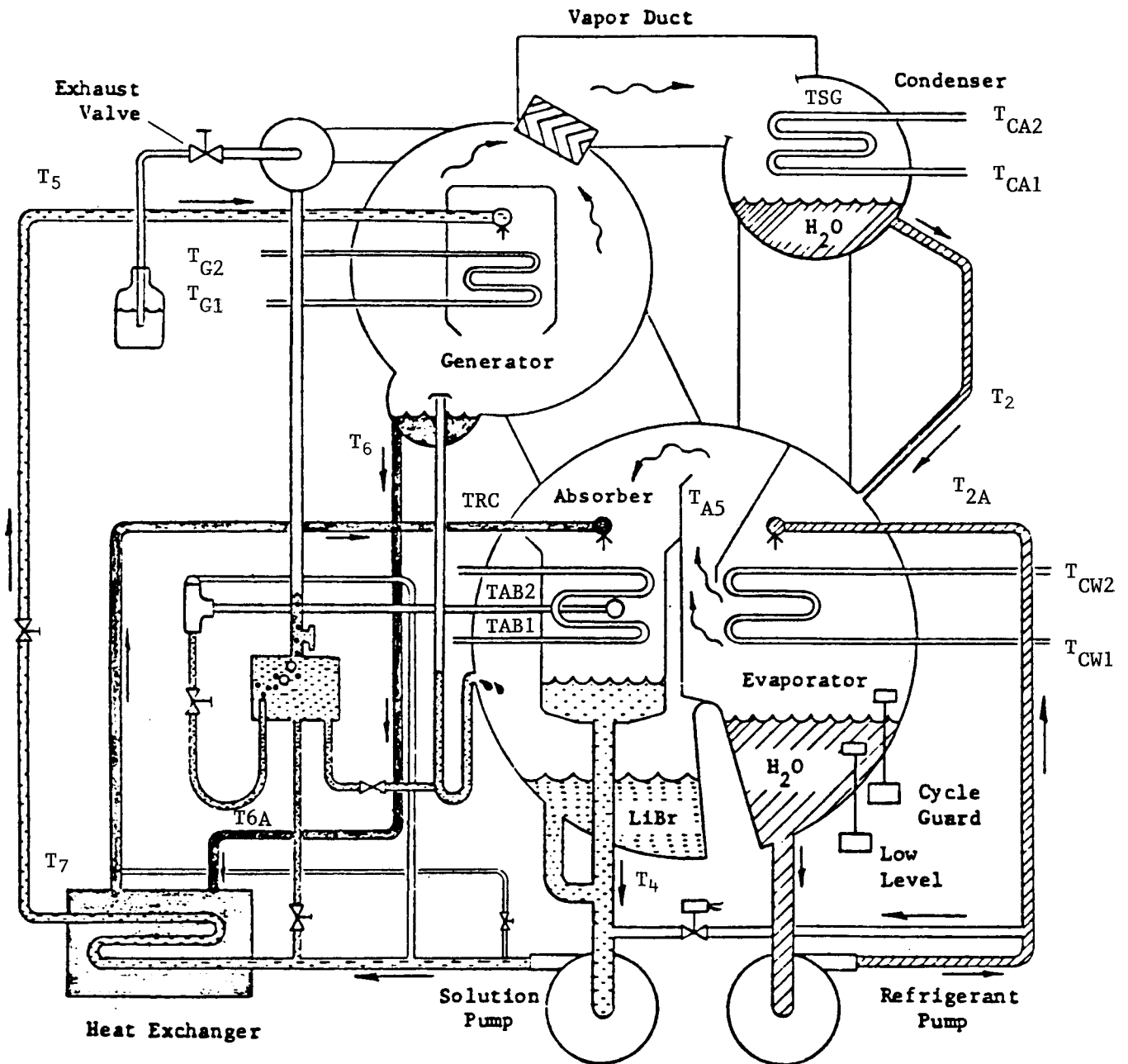


FIGURE 2.1.C

SCHMATIC DIAGRAM OF THE SOLAR ABSORPTION CHILLER (SAM)
DEVELOPED BY ENERGY SYSTEMS DIVISION, CARRIER CORPORATION

3.0 TEAR-DOWN AND MODIFICATIONS

After determining "as received" performance, the chiller was drained and rinsed. The withdrawn charge was clean, except for the portion withdrawn from the solution heat exchanger which, being the low point of the machine, had accumulated what appeared to be a significant amount of "mud."

Anticipating the need for visual information in the low temperature work, pairs of sight glasses were placed in the absorber and evaporator (one for sight, one for illumination) and one on the generator sump for solution level information.

The orifice plate in the condensate line was moved to the extreme discharge end of the condensate line to minimize the chance of ice build-up after flashing to subfreezing temperatures.

A trap in the weak solution line (protecting the generator nozzles against clogging) was cleaned but had no significant collection of material. Similarly, the water side of the tubes was brushed but likewise had no serious dirt build-up.

Finally the machine was acid cleaned (Oakite-32), the water box gaskets replaced and the machine leak tested. It was then ready for additional testing.

4.0 "CLEANED" CHILLER TEST RESULTS

Figure 4.0.A shows the data and analysis for the best of the rating points test runs of the cleaned chiller. While the thermal coefficient of performance remained high, we had actually lost capacity (about 6%) over the "as received" machine. Examination of the data showed two significant things:

- Absorber heat transfer coefficient was down.

- Solution heat exchanger effectiveness had increased from 0.7 to 0.8.

After some thought we decided that our problem was that, as a result of the increased solution heat exchanger effectiveness resulting from cleaning,

FIGURE 4.0.A - SAM 015 REDUCED DATA,
AFTER CLEANING

ESD H2O COOLED 15 TON ABSORPTION UNIT DATA REDUCTION PROGRAM

INPUT T2,TRC,T4,TAS,T5,T6,TGS,T7,T2A

?
32.1,47.8,38.5,0.0,64.8,77.1,0.0,48.1,6.4

INPUT TCW1,TCW2,TCA1,TCA2,TG1,TG2,TAB1,TAB2,TAMB,TIB

?
10.8,6.7,29.0,31.7,82.7,77.8,28.9,32.2,77.1,26.2,0.0

INPUT DTG,DTCA,DTAB,DTCW,MGW,MCA,MAB,MCW,MWK,XWK,XSTXRC,PAB,PG

?
.893,0.0,.0,____0.0,.620,50.0,47.0,58.0,36.0,3.3,57.47,60.04,59.64,6.76,3.

INPUT MONTH,DAY,YEAR,USER CODE,RUN NUMBER

?
9,7,1983,1,10

LIBR CYCLE CALCULATION

RUN: 0 DATE: 9/ 7/1983

CONDITIONS: 6.7/ 28.9/ 82.7C 44.1/ 84.0/180.9F

**** ULTRASONIC MEASUREMENT FOR MWK ****

USER: REIMANN

CYCLE STATE POINTS:

NO.	TEMP. C	CONC. %	W KG/KG	MASS FL. KG/S	ENTHALPY KJ/KG	SP.HEAT J/KG.K	IUH DWPT C	MS DWPT C
1	76.16	0.0	1.00	0.01967	2643.36	1893.14		
2	32.10	0.0	1.00	0.01967	134.55			
2A	6.40							
3	5.48	0.0	1.00	0.01967	2511.57	1880.85		
4	38.50	57.47	17.36	0.3415	98.90	2002.59	4.32	5.48
4S	39.84	57.47	17.36	0.3415	98.90	2002.59	5.48	
5	64.80	57.47	17.36	0.3415	151.57	2002.59	27.16	32.23
5A	70.49	57.47	17.36	0.3415	162.97	2002.59		
6	77.10	60.04	16.36	0.3218	186.11	1929.94	33.04	32.23
6S	76.16	60.04	16.36	0.3218	184.29	1929.94	32.23	
6A	77.10	60.04	16.36	0.3218	186.11	1929.94		
7	48.10	60.04	16.36	0.3218	130.14	1929.94	8.21	5.48
RC	47.80	59.64		0.3510	127.54		8.64	5.48
F	44.43			0.3510	127.54			

AMB 26.20
IB 0.0

UNIT CAPACITY, TONS

EVAPORATOR COPR COPW R
13.30 0.778 0.738 0.086

HEAT EXCHANGER PERFORMANCE:

HTEXST KW	HTEXWK KW	HX EFFY -	NTUHX -	UHX W/M2C	LMTDHX C
18.01	17.98	0.751	2.660	526.62	10.894

FIGURE 4.0.A - CONTINUED

EVAPORATOR PERFORMANCE:

EVAPR KW	EVAPW KW	EV EFFY -	NTUEV -	UIEV W/M2C	LMTDEV C
46.75	46.75	0.771	1.417	3064.45	2.781
HI W/M2C	HO W/M2C	QW/AD W/M2	VFLW GPM		
5182.11	2274.16	2498.81	36.00		

CONDENSER PERFORMANCE:

CONDR KW	CONDA KW	CD EFFY -	NTUCD -	UICD W/M2C	LMTDCD C
49.34	33.33	0.871	2.676	8153.87	1.493
HI W/M2C	HO W/M2C	QW/AD W/M2	VFLW GPM		
6708.73	-31390.09	7457.67	47.00		

OVERALL GENERATOR PERFORMANCE:

GTOTR KW	GTOTW KW	SUBCL C	UGI W/M2C	LMTDGO C
60.12	63.36	-0.9	985.75	8.787
HI W/M2C	HO W/M2C	QW/AD W/M2	VFLW GPM	
11957.86	316.60	2540.02	50.00	

GENERATOR SENSIBLE SECTION PERFORMANCE:

GSENR KW	GSENW KW	GS EFFY -	NTUGS -	UAGS W/C	LMTDGS C
3.90	3.90	0.428	0.566	387.04	10.066

GENERATOR LATENT SECTION PERFORMANCE:

GLATR KW	GLATW KW	GL EFFY -	NTUGL -	UAGL W/C	LMTDGL C
56.22	59.06	0.541	1.008	9012.23	6.554

ABSORBER PERFORMANCE:

ABSR KW	ABSA KW	SUBCL C	SUPHT C	UIA W/M2C	LMTDAR C
56.66	50.27	1.338	3.180	778.71	10.864
HI W/M2C	HO W/M2C	QW/AD W/M2	VFLW GPM		
6590.41	802.33	6804.08	58.00		

PURGE: 0.0 KW

HEAT BALANCE:

HBR	HBW		
0.01	0.24		
32.1000061	47.8000031	38.5000000	.0
48.1000061	6.39999962	10.8000002	6.69999981
77.8000031	28.89999939	32.19999969	77.1000061
.0	.0	.620000005	50.0000000
3.30000019	57.4700012	60.0399933	59.6399994
7.00000000	1983.00000	1.00000000	

the superheat in the strong solution entering the absorber had dropped from 3.2°C to 2°C. As a result "flashing" had lessened and solution distribution over the absorber bundle had deteriorated. Visual inspection through the newly installed sight glasses confirmed that the outside tubes were not being well wetted.

This was a useful observation because we have had a problem making capacity in some of our later SAM 015's, which apparently have too good a heat exchanger for the capacity desired, even though the good heat exchanger enhances the COP's.

4.1 Remedial Steps, At Design Runs

There are two basic design changes which would improve the overall performance:

- A. Use a less effective heat exchanger which would increase capacity but lower thermal COP.
- B. Use drippers instead of spray nozzles. This would increase capacity without loss of the nice thermal COP we are seeing.

Neither of these steps was practical within the timeframe of this schedule.

To prove the analysis, however, two things were possible and both were tried:

4.1.1 Supplementary Heat, applied to the pipe between the solution heat exchanger and the nozzle header in the absorber should improve the superheat and hence improve nozzle distribution capacity. Thermodynamically, heat added at this point would lessen, rather than improve, the capacity and COP; hence, any gains would be solely the result of improved solution distribution.

Direct application of an oxy-acetylene flame gave about 1.5°C temperature lift. We note, by comparing Figure 4.1.1.A to 4.0.A that the capacity has increased from 13.3 tons to 14.9 tons, with COP remaining high.

No means were available to add more supplemental heat to this pipe.

LIBR CYCLE CALCULATION

- 10 -

RUN: 0 DATE: 9/ 7/1983

CONDITIONS: 7.0/ 28.7/ 81.5C 44.6/ 83.7/178.7F

**** ULTRASONIC MEASUREMENT FOR MWK ****

USER: REIMANN

CYCLE STATE POINTS:

NO.	TEMP. C	CONC. %	W KG/KG	MASS FL. KG/S	ENTHALPY KJ/KG	SP.HEAT J/KG.K	DUH C	DWPT C	MS C
1	74.52	0.0	1.00	0.02202	2640.27	1892.91			
2	31.90	0.0	1.00	0.02202	133.72				
2A	6.40								
3	5.14	0.0	1.00	0.02202	2510.93	1880.78			
4	36.90	56.95	16.35	0.3601	93.41	2017.01	3.80		5.14
4S	38.43	56.95	16.35	0.3601	93.41	2017.01	5.14		
5	63.30	56.95	16.35	0.3601	146.66	2017.01	26.78		32.01
5A	69.19	56.95	16.35	0.3601	158.54	2017.01			
6	75.50	59.41	15.35	0.3381	180.34	1948.05	32.85		32.01
6S	74.52	59.41	15.35	0.3381	178.44	1948.05	32.01		
6A	75.50	59.41	15.35	0.3381	180.34	1948.05			
7	46.80	59.41	15.35	0.3381	124.44	1948.05	8.18		5.14
RC	48.20	59.07		0.3268	125.51		9.98		5.14
F	43.04			0.3268	125.51				

AMB 27.00
IB 0.0

UNIT CAPACITY, TONS

EVAPORATOR	COPR	COPW	R
14.90	0.790	0.766	-0.032

HEAT EXCHANGER PERFORMANCE:

HTEXST	HTEXWK	HX EFFY	NTUHX	UHX	LMTDHX
KW	KW	-	-	W/M2C	C
18.90	19.18	0.744	2.626	551.25	11.010

EVAPORATOR PERFORMANCE:

EVAPR	EVAPW	EV EFFY	NTUEV	UIEV	LMTDEV
KW	KW	-	-	W/M2C	C
52.35	52.35	0.720	1.154	2532.14	3.768

HI	HO	QW/AO	VFLW
W/M2C	W/M2C	W/M2	GPM
5216.37	1474.98	2798.27	36.00

CONDENSER PERFORMANCE:

CONDR	CONDA	CD EFFY	NTUCD	UICD	LMTDCD
KW	KW	-	-	W/M2C	C
55.20	38.28	0.886	2.820	8591.99	1.585

HI	HO	QW/AO	VFLW
W/M2C	W/M2C	W/M2	GPM
6681.54	-25365.11	8564.07	47.00

FIGURE 4.1.1.A - REDUCED DATA, SAM 015, WITH HEAT APPLIED TO STRONG SOLUTION LINE

OVERALL GENERATOR PERFORMANCE:

GTOTR KW	GTOTW KW	SUBCL C	-	UGI W/M2C	LMTDGO C
66.30	68.31	-1.0		1036.04	9.014
HI W/M2C	HO W/M2C	QW/AO W/M2		VFLW GPM	
11845.07	334.69	2738.70		50.00	

GENERATOR SENSIBLE SECTION PERFORMANCE:

GSENR KW	GSENW KW	GS EFFY -	NTUGS -	UAGS W/C	LMTDGS C
4.28	4.28	0.445	0.597	433.74	9.865

GENERATOR LATENT SECTION PERFORMANCE:

GLATR KW	GLATW KW	GL EFFY -	NTUGL -	UAGL W/C	LMTDGL C
62.02	63.86	0.513	0.949	9601.97	6.651

ABSORBER PERFORMANCE:

ABSR KW	ABSA KW	SUBCL C	SUPHT C	UIA W/M2C	LMTDAB C
64.09	51.79	1.535	3.547	1006.61	9.506
HI W/M2C	HO W/M2C	QW/AO W/M2	VFLW GPM		
6580.41	1080.59	7010.75	58.00		

PURGE: 0.0 KW

HEAT BALANCE:

HBR	HBW		
-0.01	0.25		
31.8999939	48.1999969	36.8999939	.0
46.8000031	6.3999962	11.8000002	7.00000000
76.1999969	28.6999969	32.1000061	75.5000000
.0	.0	.685000002	50.0000000
3.50000000	56.9499969	59.4100037	59.0700073
7.00000000	1983.00000	1.00000000	

FIGURE 4.1.1.A - CONTINUED

4.1.2 A Supplementary Pump was placed in the strong solution line between the generator and the absorber (in effect bypassing a portion of the solution heat exchanger), taking advantage of existing valves. By improving the head available to the spray nozzles, this also greatly improved both the visual distribution pattern and the performance.

The data analysis of this run is given in Figure 4.1.2 , where it will be noticed that the evaporator capacity has now climbed to 15.72 with COP remaining in the 0.75 range.

CONDITIONS: 7.6/ 29.8/ 81.8C 45.7/ 85.6/179.2F

**** ULTRASONIC MEASUREMENT FOR MWK ****

USER: REIMANN

CYCLE STATE POINTS:

NO.	TEMP. C	CONC. %	W KG/KG	MASS FL. KG/S	ENTHALPY KJ/KG	SP.HEAT J/KG.K	DUH DWPT C	MS DWPT C
1	72.59	0.0	1.00	0.02330	2636.67	1892.27		
2	33.60	0.0	1.00	0.02330	140.82			
2A	7.20							
3	5.42	0.0	1.00	0.02330	2511.45	1880.84		
4	36.30	55.87	15.72	0.3662	87.79	2046.46	5.06	5.42
4S	36.70	55.87	15.72	0.3662	87.79	2046.46	5.42	
5	59.70	55.87	15.72	0.3662	135.67	2046.46	25.52	30.92
5A	68.93	55.87	15.72	0.3662	154.59	2046.46		
6	75.60	59.10	14.72	0.3429	179.28	1956.79	33.52	30.92
6S	72.59	59.10	14.72	0.3429	173.38	1956.79	30.92	
6A	75.60	59.10	14.72	0.3429	179.28	1956.79		
7	40.70	59.10	14.72	0.3429	110.99	1956.79	3.47	5.42
RC	45.60	59.00		0.2462	120.10		7.86	5.42
F	43.00			0.2462	120.10			

AMB 25.90
IB 0.0

UNIT CAPACITY, TONS

EVAPORATOR COPR COPW R
15.72 0.754 0.745 -0.264

HEAT EXCHANGER PERFORMANCE:

HTEXST KW	HTEXWK KW	HX EFFY -	NTUHX -	UHX W/M2C	LMTDHX C
23.42	17.54	0.888	3.409	729.19	8.951

EVAPORATOR PERFORMANCE:

EVAPR KW	EVAPW KW	EV EFFY -	NTUEV -	UIEV W/M2C	LMTDEV C
55.23	55.23	0.678	1.109	2481.03	4.058

HI W/M2C	HO W/M2C	QW/AO W/M2	VFLW GPM
5262.32	1405.64	2952.36	36.00

CONDENSER PERFORMANCE:

CONDR KW	CONDA KW	CD EFFY -	NTUCD -	UICD W/M2C	LMTDCD C
58.15	41.95	0.872	-0.802	-2441.30	-5.878

HI W/M2C	HO W/M2C	QW/AO W/M2	VFLW GPM
6780.16	-1620.20	9386.73	47.00

FIGURE 4.1.2 - SAM 015 REDUCED DATA WITH SUPPLEMENTARY PUMP IN STRONG SOLUTION LINE.

OVERALL GENERATOR PERFORMANCE:

GTOTR KW	GTOTW KW	SUBCL C	-	UGI W/M2C	LMTDGO C
73.22	74.14	-3.0		970.05	10.449
HI W/M2C	HO W/M2C	QW/AO W/M2		VFLW GPM	
11848.97	311.34	2972.39		50.00	

GENERATOR SENSIBLE SECTION PERFORMANCE:

GSENR KW	GSENW KW	GS EFFY -	NTUGS -	UAGS W/C	LMTDGS C
6.93	6.93	0.548	0.810	607.49	11.405

GENERATOR LATENT SECTION PERFORMANCE:

GLATR KW	GLATW KW	GL EFFY -	NTUGL -	UAGL W/C	LMTDGL C
66.29	67.64	0.518	0.969	9833.77	6.878

ABSORBER PERFORMANCE:

ABSR KW	ABSA KW	SUBCL C	SUPHT C	UIA W/M2C	LMTDAB C
67.55	53.29	0.405	-2.263	1261.73	7.993

HI W/M2C	HO W/M2C	QW/AO W/M2	VFLW GPM
6657.09	1416.85	7213.20	58.00

PURGE: 0.0 KW

HEAT BALANCE:

HBR 0.02	HBW 0.26		
33.6000061	45.6000061	36.3000031	.0
59.6999969	75.6000061	.0	40.6999969
7.19999981	12.1999998	7.60000038	29.6999969
33.1000061	81.8000031	76.0000000	29.8000031
33.3000031	75.6000061	25.8999939	.0
1.04199982	.0	.0	.709999979
50.0000000	47.0000000	58.0000000	36.0000000
3.60000038	55.8699951	59.1000061	59.0000000
6.72999954	33.6000061	9.00000000	14.0000000
1983.00000	1.00000000		

FIGURE 4.1.2 - CONTINUED.

5.0 LOW TEMPERATURE EVAPORATOR RUNS (REFRIGERATION)

The prime purpose of these runs was to verify the calculations which told us that it would be practical to operate a chiller at a refrigerant temperature of -5°C (23°F) which would be adequate, using a "flash" evaporator instead of a tube and shell arrangement, to cool spaces for food and other perishable storage. Freezing of the refrigerant would be prevented by bleeding absorbent into the evaporator to an absorbent concentration of about 10-12%, which would prevent freezing to about -7°C (20°F) but only cost about 0.5°C (1°F) in dew point lowering.

Eventually it will be necessary to add a concentration control (optical and electrical sensors have been suggested) to the evaporator.

It was planned to try both lithium bromide and, later, Carrol (a bromide solution with antifreeze additive) to give potentially even lower temperatures.

5.1 Lithium Bromide Absorption Results

For these runs the condensing water temperature was kept at 29.4°C (85°F) and the hot water entering temperature was raised to 90°C (195°F).

Two observations were made upon coming to the operating condition:

- A. The condensate (containing no LiBr) flashed and formed some ice around the entry point to the evaporator but this flaked off rapidly without building up.
- B. The increased viscosity of the strong solution due to increased concentration exacerbated the absorber distribution problem mentioned above (Section 4.0).

Figure 5.0 shows the reduced data taken at steady state. The severely reduced capacity (3.3 tons) and COP (0.265) are consistent with the very restricted wetting seen on the absorber tube bundle.

LIBR CYCLE CALCULATION

RUN: 0 DATE: 1/ 9/ 20

CONDITIONS: -4.6/ 29.1/ 89.1C 23.7/ 84.4/192.4F

**** ULTRASONIC MEASUREMENT FOR MWK ****

CYCLE STATE POINTS:

NO.	TEMP. C	CONC. %	W KG/KG	MASS FL. KG/S	ENTHALPY KJ/KG	SF. HEAT J/KG.K	DUH C	DWPT C	MS DWPT C
1	84.36	0.0	1.00	0.00512	2659.03	1892.93			
2	30.60	0.0	1.00	0.00512	128.28				
2A	-5.20								
3	-8.36	0.0	1.00	0.00512	2486.41	1878.62			
4	34.60	63.18	73.51	0.3767	122.89	1840.21	-8.51		-8.36
4S	34.78	63.18	73.51	0.3767	122.89	1840.21	-8.36		
5	69.40	63.18	73.51	0.3767	186.92	1840.21	20.60		30.32
5A	81.36	63.18	73.51	0.3767	208.93	1840.21			
6	85.00	64.60	72.51	0.3715	222.93	1802.39	30.85		30.32
6S	84.36	64.60	72.51	0.3715	221.77	1802.39	30.32		
6A	85.00	64.60	72.51	0.3715	222.93	1802.39			
7	47.20	64.60	72.51	0.3715	154.80	1802.39	-0.35		-8.36
RC	47.10	64.49		0.3819	153.94		-0.25		-8.36
F	38.46			0.3819	153.94				

AMB 26.60
IB 0.0

UNIT CAPACITY, TONS

EVAPORATOR COPR COPW R
3.44(3.33) 0.464 0.274(2.65) 0.027

HEAT EXCHANGER PERFORMANCE:

HTEXST KW	HTEXWK KW	HX EFFY	NTUHX	UHX W/M2C	LMTDHX C
25.31	24.12	0.750	2.628	560.94	14.047

EVAPORATOR PERFORMANCE:

EVAPR KW	EVAPW KW	EV EFFY	NTUEV	UIEV W/M2C	LMTDEV C
12.08 (11.68)	12.08 (11.68)	0.347	0.342	470.18	4.684
HI W/M2C	HO W/M2C	QW/AO W/M2	VFLW GPM		

FIGURE 5.0 - SAM 015, OPERATING AT LOW EVAPORATOR TEMPERATURE, REDUCED DATA.

HI	HO	QW/AD	VFLW		
W/M2C	W/M2C	W/M2	GPM		
4338.05	155.00	645.91	36.00		
CONDENSER PERFORMANCE:					
CONDR	CONDA	CD EFFY	NTUCD	UICD	LMTDCD
KW	KW	-	-	W/M2C	C
12.97	18.52	0.937	1.384	4217.57	0.759
HI	HO	QW/AD	VFLW		
W/M2C	W/M2C	W/M2	GPM		
6667.93	10707.94	4144.27	47.00		
OVERALL GENERATOR PERFORMANCE:					
GTOTR	GTOTW	SUBCL		UGI	LMTDGO
KW	KW	C	-	W/M2C	C
20.88	44.05	-0.6		683.75	8.806
HI	HO	QW/AD	VFLW		
W/M2C	W/M2C	W/M2	GPM		
12529.13	212.79	1765.76	50.00		
GENERATOR SENSIBLE SECTION PERFORMANCE:					
GSENR	GSENW	GS EFFY	NTUGS	UAGS	LMTDGS
KW	KW	-	-	W/C	C
5.13	5.13	0.720	1.293	554.81	9.249
GENERATOR LATENT SECTION PERFORMANCE:					
GLATR	GLATW	GL EFFY	NTUGL	UAGL	LMTDGL
KW	KW	-	-	W/C	C
15.74	39.70	0.471	0.834	9092.39	4.366
ABSORBER PERFORMANCE:					
ABSR	ABSA	SUBCL	SUPHT	UIA	LMTDAB
KW	KW	C	C	W/M2C	C
19.19	30.47	0.182	9.705	448.58	6.387
HI	HO	QW/AD	VFLW		
W/M2C	W/M2C	W/M2	GPM		
6560.41	437.05	4124.51	58.00		
PURGE:	0.0	KW			

FIGURE 5.0 - CONTINUED

5.2 "Carrol" Absorption Results

The addition of glycol "anti-crystallization additive" significantly increases the viscosity of lithium bromide solutions (but without significant change in the heat-mass transfer rate). As a result the absorber distribution problem became even worse, to the extent that the solution pump motor burned out under the pumping strain. Operation under reduced capacity, however, was possible under a sustained condition.

6.0 CONCLUSIONS

From the results gathered, three technical conclusions can be established:

- A. After two seasons in the field the only deterioration of the SAM 015 was corrosion of the water box divider plates. This could have been prevented by adequate treatment of the several water streams or, more economically, by a materials change.
- B. The solution heat exchanger is too effective for a machine using nozzles in the absorber since more flashing of the entering solution is required for proper distribution. Either a reduction in heat exchanger surface is indicated, with some loss of efficiency, or a strong solution booster pump should be added, with additional parasitic power consumption.
- C. Operation of a SAM 015 at an evaporator temperature of -5°C is practical but could be done much better with a dripper distribution in the absorber rather than nozzles, which would permit continued use of the high efficiency solution solution heat exchanger. A properly sized solution pump impeller and motor suitable for the higher viscosities encountered would also be required in any case.

7.0 POSSIBLE EXTENSIONS OF THE WORK

Additional Carrier Corporation funding to modify the SAM 015 to a dripper type absorber pattern has been requested. The modified machine could then serve as a test bed for development of an appropriate sensor and control method to automatically keep the salt concentration in the refrigerant at a predetermined level.

Mr. Roberto Best has received expressions of interest from his management to seek funding for an additional cooperative venture between Carrier and appropriate Mexican agencies for an experimental installation of a low temperature chiller in a Mexican situation where lack of cool storage facilities is a community handicap.