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STUDY OF COMPONENT TECHNOLOGIES FOR FUEL CELL ON-SITE INTEGRATED ENERGY SYSTEMS

Volume II-Appendices

W. David Lee, Siegfried Mathias
Arthur D. Little, Inc.

December 1980

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Under Contract DEN 3-121

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INTRODUCTION

This data base catalogue was compiled in order to facilitate the analysis of various on-site integrated energy systems with fuel cell power plants. The catalogue is divided into two sections. The first characterizes individual components in terms of their performance profiles as a function of design parameters. The second characterizes total heating and cooling systems in terms of energy output as a function of input and control variables.

In the first section, data for each component are organized as follows:

1) Component Description

   This sheet contains the following information:

   a) Component Name

   b) Range of standard nominal sizes

   c) Average useful lifetime

   d) Physical dimensions of a representative size

   e) Standard operation conditions

   f) Parameter constraints limiting component operation

2) Component Cost

   Installed cost including overhead and profit are summarized for various component sizes. Component sizes considered are determined by the energy use profiles and design parameters for the two buildings studied.

Some components, such as terminal units, are fixed by building design loads. In such instances only the appropriate units are costed. In other instances, component size is a function of the total system configuration (e.g., compression chiller size is a function of chilled water storage and concurrent use of absorption machines). In such cases, a range of equipment size is costed. All costs are in 1978 dollars.

3) Performance Profiles

Variation of component capacity or efficiency is profiled against design and control parameters such as part load, fluid temperatures, flow rates, etc.

The second section analyzes energy systems used for heating, cooling and domestic hot water. Each system includes source of heating or cooling energy distribution components and terminal units. Design conditions are specified for the system, and energy demand for each component is specified as a function of the total system output. In addition, a control sheet is provied for each system to describe the intended energy flow control. Analysis of system input at other than design conditions can be accomplished as follows:

1) determine component energy demand under design conditions. 2) change individual component variables according to the control strategies given on the system control sheet. 3) alter component energy demand according to the profiles established in Section 1 of the catalogue

1. Component Name: FUEL CELL

2. Available nominal size: 20 to 30KW

3. Useful life: 25

4. Physical Dimensions for 703KW (200 ton) component size:

   1.1 to 1.3 ft^2/KW

5. Standard Rating Conditions:

   Fuel Cell A 80 to 140°F Return 210°F delivery

   Fuel Cell B 80 to 140°F Return 60 psig and 160°F delivery

   Fuel Cell C 120 to 200°F Return 60 psig delivery

6. Parameter Constraints:

   Fuel Cell A 20 KW minimum size module

   Fuel Cell B 20 KW minimum size module

   Fuel Cell C 100 KW minimum size module

7. Unit Cost in 1978 Dollars:

   Fuel Cell A $= 420 \cdot KW^{.93}$

   Fuel Cell B $= 615 \cdot KW^{.93}$

   Fuel Cell C $= 463 \cdot KW^{.93}$

   and $50 per KW for installation.

FIGURE 1A

POWERPLANT A ELECTRICAL EFFICIENCY

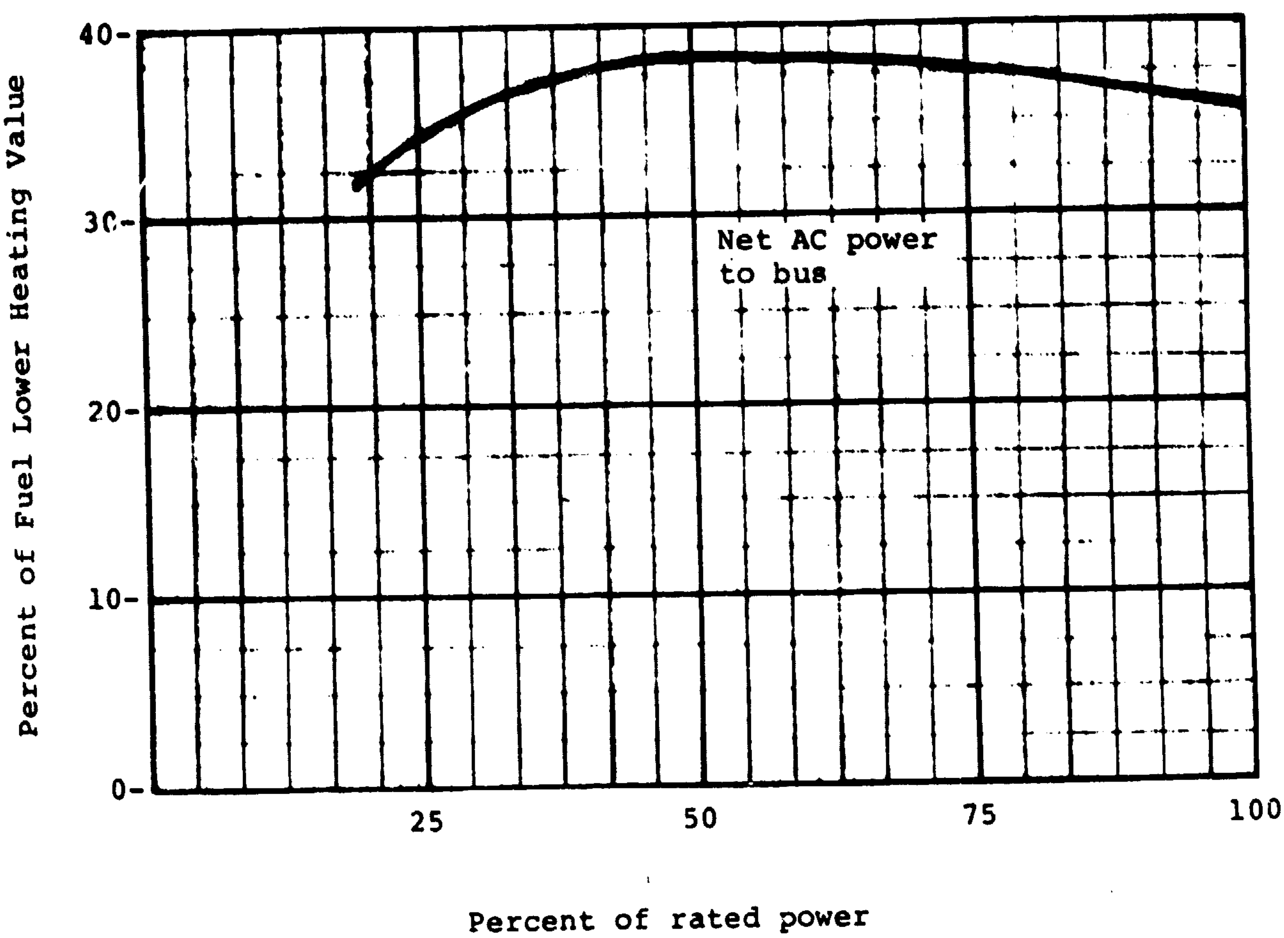
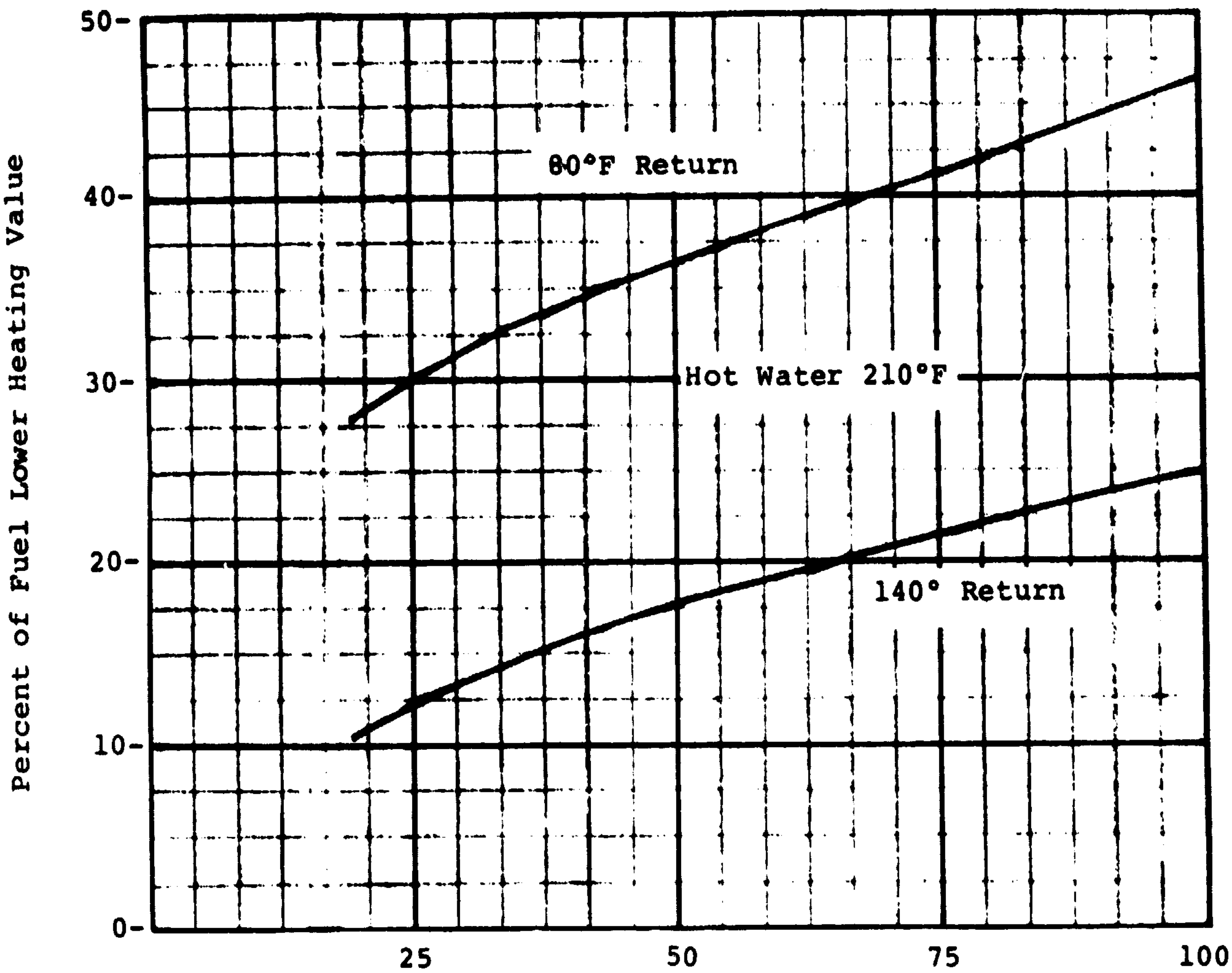


FIGURE 1B

POWER PLANT A HEAT RECOVERY EFFICIENCY



Percent of Rated Power

Revised 8-22-79

FIGURE 2A

POWERPLANT B ELECTRICAL EFFICIENCY

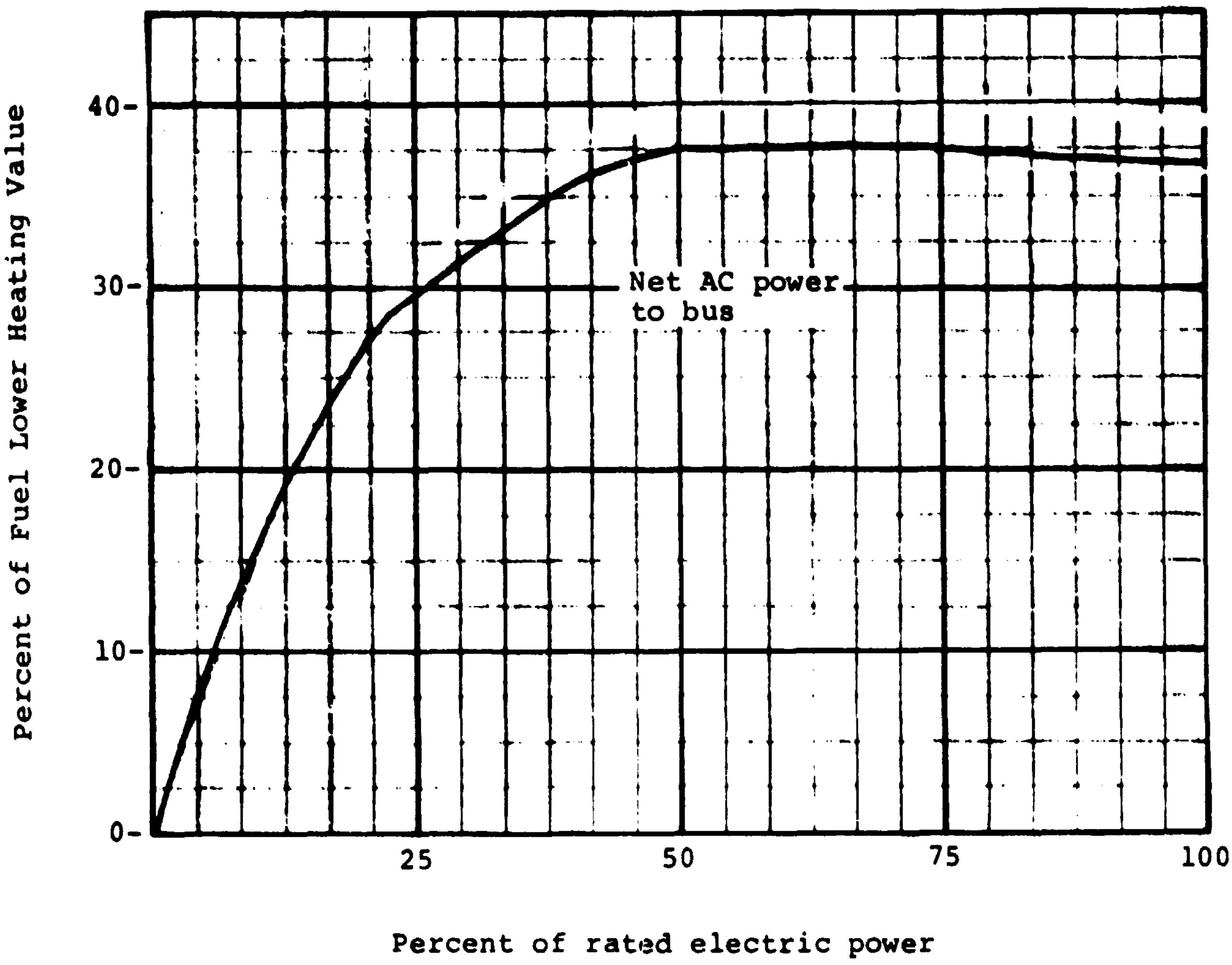


FIGURE 2B

POWERPLANT B HIGH TEMPERATURE HEAT EFFICIENCY

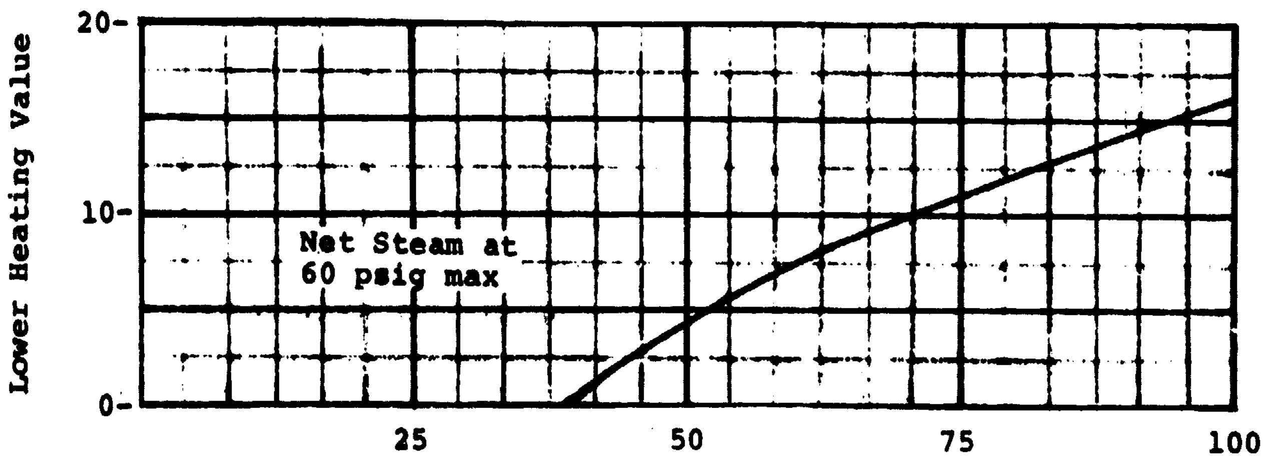


FIGURE 2C

POWERPLANT B LOW TEMPERATURE HEAT EFFICIENCY

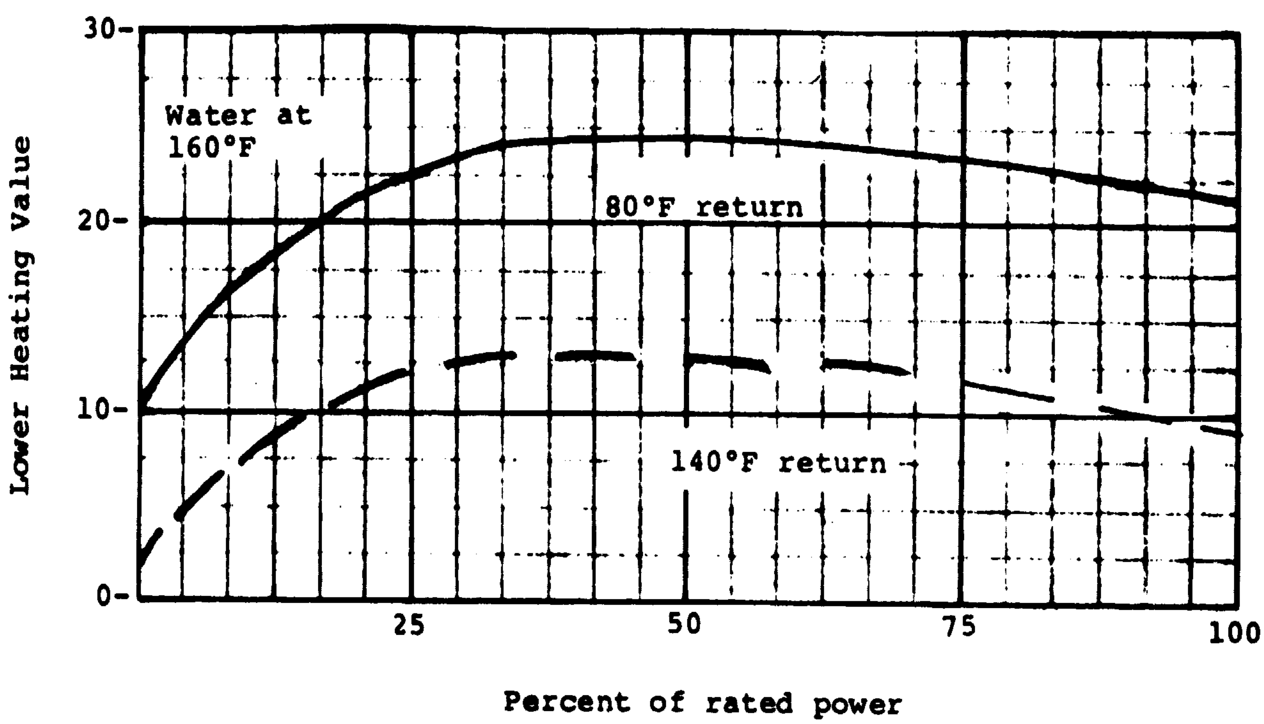


FIGURE 3A

POWERPLANT C ELECTRICAL EFFICIENCY

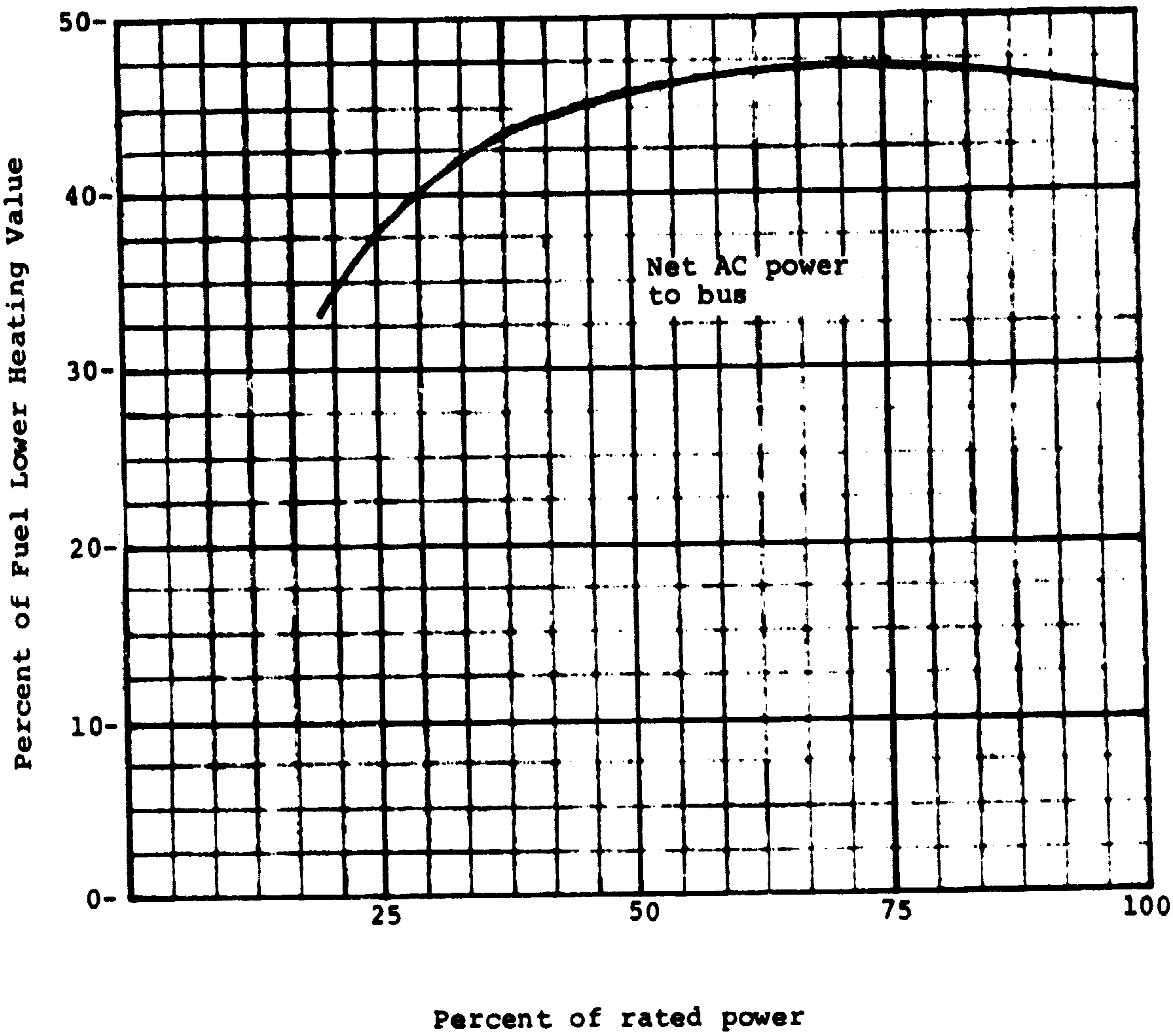
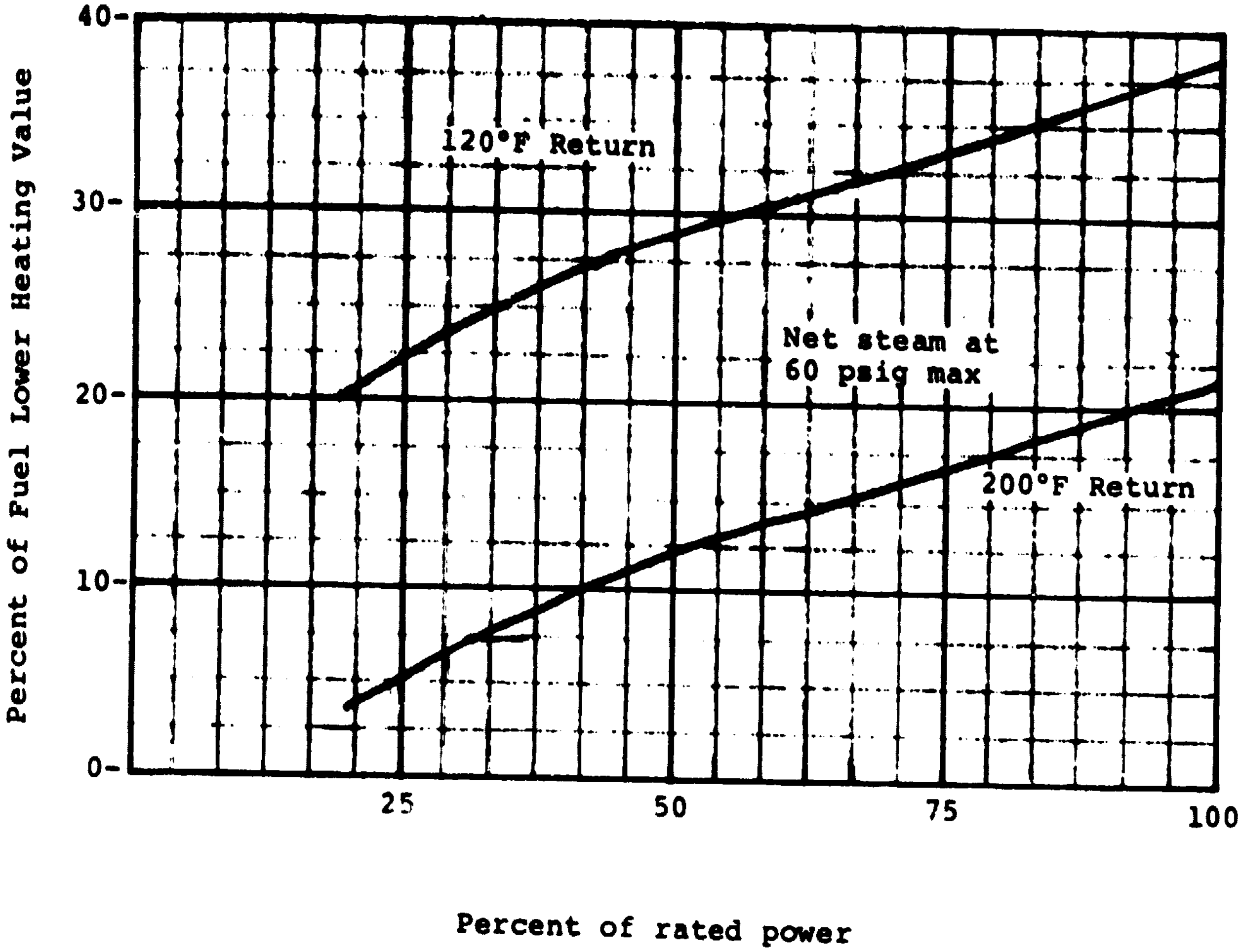


FIGURE 3B

POWERPLANT C HEAT RECOVERY EFFICIENCY



1. Component Name: CENTRIFUGAL CHILLERS

2. Available nominal size: 281KW to 7032KW (80 tons to 2000 tons)

3. Useful life: 20 years

4. Physical Dimensions for 703KW (200 ton) component size:

   8.8M x 2.8M x 2M (29' x 9' x 7') space required

5. Standard Rating Conditions:

   Evaporator:

   .043 l/s per KW (2.4 gpm/ton) flow rate

   6.7°C (44°F) Leaving water temperature

   12.2°C (54°F) Entering water temperature

   Condenser:

   .054 l/s per KW (3 gpm/ton) flow rate

   35°C (95°F) Leaving water temperature

   29.4°C (85°F) Entering water temperature

   Fouling Factor .00009 $M^3 \cdot K/W$ (.0005 $h \cdot ft^2 \cdot F/BTU$

6. Parameter Constraints:

   A. Water flow rates between 1 M/s and 3.66 M/s (3 1/3 fps and 12 fps)

   B. Minimum load 10% full load

   C. Condenser water temperature range between 1.7°C and 11.1°C (3°F and 20°F)

   D. Leaving evaporator water temperature between 4.4°C and 10°C (40°F and 50°F)

CENTRIFUGAL CHILLERS

COST DATA

Component Size in rated KW (tons)		Installed Cost*	Unit Cost in $/KW (ton)	
352	(100)	$ 41,000	$117	($410)
527	(150)	49,300	94	(330)
703	(200)	56,500	80	(282)
721	(250)	63,600	72	(254)
1054	(300)	67,300	64	(224)
1406	(400)	82,225	58	(205)

O&M as % installed cost = 7.5%

* Including overhead and profit.

CENTRIFUGAL CHILLER

INCREMENTAL INSTALLED COST VS. COP+

Capital Cost*	COP	KW/ton
$43,000	5.5	.64
37,500	4.6	.77

Incremental Capital Cost:

$6000 increase per cop increase of 1

($4200 increase per .1 KW/ton power decrease)

Incremental Installed Cost:

$8400 increase per cop increase of 1

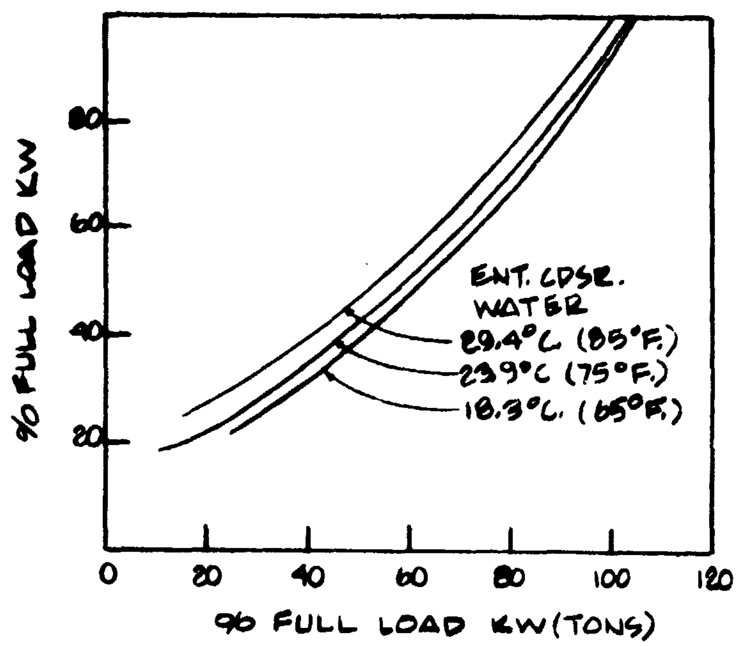
($6000 increase per .1 KW/ton power decrease)

* These are representative numbers for a 700 KW (200 ton) unit.

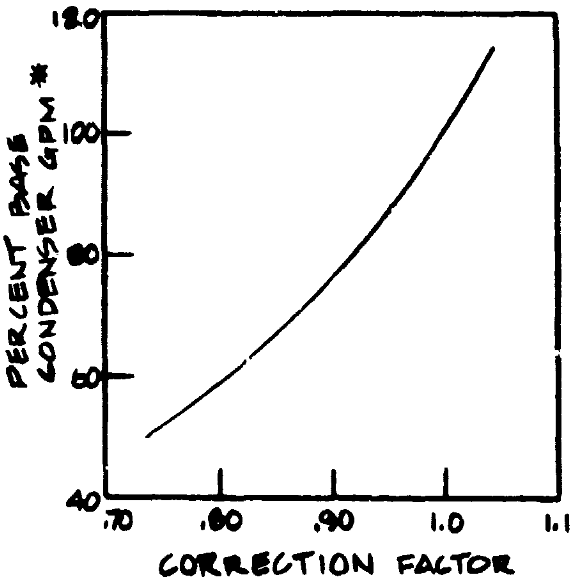
+ Applicable for range of cop from 4.2 to 5.6

CENTRIFUGAL CHILLER

COP AT PART LOAD



CAPACITY AS A FUNCTION OF CONDENSER WATER FLOW



* BASE FLOW = 3 GPM/TON

CENTRIFUGAL CHILLER

CAPACITY VS. LEAVING CHILLED WATER TEMP. (LCWT)

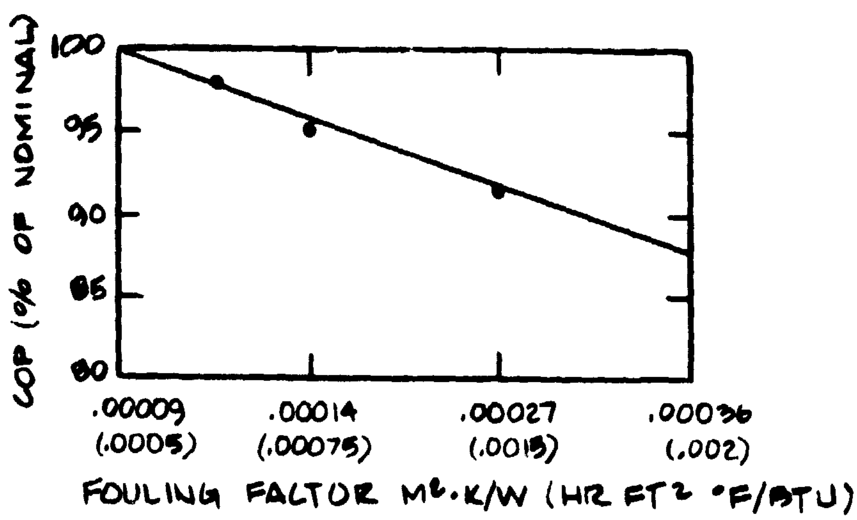
(Leaving condenser water temperature 35°C (95°F))

LCWT °C	LCWT °F	Average % Capacity increase over base*
4.4	(40°)	-7
5.5	(42°)	-3
6.7	(44°)	0
7.8	(46°)	4
8.9	(48°)	7
10.0	(50°)	11

* Average values taken for 3 units of nominal capacity 200, 350 and 650 tons

CENTRIFUGAL CHILLER

COP VS. FOULING FACTOR
OF CONDENSER OR EVAPORATOR



1. Component Name: RECIPROCATING CHILLERS

2. Available nominal size: 35KW to 843KW (10 tons to 240 tons)

3. Useful life: 20 years

4. Physical Dimensions for 352KW (100 ton) component size:

   5M x 2M x 1.5M (17' x 6' x 5') space required

5. Standard Rating Conditions:

   Evaporator:

   .043 l/s per KW (2.4 gpm/ton) flow rate

   6.7°C (44°F) Leaving water temperature

   12.2°C (54°F) Entering water temperature

   Condenser:

   .054 l/s per KW (3 gpm/ton) flow rate

   35°C (95°F) Leaving water temperature

   29.4°C (85°F) Entering water temperature

   Fouling Factor .00009 $M^3 \cdot K/W$(.0005 $h \cdot ft^2 \cdot F$/BTU)

6. Parameter Constraints:

   A. Water flow rates between 1 M/s and 3.66 M/s (3 1/3 fps and 12 fps)

   B. Minimum load 10% full load

   C. Condenser water temperature range between 1.7°C and 11.1°C (3°F and 20°F)

   D. Leaving evaporator water temperature between 4.4°C and 10°C (40°F and 50°F)

RECIPROCATING CHILLER

COST DATA

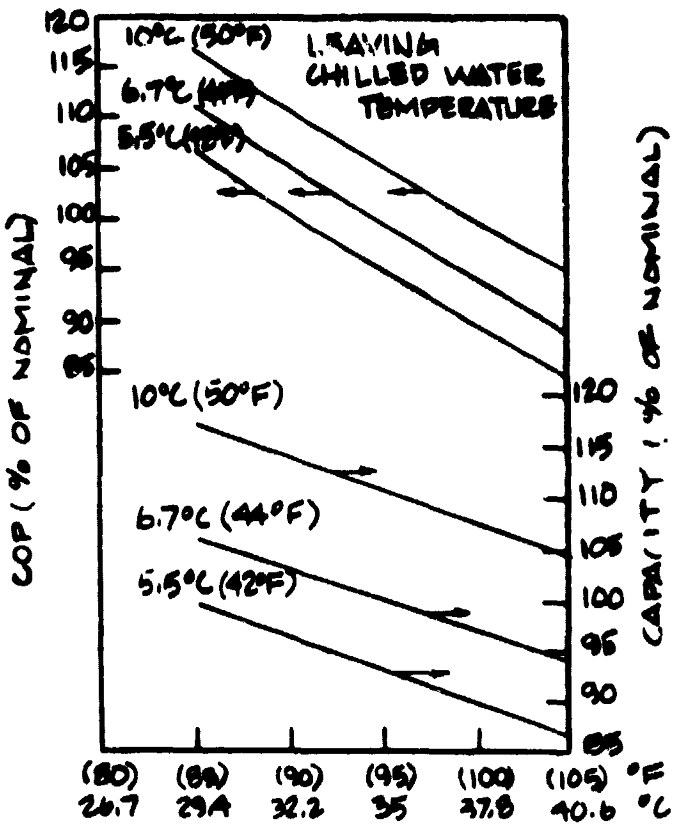
Component Size in rated KW (tons)		Installed Cost*	Unit Cost In $/KW (ton)	
88	(25)	$ 11,500	$131	($460)
176	(50)	16,950	96	(339)
264	(75)	26,650	101	(355)
352	(100)	28,250	80	(282)
527	(150)	45,200	85	(300)
703	(200)	63,000	90	(315)

O&M as % installed cost = 6%

* Including overhead and profit

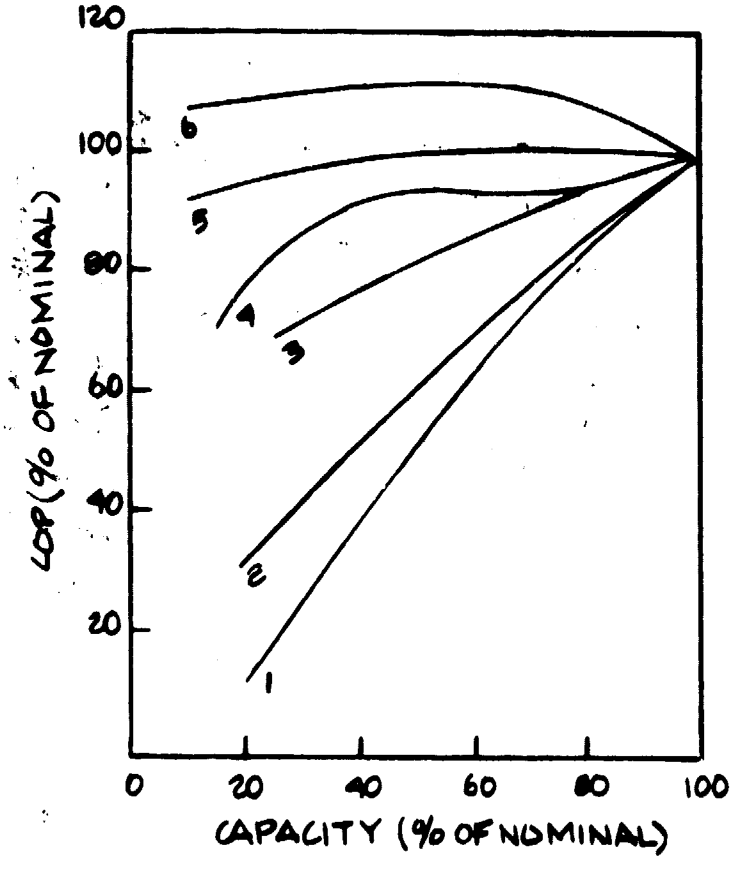
RECIPROCATING CHILLER

COP AND CAPACITY AT VARIOUS LEAVING CONDENSER AND LEAVING CHILLED WATER TEMPERATURES



RECIPROCATING CHILLER

COP AT PART LOAD FOR VARYING CAPACITY CONTROL



1. HOT GAS BYPASS
2. BACKPRESSURE VALVE
3. SUCTION VALVE-LIFT UNLOADING SINGLE COMPRESSOR
4. SUCTION VALVE-LIFT UNLOADING TWO COMPRESSORS
5. SUCTION VALVE-LIFT UNLOADING THREE COMPRESSORS
6. SUCTION VALVE- LIFT UNLOADING FOUR COMPRESSORS

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RECIPROCATING CHILLERS

COP AT PART LOAD

Capacity Control	Range of (X)	Coefficients A	B	C	D
					$Y=A+BX+CX^2+DX^3$
1. Hot Gas Bypass	20<x<100	-2.83	1.181	-0.00153	
2. Back Pressure Valve	20<x<100	20.56	0.7144	0.0008	
3. Cylinder-head Bypass Single Compressor	25<x<100	56.14	0.58143	-0.0014286	
4. Cylinder-Head Bypass Two Compressors	15<x<100	37.5	2.75	-0.043125	0.00021875
5. Cylinder-Head Bypass Three Compressors	10<x<100	92.28	0.162857	-0.0008571	
6. Cylinder-Head Bypass Four Compressors	10<x<100	105.72	0.282143	-0.0033929	

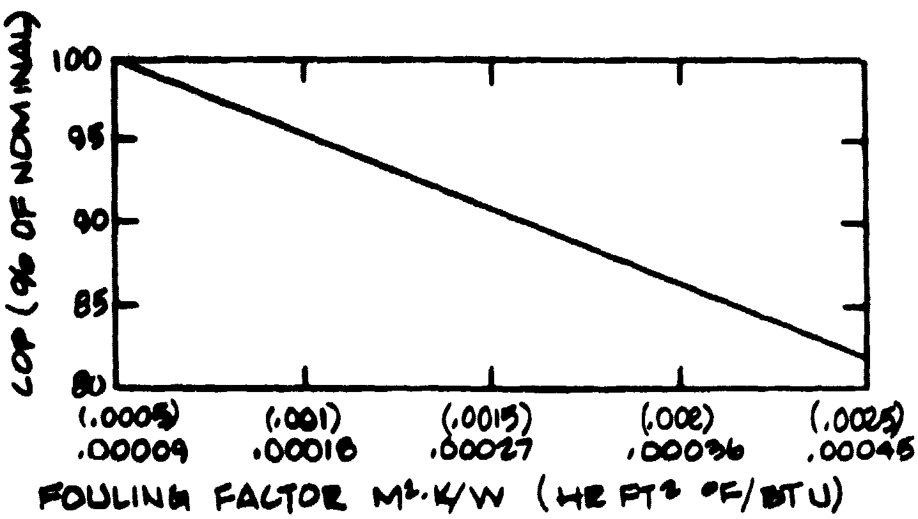
RECIPROCATING CHILLERS

PART LOAD PERFORMANCE

% Load	% COP
100	100
90	98
80	94
70	91
60	87
50	82
40	74
30	65
20	53
10	33

RECIPROCATING CHILLER

COP VS. FOULING FACTOR
OF CONDENSER OR EVAPORATOR



1. Component Name: ABSORPTION CHILLERS

2. Available nominal size: 10KW to 5837KW (3 tons to 1660 tons)

3. Useful life: 20 years

4. Physical Dimensions for 703KW (200 ton) component size:

   8.5M x 3M x 2.5M (28' x 10' x 8') space required

5. Standard Rating Conditions:

   A. 83 K^Pa (12 psig) steam or 115.6°C (240°F) hot water at .050 l/s per KW (2.8 gpm/ton)

   B. 29.4°C (85°F) entering condenser water temperature

   C. .064 l/s per KW (3.6 gpm/ton) condenser water flow

   D. 6.7°C (44°F) leaving evaporator water temperature

   E. .043 l/s per KW (2.4 gpm/ton) evaporator water flow rate

6. Parameter Constraints:

   A. Leaving evaporator water temperature between 4.4°C and 10°C (40°F and 50°F)

   B. Entering condenser water temperature greater than 12.8°C (55°F)

   C. Maximum design load - 113% nominal

   D. Maximum operating capacity 140% nominal

   E. Maximum steam temperature 171.1°C (340°F)

   F. Maximum hot water temperature 132.2°C (270°F)

   G. Maximum evaporator flow 3 M/s (10 fps)

ABSORPTION CHILLERS

COST DATA

Single Effect (18.7# Steam Per Ton-Hour)

Component Size in rated KW (tons)		Installed Cost*	Unit Cost in $/KW (ton)	
355	(101)	$60,000	$171	($600)
454	(129)	59,500	131	(460)
612	(174)	67,500	110	(388)
802	(228)	76,280	95	(334)
1034	(294)	89,300	85	(300)
1353	(385)	106,500	78	(276)
88+	(25+)	22,125	252	(885)

Double Effect (12.0# Steam Per Ton-Hour)

1353	(385)	148,208	109	(385)
3730	(1060)	301,136	80	(284)

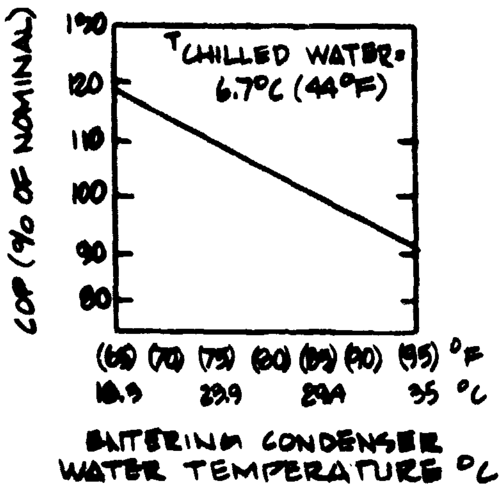
O&M as % installed cost = 4%

* Including overhead and profit (32%)

\+ Arkla, Steam

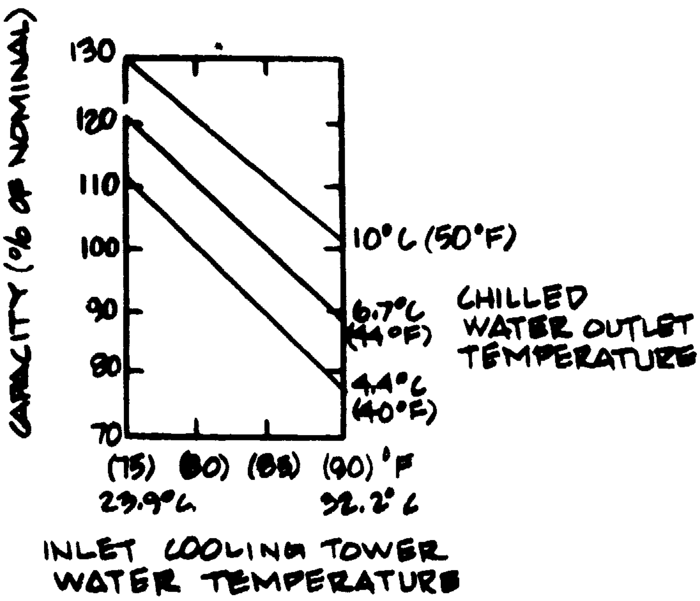
ABSORPTION CHILLER

COP VS. CONDENSER WATER TEMPERATURE

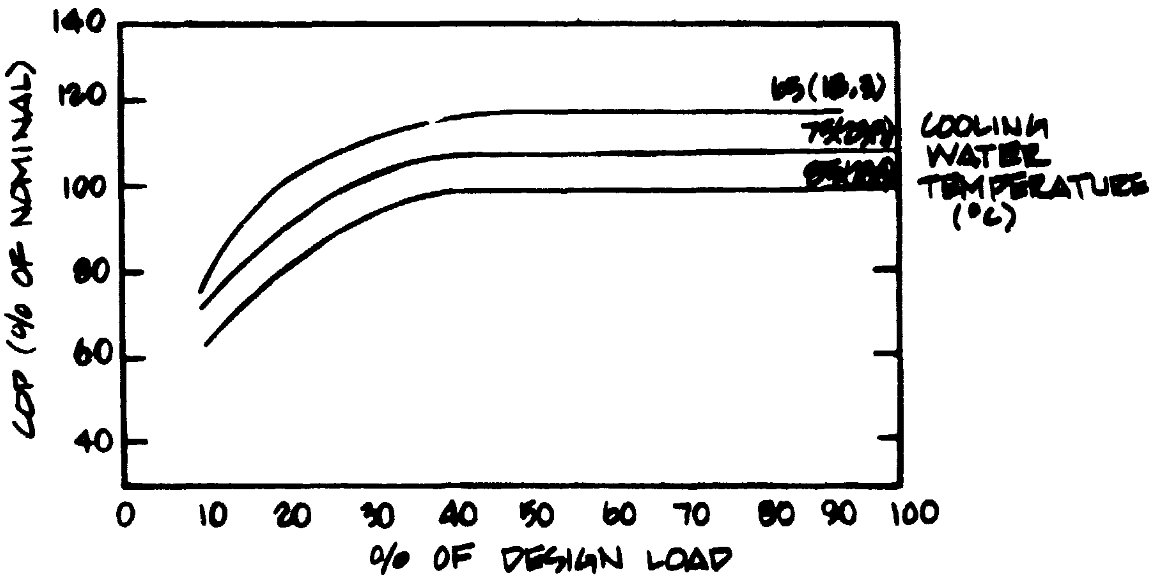


CAPACITY VS. CONDENSER WATER TEMPERATURE

(Same for Double/Single Effect)

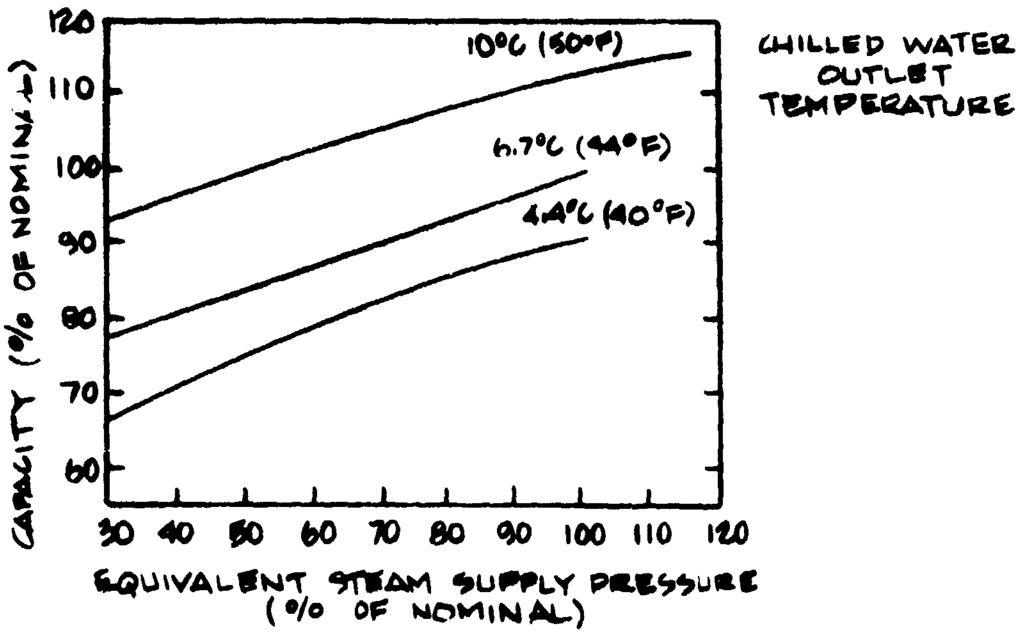


PERFORMANCE AT PART LOAD

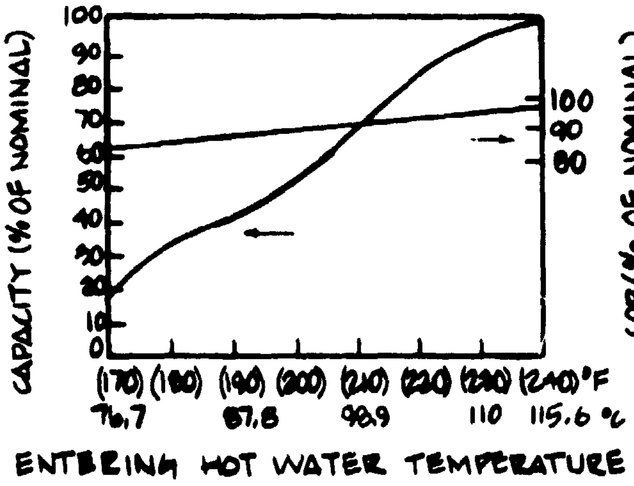


ABSORPTION CHILLER

CAPACITY VS. STEAM SUPPLY PRESSURE



CAPACITY AND COP VS. HOT WATER TEMPERATURE



ABSORPTION CHILLER

CAPACITY vs. CHILLED WATER AND COOLING TOWER WATER TEMPERATURES

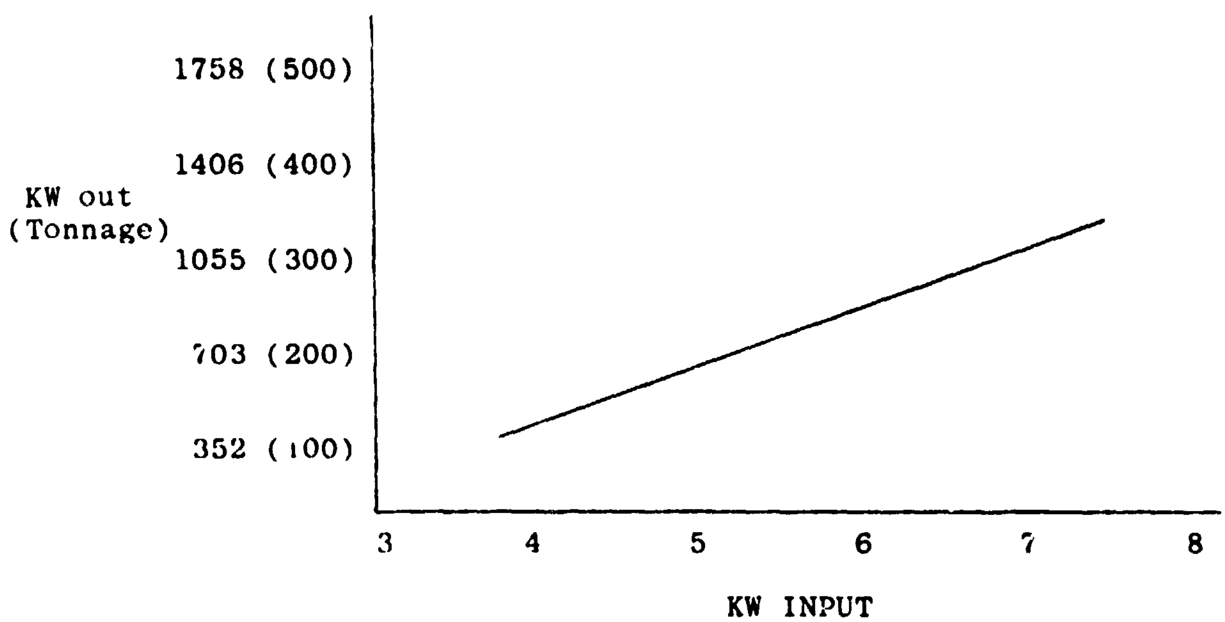
Capacity as % of Nominal

Entering Cooling Water (Tower) Temperature (°F)	LEAVING CHILLED WATER TEMPERATURE °C (40)	(42)	(44)	(45)	(46)	(48)	(50)	(52)	(54)	(55)	(56)	(58)	(60)
°C	4.4	5.5	6.7	7.2	7.8	8.9	10	11.1	12.2	12.8	13.3	14.4	15.6
18.3°C (65)	1.28	1.32	1.37	1.40	1.42	1.46	1.50	-	-	-	-	-	-
23.9°C (75)	1.13	1.19	1.26	1.29	1.32	1.38	1.44	1.47	1.50	1.52	1.53	1.56	1.59
26.7°C (80)	1.03	1.09	1.13	1.15	1.18	1.23	1.27	1.32	1.37	1.39	1.40	1.43	1.46
29.4°C (85)	0.90	0.95	1.00	1.02	1.05	1.10	1.14	1.19	1.23	1.25	1.26	1.30	1.33
32.2°C (90)	0.77	0.82	0.87	0.89	0.92	0.96	1.01	1.06	1.11	1.13	1.15	1.18	1.21
35.0°C (95)	0.60	0.61	0.71	0.74	0.76	0.81	0.86	0.90	0.94	0.96	0.98	1.01	1.04

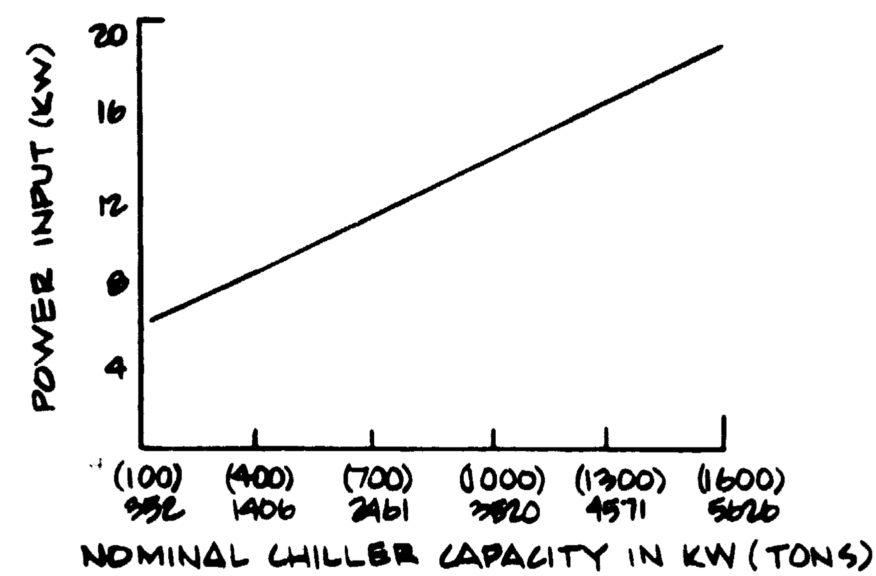
ABSORPTION CHILLER

AUXILIARY ELECTRIC REQUIREMENTS FOR SINGLE EFFECT MACHINES

KW out	(Tonnage)	KW Input
355	(101)	3.8
394	(112)	3.8
454	(129)	4.2
520	(148)	4.2
612	(174)	5.1
802	(228)	5.8
1034	(294)	7.2
1245	(354)	7.5
1635	(465)	8.0



AUXILIARY ELECTRIC REQUIREMENTS FOR DOUBLE EFFECT MACHINES



1. Component Name: COOLING TOWERS

2. Available nominal size: 10KW to 5625KW (3 tons to 1600 tons)

3. Useful life: Steel - 15 years

4. Physical Dimensions for 703KW (200 tons) component size:

   2M x 4.3M x 2.4M (7' x 14' x (8' high))space required

5. Standard Rating Conditions:

   0.54 l/s per KW* (3 gpm/ton) cooled from 35°C to 29.4°C at 25.6° C.W.B. (95°F to 85°F at 78°F.W.B.)

   * Cooling tower heat rejection = 1.25 KW per KW refrigeration (15,000 BTUH/ton)

6. Parameter Conditions:

   Freeze protection needed to operate below 0°C.W.B. (32°F.W.B.)

COOLING TOWERS

COST DATA

Component Size in rated KW (tons)		Installed Cost*	Unit Cost in $/KW (ton)
440	(125)	$ 9,900	$ 23 ($79)
703	(200)	13,900	20 (70)
1143	(325)	21,300	19 (66)
1406	(400)	25,000	18 (62)
1582	(450)	27,000	17 (60)
2110	(600)	39,300	18 (65)

O&M as % installed cost = 15%

* Including overhead and profit

COOLING TOWERS

POWER CONSUMPTION vs. RATED FLOW

Rated size in l/s (gpm) for 35°C/29.4°C (95°F/85°F) condenser water and 25.6° CWB (78° FWB)		Fan KW (hp)	
18.9	(300)	3.7	(5)
23.7	(375)	5.6	(7.5)
28.4	(450)	5.6	(7.5)
33.1	(525)	5.6	(7.5)
37.9	(600)	7.5	(10)
47.3	(750)	7.5	(10)
52.1	(825)	11.2	(15)
56.8	(900)	11.2	(15)
61.5	(975)	11.2	(15)
66.3	(1050)	11.2	(15)
71.0	(1125)	14.9	(20)
75.7	(1200)	14.9	(20)
80.5	(1275)	14.9	(20)
85.2	[illegible]350)	18.6	(25)
89.9	[illegible]	14.9	(20)
94.7	(1500)	18.6	(25)

Summary Power Consumption:

1. At rated conditions average KW/l/s = 11.8) (Avg. hp/gpm = .017)

2. At 23.3°C WB (74° F WB) and 35°C/29.4°C (95°F/85°F) Average KW/l/s = 8.7 (Avg. hp/gpm = .013)

3. At 23.3°C WB (74°F WB) and 39.4°C/29.4°C (103°F/85°F) Average kw/l/s = 9.5 (Avg. hp/gpm = .014)

COOLING TOWERS

LEAVING COOLING TOWER WATER AS A FUNCTION OF LOAD AND AMBIENT WET BULB TEMPERATURE

1. Part Load:

   A. Percent decrease in load = Percent decrease in approach.

   B. Leaving cooling tower water temperature = design cooling tower water temperature minus (percent decrease in load x design approach).

2. Reduced ambient temperature:

   A. .56°C.W.B (1°F.W.B) decrease in wet bulb temperature results in .371°C (.67°F) leaving cooling tower water temperature.

   B. Leaving cooling tower water temperature = design cooling tower water temperature minus [(.37 (.67) x ambient wet bulb temperature reduction)].

1. Component Name: HOT WATER BOILERS - PACKAGED

2. Available nominal size: 10KW to 20,000KW

3. Useful life: 20 years

4. Physical Dimensions for 980KW (100Bhp) component size:

   4.3M x 1.8M x 2M (14' x 6' x 7') space required

5. Standard Rating Conditions:

   I = B = R for cast iron oil fired

   1) 10% Co_2 in the flue gas

   2) Not more than No. 2 Shell Smoke Scale Reading

   3) Flue gas temperature at Gross Output less than 316°C (600°F)

   4) Draft loss through boiler must not exceed specified values

   5) Minimum overall efficiency not less than 70%

6. Parameter Constraints:

   121.1°C (250°F) maximum water temperature

HOT WATER BOILERS

COST DATA

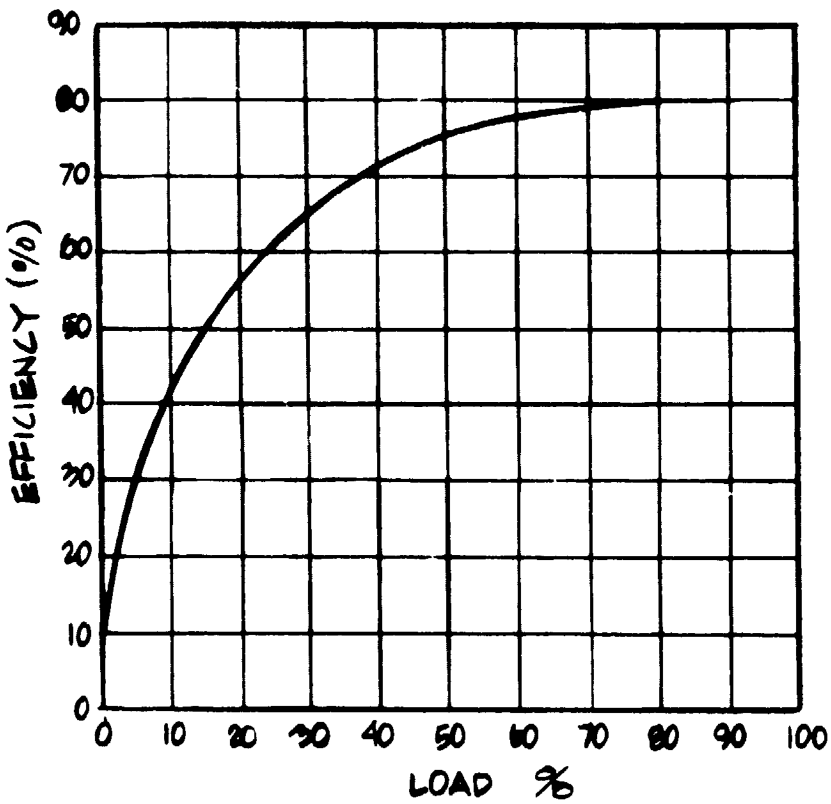
Component Size in rated KW (MBH) out		Installed Cost*	Unit Cost in $/KW (MBH) out	
70	(240)	$ 2000	$ 28.70	($8.40)
117	(400)	3340	28.70	(8.40)
176	(600)	4650	26.60	(7.80)
234	(800)	5730	24.40	(7.16)
352	(1200)	8456	23.90	(7.0)
469	(1600)	10,600	22.50	(6.6)

O&M as % installed cost = 5%

* Including overhead and profit

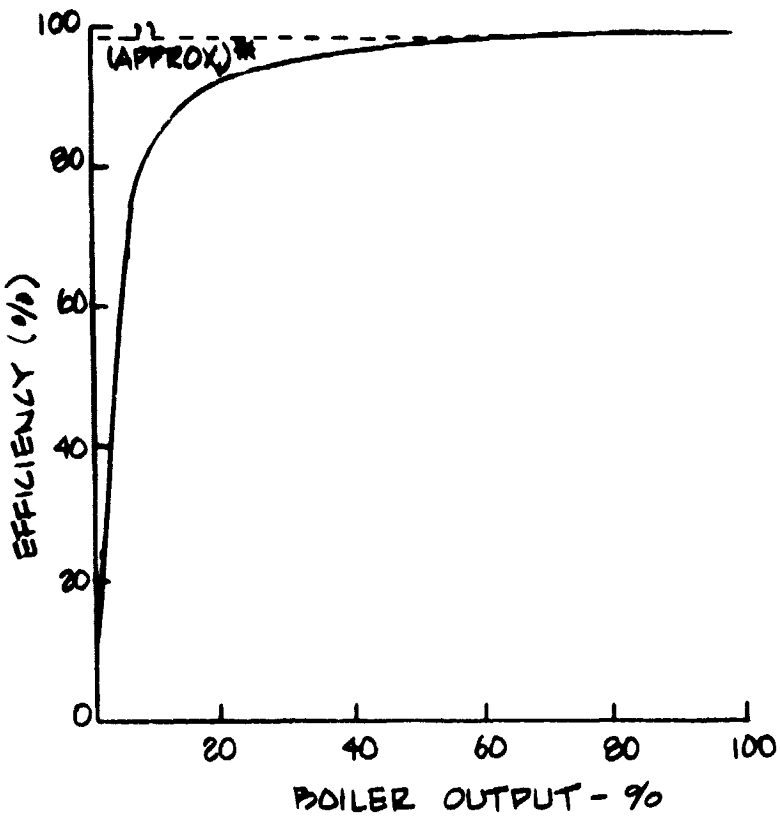
BOILER - GAS/OIL

EFFICIENCY VS. LOAD



BOILER - ELECTRIC (HIGH VOLTAGE)

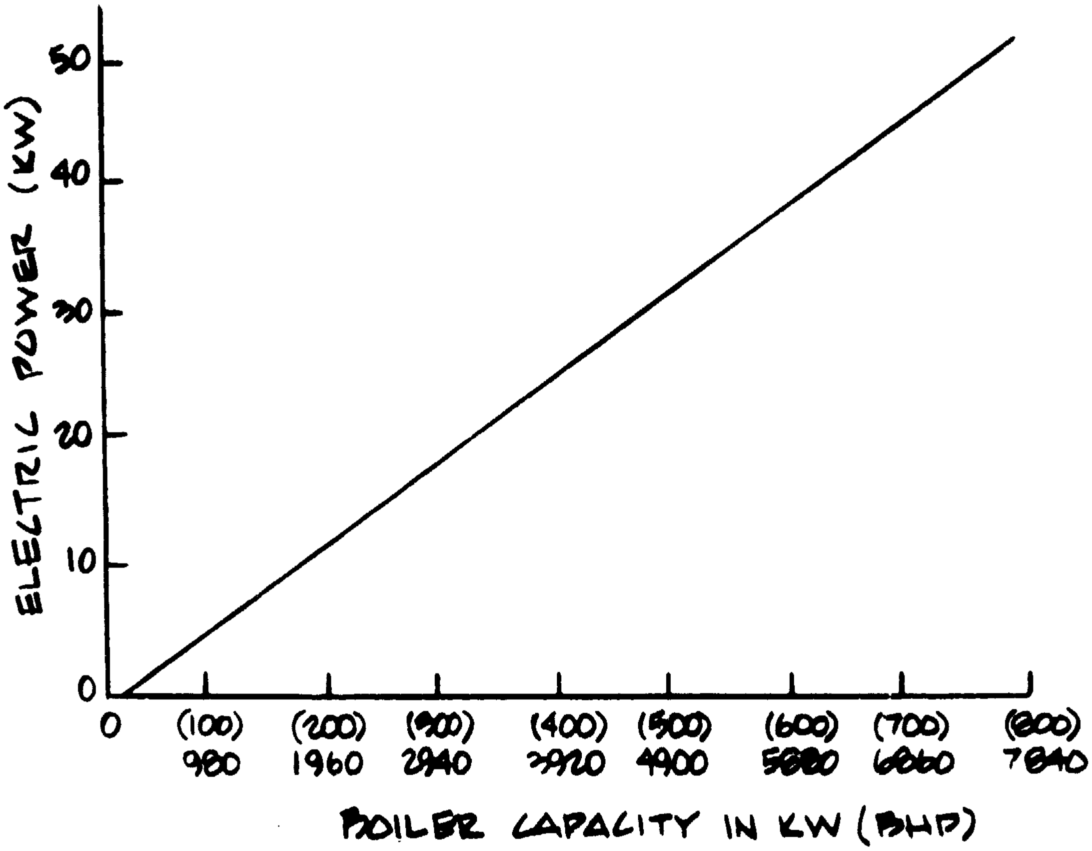
EFFICIENCY AT PART LOAD



* DEPENDENT UPON INSTALLATION HEAT LOSSES

BOILER - GAS/OIL

AUXILIARY ELECTRIC INPUTS*



* AUXILIARY ELECTRIC POWER REQUIRED BY BLOWER, FUEL PUMP, AND AIR PUMP FOR FIRETUBE BOILERS

1. Component Name: WATER-WATER HEAT PUMP (TEMPLIFIER)

2. Available nominal size: 15KW to 220KW (50MBH to 750MBH)

3. Useful life: 15 years

4. Physical Dimensions for 73KW (250MBH) component size:

   2.7M x .9M x 1.2M (9' x 3' x 4') space required

5. Standard Rating Conditions:

   None

6. Parameter Constraints:

   Maximum leaving hot water temperature 104.4^{O}C (220^{O}F)

WATER-WATER HEAT PUMP (TEMPLIFIER)

COST DATA

Component Size in rated KW	(MBH)	Installed Cost*
66	(224)	$ 14,500
86	(294)	15,600
110	(374)	17,200
164	(561)	20,520
196	(668)	24,300
219	(748)	25,200

O&M as % installed cost = 5%

* Including overhead and profit

TEMPLIFIER

COP vs. INLET AND OUTLET WATER TEMPERATURES

TEMPLIFIER

Leaving Source Water Temp. °C (°F)		LEAVING HOT WATER TEMP. °C (°F) 43.3 (110)	48.9 (120)	54.4 (130)	60 (140)	65.6 (150)	71.1 (160)	76.7 (170)	82.2 (180)	93.3 (200)
51.7	(125)	--	--	--	--	--	--	--	--	3.32
48.9	(120)	--	--	--	--	--	--	--	--	3.15
46.1	(115)	--	--	--	--	4.47	4.13	3.88	3.62	2.98
43.3	(110)	--	--	--	--	4.33	4.01	3.76	3.50	2.80
40.6	(105)	--	--	--	--	4.21	3.87	3.65	3.37	2.79
37.8	(100)	--	--	--	--	4.08	3.73	3.51	3.29	2.75
35.0	(95)	--	--	4.81	4.35	3.93	3.63	3.41	3.14	2.67
32.2	(90)	--	--	4.66	4.19	3.80	3.50	3.27	3.05	2.56
29.4	(85)	5.67	5.05	4.52	4.07	3.68	3.37	3.16	2.93	--
26.7	(80)	5.43	4.84	4.31	3.91	3.53	3.24	3.02	2.82	--

1. Component Name: DOMESTIC HOT WATER BOILERS - PACKAGED

2. Available nominal size. 114ℓ to 379ℓ (30 gal to 100 gal)

3. Useful life: 7 years

4. Physical Dimensions for 303 (80 gal) component size:

   .74M diameter x 1.6M high (29" diameter x 63" high)
   space required

5. Standard Rating Conditions:

   AGA

6. Parameter Constraints:

   121.1°C (250°) Maximum water temperature

DOMESTIC HOT WATER BOILER

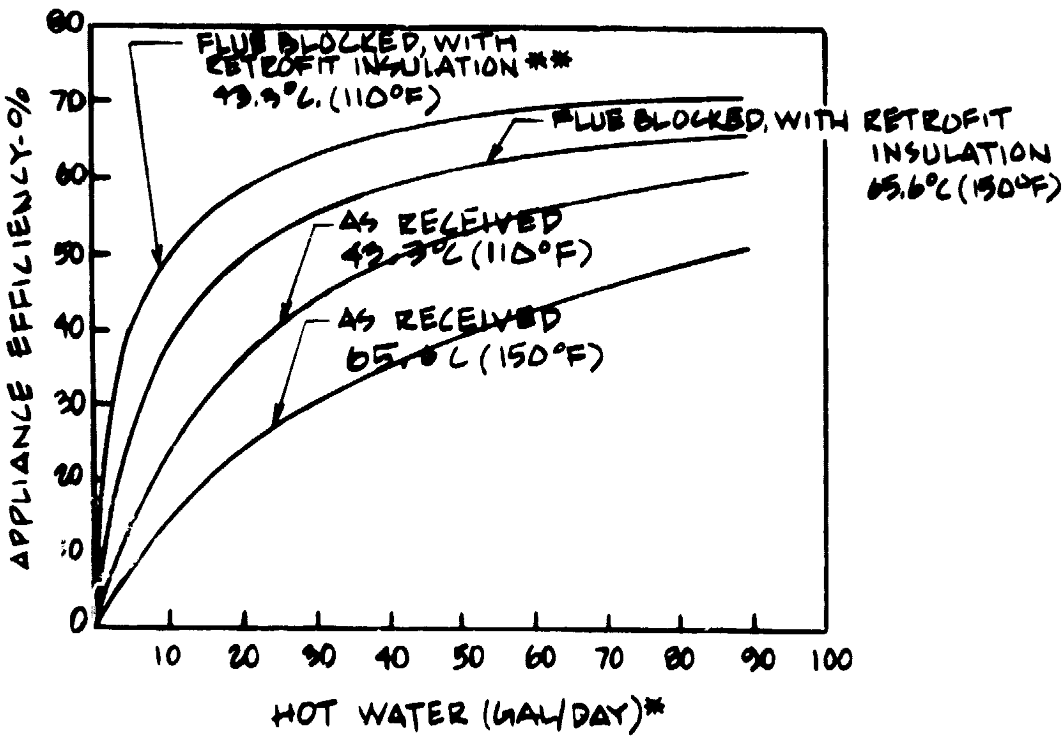
COST DATA

Component Size in rated ℓ (gal)		Installed Cost*
284	(75)	$ 650
3786	(1000)	15,000
7572	(2000)	16,500

O&M as % installed cost = 5%

* Including overhead and profit

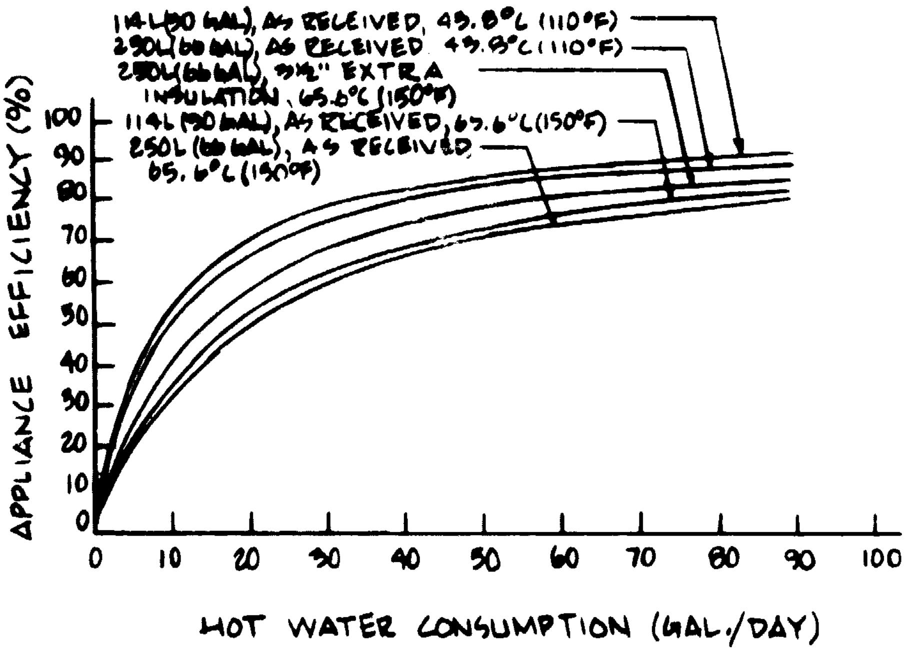
EFFICIENCY VS. CONSUMPTION AND TEMPERATURE



* THROUGH 90°F TEMPERATURE

** INSULATION THICKNESS 3½"

EFFICIENCY AS A FUNCTION OF CONSUMPTION AND TEMPERATURE



1. Component Name: WATER TO WATER HEAT EXCHANGER

2. Nominal sizes: 91.7 W/°C to 4745 W/°C (174 BTU/HR °F to 9000 BTU/HR °F)

3. Useful life: 20 years

4. Physical Dimensions for 2025W/°C:

   0.34M x 0.064M x 0.087M
   (13.4 IN x 2.5 IN x 3.44 IN)

5. Standard Rating Conditions

   A. 60°C (140°F) outlet cold water temperature

   B. 21°C (70°F) inlet cold water temperature

   C. 60°C (140°F) outlet hot water temperature

   D. 82°C (180°F) inlet hot water temperature

6. Parameter Constraints

   A. Entering hot water temperature must be between 0°C and lower than 100°C (32°F to 212°F)

   B. Entering cold water temperature must be between 0°C and 100°C

7. Performance Rating:

Known Paramers:

UA - The overall heat transfer-area product of the heat exchanger.

T_{CIN} - Inlet cold side temperature.

T_{COUT} - Outlet cold side temperature.

T_{HIN} - Inlet hot side temperature.

T_{HOMIN} - Maximum outlet hot side temperature.

M_{CMAX} - Maximum mass flow rate on the cold side.

Unknown Parameters:

M_{COLD} - Mass flow rate on the cold side.

M_{HOT} - Mass flow rate on the hot side.

Q - Heat transferred by the heat exchanger.

T_{HOUT} - Outlet hot side temperature.

The following equations are solved simultaneously to calculate the unknown parameters:

Equation for a heat exchanger:

$$Q = UA\,\Delta T_{LM}$$

Where: $$\Delta T_{LM} = \frac{(T_{HOUT} - T_{CIN}) - (T_{HIN} - T_{COUT})}{L_n[(T_{HOUT} - T_{CIN})/(T_{HIN} - T_{COUT})]}$$

Energy Balance:

$$Q = M_{COLD}\,(T_{COUT} - T_{CIN})$$

$$Q = M_{HOT}\,(T_{HIN} - T_{HOUT})$$

User Constraints:

The user sets the cold side mass flow rate equal to the maximum mass flow rate on the cold side, i.e.,

$$M_{COLD} = M_{CMAX}$$

There are now 3 equations and 3 unknowns. The user solves for the unknown parameters and if:

$$T_{HOUT} \leq T_{HOMAX}$$

The user is finished.

If $T_{HOUT} > T_{HOMAX}$, which implies the heat exchanger is too small to handle the maximum mass flow rate on the cold side, the user sets.

$$T_{HOUT} = T_{HOMAX}$$

and solves for M_{COLD}, M_{HOT} and Q with the 3 equations.

WATER TO WATER HEAT EXCHANGER

COST DATA

Component Size in Overall Heat Transfer Coefficient Times Area W/°C	(BTU/HR-°F)	Installed Cost*
91.7	174	131
633	1200	374
2025	3840	749
4745	9000	1324

O&M as % installed cost = %

*Including overhead and profit

1. Component Name: STEAM/WATER HEAT EXCHANGE

2. Nominal Sizes: 1500W/°K to 6500W/°K (2888 BTU/HR °F to 12300 BTU/HR°F)

3. Useful life: 20 years

4. Physical Dimensions for 1500W/°C:

   0.9M x 0.17M x 0.138M

   (35.5 IN x 6.72 IN x 5.44 IN)

5. Standard Rating Conditions:

   A. 446KPA (50PSIG) steam

   B. 10°C (50°F) entering cold water temperature

   C. 44°K (80°F) cold water temperature rise

6. Parameter Constraints:

   A. Entering steam between 100 and 1100KPA (0 and 150 PSIG)

   B. Entering water temperature between 0 and 100°C (32 and 212°F)

7. Performance Rating:

   Known Parameters:

   UA - The overall heat transfer-area product of the heat exchanger.

   T_{STM} - The temperature of the steam.

   T_{COUT} - Outlet cold side temperature.

   T_{CIN} - Inlet cold side temperature.

   H_{FGSTM} - Heat of condensation of the steam.

   Unknown Parameters:

   M_{COLD} - Mass flow rate on the cold side.

   M_{HOT} - Mass flow rate on the hot side.

Q - Maximum heat transfer possible by the heat exchanger.

The following equations are solved simultaneously to calculate the unknown parameters:

Equation for a heat exchanger:

$$Q - UA\ \Delta T_{LM}$$

Where: $$\Delta T_{LM} = \frac{T_{COUT} - T_{CIN}}{L_n[(T_{STM} - T_{CIN})/(T_{STM} - T_{COUT})]}$$

$$Q = M_{COLD}\ (T_{COUT} - T_{CIN})$$

$$Q = M_{HOT} \times H_{FGSTM}$$

The user will find that if the steam condensate is not allowed to subcool, the heat exchanger can only be operated at full capacity. In practice we allow the condensate to subcool (but do not calculate the subcooling since the additional heat is negligible compared to the heat of vaporization) which permits operation of the heat exchanger from zero to full capacity. Given the rate of cold water heating required, the mass of steam needed is:

$$M_{HOT} = \frac{M_{COLD}\ (T_{COUT} - T_{CIN})}{H_{FGSTM}}$$

Provided we do not exceed the heat exchanger's maximum rate as calculated previously.

STEAM/WATER HEAT EXCHANGER

COST DATA

Component Size in Overall Heat Transfer Coefficient Times Area W/°C	(BTU/HR°F)	Installed* Cost ($)
1522	(2888)	1025
3696	(7010)	1070
6462	(12260)	1196

O&M Costs as a % of installed costs =

*Including overhead and profit

1. Component Name: FAN COIL UNITS

2. Available nominal size: 1.76KW to 10.5KW (.5 tons to 3 tons)

3. Useful life: 20 years

4. Physical Dimensions for .15 M^3/s (300 CFM) component size:

   1.5M x .3M x .76M (5' x 1' x (2.5' high)) space required

5. Standard Rating Conditions at nominal CFM

   Cooling:

   (25.6° C.D.B./18.3° C.W.B. or 26.7° C.D.B./19.4° C.W.B.) (78° F.D.B./ 65° F.W.B. or 80° F.D.B./67° F.W.B.) entering air temperature

   7.2°C (45°F) entering chilled water temperature

   5.5°C (10°F) chilled water temperature rise

   Heating:

   21.1°C.D.B. (70° F.D.B.) entering air temperature

   82.2°C (180°F) entering water temperature

   Water flow rate as specified by cooling

6. Parameter Constraints

   Minimum chilled water flow = .032 l/s (.5gpm)

FAN COIL UNITS

COST DATA

Component Size in rated M^3/s (CFM)		Installed Cost*
.14	(300)	$ 340
.28	(600)	430

O&M as % installed cost = 10%

* Including overhead and profit

FAN COIL UNITS

HEATING CAPACITY vs. ENTERING WATER TEMPERATURE AND ENTERING AIR TEMPERATURE

$$H = .00972\ H_o\ (\frac{9}{5} \times ITD)^{*}.98571$$

ENTERING WATER TEMPERATURE °C (°F)

Ent. Air °C	(°F)	37.8 (100°)	43.3 (110°)	48.9 (120°)	54.4 (130°)	60 (140°)	65.6 (150°)	71.1 (160°)	76.7 (170°)	82.2 (180°)	87.8 (190°)	93.3 (200°)
10	(50)	.46	.55	.64	.73	.82	.91	1.00	1.09	1.18	1.27	1.36
12.8	(55)	.41	.50	.59	.68	.77	.86	.96	1.05	1.14	1.23	1.32
15.6	(60)	.36	.46	.55	.64	.73	.82	.91	1.00	1.09	1.18	1.27
18.3	(65)	.32	.41	.50	.59	.68	.77	.86	.96	1.05	1.14	1.23
21.1	(70)	.27	.36	.46	.55	.64	.73	.82	.91	1.00	1.09	1.18
23.9	(75)	.23	.32	.41	.50	.59	.68	.77	.86	.96	1.05	1.14
26.7	(80)	.18	.27	.36	.46	.55	.64	.73	.62	.91	1.00	1.09

H = capacity at given conditions

H_o = rated capacity at 82.2°C (180°F) EWT
21.1°C (70°F) EAT

* ITD = EWT - EAT in degree C

1. Component Name: AIR HANDLING UNIT

2. Available nominal size: .3 M^3/s to 31 M^3/s (600 CFM to 65,000 CFM)

3. Useful life: 20 years

4. Physical Dimensions for 19 M^3/s (40,000 CFM) component size:

   3.7M x 4.9M x 3.7M (12' x 16' x 12') space required

5. Standard Rating Conditions:

   Cooling:

   (25.6°C.D.B./18.3°C.W.B. or 26.7°C.D.B./19.4°C.W.B.) (78°F.D.B./65°F.W.B. or 80° F.D.B./67°F.W.B.) entering air temperature

   7.2°C (45°F) entering chilled water temperature

   5.5°C (10°F) chilled water temperature rise

   Heating

   21.1°C.W.B(70°F.D.B.) entering air temperature

   82.2°C (180°F) entering water temperature

   Water flow rate as specified by cooling

6. Parameter Constraints

   Maximum water velocity in coils 2.3 M/s (7.5 fps)

   Maximum face velocity across coils 3.6 M/s (700 fps) outlet velocity

AIR HANDLING UNIT

COST DATA

Component Size in rated CFM	Installed Cost*
40,000	
a) Fan & Housing	$ 20,240
b) heating coils	3,900
c) cooling coils	10,250

O&M as % installed cost = 5%

* Including overhead and profit

AIR HANDLING UNIT

FAN POWER REQUIREMENT vs. ENTERING WATER TEMPERATURE AND FLOW RATE

1. Power correction factor for various water temperatures at a flow rate of 8.52 l/s (135 gpm).

% FAN ON TIME FOR HEATING+ VS ENTERING WATER TEMPERATURE

EWT °C	(°F)	% FAN ON TIME		
60	(140°)	3/31	=	.097
54.4	(130°)	3/27		.111
48.9	(120°)	3/22		.136
43.3	(110°)	3/19		.158
37.8	(100°)	3/15		.20

2. Power correction factor for various flow rates.

M/S (fps)	l/s (GPM)	C.F.	Nominalized to .9M/s (3 fps)
2.3 (7½)	8.5 (135)	1	.88
2.1 (7)	8.0 (127)	1	.88
1.8 (6)	6.8 (108)	1.025	.90
1.5 (5)	5.7 (90)	1.05	.92
1.2 (4)	4.5 (72)	1.09	.96
.9 (3)	3.4 (54)	1.14	1
.6 (2)	2.3 (36)	1.26	1.11
.3 (1)	1.1 (18)	1.64	1.40

+ Fan is on 100% time for cooling mode.

1. Component Name: CABINET UNIT HEATERS

2. Available nominal size: 3KW to 73KW (10MBH to 250MBH)

3. Useful life: 20 years

4. Physical Dimensions for 29.3KW (100MBH) component size:

   1.5M x .3M x .76M (5' x 1' x (2.5' high)) space required

5. Standard Conditions:

   93.3°C (200°F) entering water temperature

   11.1°C (20°F) water temperature drop

   15.6°C or 21.1°C (60°F or 70°F) entering air temperature

6. Parameter Constraints:

   Minimum flow rate = .15 M/s (.5 ft/sec)

CABINET UNIT HEATERS

COST DATA

Component Size in rated KW (MBH)		Installed Cost*	Unit Cost in $/KW (MBH)	
5.9	(20)	$ 400	$ 68	($20)
11.7	(40)	520	44	(13)
17.6	(60)	640	38	(11)
23.4	(80)	760	32	(9.5)
29.3	(100)	950	32	(9.5)

O&M as % installed cost = 2%

* Including overhead and profit

UNIT HEATERS/CABINET

CAPACITY AS A FUNCTION OF ENTERING AIR TEMPERATURE AND ENTERING WATER TEMPERATURE

$$H = H_o \times .00835^{*} \times (\frac{9}{5} \Delta t)$$

H_o normalized to 15.6°C (60°F) EAT
82.2°C (180°F) EWT

ENTERING WATER TEMPERATURE °C (°F)

Ent. Air Temp. °C	(°F)	35 (95)	37.8 (100)	43.3 (110)	48.9 (120)	54.4 (130)	60.0 (140)	65.6 (150)	71.1 (160)	76.7 (170)	82.2 (180)	87.8 (190)	93.3 (200)	98.9 (210)	104.4 (220)
4.4	(40)	.458	.500	.583	.666	.75	.833	.917	1.00	1.08	1.16	1.25	1.33	1.42	1.50
10.0	(50)	.375	.417	.500	.583	.666	.75	.835	.917	1.00	1.08	1.16	1.25	1.33	1.42
15.6	(60)	.292	.333	.417	.500	.583	.666	.750	.835	.917	1.00	1.08	1.16	1.25	1.33
21.1	(70)	.208	.250	.333	.417	.500	.583	.666	.750	.835	.917	1.00	1.08	1.16	1.25
26.7	(80)	.125	.167	.250	.333	.417	.500	.583	.666	.750	.835	.917	1.00	1.08	1.16

* $H = H_o \times .0092 \times \frac{9}{5} \times \Delta T$ if rated at 21.1° (70°F) EAT, and 82.2°C (180°F) EWT

UNIT HEATERS/CABINET

CAPACITY AND FRICTION HEAD vs. FLOW RATE

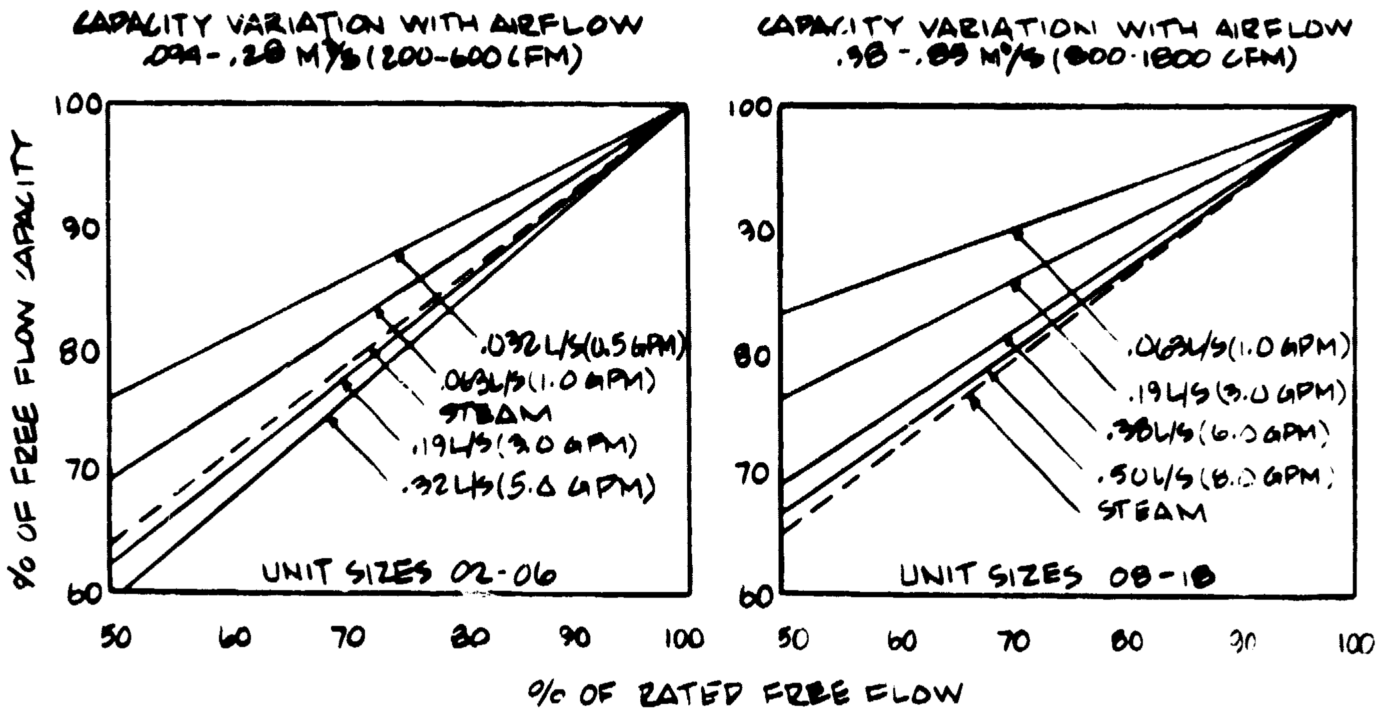
PRESSURE LOSS AND HEATING CAPACITY FACTORS FOR VARIOUS RATES OF WATER FLOW

	% OF RATED WATER FLOW						
	25	50	75	100	125	150	175
Friction Head Factor	.085	.254	.575	1.00	2.18	2.32	3.85
Heating Capacity Factor	.80	.89	.96	1.00	1.04	1.07	1.10

$$CAP = CAP_o \left(\frac{\%\ \text{rated flow}}{100} \right)^{.17}$$

where CAP_o = Capacity at rated flow

CAPACITY VS. AIR FLOW



1. Component Name: <u>THERMAL STORAGE TANK</u>

2. Available Nominal Sizes: <u>379 l to 190,000 l</u>

   (100 gal to 50,000 gal)

3. Useful life: <u>20 years</u>

4. Physical Dimensions for 7570 l (2000 gallon) Tank

   <u>1.63 M diamter x 3.68 l high</u> (64" diameter x 145" high)

5. Standard Rating Conditions:

   A. The Stored water must be between 0 and 100°C (32 and 212°F)

   B. The tank is above ground.

6. Jacket Loss:

   The user specifies the overall heat transfer coefficient area product (UA). The percent loss is calculated by:

   $$\% \text{ loss} = \frac{Q \text{ Loss}}{Q \text{ Total}} \times 100$$

   where $Q_{Total} = M\,C_p\,\Delta T$

   and M = Mass of water in the tank

   C_p = Water heat capacity

   ΔT = Temperature difference between the tank contents and the room.

   $Q \text{ Loss} = UA\Delta T$

   thus: $$\% \text{ Loss} = \frac{UA}{M\,C_p} \times 100$$

   To obtain the tank cost the user interpolates the cost versus % loss numbers.

THERMAL STORAGE TANK

COST DATA

Component Size liters	(gal)	% loss/day 52°C (125°F) Tank Temp. 1%	2%	5%	5%/Liter
		Installed Cost*			
379	(100)	$ 264	191	148	
1893	(500)	447	323	248	
2271	(600)	1481	1347	1273	
3785	(1000)	1699	1538	1451	
18927	(5000)	3597	3287	3101	
37854	(10000)	5830	5582	5334	.140
189271	(50000)	23569	22948	22948	.121

O&M Costs as a % of installed costs =

*Including overhead and profit

SUBSYSTEM ELEMENTS

To assure accurate system modelling several common subsystem designs (combinations of components) were developed to identify interconnection components such as pumps and controls. Also, interconnection flow rates were identified so that proper component sizing could be maintained. The following section is a summary of the subsystem elements.

System Description: VAPOR COMPRESSION CHILLER WITH CENTRAL STATION AIR HANDLING UNITS

System Output: Design KW output = DKWO
Design tonnage = DT

Design Conditions:

1. .043 l/s per KW (2.4 gpm/ton) evaporator
2. .054 l/s per KW (3 gpm/ton) condenser
3. 7.2°C (45°F) leaving evaporator water temperature
4. 29.4°C (85°F) entering condenser water temperature
5. 210 KPa (70 ft) evaporator side pressure drop
6. 150 KPa (50 ft) condenser side pressure drop
7. .054 M^3/s per KW (400 CFM/ton) at AHU

Component	Design KW Input
1. Centrifugal Chiller	DKWO/Design COP
	DT x Design KW/Ton*
2. Cooling Tower Fan	.00924 DKWO
	$\frac{DT \times .013\,hp/gpm \times 3\,gpm/ton \times .75\,KW/hp}{.9\ eff}$
3. Evaporator Water Pumps	.0134 DKWO
	$\frac{DT \times 2.4\,gpm/ton \times 70'}{3960 \times .75\ eff} \times \frac{.75\,KW/hp}{.9\ eff}$

(cont'd)

Component	Design KW Input
4. Condenser water pumps	.0120 DKWO
	$\frac{DTx3gpm/tonx50'}{3960 \times .75 \text{ eff}} \times \frac{.75KW/hp}{.9 \text{ eff}}$
5. AHU	.0622 DKWO
	$\frac{DTx400CFM/tonx2.5''}{6346 \times .6 \text{ eff}} \times \frac{.75KW/hp}{.9 \text{ eff}}$

* .78KW/ton Centrifugal
.95KW/ton Reciprocating

Vapor Compression Chiller with AHU Control Sheet

1. Centrifugal Chiller

   a) Water flow rates constant

   b) Cop (KW/ton) corrected for part load

   c) Leaving evaporator water temperature constant

   d) Entering condenser water temperature constant

2. Cooling Tower Fan

   Cycle to maintain constant entering condenser water temperature with a given reduction in wet bulb temperature and part load.

3. Evaporator water pumps

   Water flow rate constant

4. Condenser water pumps

   Water flow rate constant

5. AHU fans

   Cycle during heating only

System Description: ABSORPTION CHILLER WITH CENTRAL STATION AIR HANDLING UNIT

System Output: Design KW output = DKWO
Design tonnage = DT

Design Conditions:

1. .043 l/s per KW (2.4 gpm/ton) evaporator
2. .064 l/s per KW (3.6 gpm/ton) condenser
3. 7.2°C (45°F) Leaving evaporator water temperature
4. 29.4°C (85°F) Entering condenser water temperature
5. 210 KPa (70') Evaporator side pressure drop
6. 150 KPa (50') Condenser side pressure drop
7. .054 M^3/s per KW (400 CFM/ton) at AHU

Component	Design KW Input
1. Absorption Chiller	DKWO x f(DKWO)
	DT x f(DT)*
2. Cooling Tower Fan	.012 DKWO
	$\frac{DT \times .014 hp/gpm \times 3.6 gpm/ton \times .75 KW/hp}{.9 \, eff}$
3. Evaporator Water Pumps	.0134 DKWO
	$\frac{DT \times 2.4 gpm/ton \times 70'}{3960 \times .75 \, eff} \times \frac{.75 KW/hp}{.9 \, eff}$

(cont'd)

Component	Design KW Input
4. Condenser Water Pumps	.0144 DKWO
	$\frac{DTx3.6gpm/tonx50'}{3960 \times .75\ eff} \times \frac{.75KW/hp}{.9\ eff}$
5. AHU fans	.0622 DKWO
	$\frac{DTx400CFM/tonx2.5''}{6346 \times .6\ eff} \times \frac{.75KW/hp}{.9\ eff}$

* See Absorption Chiller section for power consumption

Absorption Chiller with AHU Control Sheet

1. Absorption Chiller

   a) Electric input constant

   b) Steam or hot water input varies with part load. (LEWT and ECWT are constant)

2. Cooling Tower Fan

   Cycle to maintain constant entering condenser water temperature with a given reduction in wet bulb temperature and part load.

3. Evaporator Water Pumps

   Water flow rate constant

4. Condenser Water Pumps

   Water flow rate constant

5. AHU Fans

   Cycle during heating only

System Description: VAPOR COMPRESSION CHILLER WITH FAN COIL UNIT

System Output: Design KW output = DKWO
Design Tonnage = DT

Design Conditions:

1. .034 l/s per KW (2.4 gpm/ton) evaporator
2. .054 l/s per KW (3 gpm/ton) condenser
3. 7.2°C (45°F) leaving evaporator water temperature
4. 29.4°C (85°F) entering condenser water temperature
5. 210 KPa evaporator side pressure drop
6. 150 KPa condenser side pressure drop
7. .142 M^3/s (300CFM) for (1.76KW) 1/2 ton unit; .284 M^3/s (600 CFM) for 3.5 KW (1 ton) unit

Component	Design KW Input
1. Centrifugal Chiller	$\frac{\text{DKWO}}{\text{Design Cop}}$
	DT x Design KW/ton
2. Cooling Tower fan	.00924 DKWO
	$\frac{\text{DTx.013hp/gpm x3gpm/ton x .75KW/hp}}{\text{.9 eff}}$
3. Evaporator water pumps	.0134 DKWO
	$\frac{\text{DTx2.4gpm/tonx70'}}{\text{3960 x .75 eff}} \times \frac{\text{.75KW/hp}}{\text{.9 eff}}$

(cont'd)

Component	Design KW Input
4. Condenser Water pumps	.0120 DKWO
	$\frac{DTx3gpm/tonx50'}{3960 \times .75\ eff} \times \frac{.75KW/hp}{.9\ eff}$
5. Fan Coil Unit	19.2KW
	100 watts per 1.76KW(½ ton) unit times 192 units
	16.8KW
	175 watts per 3.516KW(1 ton) unit times 96 units

Vapor Compression Chiller with FCU Control Sheet

1. Centrifugal Chiller

    a) Water flow rates constant

    b) COP (KW/ton) corrected for part load

    c) Leaving evaporator water temperature constant

    d) Entering condenser water temperature constant

2. Cooling tower fan

    Cycle to maintain constant entering condenser water temperature with a given reduction in wet bulb temperature and part load.

3. Evaporator water pumps

    Water flow rate constant

4. Condenser water pumps

    Water flow with constant

5. FCU

    Cycle during heating only

System Description: ABSORPTION CHILLER WITH FCU

System Output: Design KW output = DKWO
Design ton = DT

Design Conditions:

1. .043 l/s per KW (2.4 gpm/ton) evaporator
2. .064 l/s per KW (3.6 gpm/ton) condenser
3. 7.2°C (45°F) leaving evaporator water temperature
4. 29.4°C (85°F) entering condenser water temperature
5. 210 KPa (70') evaporator side pressure drop
6. 150 KPa (50') condenser side pressure drop

Component	Design KW Input
1. Absorption Chiller	DKWO x f(DKWO)*
	Dt x f(DT)*
2. Cooling Tower fan	.012 DKWO
	$\frac{DT x .014 hp/gpm x 3.6 gpm/ton \times .75 KW/hp}{.9 \text{ eff}}$
3. Evaporator Water pumps	.0134 DKWO
	$\frac{DT x 2.4 gpm/ton x 70'}{3960 \times .75 \text{ eff}} \times \frac{.75 KW/hp}{.9 \text{ eff}}$

(cont'd)

Component	Design KW Input
4. Condenser Water Pumps	.0144 DKWO $\frac{DT \times 3.6gpm/ton \times 50'}{3960 \times .75\ eff} \times \frac{.75KW/hp}{.9\ eff}$
5. Fan Coil Units	.01622 DKWO 100 Watts per 1.75KW(½ ton) unit times 192 units 175 watts per 3.516KW(1 ton) unit times 96 units

* See absorption chiller section for power consumption

Absorption Chiller with FCU Control Sheet

1. <u>Absorption Chiller</u>

   a) Electric input constant

   b) Steam or hot water input varies with part load (LEWT and ECWT are constant)

2. <u>Cooling Tower Fan</u>

   Cycle to maintain constant entering condenser water temperature with a given reduction on wet bulb temperature and part load.

3. <u>Evaporator Water Pump</u>

   Water flow rate constant

4. <u>Condenser Water Pumps</u>

   Water flow rate constant

5. <u>FCU Fans</u>

   Cycle during heating only

System Description: GAS/OIL BOILER WITH FCU

System Output: Design KW output = DKWO
Design MBH = DMBH

Design Conditions:

1. Select Hot Water Temperature
2. 75 KPa (25') pressure drop
3. .054 l/s per KW (3 gpm/ton) hot water flow rate established by cooling

Component	Design KW Input
1. Circulating Pump	.0048 DKWO
	$\frac{(DT \times 2.4 \text{ gpm/ton} \times 25' \times (.75 KW/hp))}{3960 \times .75 \text{ eff}}$
2. FCU fans	9.6 KW
	.5x100W per 1.70KW(½ ton) unit times 192 units
	8.4 KW
	.5x175W per 3.516KW(1 ton) unit times 96 units

Gas/Oil Boiler with FCU Control Sheet

1. Water flow rate constant

2. Cycle fans

System Description: GAS/OIL BOILER WITH CUH

System Output: Design KW output = DKWO
Design MBH = DMBH

Design Conditions:

1. Select Hot water temperature
2. 75 KPa (25') pressure drop
3. 11.1°C (20°F) Hot water temperature drop
4. (.0215 DKWO) 1/s ((.1 DMBH)gpm) Hot water flow rate

Component	Design KW Input
1. Circulating Pump	.0024 DKWO
	$\frac{(\frac{DMBH}{10})\ 25' \times .75KW/hp}{3960 \times .75\ eff\ \ .9\ eff}$
2. CUH fans	$\frac{CUH\ rated\ watts^* \times No.\ of\ CUH}{.5\ eff}$

* Use largest units available (≈.35KW) and select hot water temperature and no. of units to meet DMBH

Gas/Oil Boiler with CUH Control Sheet

1. Circulating Pump

   Water flow rate constant

2. CUH fans

   Fans constant on

System Description: GAS/OIL BOILER WITH AHU

System Output: Design KW output = DKWO
Design MBH = DMBH

Design Conditions:

1. Select hot water temperature
2. 75 KPa 25' potential drop
3. .3048 M/s (3 fps $\approx$ 55gpm/coil) water flow rate

Component	Design KW Input
1. Circulating pump	4.6 KW (55 gpm/coilx3 coil/unitx4 units) x 25' x .75 KW/hp ÷ (3960)x(.75 eff)x(.9 eff)
2. AHU fans	.0622 DKWO $\frac{\text{DTx400CFM/tonx2.5"}}{\text{6346 x .6 eff}} \times \frac{\text{.75 KW/hp}}{\text{.9 eff}}$

Gas/Oil Boiler with AHU Control Sheet

1. Water flow rate constant

2. Cycle fans

GLOSSARY OF HEATING, VENTILATING AND AIR CONDITIONING (HVAC) TERMS

Absorption Chiller: An absorption chiller is a heat (steam, hot water, or gas fired) driven machine for providing chiller water to a building. A relatively small amount of electric power for pumps and fans is needed while the major source of input power is thermal.

Air Handling Unit: A central air handling unit conditions the air and supplies either a mixture of outdoor and return air or 100 percent outdoor air to the room unit. The apparatus contains fan(s), filters to clean the air, preheat coils (if required) to temper cold winter air, and a dehumidifier to cool and remove excess moisture from warm humid air or to add winter humification.

Boiler Efficiency: This is the ratio of BTU output divided by BTU input. It includes allowance for stack, radiation, convection and other losses.

Boiler Horsepower: A boiler horsepower (BHP) is defined as the evaporation of 34.5 lb. of water per hour from a temperature of 212°F into dry saturated steam at the same temperature.

Boiler, Packaged: A boiler equipped and shipped complete with fuel burning equipment, mechanical draft equipment, automatic controls and accessories. Usually shipped in one or more major sections.

British Thermal Unit (BTU): The amount of energy required to raise one pound of water 1 degree Fahrenheit.

Centrifugal Chiller: A centrifugal refrigeration machine consists basically of a centrifugal compressor, a cooler and a condenser. It may be driven by an electric motor, steam turbine or internal combustion engine.

Cooling Tower: A device that cools water directly by evaporation.

Fan Coil Terminal Unit: This is a room type terminal unit of the factory-fabricated, cabinet style package with fan, filters, chilled water and hot water coils.

Fouling Factor: Fouling factors represent the thermal resistance to heat flow introduced by scale and other water impurities in a heat exchanger. Normally, manufacturers rate a water-cooled condenser for various values of water side fouling.

Heat Exchanger: A device specifically designed to transfer heat between two physically separated fluids.

Heat Pump: A refrigerating system designed to utilize alternately the heat extracted at a low temperature and the heat rejected at a higher temperature for cooling and heating functions respectively.

Split System: Unitary equipment, incorporating the following possible arrangements:

1. Air handling unit with coil and compressor and remote condenser.

2. Air handling unit with coil and remote condensing unit.

Ton of Refrigeration: A refrigerating unit equal to 3,516 watts (12,000 BTU/hr), the rate at which it is necessary to freeze water in order to produce a ton of ice in 24 hours. The size of refrigeration and air conditioning systems is usually indicated in terms of "tons".

Two Pipe/Four-Pipe Systems: A two-pipe system contains a single piping system used to circulate chilled or hot water to a single air handling unit coil. A four-pipe system completely isolates the chilled and hot water systems so that the piping for each system may be designed independently.

Unitary Equipment: A unitary air conditioning unit, sometimes referred to as packaged equipment, consists of one or more factory-fabricated assemblies designed to provide the functions of air moving, air cleaning, cooling and dehumidification. The functions of heating and humidifying are also usually possible with such equipment. Unitary equipment includes a direct expansion cooling coil and a compressor condenser combination in addition to fans, auxiliaries and internal wiring and piping.

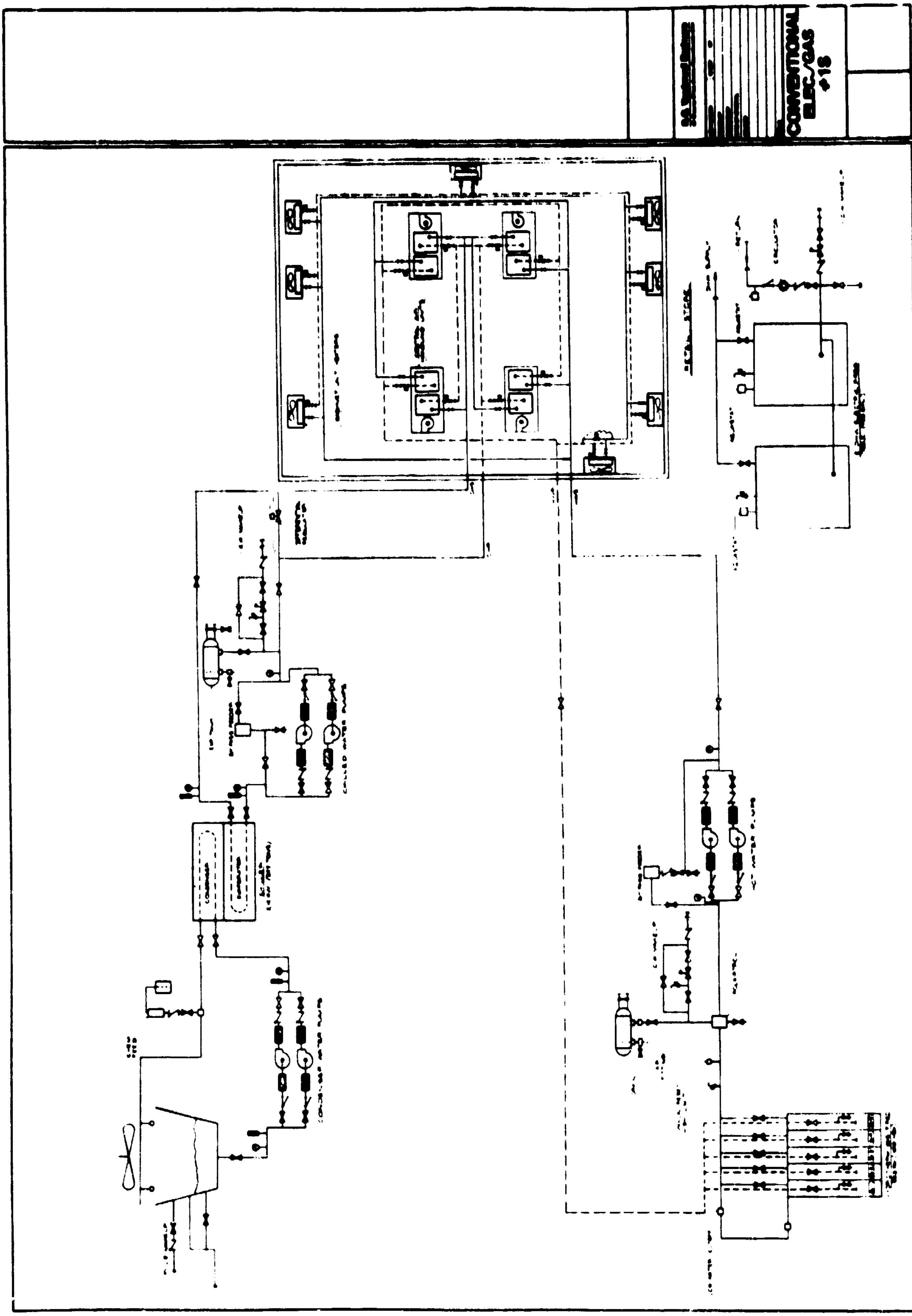
Unit Heater: The term unit heater denotes an assembly of elements, the principal function of which is to heat a space. The essential elements are a fan and motor, a heating element, an an enclosure. Filters, dampers, directional outlets, duct collars, combustion chambers, and flues may also be included.

VENDOR NAMES

1.	Centrifugal Chillers	-	Trane Centravac DS CTV1 Carrier York Turbopak
2.	Reciprocating Chillers	-	Trane Carrier York
3.	Absorption Chillers	-	Trane Absorption Cold Generator Arkla York Absorption Liquid Chillers Model ES Carrier Hemetic Absorption Liquid Chillers
4.	Hot Water Packaged Boilers	-	Hydrotherm - Mult-Temp Burnham Kewanee
5.	Cooling Towers	-	Baltimore Air Coil Engineering Manual
6.	Fan Coil Units	-	Trane Fan-Coil Unitrane
7.	Cabinet Unit Heaters	-	Trane
8.	Water - Water Heat Pump	-	Templifier
9.	Air Handling Units	-	Trane Catalog Aerofin Catalog

2. INTEGRATED FUEL CELL SYSTEMS DIAGRAMS

The following pages illustrate the final baseline system diagrams for the system identified in Tables 19 and 20 of Volume I and follow the System Master List convention code.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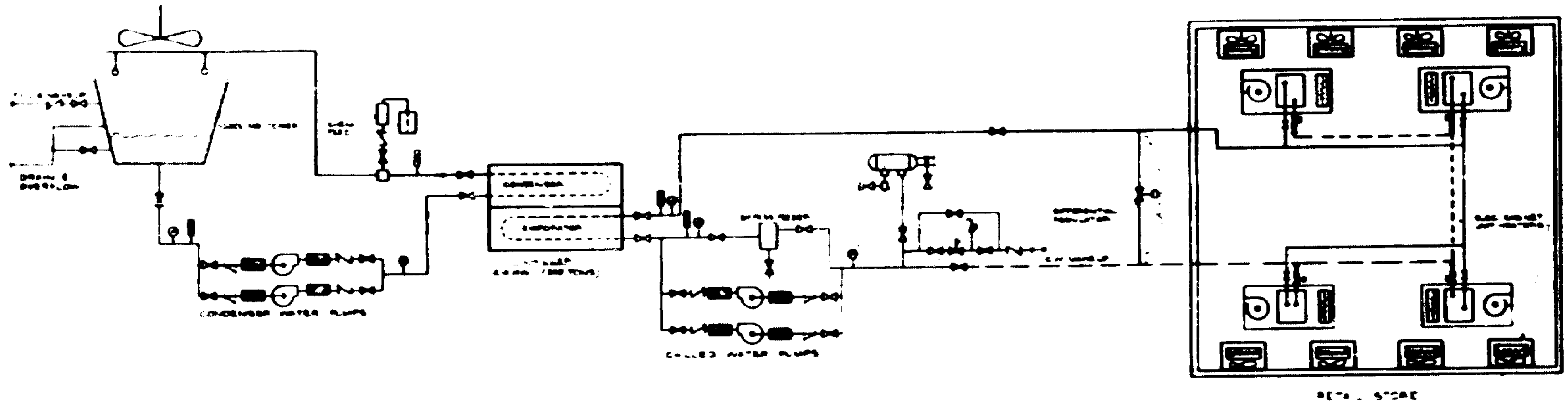

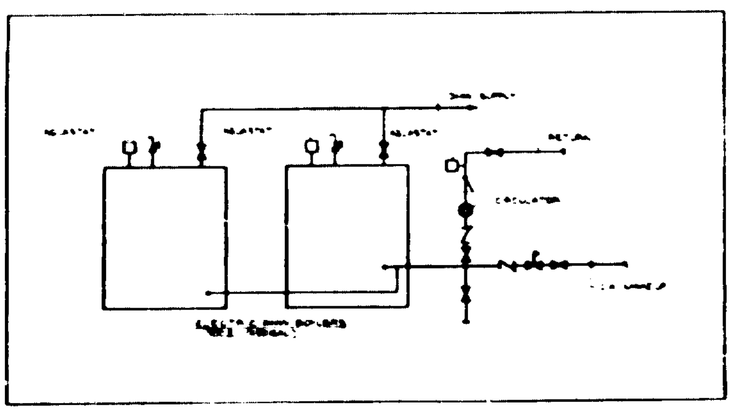

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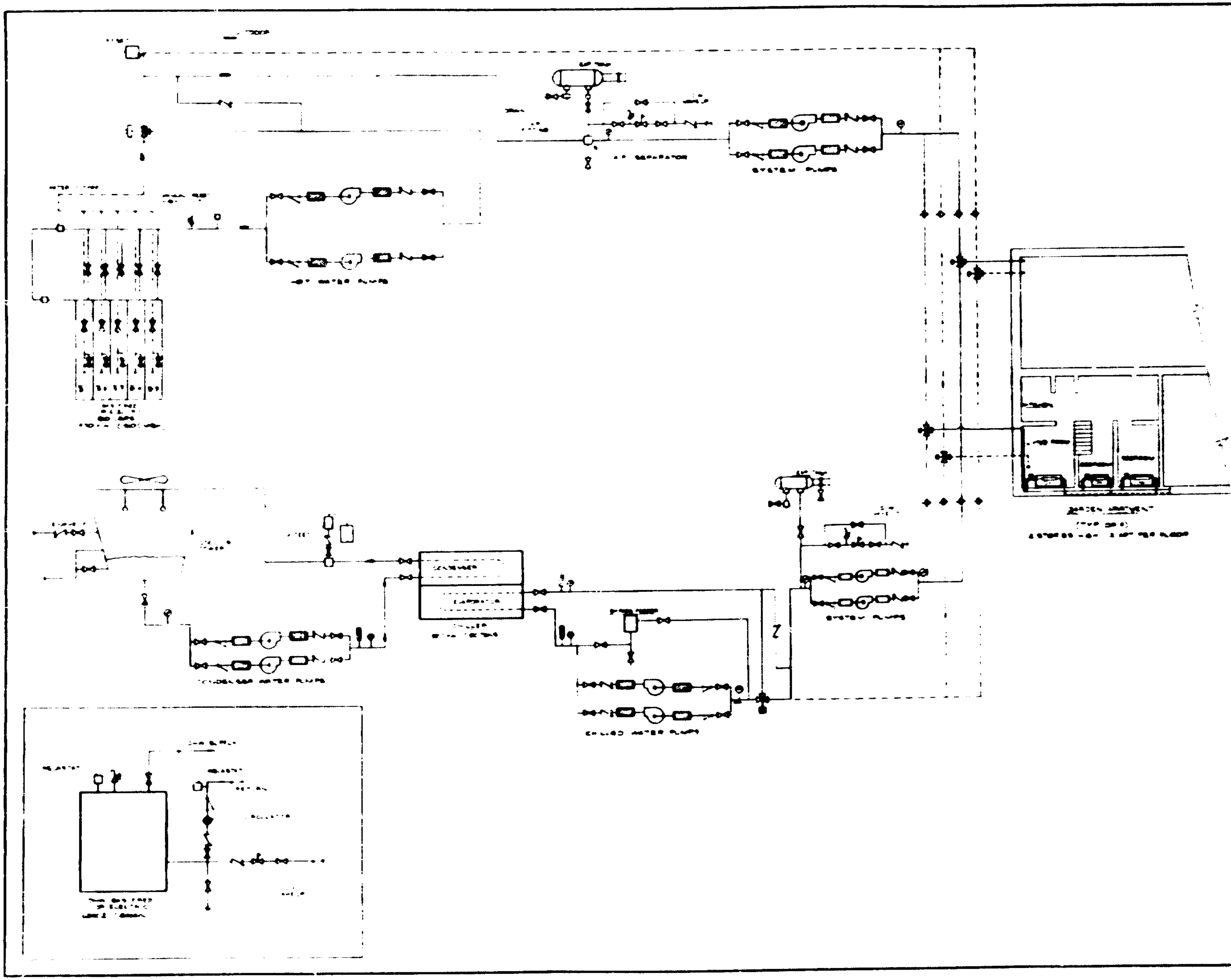

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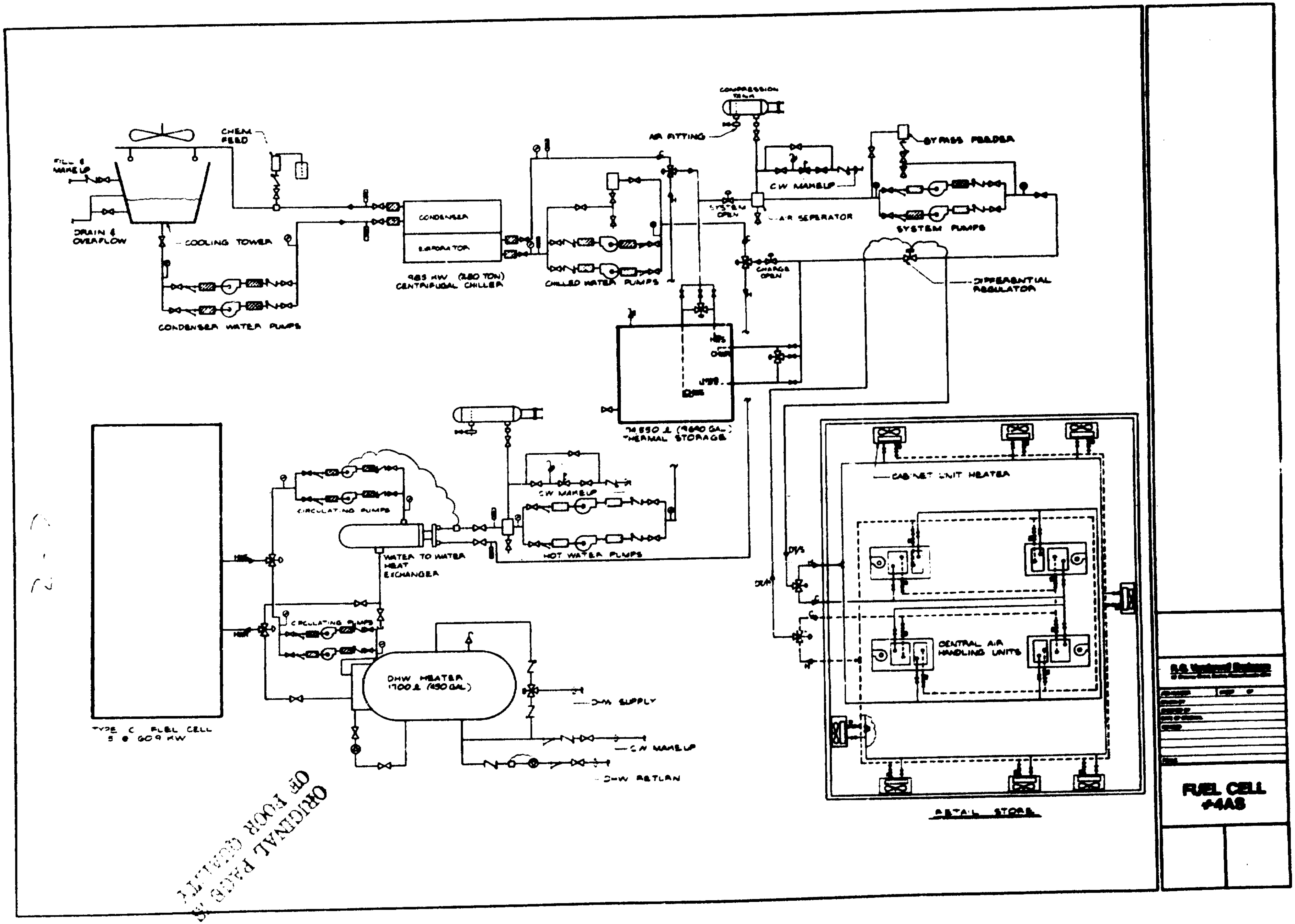
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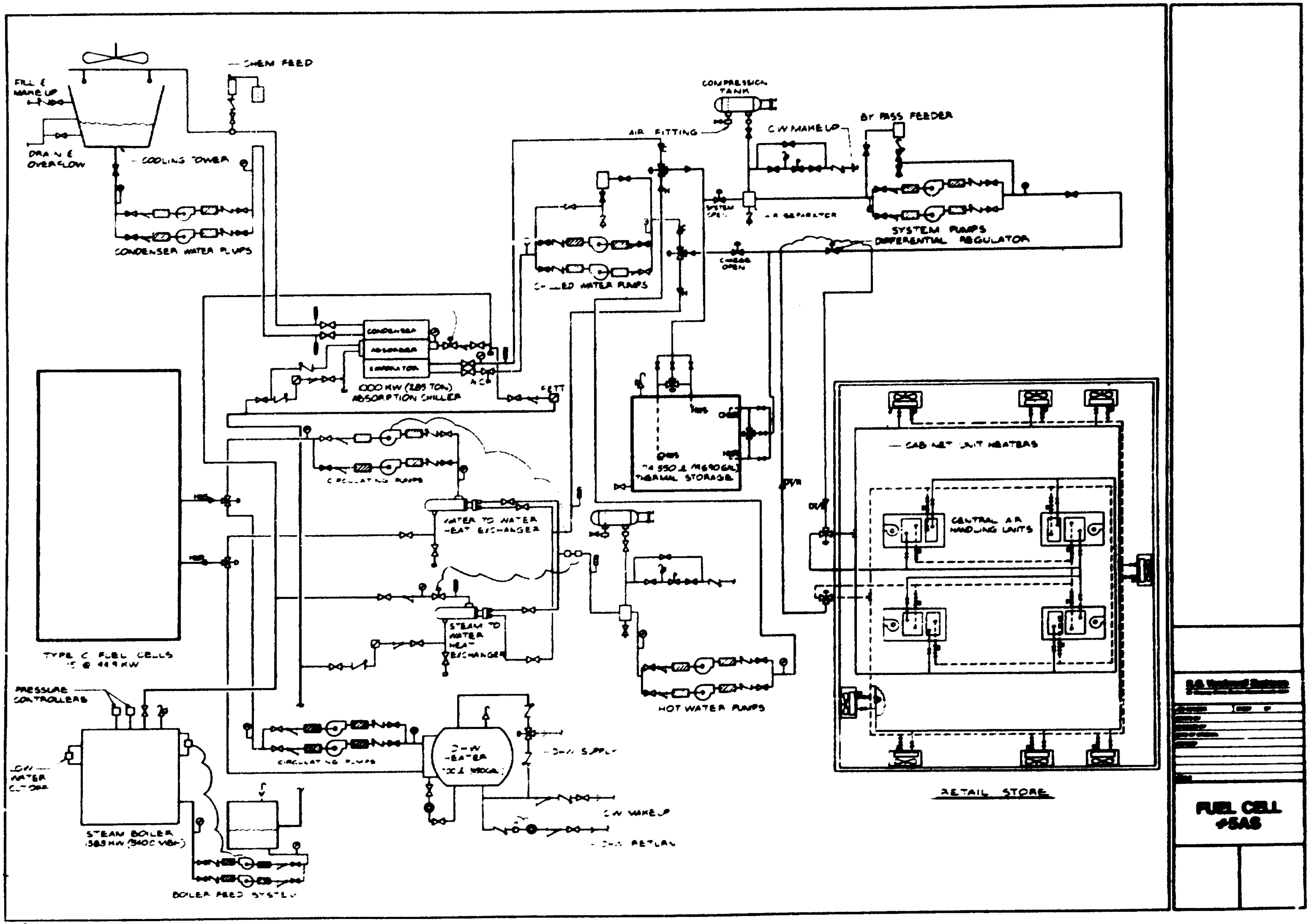
FILL & MAKEUP
DRAIN & OVERFLOW
COOLING TOWER
CONDENSER WATER PUMPS
CONDENSER
EVAPORATOR
985 KW (280 TON) CENTRIFUGAL CHILLER
CHILLED WATER PUMPS
AIR FITTING
COMPRESSION TANK
SYSTEM OPEN
AIR SEPERATOR
C/W MAKEUP
BYPASS FEEDER
SYSTEM PUMPS
CHARGE OPEN
DIFFERENTIAL REGULATOR
THERMAL STORAGE
CIRCULATING PUMPS
WATER TO WATER HEAT EXCHANGER
HOT WATER PUMPS
DHW HEATER 1700 ℓ (450 GAL)
DHW SUPPLY
C/W MAKEUP
DHW RETURN
TYPE C FUEL CELL
CABINET UNIT HEATER
CENTRAL AIR HANDLING UNITS
RETAIL STORE
FUEL CELL #4AS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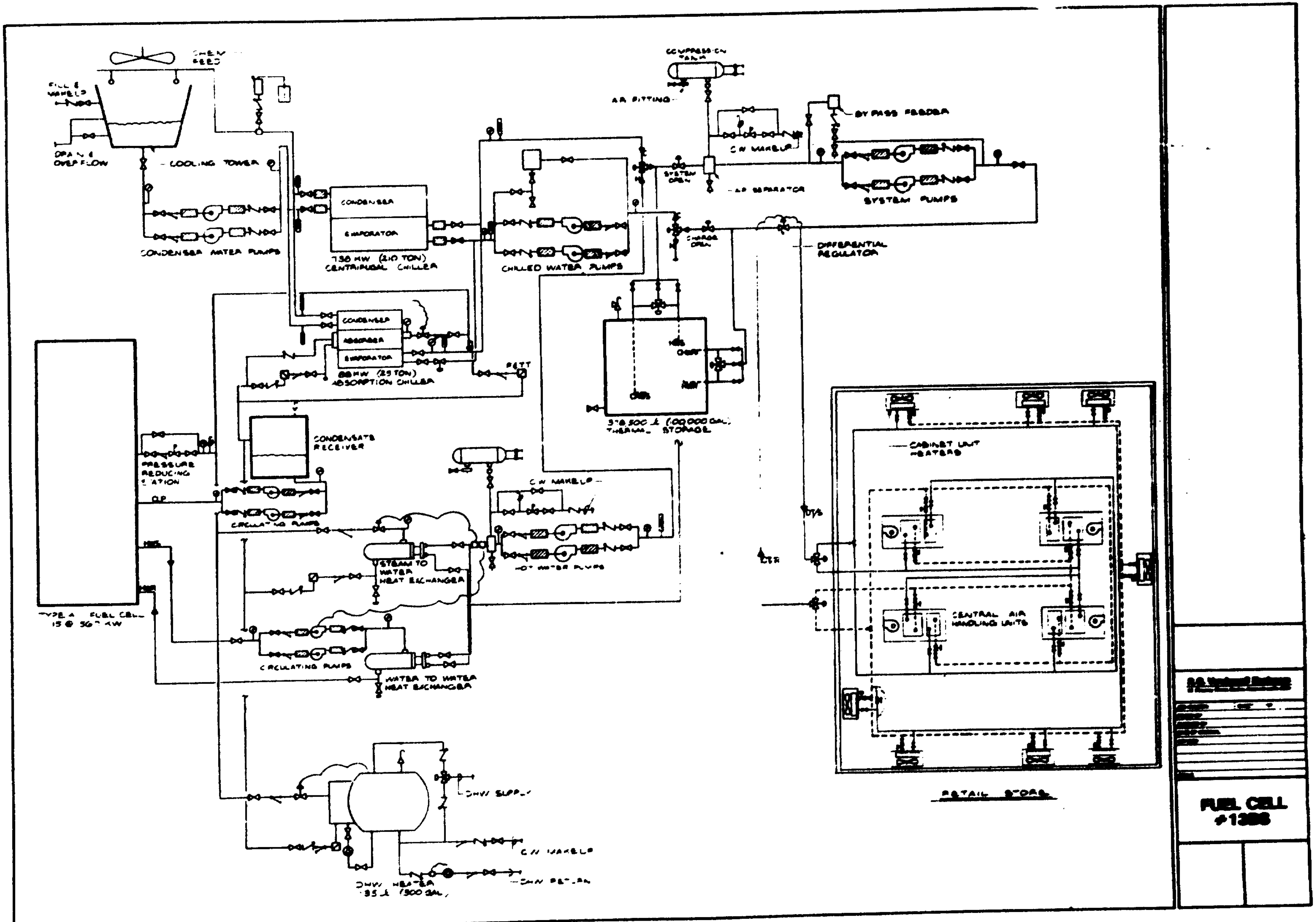
DRAIN & OVERFLOW
COOLING TOWER
CONDENSER WATER PUMPS
COMPRESSION TANK
AIR FITTING
C.W. MAKE UP
BY PASS FEEDER
SYSTEM PUMPS
DIFFERENTIAL REGULATOR
CHILLED WATER PUMPS
1000 KW (285 TON) ABSORPTION CHILLER
CIRCULATING PUMPS
WATER TO WATER HEAT EXCHANGER
STEAM TO WATER HEAT EXCHANGER
THERMAL STORAGE
HOT WATER PUMPS
TYPE C FUEL CELLS
PRESSURE CONTROLLERS
LOW WATER CUTOFF
STEAM BOILER
BOILER FEED SYSTEM
C.W. MAKE UP
CABINET UNIT HEATERS
CENTRAL AIR HANDLING UNITS
RETAIL STORE
FUEL CELL #5AS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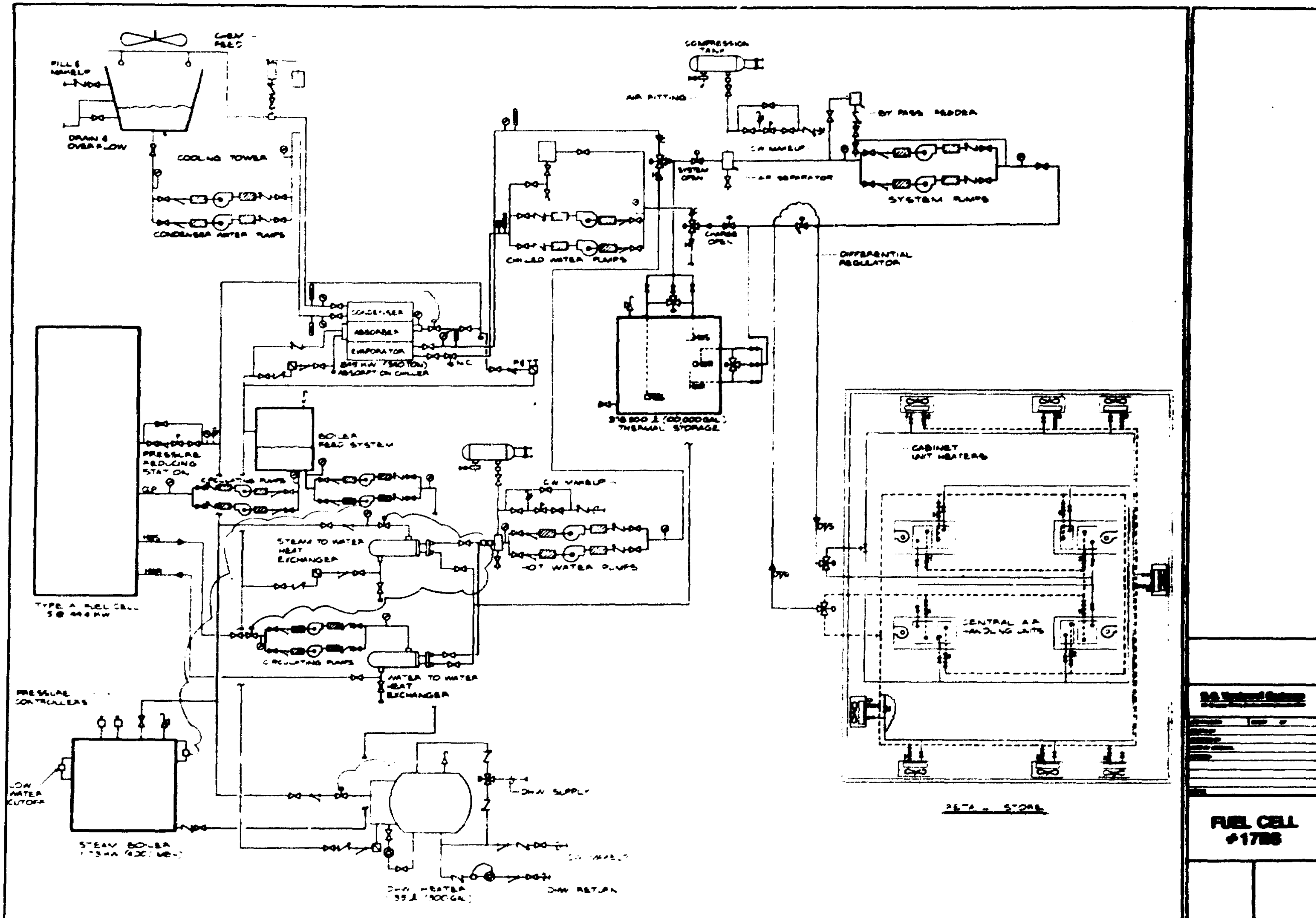
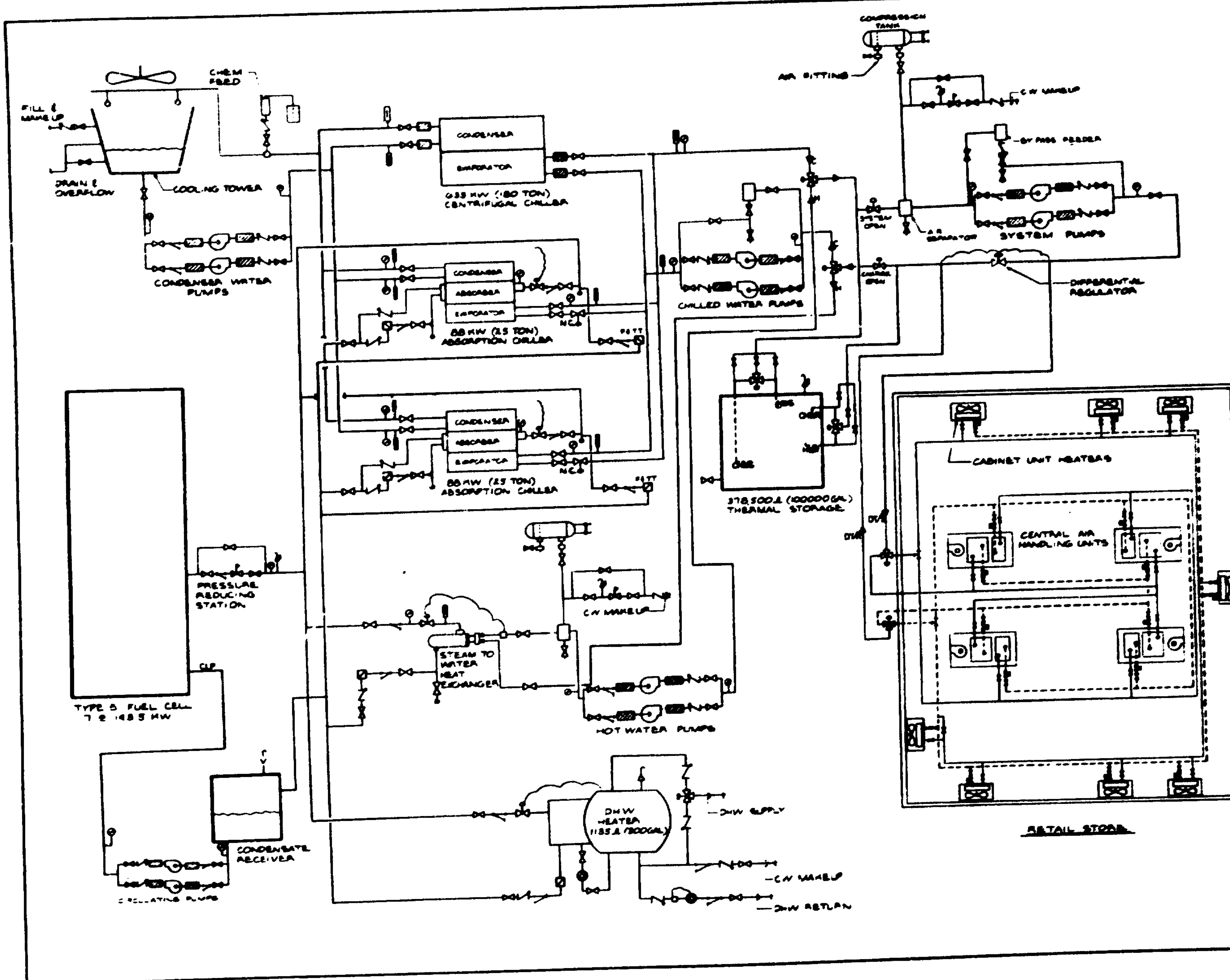
FILL & MAKEUP
DRAIN & OVERFLOW
COOLING TOWER
CONDENSER WATER PUMPS
CONDENSER
EVAPORATOR
738 KW (210 TON) CENTRIFUGAL CHILLER
CHILLED WATER PUMPS
COMPRESSION TANK
AIR FITTING
SYSTEM DRAIN
AIR SEPARATOR
C.W. MAKEUP
BY PASS FEEDER
SYSTEM PUMPS
CHARGE DRAIN
DIFFERENTIAL REGULATOR
CONDENSER
ABSORBER
EVAPORATOR
88 KW (25 TON) ABSORPTION CHILLER
PETT
378,500 L (100,000 GAL) THERMAL STORAGE
CONDENSATE RECEIVER
PRESSURE REDUCING STATION
TYPE A FUEL CELL 15 @ 56 KW
CIRCULATING PUMPS
STEAM TO WATER HEAT EXCHANGER
C.W. MAKEUP
HOT WATER PUMPS
CIRCULATING PUMPS
WATER TO WATER HEAT EXCHANGER
DHW SUPPLY
C.W. MAKEUP
DHW RETURN
DHW HEATER 1135 L (300 GAL)
CABINET UNIT HEATERS
CENTRAL AIR HANDLING UNITS
RETAIL STORE
FUEL CELL #1388


COOLING TOWER
DRAIN & OVERFLOW
CONDENSER WATER PUMPS
COMPRESSION TANK
AIR FITTING
BY PASS FEEDER
SYSTEM PUMPS
CHILLED WATER PUMPS
DIFFERENTIAL REGULATOR
CONDENSER
ABSORBER
EVAPORATOR
ABSORPTION CHILLER
THERMAL STORAGE
BOILER FEED SYSTEM
PRESSURE REDUCING STATION
CIRCULATING PUMPS
STEAM TO WATER HEAT EXCHANGER
HOT WATER PUMPS
WATER TO WATER HEAT EXCHANGER
TYPE A FUEL CELL
PRESSURE CONTROLLERS
LOW WATER CUTOFF
STEAM BOILER
DHW HEATER
DHW SUPPLY
DHW RETURN
CABINET UNIT HEATERS
CENTRAL AIR HANDLING UNITS
FUEL CELL



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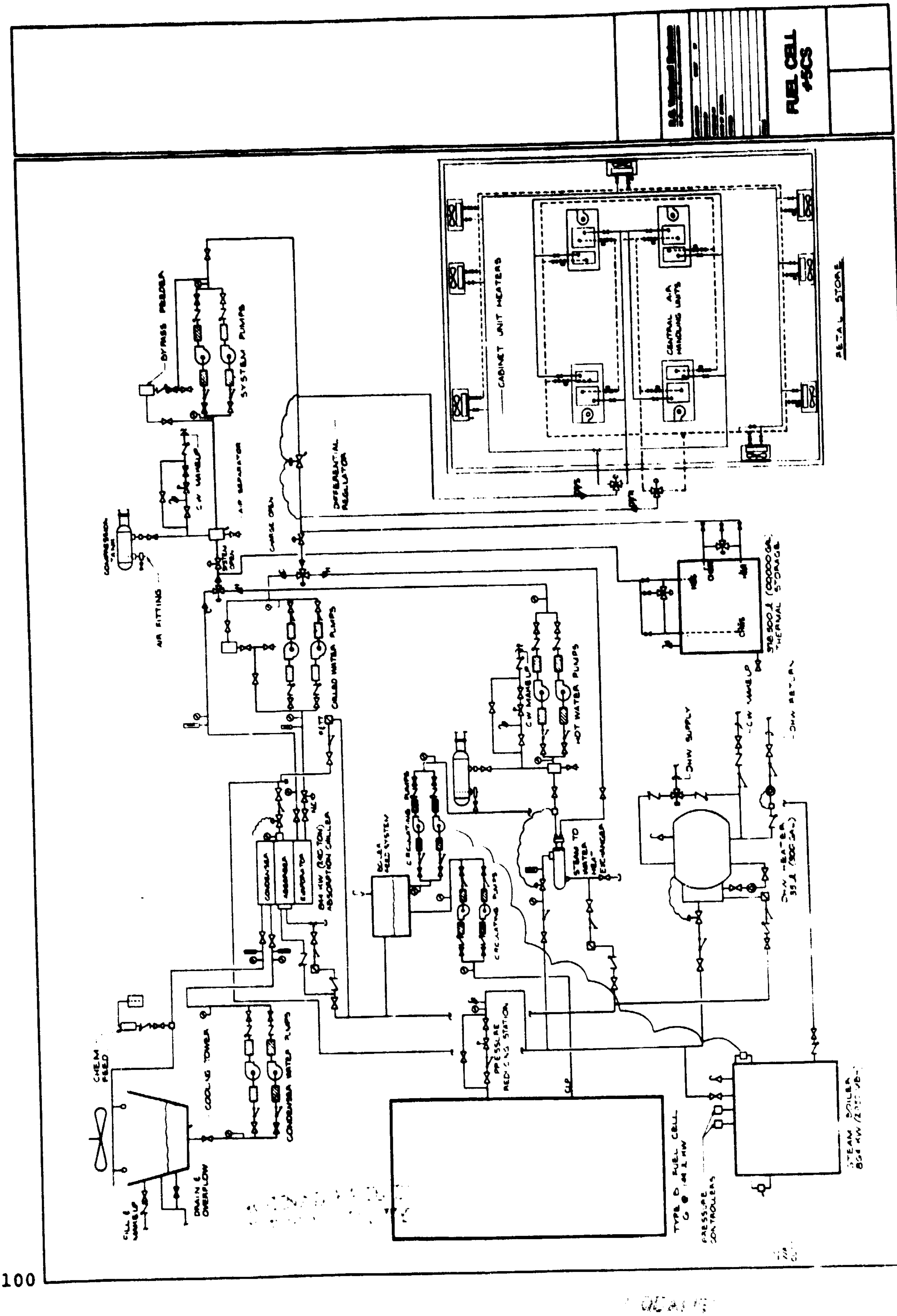
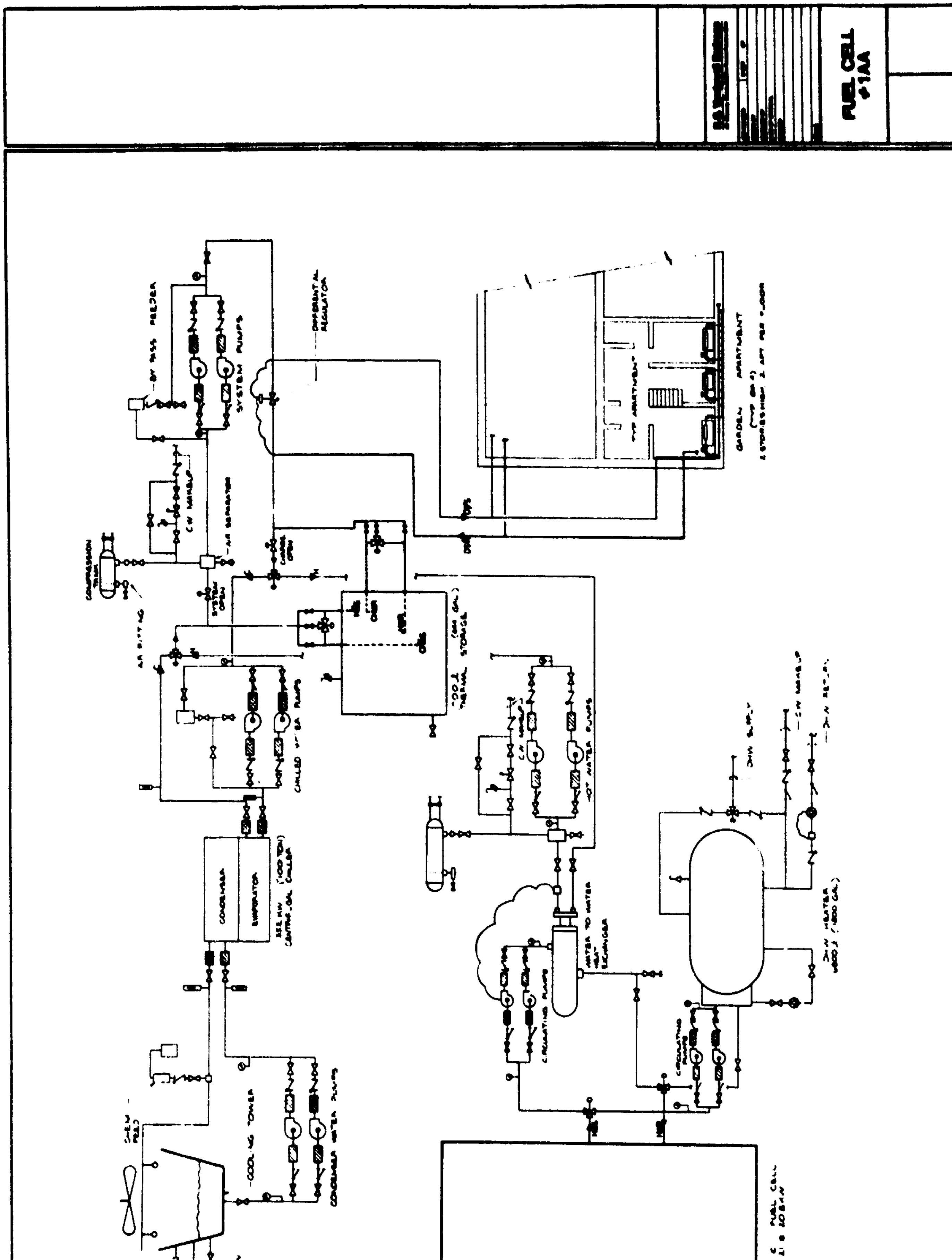

FUEL CELL
COOLING TOWER
CHEM FEED
FILL & MAKEUP
DRAIN & OVERFLOW
CONDENSER WATER PUMPS
PRESSURE REDUCING STATION
CONDENSER
ABSORBER
EVAPORATOR
ABSORPTION CHILLER
CIRCULATING PUMPS
CHILLED WATER PUMPS
HOT WATER PUMPS
CW MAKEUP
DHW SUPPLY
DHW HEATER
STEAM BOILER
PRESSURE CONTROLLERS
THERMAL STORAGE
AIR FITTING
COMPRESSION TANK
AIR SEPARATOR
SYSTEM PUMPS
BYPASS FEEDER
DIFFERENTIAL REGULATOR
CABINET UNIT HEATERS
CENTRAL AIR HANDLING UNITS
RETAIL STORE


FUEL CELL
#1AA
COOLING TOWER
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EVAPORATOR
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SYSTEM PUMPS
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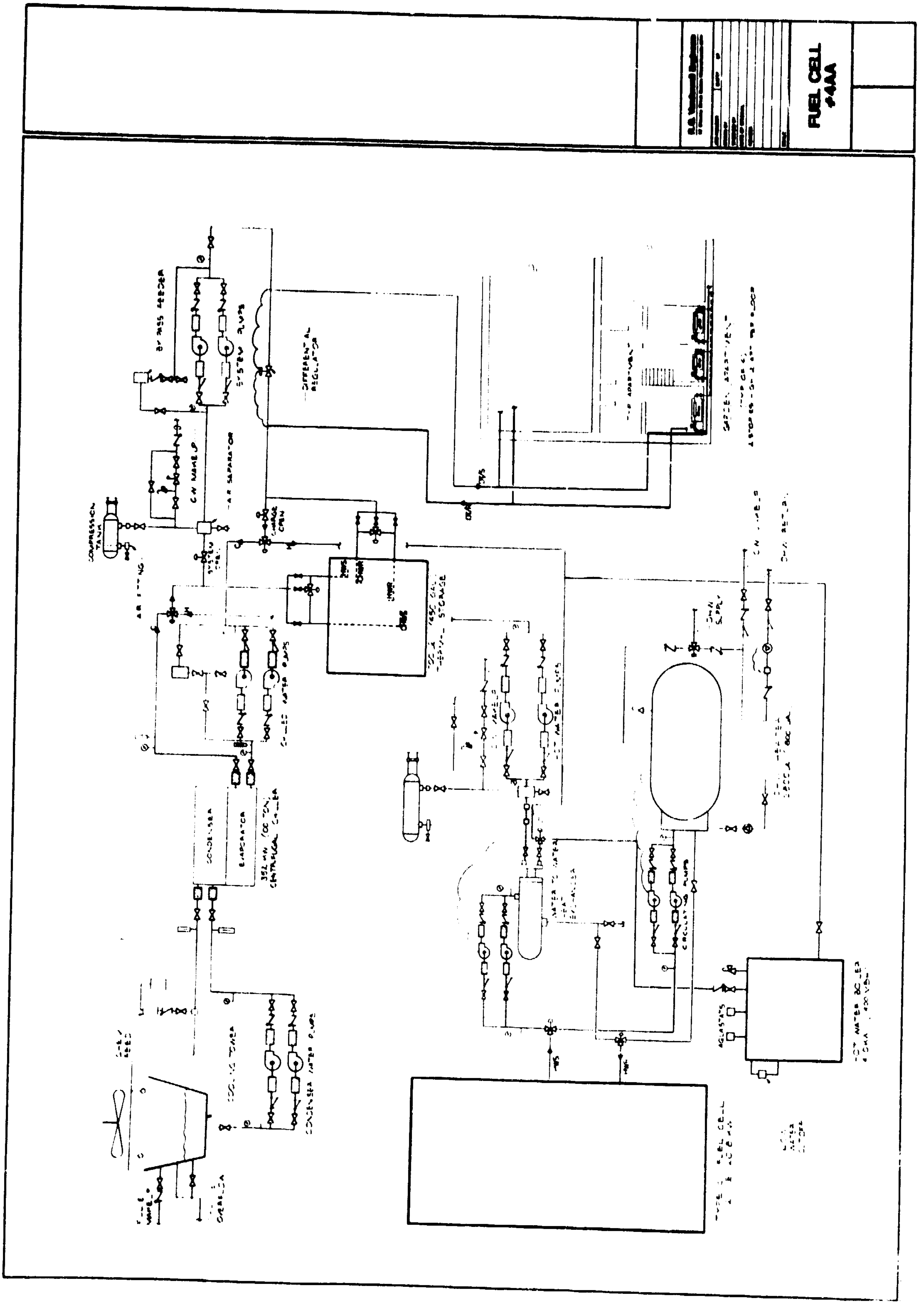
COMPRESSION TANK
GARDEN APARTMENT
CIRCULATING PUMPS
WATER TO WATER HEAT EXCHANGER
TYPE C FUEL CELL


FUEL CELL
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COMPRESSION TANK
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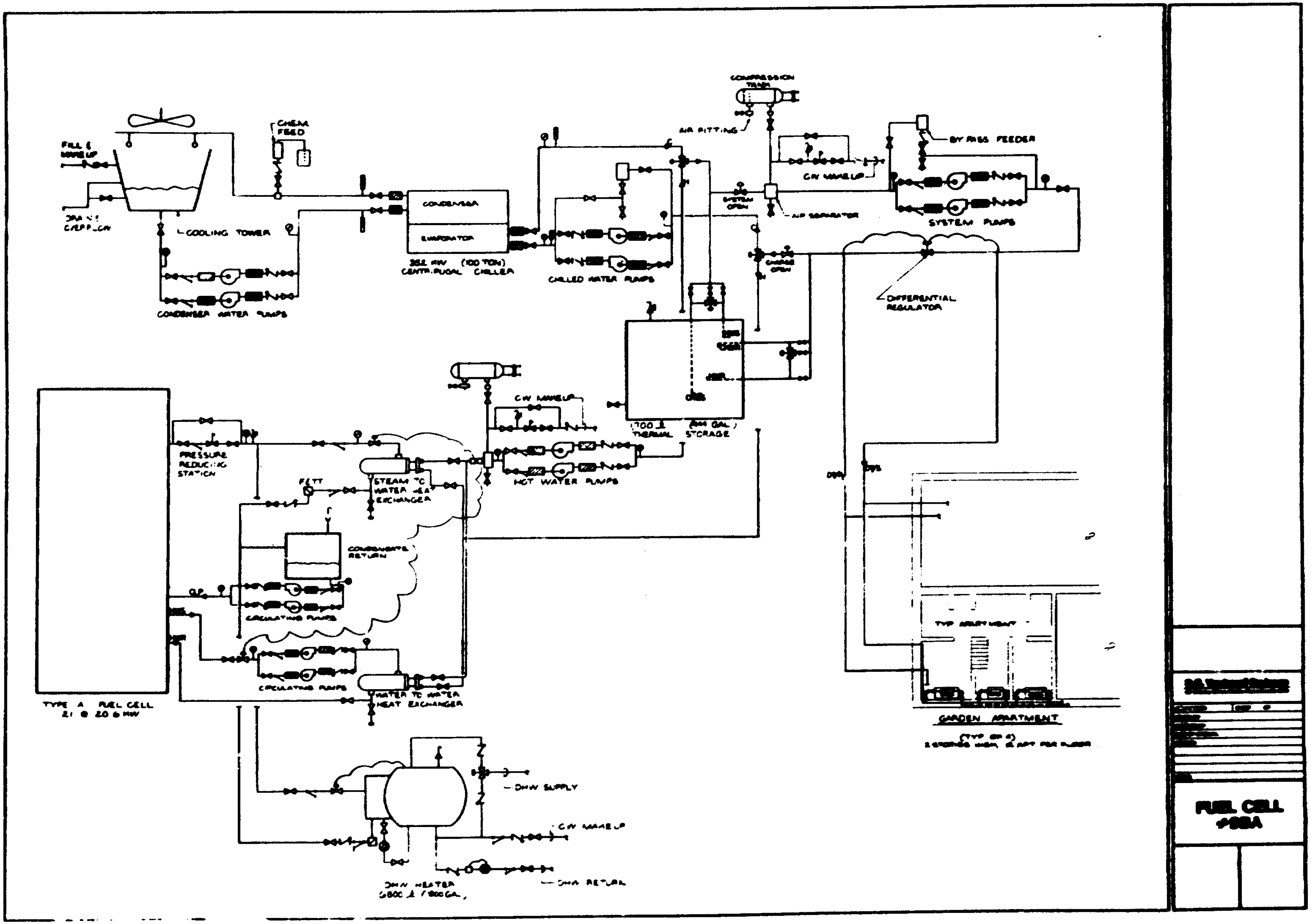
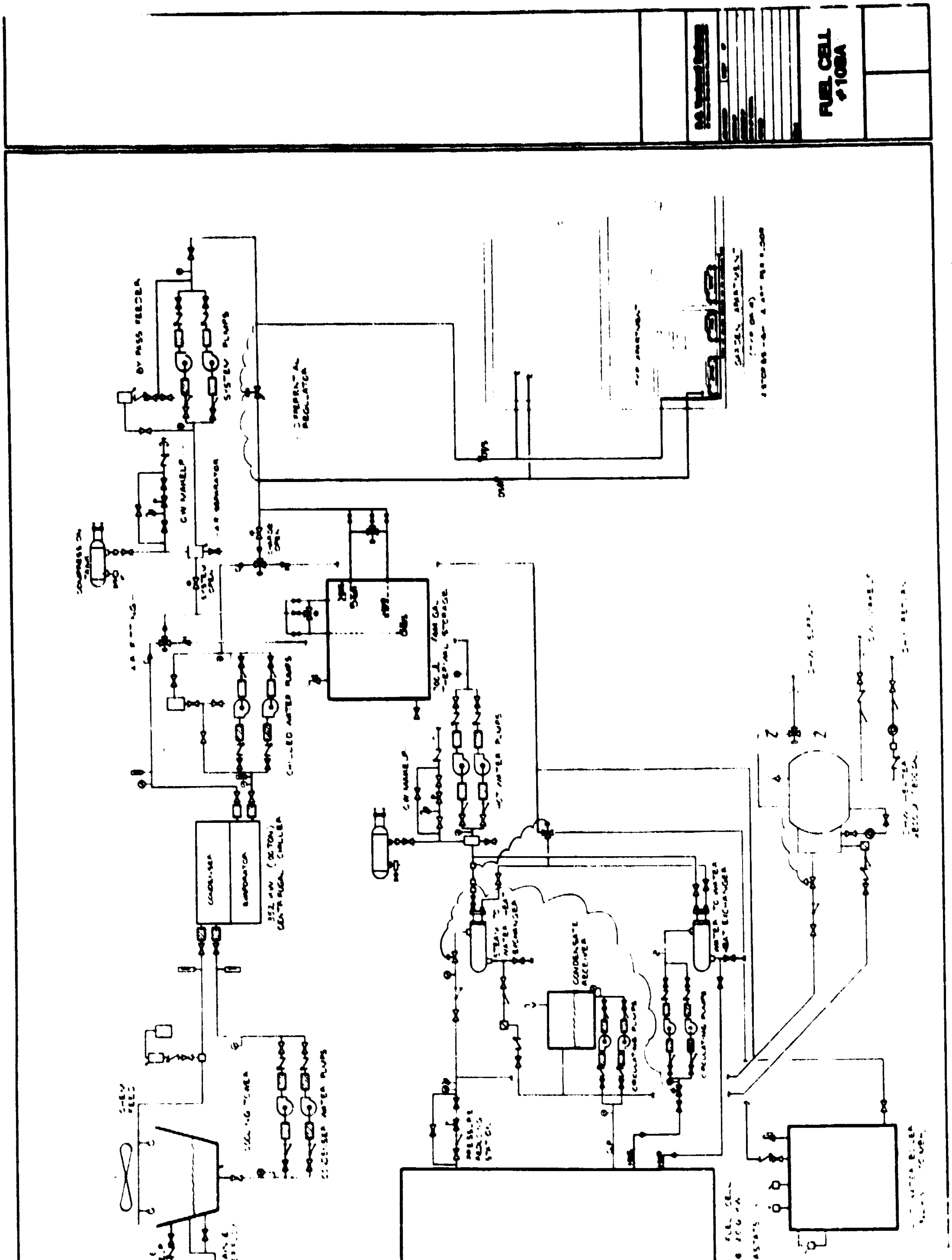
AQUASTATS



FILL & MAKEUP
COOLING TOWER
CONDENSER WATER PUMPS
CHEM FEED
CONDENSER
EVAPORATOR
CENTRIFUGAL CHILLER
CHILLED WATER PUMPS
COMPRESSION TANK
AIR FITTING
SYSTEM OPEN
AIR SEPARATOR
CW MAKEUP
BY PASS FEEDER
SYSTEM PUMPS
CHARGE OPEN
DIFFERENTIAL REGULATOR
THERMAL STORAGE
CW MAKEUP
HOT WATER PUMPS
PRESSURE REDUCING STATION
STEAM TO WATER HEAT EXCHANGER
CONDENSATE RETURN
CIRCULATING PUMPS
CIRCULATING PUMPS
WATER TO WATER HEAT EXCHANGER
TYPE A FUEL CELL
DHW SUPPLY
CW MAKEUP
DHW RETURN
DHW HEATER
TYP APARTMENT
GARDEN APARTMENT
FUEL CELL


FUEL CELL
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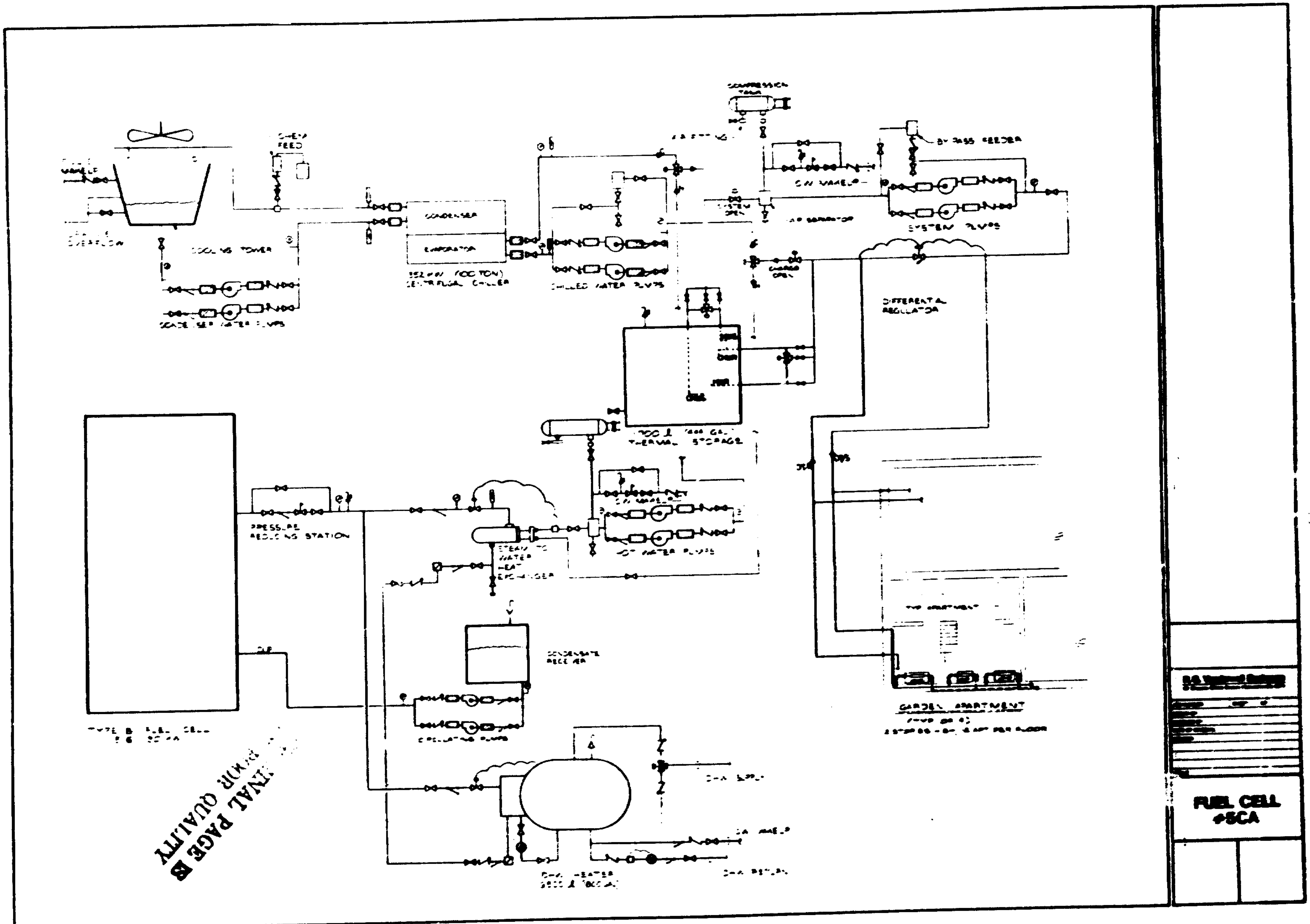
COOLING TOWER
CHEM FEED
CONDENSER
EVAPORATOR
CENTRIFUGAL CHILLER
CONDENSER WATER PUMPS
CHILLED WATER PUMPS
COMPRESSION TANK
BY PASS FEEDER
C.W. MAKEUP
AIR SEPARATOR
SYSTEM PUMPS
DIFFERENTIAL REGULATOR
THERMAL STORAGE
PRESSURE REDUCING STATION
STEAM TO WATER HEAT EXCHANGER
HOT WATER PUMPS
CONDENSATE RECEIVER
CIRCULATING PUMPS
DHW SUPPLY
DHW RETURN
DHW HEATER
GARDEN APARTMENT
TYPE B FUEL CELL
FUEL CELL #SCA
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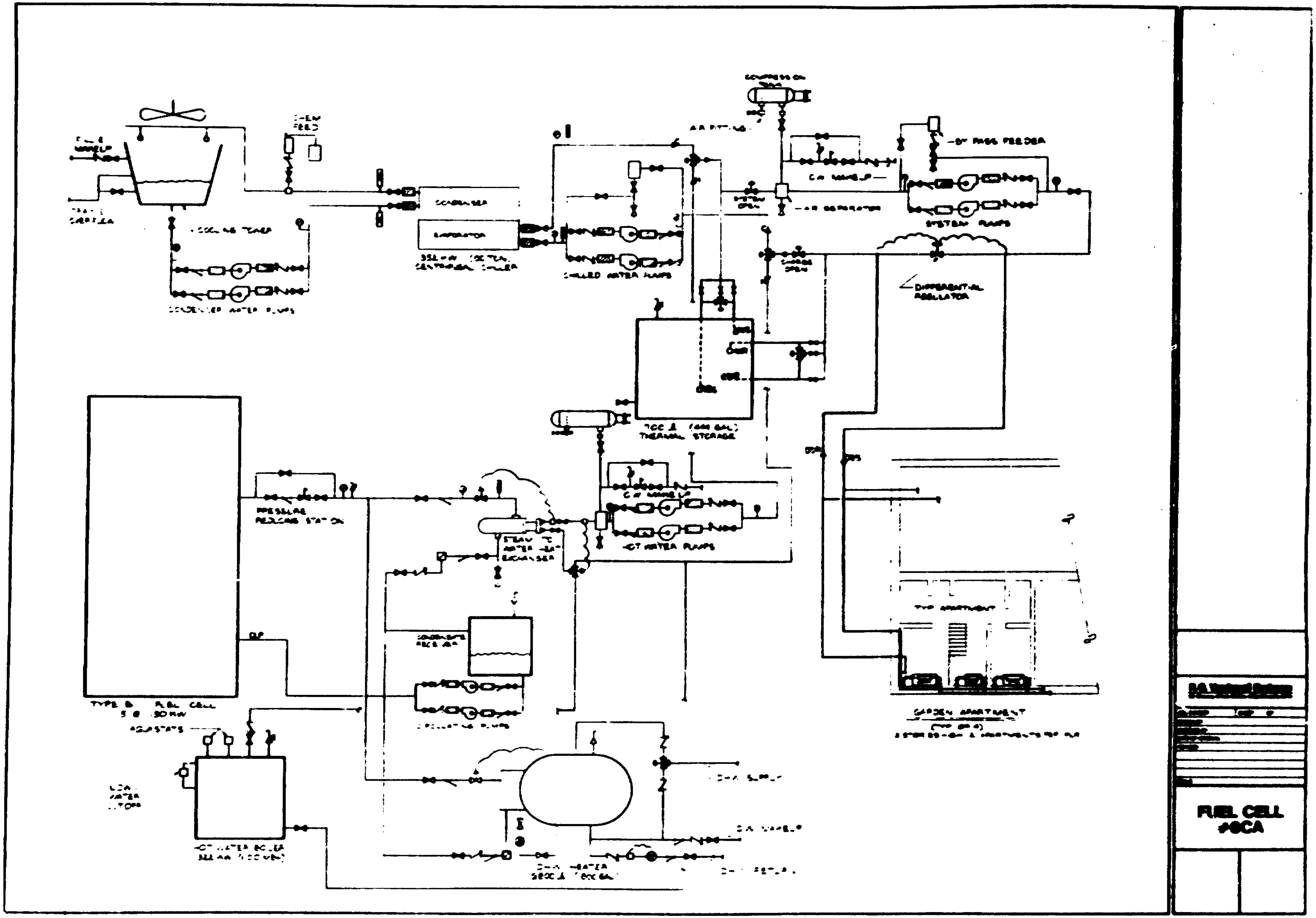

COOLING TOWER
CONDENSER WATER PUMPS
CHEM FEED
CONDENSER
EVAPORATOR
CHILLED WATER PUMPS
AIR FITTING
C.W. MAKE-UP
AIR SEPARATOR
BY PASS FEEDER
SYSTEM PUMPS
DIFFERENTIAL REGULATOR
THERMAL STORAGE
PRESSURE REDUCING STATION
HOT WATER PUMPS
CONDENSATE RECEIVER
CIRCULATING PUMPS
AQUASTATS
HOT WATER BOILER
TYP. APARTMENT
GARDEN APARTMENT
FUEL CELL #6CA

3. COMPUTER ANALYSIS OF SYSTEMS

All systems analyzed in this project are summarized on the following Master List of Tables. This list is repeated in Section 4 of Volume I for completeness. The first set of tables provides the component size and brief description for the key components of each system. Each system is assigned a system number or computer run number and these are used throughout the report.

The second set of data summarizes the performance and cost results of the analysis. All costs are in 1978 dollars.

TABLE 4A

FUEL CELL A APARTMENT

RUN	FUEL CELL		BOILER	CHILLER		THERMAL STORAGE			NOTES
	NUMBER	MODULE SIZE KW	KW	ABSORPTION KW	ELECTRIC KW	DISCHARGE DUR.HRS.	LITERS	DOMESTIC HOT WATR. LITERS	
1AA	21	20.8	0	0	351	1	1680	6814	
2AA	21	20.8	0	0	351	2	2404	6814	
3AA	21	20.8	0	0	351	0	0	6814	
4AA	21	20.8	410	0	351	1	1680	6814	
5AA	21	20.8	0	88	351	1	1680	6814	6
6AA	21	20.8	410	0	351	1	1680	6814	2
7AA	14	28.0	586	316	351	1	1680	6814	2
8AA-1000	13	20.2	410	0	351	1	1680	6814	2, 3
8AA-500	18	20.4	410	0	351	1	1680	6814	2, 4
9AA	14	28.1	527	316	351	1	1680	6814	5

1 - Water to Water Heat Exchanger Used Throughout - 8098 Watts/°C
2 - High Efficiency Modulated Boiler
3 - Battery Storage 1000 KWH
4 - Battery Storage 500 KWH
5 - The Absorption Chiller Attempts to Limit the Fuel Cell to 200KW
6 - Water-fired Absorption Unit

3. COMPUTER ANALYSIS OF SYSTEMS

All systems analyzed in this project are summarized on the following Master List of Tables. This list is repeated in Section 4 of Volume I for completeness. The first set of tables provides the component size and brief description for the key components of each system. Each system is assigned a system number or computer run number and these are used throughout the report.

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TABLE 4A

FUEL CELL A APARTMENT

RUN	FUEL CELL		BOILER	CHILLER		THERMAL STORAGE			NOTES
	NUMBER	MODULE SIZE KW	KW	ABSORP-TION KW	ELECTRIC KW	DIS-CHARGE DUR.HRS.	LITERS	DOMESTIC HOT WATR. LITERS	
1AA	21	20.8	0	0	351	1	1680	6814	
2AA	21	20.8	0	0	351	2	2404	6814	
3AA	21	20.8	0	0	351	0	0	6814	
4AA	21	20.8	410	0	351	1	1680	6814	
5AA	21	20.8	0	88	351	1	1680	6814	6
6AA	21	20.8	410	0	351	1	1680	6814	2
7AA	14	28.0	586	316	351	1	1680	6814	2
8AA-1000	13	20.2	410	0	351	1	1680	6814	2, 3
8AA-500	18	20.4	410	0	351	1	1680	6814	2, 4
9AA	14	28.1	527	316	351	1	1680	6814	5

1 - Water to Water Heat Exchanger Used Throughout - 8098 Watts/°C
2 - High Efficiency Modulated Boiler
3 - Battery Storage 1000 KWH
4 - Battery Storage 500 KWH
5 - The Absorption Chiller Attempts to Limit the Fuel Cell to 200KW
6 - Water-fired Absorption Unit

TABLE 4B

MASTER SYSTEM LIST

FUEL CELL B - APARTMENT

RUN	FUEL CELL		BOILER	CHILLER		THERMAL STORAGE			NOTES
	NUMBER	MODULE SIZE KW	KW	ABSORPTION KW	ELECTRIC KW	DISCHARGE DUR. HRS.	LITERS	DOMESTIC HOT WATR. LITERS	
1BA	14	31.1	0	1-88	351	1	1,680	6814	1,2,3
2BA	14	31.1	0	1-88	351	2	2,404	6814	1,2,3
3BA	15	28.7	0	1-88	351	4	10,390	6814	1,2,3
4BA	17	25.5	0	1-88	351	8	36,560	6814	1,2,3
5BA	18	25.9	0	1-88	351	12	63,080	6814	1,2,3
6BA	18	24.4	0	0	351	0	0	6814	1,2,3
7BA	14	31.1	0	1-88	351	0	0	6814	1,2,3
8BA	18	24.4	0	0	351	1	1,680	6814	1,2,3
9BA	21	20.5	0	0	351	1	1,680	6814	1,3
10BA	21	20.5	322	0	351	1	1,680	6814	1,3
11BA	21	20.8	0	175	316	1	1,680	6814	1,3
12BA	21	20.5	0	0	351	1	1,680	13630	1,12
13BA	21	20.5	322	0	351	1	1,680	6814	1,3,9
14BA-8000	17	22.8	0	0	351	1	1,680	6814	1,3,4
14BA-4000	20	20.0	0	0	351	1	1,680	6814	1,3,5
14BA-2000	21	20.6	0	0	351	1	1,680	6814	1,3,6
14BA-1000	16	21.3	0	0	351	1	1,680	6814	1,3,7
14BA-500	18	20.4	0	0	351	1	1,680	6814	1,3,8
15BA	14	28.0	527	351	351	1	1,680	6814	1,3
16BA-1000	13	20.0	322	0	351	1	1,680	6814	1,3,10
16BA-500	18	20.4	322	0	351	1	1,680	6814	1,3,11

1 - A 7832 Watts/°C steam to water heat exchanger
2 - A 8097 Watts/°C water to water heat exchanger
3 - A 8182 liter hot water storage tank
4 - 8000 KWH battery limiting the load to 250 KW
5 - 4000 KWH battery limiting the load to 150KW
6 - 2000 KWH battery limiting the load to 150KW
7 - 1000 KWH battery limiting the load to 200KW
8 - 500 KWH battery limiting the load to 200 KW
9 - High efficiency modulating boiler trying to limit the load to 200KW
10 - 1000 KWH battery limiting the load to 200 KW
11 - 500 KWH battery limiting the load to 200 KW
12 - A 16365 liter hot water storage tank

TABLE 4C

FUEL CELL C - APARTMENT

RUN	FUEL CELL		BOILER	CHILLER		THERMAL STORAGE			NOTES
	NUMBER	MODULE SIZE KW	KW	ABSORPTION KW	ELECTRIC KW	DISCHARGE DUR.HRS.	LITERS	DOMESTIC HOT WATR. LITERS	
1CA	5	128.0	0	1-88	351	2	2,404	6814	1
2CA	5	128.0	0	1-88	351	4	10,390	6814	1
3CA	5	128.0	0	1-88	351	1	1,680	6814	1
4CA	5	128.0	0	1-88	351	0	0	6814	1
5CA	5	130.0	0	0	351	1	1,680	6814	1
6CA	5	130.0	322	0	351	1	1,680	6814	1
7CA	5	118.1	0	1-176	228	1	1,680	6814	1
8CA	5	130.1	322	0	351	1	1,680	6814	1, 2
9CA	5	110.8	439	316	264	1	1,680	6814	1, 2

1 - A steam to water heat exchanger 7832 watt/°C is used.

2 - High efficiency modulating boiler.

TABLE 4D

RETAIL STORE

RUN	FUEL CELL		BOILER	CHILLER		THERMAL STORAGE			NOTES
	NUMBER	MODULE SIZE KW	KW	ABSORPTION KW	ELECTRIC KW	DISCHARGE DUR.HRS.	LITERS	DOMESTIC HOT WATR. LITERS	
1AS	15	61.48	0	0	984	8	143,800	1700	1
2AS	15	56.71	0	0	984	13	450,460	1700	1
3AS	15	56.95	0	0	773	13	450,460	1700	
4AS	15	60.93	0	0	984	4	74,550	1700	
5AS	15	44.97	1582	1002	0	4	74,550	1700	
6AS	15	65.5	0	0	1125	2	18,313	1700	
7AS	11	85.8	0	1-88	932	4	74,550	1700	
8AS	11	65.0	1582	1002	0	4	74,550	1700	
9AS	10	88.5	644	422	844	4	74,550	1700	
1CS	15	65.5	0	2-88	984	13	450,460	1700	2
2CS	10	107.6	0	2-88	808	8	143,770	1700	2
3CS	7	139.6	0	2-88	633	13	450,460	1700	3
4CS	7	143.5	0	2-88	633	13	378,540	1135	3
4CS-36	9	110.9	0	2-88	633	13	378,540	1135	3,4
5CS	6	144.2	864	844	0	13	378,540	1135	3
6CS	7	136.0	0	2-175	492	13	378,540	1135	3
7CS	7	143.0	0	1-175	633	13	378,540	1135	3
8CS	6	144.0	864	844	0	13	378,540	1135	3
9CS	6	147.0	849	844	492	13	378.540	1135	3

1 - H_2O to H_2O heat exchanger only 2024/watts/°C for all Fuel Cell C cases.

2 - Steam H_2O heat exchanger 1957 watts/°C and 3163 watts/°C H_2O to H_2O.

3 - 1957 watts/°C steam to H_2O heat exchanger only.

4 - This run represented 36 days of data. Otherwise it is exactly the same as 4CS.

TABLE 4E

RETAIL STORE ANALYSIS

(8-125,000 Cabinet Unit Heaters
4 Air Handling Units)

RUN	FUEL CELL		BOILER	CHILLER		THERMAL STORAGE			NOTES
	NUMBER	MODULE SIZE KW	KW	ABSORPTION KW	ELECTRIC KW	DISCHARGE DUR.HRS.	LITERS	DOMESTIC HOT WATR. LITERS	
1S	None								
2S									
1BS	15	62.1	0	2-88	984	1	866	1700	
2BS	15	60	0	2-88	984	2	18,314	1700	
3ABS	15	57.6	0	2-88	805	8	143,770	1700	
3BS	15	57.6	0	2-88	984	4	74,550	1700	
4BS	15	57.8	0	2-88	984	8	143,770	1700	
5BS	15	54.0	0	2-88	984	13	453,890	1700	
6BS	15	53.85	0	2-88	633	13	453,890	1700	
7BS	15	58.0	0	2-88	823	4	74,550	1700	
8BS	15	56.8	0	1-88	738	13	378,540	1700	
9BS	15	55.3	0	2-88	633	13	378,540	1700	
10BS	15	53.2	0	0	826	13	378,540	1700	
11BS	15	56.8	0	1-88	738	13	378,540	2271	
12BS	15	56.8	0	1-88	738	13	378,540	1135	
13BS	15	56.7	0	1-88	738	13	378,540	1135	1
14BS	15	55.2	0	2-88	633	13	378,540	1135	1,2
15BS	15	55.3	0	2-88	633	13	378,540	1135	1,3
16BS	15	45.4	1671	1231	0	0	0	1135	1
17BS	11	64.2	1172	844	0	13	378,540	1135	1
18BS	10	80	0	2-88	633	13	378,540	1135	1,4
20BS	15	44.4	1172	844	0	13	378,540	1135	1,5
21BS	15	57.0	0	1-88	879	15	378,540	1135	5
22BS	11	64.2	1172	844	0	13	378,540	1135	6

1 - Eliminate 509 Watts/°C H_2O to H_2O Heat Exchanger, Use Steam to H_2O Heat Exchanger 1957 Watts/°C Only.
2 - High Efficiency (Custom) Absorption Chiller 12# Steam Ton-HR
3 - Relax Fuel Cell Reliability to 30 Hours per 10,000
4 - Relax Fuel Cell Reliability to 10 Hours per 10,000
5 - High Efficiency Absorption Chiller 10# Steam/Ton-HR
6 - High Efficiency Modulating Boiler

TABLE 4F

RETAIL STORE ANALYSIS
(Continued)

RUN	FUEL CELL		BOILER	CHILLER		THERMAL STORAGE			NOTES
	NUMBER	MODULE SIZE KW	KW	ABSORP-TION KW	ELECTRIC KW	DIS-CHARGE DUR.HRS.	LITERS	DOMESTIC HOT WATR. LITERS	
23BS-350	11	65.9	1347	844	510	13	378,540	1135	7
23BS-400	11	65.9	1347	844	510	13	378,540	1135	8
23BS-500	11	74.1	1347	844	510	13	378,540	1135	9
23BS-600	11	76.5	1347	844	510	13	378,540	1135	10
23BS-700	11	78.6	586	334	703	13	378,540	1135	11
25BS	11	64.2	879	844	0	13	378,540	1135	14, 16
26BS	11	64.2	351	844	0	13	378,540	1135	15, 17
27BS	13	35.1	1172	844	0	13	378,540	1135	12
28BS	15	55.3	0	2-88	633	13	378,540	1135	14
29BS	15	55.3	0	2-88	633	13	378,540	1135	15
30BS	15	59.2	0	2-88	633	13	378,540	1135	13

7 - 350KW Peak Limiting by Absorption Unit
8 - 400KW Peak Limiting by Absorption Unit
9 - 500KW Peak Limiting by Absorption Unit
10 - 600KW Peak Limiting by Absorption Unit
11 - 700KW Peak Limiting by Absorption Unit
12 - 3000KWH Battery Trying to Hold the Load at 350KW
13 - Adiabatic Thermal Storage Tank
14 - High Efficiency Absorption Chiller 12# Steam/Ton-Hour
15 - Higher Efficiency Absorption Chiller 6# Steam/Ton-Hour
16 - 880KW Boiler
17 - 350KW Boiler

FUEL CELL A STORE

EXTRA NO. OF FUEL CELLS	1.00
KWH FOR THE LIGHTS/NON HVAC EQUIPMENT	21876.00
FUEL CELL INSTALLATION COST ($/KW)	50.00
TYPE OF FUEL CELL (1 = A, 2 = B, 3 = C)	1.00
$/MM BTU ORIGINAL GAS COST	3.03

FOR THE LEVELIZED ANNUAL COST THE FOLLOWING CONSTANTS ARE DEFINED :

FIXED CHARGE RATE	0.14440
FUEL ENERGY COSTS IN $/MILLION BTU	3.03000
ESCALATION IN FUEL ENERGY COSTS (DECIMAL)	0.02400
WEIGHTED COST OF CAPITAL (R)	0.10000
SYSTEM LIFE (YEARS)	25.00
ELECTRIC UTILITY ELECTRICITY COSTS ($/KWH)	0.04230
ESCALATION IN ELECTRICITY COSTS (DECIMAL)	0.00600

RUN	F.C. SIZE (KW)	HVAC KWH	CAPITAL COST EXCEPT FUEL CELLS	OPERATION AND MAINTENANCE EXCEPT TAXES + INSURANCE	GAS COSTS $	NO OF FUEL CELLS	CORRECTION TO LIGHTS KWH
1S	0.0	7814.0	259204.00	15719.00	5312.50	0.0	0.0
2S	0.0	11552.0	243030.00	16330.00	0.0	0.0	0.0
2S-36	0.0	9932.0	243030.00	16330.00	0.0	0.0	1020.0
1AS	61.43	7256.0	250087.00	31355.00	76504.00	15.0	0.0
2AS	55.71	7259.0	295357.00	31754.00	76707.00	15.0	0.0
3AS	55.95	6935.0	285325.00	30549.00	75781.00	15.0	0.0
4AS	60.93	6806.0	250147.00	31096.00	75613.00	15.0	0.0
5AS	44.97	3071.0	334169.00	30943.00	101173.00	15.0	0.0
6AS	65.54	6690.0	250405.00	31915.00	76568.00	15.0	0.0
7AS	85.84	6831.0	272196.00	32072.00	75817.00	11.0	0.0
8AS	65.02	3103.0	334169.00	30970.00	99300.00	11.0	0.0
9AS	89.51	7401.0	313454.00	34627.00	80911.00	10.0	0.0

RUN	LEV ANNUAL $	CAPITAL $	OP + MAINT $	TOTAL ENERGY $	GAS $	ELECTRICITY $
1S	189952.12	258204.00	24465.12	119912.05	5312.49	114599.62
2S	194535.97	243030.00	23620.90	129027.87	0.0	129027.87
2S-36	192097.37	243030.00	23620.90	126711.94	0.0	126711.94
1AS	229371.31	599507.44	49960.22	76603.87	76603.87	0.0
2AS	232506.00	607194.12	49979.82	76706.87	76706.87	0.0
3AS	225612.50	593401.75	49501.05	75780.87	75780.87	0.0
4AS	225394.55	583738.56	49599.16	75612.87	75612.87	0.0
5AS	259055.75	584945.94	48491.37	101172.87	101172.87	0.0
6AS	232556.31	607660.44	50144.81	76567.81	76567.81	0.0
7AS	232155.56	609792.31	50365.77	75816.87	75816.87	0.0
8AS	257382.06	594202.25	48796.07	99299.87	99299.87	0.0
9AS	264426.31	629322.62	53506.68	80910.87	80910.87	0.0

FUEL CELL 3 STORE

EXTRA NO. OF FUEL CELLS	1.00
KWH FOR THE LIGHTS/NON HVAC EQUIPMENT	21876.00
FUEL CELL INSTALLATION COST ($/KW)	50.00
TYPE OF FUEL CELL (1 = A, 2 = B, 3 = C)	2.00
$/MM BTU ORIGINAL GAS COST	3.03

FOR THE LEVELIZED ANNUAL COST THE FOLLOWING CONSTANTS ARE DEFINED :

FIXED CHARGE RATE	0.14440
FUEL ENERGY COSTS IN $/MILLION BTU	3.03000
ESCALATION IN FUEL ENERGY COSTS (DECIMAL)	0.02400
WEIGHTED COST OF CAPITAL (R)	0.10000
SYSTEM LIFE (YEARS)	25.00
ELECTRIC UTILITY ELECTRICITY COSTS ($/KWH)	0.04230
ESCALATION IN ELECTRICITY COSTS (DECIMAL)	0.00600

RUN	F.C. SIZE (KW)	HVAC KWH	CAPITAL COST EXCEPT FUEL CELLS	OPERATION AND MAINTENANCE EXCEPT TAXES + INSURANCE	GAS COSTS $	NO OF FUEL CELLS	CORRECTION TO LIGHTS KWH
1S	0.0	7814.0	259204.00	16719.00	5312.50	0.0	0.0
2S	0.0	11552.0	243030.00	16330.00	0.0	0.0	0.0
19S	62.11	5045.0	294070.00	33335.00	74431.81	15.0	0.0
28S	57.93	5132.0	291050.00	33235.00	73753.00	15.0	0.0
3A8S	57.51	6632.0	297625.00	33295.00	73865.00	15.0	0.0
38S	57.33	6433.0	297541.00	32372.00	73327.00	15.0	0.0
43S	57.75	5875.0	305555.00	33471.00	74314.00	15.0	0.0
59S	54.05	6937.0	342835.00	33951.00	74512.00	15.0	0.0
69S	53.95	6246.0	324912.00	31726.00	72794.00	15.0	0.0
79S	57.93	6450.0	295547.00	32522.00	73419.00	15.0	0.0
89S	55.75	6424.0	297840.00	31149.00	73041.00	15.0	0.0
93S	55.29	6179.0	315912.00	31639.00	72473.00	15.0	0.0
102S	53.20	5832.0	278822.00	30695.00	74272.00	15.0	0.0
118S	59.75	6425.0	300155.00	31254.00	73041.00	15.0	0.0
120S	55.75	5424.0	295511.00	31033.00	73049.00	15.0	0.0
136S	55.73	5423.0	295194.00	31016.00	73040.00	15.0	0.0
149S	55.25	6222.0	314509.00	31596.00	72532.00	15.0	0.0
158S	55.25	6222.0	314509.00	31597.00	72523.00	15.0	0.0
168S	45.37	2923.0	321613.00	31076.00	99425.00	15.0	0.0
178S	44.44	3073.0	324150.00	29013.00	96092.00	15.0	0.0
179S-1	64.19	3072.0	325175.00	29013.00	95019.00	11.0	0.0
188S	73.93	5200.0	313484.00	31439.00	72471.00	10.0	0.0
208S	44.44	3073.0	337204.00	29553.00	91309.00	15.0	0.0
218S	57.01	6721.0	304585.00	31975.00	73372.00	15.0	0.0
228S	64.19	3073.0	333929.00	29563.00	94313.00	11.0	0.0
238S-350	65.90	5945.0	399022.00	36113.00	95720.00	11.0	0.0
238S-400	65.93	5932.0	399022.00	36133.00	96395.00	11.0	0.0
238S-500	74.14	6509.0	399022.00	36417.00	92512.00	11.0	0.0
238S-600	76.50	5875.0	399022.00	35537.00	90219.00	11.0	0.0
239S-700	73.59	7110.0	327617.00	33303.00	92454.00	11.0	0.0
259S	64.19	3072.0	319542.00	28651.00	83771.00	11.0	0.0
268S	64.19	3072.0	307111.00	28110.00	71166.00	11.0	0.0
278S	35.09	5929.0	481810.00	38408.00	106077.00	13.0	0.0
293S	55.25	6023.0	314509.00	31328.00	72100.00	15.0	0.0
298S	55.25	5842.0	314509.00	31298.00	71663.00	15.0	0.0
308S	55.22	6212.0	314509.00	31501.00	72507.00	15.0	0.0

RUN	LEV ANNUAL $	CAPITAL $	OP + MAINT $	TOTAL ENERGY $	GFS $	ELECTRICITY $
1S	199952.12	258204.00	24465.12	119912.05	5312.49	114599.62
2S	124531.97	243030.00	23620.90	129027.97	0.0	129027.87
19S	253775.52	763799.52	56249.99	74431.69	74431.59	0.0
20S	255512.56	751550.97	55781.52	73762.87	73762.97	0.0
3A6S	253459.56	740798.25	55527.54	73964.87	73954.97	0.0
39S	252555.74	743210.94	54666.33	73324.97	73324.97	0.0
49S	255150.47	750009.50	55971.29	74313.91	74313.91	0.0
59S	253522.00	760490.91	55675.42	74511.97	74511.87	0.0
68S	253972.06	741109.81	53959.29	72793.87	72783.97	0.0
78S	253169.25	744649.25	54261.48	73417.97	73417.87	0.0
98S	249959.97	735072.12	53260.16	73040.87	[illegible]0.87	0.0
[illegible]8S	250696.69	742354.91	53979.64	72472.97	72472.97	0.0
108S	249213.06	725437.37	52479.12	74271.97	74271.97	0.0
118S	250190.37	737397.12	53385.91	73040.97	73049.97	0.0
128S	249135.50	732743.12	53015.29	73039.94	73039.94	0.0
138S	249026.59	732209.75	52982.29	73039.94	73039.94	0.0
146S	250392.52	740935.12	53731.05	72531.94	72531.94	0.0
158S	250392.44	740935.12	53732.05	72522.87	72522.87	0.0
1[illegible]S	273597.50	675090.94	51359.73	98424.97	98424.97	0.0
170S	264942.19	671917.19	49163.52	96091.87	96091.97	0.0
178S-1	267193.19	694978.62	49552.36	95017.91	96017.91	0.0
188S	245730.44	714575.37	52935.26	72470.97	72470.97	0.0
208S	250404.94	695571.19	50130.13	81907.87	81907.97	0.0
218S	253129.24	743620.75	54284.62	73971.97	73971.97	0.0
228S	269038.59	698731.62	50524.95	94312.87	94312.97	0.0
238S-350	287609.75	767797.00	59145.91	96719.81	96719.81	0.0
236S-400	289229.06	767797.00	59165.91	96394.87	96394.97	0.0
236S-500	292215.59	810935.19	60742.05	92511.97	92511.87	0.0
239S-600	292595.75	823105.25	61330.16	90909.87	90909.97	0.0
238S-700	265234.00	762546.52	56179.40	82493.87	82493.97	0.0
258S	259566.12	674344.62	49031.34	83770.81	83770.81	0.0
268S	232415.62	666913.62	48117.41	71165.87	71165.97	0.0
278S	295705.37	723249.00	60105.47	106076.87	106076.87	0.0
288S	249750.37	740835.12	53623.05	72099.87	72099.87	0.0
298S	249110.06	740835.12	53523.05	71662.87	71662.87	0.0
308S	250310.81	740618.25	53719.56	72506.87	72506.87	0.0

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FUEL CELL C   STORE

EXTRA NO. OF FUEL CELLS	1.00
KWH FOR THE LIGHTS/NON HVAC EQUIPMENT	21575.00
FUEL CELL INSTALLATION COST ($/KW)	50.00
TYPE OF FUEL CELL (1 = A, 2 = B, 3 = C)	3.00
$/MM BTU ORIGINAL GAS COST	3.03

FOR THE LEVELIZED ANNUAL COST THE FOLLOWING CONSTANTS ARE DEFINED :

FIXED CHARGE RATE	0.14440
FUEL ENERGY COSTS IN $/MILLION BTU	3.03000
ESCALATION IN FUEL ENERGY COSTS (DECIMAL)	0.02400
WEIGHTED COST OF CAPITAL (R)	0.10000
SYSTEM LIFE (YEARS)	25.00
ELECTRIC UTILITY ELECTRICITY COSTS ($/KWH)	0.04230
ESCALATION IN ELECTRICITY COSTS (DECIMAL)	0.00600

RUN	F.C. SIZE (KW)	HVAC KWH	CAPITAL COST EXCEPT FUEL CELLS	OPERATION AND MAINTENANCE EXCEPT TAXES + INSURANCE	GAS COSTS $	NO OF FUEL CELLS	CORRECTION TO LIGHTS KWH
1S	0.0	7814.0	259204.00	15719.00	5312.50	0.0	0.0
2S	0.0	11552.0	243930.00	16330.00	0.0	0.0	0.0
1CS	65.56	6546.0	324934.00	34914.00	63458.00	15.0	0.0
2CS	107.57	6195.0	299757.00	32574.00	59252.00	10.0	0.0
3CS	132.57	6035.0	325619.00	31567.00	57734.00	7.0	0.0
4CS	143.47	5942.0	314191.00	31407.00	57799.00	7.0	0.0
4CS-36	110.77	5942.0	314191.00	32146.00	60500.00	9.0	1020.0
5CS	144.24	3042.0	331645.00	29229.00	77025.00	6.0	0.0
6CS	136.05	5202.0	353939.00	32574.00	56475.00	7.0	0.0
7CS	143.47	5754.0	314191.00	31325.00	57556.00	7.0	0.0
8CS	144.24	3042.0	331645.00	29228.00	78132.00	6.0	0.0
9CS	147.37	5833.0	380187.00	35362.00	65457.00	6.0	0.0

[illegible]	LCC ANNUAL $	CAPITAL $	OP + MAINT $	TOTAL ENERGY $	GAS $	ELECTRICITY $
1S	[illegible].12	259204.00	24465.12	11[illegible]912.05	5312.43	114599.62
2S	[illegible].47	24[illegible]030.00	23[illegible]20.90	12[illegible]027.87	0.0	129027.87
1CS	[illegible]	713632.00	55322.95	63437.34	63437.34	0.0
2CS	[illegible].75	711590.25	53921.71	59251.92	59251.92	0.0
3CS	224412.13	694553.81	52506.51	57903.94	57903.94	0.0
4CS	[illegible].00	692953.25	52192.60	57799.94	57799.94	0.0
4CS-[illegible]	[illegible].13	695456.62	5303[illegible].70	60592.92	60592.92	0.0
5CS	233201.00	657948.62	49963.46	77027.97	77027.97	0.0
9CS	225950.97	714177.56	53999.32	56477.92	56477.92	0.0
7CS	223325.24	692853.25	52110.60	57555.95	57555.95	0.0
8CS	239117.81	657848.62	48963.46	76151.87	76151.87	0.0
9CS	741698.62	719035.44	56933.06	45456.92	65456.92	0.0

FUEL CELL A APARTMENTS

EXTRA NO. OF FUEL CELLS	0.0
KWH FOR THE LIGHTS/NON HVAC EQUIPMENT	11133.00
FUEL CELL INSTALLATION COST ($/KW)	50.00
TYPE OF FUEL CELL (1 = A, 2 = B, 3 = C)	1.00
$/MM BTU ORIGINAL GAS COST	3.03

FOR THE LEVELIZED ANNUAL COST THE FOLLOWING CONSTANTS ARE DEFINED :

FIXED CHARGE RATE	0.14440
FUEL ENERGY COSTS IN $/MILLION BTU	3.03000
ESCALATION IN FUEL ENERGY COSTS (DECIMAL)	0.02400
WEIGHTED COST OF CAPITAL (R)	0.10000
SYSTEM LIFE (YEARS)	25.00
ELECTRIC UTILITY ELECTRICITY COSTS ($/KWH)	0.04230
ESCALATION IN ELECTRICITY COSTS (DECIMAL)	0.00600

RUN	F.C. SIZE (KW)	HVAC KWH	CAPITAL COST EXCEPT FUEL CELLS	OPERATION AND MAINTENANCE EXCEPT TAXES + INSURANCE	GAS COSTS $	NO OF FUEL CELLS	CORRECTION TO LIGHTS KWH
1A	0.0	13530.0	189041.00	16612.00	9143.96	0.0	0.0
2A	0.0	20567.0	174549.00	15257.00	0.0	0.0	0.0
3A	0.0	5513.0	192548.00	16787.00	20937.44	0.0	0.0
1AA	20.94	5541.0	185355.00	25597.00	49797.00	21.0	0.0
2AA	20.34	5541.0	185444.00	25659.00	49766.00	21.0	0.0
3AA	20.84	5544.0	184944.00	25525.00	49947.00	21.0	0.0
4AA	20.84	5541.0	194893.00	25042.00	49450.00	21.0	0.0
5AA	20.84	5710.0	209869.00	27911.00	49140.00	21.0	0.0
6AA	20.84	5575.0	194893.00	26055.00	44906.00	21.0	0.0
7AA	29.05	5545.0	240255.00	28679.00	50737.00	14.0	0.0
8AA-1000	20.19	5994.0	244893.00	28769.00	45279.00	13.0	0.0
8AA-500	20.44	5806.0	219893.00	27420.00	45086.00	18.0	0.0
9AA	28.05	5545.0	238928.00	28613.00	51422.00	14.0	0.0

RUN	LEV ANNUAL $	CAPITAL $	OP + MAINT $	TOTAL ENERGY $	GAS $	ELECTRICITY $
1A	[illegible]	187041.00	22283.23	104340.00	9143.35	95196.05
2A	[illegible]	174549.00	21423.44	122359.00	0.0	122359.00
3A	[illegible]	192549.00	22563.44	85188.97	20937.42	64251.47
1AA	[illegible]	355855.19	37272.55	48725.25	48725.25	0.0
2AA	[illegible]	355934.19	37387.02	48765.92	48765.92	0.0
3AA	[illegible]	355434.19	37283.02	48945.95	48945.95	0.0
4AA	[illegible]	365383.19	37003.49	49449.37	49449.97	0.0
5AA	[illegible]	323359.19	39321.77	49132.92	49132.92	0.0
6AA	145304.55	365383.19	37017.49	44905.95	44905.95	0.0
7AA	159516.69	390423.37	40393.80	50735.94	50735.94	0.0
8AA-1000	145332.12	347340.62	39189.22	45278.92	45278.92	0.0
8AA-500	145543.87	363392.19	38321.77	45085.94	45085.94	0.0
9AA	160066.25	383166.37	40287.99	51421.92	51421.92	0.0

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FUEL CELL B APARTMENTS

EXTRA NO. OF FUEL CELLS	0.0
KWH FOR THE LIGHTS/NON HVAC EQUIPMENT	11133.00
FUEL CELL INSTALLATION COST ($/KW)	50.00
TYPE OF FUEL CELL (1 = A, 2 = B, 3 = C)	2.00
$/MM BTU ORIGINAL GAS COST	3.03

FOR THE LEVELIZED ANNUAL COST THE FOLLOWING CONSTANTS ARE DEFINED :

FIXED CHARGE RATE	0.14440
FUEL ENERGY COSTS IN $/MILLION BTU	3.03000
ESCALATION IN FUEL ENERGY COSTS (DECIMAL)	0.02400
WEIGHTED COST OF CAPITAL (R)	0.10000
SYSTEM LIFE (YEARS)	25.00
ELECTRIC UTILITY ELECTRICITY COSTS ($/KWH)	0.04230
ESCALATION IN ELECTRICITY COSTS (DECIMAL)	0.00600

RUN	F.C. SIZE (KW)	HVAC KWH	CAPITAL COST EXCEPT FUEL CELLS	OPERATION AND MAINTENANCE EXCEPT TAXES + INSURANCE	GAS COSTS $	NO OF FUEL CELLS	CORRECTION TO LIGHTS KWH
1A	0.0	13530.0	189041.00	16612.00	9143.96	0.0	0.0
2A	0.0	20567.0	174548.00	16257.00	0.0	0.0	0.0
3A	0.0	5513.0	192543.00	16797.00	20737.44	0.0	0.0
1BA	31.13	5510.0	213310.00	28202.00	49158.00	14.0	0.0
2BA	31.12	5510.0	214382.00	29293.00	49274.00	14.0	0.0
3BA	23.75	5522.0	215416.00	28359.00	49367.00	15.0	0.0
4BA	25.51	5530.0	218565.00	28700.00	50237.00	17.0	0.0
5BA	25.91	5559.0	221674.00	29140.00	51532.00	19.0	0.0
6BA	24.41	5559.0	199385.00	27020.00	49564.00	19.0	0.0
7BA	31.11	5512.0	212882.00	29237.00	49371.00	14.0	0.0
8BA	24.41	5555.0	199806.00	26926.00	49411.00	19.0	0.0
9BA	20.55	5541.0	187530.00	26950.00	49474.00	21.0	0.0
10BA	20.55	5540.0	195304.00	25985.00	49743.00	21.0	0.0
11BA	20.57	5730.0	233693.00	29227.00	49359.00	21.0	0.0
12BA	20.56	5541.0	215454.00	28343.00	49459.00	21.0	0.0
13BA	20.56	5540.0	195304.00	25995.00	46802.00	21.0	0.0
14BA-8000	22.78	10225.0	587530.00	48690.00	57547.00	17.0	0.0
14BA-4000	20.04	4495.0	387530.00	36394.00	47442.00	20.0	0.0
14BA-2000	20.56	5195.0	287530.00	31777.00	49222.00	21.0	0.0
14BA-1000	21.25	5260.0	237530.00	29540.00	49735.00	16.0	0.0
14BA-500	20.40	5772.0	212530.00	28267.00	49704.00	18.0	0.0
15BA	28.04	5576.0	245713.00	28916.00	55075.00	14.0	0.0
16BA-1000	20.06	5959.0	245304.00	28715.00	50095.00	13.0	0.0
16BA-500	20.40	5771.0	220304.00	27362.00	49972.00	18.0	0.0

RUN	LEV ANNUAL $	CAPITAL $	OP + MAINT $	TOTAL ENERGY $	GAS $	ELECTRICITY $
1A	151095.55	130041.00	22283.23	104340.00	9143.95	95196.05
2A	175423.50	174543.00	21493.44	122359.00	0.0	122359.00
3A	163499.59	162548.00	22563.44	85188.89	20937.42	64251.47
13A	155732.55	445798.59	41575.95	49157.92	49157.92	0.0
23A	157142.94	445907.31	41697.22	49273.94	49273.94	0.0
33A	157302.00	446530.55	41755.91	49365.94	49365.94	0.0
43A	159794.44	452849.94	42285.50	50235.92	50235.92	0.0
53A	175115.25	473390.44	43341.41	51531.94	51531.94	0.0
63A	152652.31	426419.44	39812.59	49563.95	49563.95	0.0
73A	155933.05	445237.59	41534.13	49370.92	49370.92	0.0
83A	152533.05	425940.44	39901.21	49410.94	49410.94	0.0
93A	152094.75	424002.50	39670.07	49453.94	49453.94	0.0
103A	152739.62	431776.50	39939.29	49747.92	49747.92	0.0
113A	173035.12	473507.50	43432.22	49894.92	49894.92	0.0
123A	153354.27	451926.50	41205.79	49493.95	49493.95	0.0
133A	151629.37	431776.50	39939.29	48801.92	48801.92	0.0
148A-3000	253051.25	798251.94	72637.50	57546.92	57546.92	0.0
148A-4000	200795.56	607403.75	54615.11	47441.92	47441.92	0.0
148A-2000	184025.44	524002.50	47497.07	49221.95	49221.95	0.0
148A-1000	164869.94	423355.75	42240.67	49734.94	49734.94	0.0
148A-500	161892.19	413743.31	40679.30	49703.92	49703.92	0.0
159A	176632.31	456518.19	42611.54	55074.95	55074.95	0.0
168A-1000	159399.75	388355.69	40365.67	50097.94	50097.94	0.0
168A-500	152664.37	421517.31	40007.52	49971.94	49971.94	0.0

FUEL CELL C APARTMENTS

EXTRA NO. OF FUEL CELLS	0.0
KWH FOR THE LIGHTS/NON HVAC EQUIPMENT	11133.00
FUEL CELL INSTALLATION COST ($/KW)	[illegible]
TYPE OF FUEL CELL (1 = A, 2 = B, 3 = C)	3.00
$/MM BTU ORIGINAL GAS COST	3.03

FOR THE LEVELIZED ANNUAL COST THE FOLLOWING CONSTANTS ARE DEFINED :

FIXED CHARGE RATE	0.14440
FUEL ENERGY COSTS IN $/MILLION BTU	3.03000
ESCALATION IN FUEL ENERGY COSTS (DECIMAL)	0.02400
WEIGHTED COST OF CAPITAL (R)	0.10000
SYSTEM LIFE (YEARS)	25.00
ELECTRIC UTILITY ELECTRICITY COSTS ($/KWH)	0.04230
ESCALATION IN ELECTRICITY COSTS (DECIMAL)	0.00600

RUN	F.C. SIZE (KW)	HVAC KWH	CAPITAL COST EXCEPT FUEL CELLS	OPERATION AND MAINTENANCE EXCEPT TAXES + INSURANCE	GAS COSTS $	NO OF FUEL CELLS	CORRECTION TO LIGHTS KWH
1A	0.0	13530.0	193041.00	15512.00	9143.96	0.0	0.0
2A	0.0	20557.0	174548.00	15257.00	0.0	0.0	0.0
3A	0.0	5513.0	192543.00	16737.00	20937.44	0.0	0.0
1CA	128.00	5361.0	213112.00	28515.00	40782.00	5.0	0.0
2CA	128.00	5320.0	214140.00	29538.00	40255.00	5.0	0.0
3CA	128.00	5351.0	212034.00	28454.00	40825.00	5.0	0.0
4CA	128.00	5363.0	211613.00	28450.00	40547.00	5.0	0.0
5CA	129.99	5528.0	197530.00	27359.00	41462.00	5.0	0.0
6CA	129.99	5527.0	195304.00	26137.00	42341.00	5.0	0.0
7CA	118.13	5019.0	228214.00	28698.00	40083.00	5.0	0.0
8CA	129.99	5527.0	195304.00	26137.00	41801.00	5.0	0.0
9CA	110.89	5283.0	233647.00	27991.00	44471.00	5.0	0.0

RUN	LEV ANNUAL $	CAPITAL $	OP + MAINT $	TOTAL ENERGY $	GAS $	ELECTRICITY $
1A	151095.56	185041.00	22283.23	104340.00	9143.95	95196.05
2A	175493.50	174549.00	21493.44	122359.00	0.0	122359.00
3A	[illegible]	172549.00	[illegible]	85188.97	20937.42	64251.47
1CA	153423.59	456079.06	42197.97	40799.94	40799.94	0.0
2CA	153554.47	457127.06	42301.81	40955.97	40955.97	0.0
3CA	154290.50	455021.06	42104.53	40925.95	40925.95	0.0
4CA	153239.00	454500.06	42033.00	40845.94	40845.94	0.0
5CA	154325.94	434063.62	40380.91	41461.94	41461.94	0.0
6CA	155547.56	441837.62	39392.13	42340.92	42340.92	0.0
7CA	157351.25	453561.37	42294.84	40082.95	40082.95	0.0
8CA	154879.97	441937.62	39392.13	41800.94	41800.94	0.0
9CA	160757.87	445980.81	41370.42	44470.94	44470.94	0.0

4. CASH FLOWS FOR BASELINE SYSTEMS

Cash flows following the format of Section 4.2 are given in the following pages.

The percentage (%) entry at the top of the column entitled, "Discounted Cash Flow" is the Internal Rate of Return.

YEAR	BASELINE 2S	SYSTEM 4AS	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 5.94 %
0	243030.00	583738.56	-340708.56	-340708.56
1	145337.37	106678.37	38659.00	36491.29
2	146131.94	108513.50	37618.44	33518.00
3	146910.62	110371.62	36539.00	30730.71
4	147693.94	112274.37	35419.57	28118.89
5	148482.00	114222.81	34259.19	25672.65
6	149274.81	116218.00	33056.81	23362.63
7	150072.25	118261.12	31811.12	21239.79
8	150874.56	120353.25	30521.31	19235.92
9	151681.69	122495.56	29186.12	17363.01
10	152493.69	124689.31	27804.37	15613.51
11	153310.50	126935.69	26374.81	13980.27
12	154132.19	129236.00	24896.19	12436.35
13	154958.87	131591.44	23367.44	11036.08
14	155790.56	134003.44	21787.12	9712.75
15	156627.19	136473.37	20153.81	8480.83
16	157468.87	139002.56	18466.31	7335.00
17	158315.56	141592.44	16723.12	6270.12
18	159167.31	144244.56	14922.75	5281.36
19	160024.25	146960.19	13064.06	4354.29
20	160886.31	149741.06	11145.25	3514.51
21	161753.62	152588.69	9164.94	2727.99
22	162626.00	155504.56	7121.44	2000.87
23	163503.62	158490.50	5013.12	1329.53
24	164386.50	161548.06	2838.44	713.57
25	165274.69	164679.00	595.69	140.76

YEAR	BASELINE 2S	SYSTEM 5AS	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 0.0 %
0	243030.00	584945.94	-341915.94	-341915.94
1	145357.87	132115.87	13242.00	12038.19
2	146131.94	134543.94	11588.00	9576.67
3	146910.62	137030.19	9880.44	7423.34
4	147693.94	139575.12	8117.81	5544.59
5	148482.00	142183.19	6298.81	3911.08
6	149274.81	144852.87	4421.94	2496.08
7	150072.25	147586.62	2485.62	1275.53
8	150874.56	150385.94	488.62	227.95
9	151681.69	153252.44	-1570.75	-666.16
10	152493.69	156187.75	-3694.06	-1424.23
11	153310.50	159193.50	-5883.00	-2061.97
12	154132.19	162271.37	-8139.19	-2593.42
13	154958.87	165423.06	-10464.19	-3031.13
14	155790.56	168650.44	-12859.87	-3386.44
15	156627.19	171955.31	-15328.12	-3669.47
16	157468.87	175339.44	-17870.56	-3889.20
17	158315.56	178804.81	-20489.25	-4053.74
18	159167.31	182353.37	-23186.06	-4170.27
19	160024.25	185987.06	-25962.81	-4245.18
20	160886.31	189707.94	-28821.62	-4284.21
21	161753.62	193518.19	-31764.56	-4292.43
22	162626.00	197419.75	-34793.75	-4274.34
23	163503.62	201415.06	-37911.44	-4233.95
24	164386.50	205506.19	-41119.69	-4174.77
25	165274.69	209695.50	-44420.81	-4099.93

YEAR	BASELINE 25	SYSTEM 138S	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 2.88 %
0	243030.00	732209.75	-489179.75	-489179.75
1	145357.87	104055.94	41301.94	40144.59
2	146131.94	105808.81	40323.12	38094.96
3	146910.62	107603.69	39306.94	36094.34
4	147693.94	109441.75	38252.19	34141.53
5	148482.00	111323.87	37158.12	32235.71
6	149274.81	113251.19	36023.62	30375.79
7	150072.25	115224.75	34847.50	28563.66
8	150874.56	117245.69	33628.87	26789.58
9	151681.69	119315.12	32366.56	25061.49
10	152493.69	121434.19	31059.50	23375.54
11	153310.50	123604.12	29706.37	21730.68
12	154132.19	125826.12	28306.06	20126.11
13	154958.87	128101.50	26857.37	18560.96
14	155790.56	130431.44	25359.12	17034.44
15	156627.19	132817.25	23809.94	15545.64
16	157468.87	135260.37	22208.50	14093.74
17	158315.56	137762.19	20553.37	12677.89
18	159167.31	140324.00	18843.31	11297.36
19	160024.25	142947.25	17077.00	9951.50
20	160886.31	145633.50	15252.81	8639.40
21	161753.62	148384.19	13369.44	7360.44
22	162626.00	151200.87	11425.12	6113.76
23	163503.62	154085.25	9418.37	4898.69
24	164386.50	157038.75	7347.75	3714.62
25	165274.69	160063.12	5211.56	2560.86

YEAR	BASELINE 25	SYSTEM 17ES	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 0.0 %
0	243030.00	671817.19	-428787.19	-428787.19
1	145357.87	125094.87	20263.00	18420.92
2	146131.94	127400.75	18731.19	15480.34
3	146910.62	129761.87	17148.75	12884.14
4	147693.94	132179.75	15514.19	10596.43
5	148482.00	134655.62	13826.37	8585.12
6	149274.81	137190.94	12083.87	6821.07
7	150072.25	139787.12	10285.12	5277.93
8	150874.56	142445.62	8428.94	3932.19
9	151681.69	145167.87	6513.81	2762.51
10	152493.69	147955.44	4538.25	1749.71
11	153310.50	150809.94	2500.55	876.44
12	154132.19	153732.94	399.25	127.21
13	154958.87	156726.06	-1767.19	-511.90
14	155790.56	159791.06	-4000.50	-1053.47
15	156627.19	162929.56	-6302.37	-1508.76
16	157468.87	166143.44	-8674.56	-1887.86
17	158315.56	169434.44	-11118.87	-2199.84
18	159167.31	172804.44	-13637.12	-2452.79
19	160024.25	176255.25	-16231.00	-2653.93
20	160886.31	179788.94	-18902.62	-2809.79
21	161753.62	183407.44	-21653.81	-2926.14
22	162626.00	187112.69	-24486.69	-3008.14
23	163503.62	190906.94	-27403.31	-3060.40
24	164386.50	194792.19	-30405.69	-3087.01
25	165274.69	198770.69	-33496.00	-3091.60

YEAR	BASELINE 2S	SYSTEM 17CS-1	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 0.0 %
0	243030.00	684978.62	-441948.62	-441948.62
1	145357.87	125030.81	20327.06	18479.16
2	146131.94	127335.12	18796.81	15534.58
3	146910.62	129694.69	17215.94	12934.62
4	147693.94	132110.94	15583.00	10643.43
5	148482.00	134585.19	13896.81	8628.86
6	149274.81	137118.81	12156.00	6861.78
7	150072.25	139713.25	10359.00	5315.84
8	150874.56	142369.94	8504.62	3967.50
9	151681.69	145090.44	6591.25	2795.35
10	152493.69	147876.12	4617.56	1780.26
11	153310.50	150728.75	2581.75	904.90
12	154132.19	153649.81	482.37	153.70
13	154958.87	156640.94	-1682.06	-487.24
14	155790.56	159703.81	-3913.25	-1030.49
15	156627.19	162840.31	-6213.12	-1487.39
16	157468.87	166052.00	-8583.12	-1867.96
17	158315.56	169340.81	-11025.25	-2181.31
18	159167.31	172708.56	-13541.25	-2435.54
19	160024.25	176157.06	-16132.81	-2637.88
20	160886.31	179688.37	-18802.06	-2794.85
21	161753.62	183304.50	-21550.87	-2912.23
22	162626.00	187007.25	-24381.25	-2995.18
23	163503.62	190799.00	-27295.37	-3048.35
24	164386.50	194681.62	-30295.12	-3075.78
25	165274.69	198657.50	-33362.81	-3081.15

YEAR	BASELINE 2S	SYSTEM 4CS	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 10.17 %
0	243030.00	692853.25	-449823.25	-449823.25
1	145357.87	89195.94	56161.94	50976.78
2	146131.94	90582.81	55549.12	45765.49
3	146910.62	92002.94	54907.69	41060.54
4	147693.94	93457.12	54236.81	36814.27
5	148482.00	94946.25	53535.75	32983.48
6	149274.81	96471.19	52803.62	29528.87
7	150072.25	98032.62	52039.62	26414.82
8	150874.56	99631.62	51242.94	23639.02
9	151681.69	101268.94	50412.75	21082.13
10	152493.69	102945.56	49548.12	18807.53
11	153310.50	104662.37	48648.12	16761.04
12	154132.19	106420.44	47711.75	14920.75
13	154958.87	108220.69	46738.19	13266.84
14	155790.56	110064.12	45726.44	11781.30
15	156627.19	111951.81	44675.37	10447.79
16	157468.87	113884.81	43584.06	9251.55
17	158315.56	115864.19	42451.37	8179.16
18	159167.31	117891.06	41276.25	7218.51
19	160024.25	119966.62	40057.62	6358.62
20	160886.31	122091.94	38794.37	5589.55
21	161753.62	124268.31	37485.31	4902.30
22	162626.00	126496.87	36129.12	4288.71
23	163503.62	128778.94	34724.69	3741.43
24	164386.50	131115.75	33270.75	3253.81
25	165274.69	133508.62	31766.06	2819.83

YEAR	BASELINE 2S	SYSTEM SCS	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 0.0 %
0	243030.00	657848.62	-414818.62	-414818.62
1	145357.87	106255.87	39102.00	35547.29
2	146131.94	108104.44	38027.50	31427.73
3	146910.62	109997.37	36913.25	27733.54
4	147693.94	111935.75	35758.19	24423.40
5	148482.00	113920.62	34561.37	21459.98
6	149274.81	115953.19	33321.62	18809.26
7	150072.25	118034.50	32037.75	16440.53
8	150874.56	120165.75	30708.81	14325.98
9	151681.69	122348.19	29333.50	12440.36
10	152493.69	124582.94	27910.75	10760.89
11	153310.50	126871.37	26439.12	9266.83
12	154132.19	129214.75	24917.44	7939.54
13	154958.87	131614.31	23344.56	6762.16
14	155790.56	134071.44	21719.12	5719.33
15	156627.19	136587.56	20039.62	4797.38
16	157468.87	139164.06	18304.81	3983.71
17	158315.56	141802.44	16513.12	3267.07
18	159167.31	144504.12	14663.19	2637.34
19	160024.25	147270.62	12753.62	2085.35
20	160886.31	150103.50	10782.81	1602.32
21	161753.[illegible]	153004.44	8749.19	1182.30
22	162626.[illegible]	155974.94	6651.00	817.07
23	163503.62	159016.75	4486.87	501.09
24	164386.50	162131.50	2255.00	228.94
25	165274.69	1653[illegible]1.06	-46.38	-4.26

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[illegible]

YEAR	BASELINE 2A	SYSTEM 1AA	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 34.03 %
0	174548.00	355855.19	-181307.19	-181307.19
1	138615.00	75393.94	63221.06	47171.09
2	139349.06	76565.00	62784.06	34952.47
3	140087.50	77764.19	62323.31	25887.69
4	140830.31	78992.12	61838.19	19165.21
5	141577.62	80249.50	61328.12	14181.78
6	142329.44	81537.12	60792.31	10489.00
7	143085.69	82855.69	60230.00	7753.76
8	143846.50	84205.81	59640.69	5728.70
9	144611.87	85588.37	59023.50	4230.12
10	145381.94	87004.12	58377.81	3121.69
11	146156.50	88453.81	57702.69	2302.25
12	146935.75	89938.31	56997.44	1696.78
13	147719.69	91458.44	56261.25	1249.67
14	148508.37	93015.00	55493.37	919.69
15	149301.75	94609.00	54692.75	676.31
16	150099.94	96241.19	53858.75	496.92
17	150902.87	97912.62	52990.25	364.79
18	151710.56	99624.12	52086.44	267.54
19	152523.19	101376.69	51146.50	196.01
20	153340.75	103171.31	50169.44	143.46
21	154163.19	105009.06	49154.12	104.87
22	154990.50	106890.81	48099.69	76.57
23	155822.75	108817.81	47004.94	55.83
24	156660.00	110791.00	45869.00	40.65
25	157502.25	112811.56	44690.69	29.55

YEAR	BASELINE 2A	SYSTEM 4AA	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 32.19 %
0	174548.00	365383.19	-190835.19	-190835.19
1	138615.00	75491.94	63123.06	47751.96
2	139349.06	76678.69	62670.37	35864.82
3	140087.50	77893.87	62193.62	26924.98
4	140830.31	79138.31	61692.00	20204.20
5	141577.62	80412.50	61165.12	15153.74
6	142329.44	81717.37	60612.06	11360.00
7	143085.69	83053.56	60032.12	8511.50
8	143846.50	84421.75	59424.75	6373.72
9	144611.87	85822.81	58789.06	4770.07
10	145381.94	87257.50	58124.44	3567.72
11	146156.50	88726.56	57429.94	2666.70
12	146935.75	90230.94	56704.81	1991.86
13	147719.69	91771.44	55948.25	1486.72
14	148508.37	93348.87	55159.50	1108.83
15	149301.75	94964.12	54337.62	826.32
16	150099.94	96618.19	53481.75	615.26
17	150902.87	98312.00	52590.87	457.68
18	151710.56	100046.37	51664.19	340.13
19	152523.19	101822.44	50700.75	252.51
20	153340.75	103641.06	49699.69	187.25
21	154163.19	105503.37	48659.81	138.69
22	154990.50	107410.37	47580.12	102.59
23	155822.75	109363.12	46459.62	75.78
24	156660.00	111362.69	45297.31	55.89
25	157502.25	113410.31	44091.94	41.16

YEAR	BASELINE 2A	SYSTEM 6CA	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 25.64 %
0	174548.00	441837.62	-267289.62	-267289.62
1	138615.00	68477.87	70137.12	55825.02
2	139349.06	69494.06	69855.00	44254.71
3	140087.50	70534.56	69552.94	35071.84
4	140830.31	71600.00	69230.31	27785.64
5	141577.62	72691.06	68886.56	22005.92
6	142329.44	73808.31	68521.12	17422.50
7	143085.69	74952.44	68133.25	13780.79
8	143846.50	76123.94	67722.56	10908.91
9	144611.87	77323.56	67288.31	8627.17
10	145381.94	78552.00	66829.94	6819.95
11	146156.50	79809.87	66346.62	5389.02
12	146935.75	81098.00	65837.75	4256.44
13	147719.69	82417.00	65302.69	3360.35
14	148508.37	83767.62	64740.75	2651.62
15	149301.75	85150.75	64151.00	2031.31
16	150099.94	86567.00	63532.94	1648.52
17	150902.87	88017.25	62885.62	1298.76
18	151710.56	89502.31	62208.25	1022.60
19	152523.19	91023.00	61500.19	804.67
20	153340.75	92580.25	60760.50	632.76
21	154163.19	94174.81	59988.37	497.24
22	154990.50	95807.62	59182.87	390.46
23	155822.75	97479.69	58343.06	306.37
24	156660.00	99191.81	57468.19	240.20
25	157502.25	100945.00	56557.25	188.15

YEAR	BASELINE 2A	SYSTEM 9BA	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 23.90 %
0	174548.00	424002.50	-249454.50	-249454.50
1	138615.00	76443.94	62171.06	50176.75
2	139349.06	77631.75	61717.31	40230.87
3	140087.50	78848.00	61239.50	32193.96
4	140830.31	80093.50	60736.81	25769.68
5	141577.62	81368.87	60206.75	20617.26
6	142329.44	82674.87	59654.56	16486.53
7	143085.69	84012.25	59073.44	13176.26
8	143846.50	85381.69	58464.81	10524.07
9	144611.87	86783.94	57827.94	8401.68
10	145381.94	88219.94	57162.00	6702.70
11	146156.50	89690.31	56466.19	5343.74
12	146935.75	91196.06	55739.69	4257.31
13	147719.69	92737.87	54981.81	3389.26
14	148508.37	94316.69	54191.69	2696.08
15	149301.75	95933.44	53368.31	2142.66
16	150099.94	97588.94	52511.00	1701.68
17	150902.87	99284.25	51618.62	1350.05
18	151710.56	101020.19	50690.37	1070.00
19	152523.19	102797.81	49725.37	847.13
20	153340.75	104619.06	48722.69	669.91
21	154163.19	106482.00	47681.19	529.11
22	154990.50	108390.69	46599.81	417.35
23	155822.75	110345.19	45477.56	328.72
24	156660.00	112316.56	44313.44	258.51
25	157502.25	114396.00	43106.25	202.95

YEAR	BASELINE 2A	SYSTEM 5CA	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 26.33 %
0	174548.00	434063.62	-259515.62	-259515.62
1	138615.00	68820.94	69794.06	55245.87
2	139349.06	69815.94	69533.12	43566.71
3	140087.50	70834.37	69252.62	34346.37
4	140830.31	71878.25	68952.06	27069.07
5	141577.62	72946.62	68631.00	21326.90
6	142329.44	74040.69	68288.75	16797.25
7	143085.69	75161.00	67924.69	13225.07
8	143846.50	76308.25	67538.25	10408.82
9	144611.87	77482.94	67128.94	8189.23
10	145381.94	78695.87	66696.06	6440.43
11	146156.50	79917.69	66238.81	5063.00
12	146935.75	81179.00	65756.75	3978.49
13	147719.69	82470.62	65249.06	3124.66
14	148508.37	83793.25	64715.12	2453.28
15	149301.75	85147.62	64154.12	1925.07
16	150099.94	86534.50	63565.44	1509.82
17	150902.87	87954.62	62948.25	1183.50
18	151710.56	89408.87	62301.69	927.19
19	152523.19	90898.00	61625.19	725.95
20	153340.75	92422.87	60917.87	568.03
21	154163.19	93984.37	60178.81	444.18
22	154990.50	95583.31	59407.19	347.08
23	155822.75	97220.62	58602.12	271.01
24	156660.00	98897.19	57762.81	211.45
25	157502.25	100614.06	56888.19	164.84

YEAR	BASELINE 2A	SYSTEM 10BA	INCREMENTAL CASH FLOW	DISCOUNTED CASH FLOW AT 23.42 %
0	174548.00	431776.50	-257228.50	-257228.50
1	138615.00	75732.87	62882.12	50951.41
2	139349.06	76926.81	62422.25	40982.43
3	140087.50	78149.31	61938.19	32949.29
4	140830.31	79401.19	61429.12	26478.36
5	141577.62	80683.12	60894.50	21267.36
6	142329.44	81995.81	60333.62	17073.96
7	143085.69	83340.06	59745.62	13699.07
8	143846.50	84716.50	59130.00	10986.04
9	144611.87	86126.00	58485.87	8804.67
10	145381.94	87569.31	57812.62	7052.02
11	146156.50	89047.31	57109.19	5644.51
12	146935.75	90560.75	56375.00	4514.77
13	147719.69	92110.44	55609.25	3608.49
14	148508.37	93697.37	54811.00	2881.88
15	149301.75	95322.44	53979.31	2299.66
16	150099.94	96986.44	53113.50	1833.46
17	150902.87	98690.44	52212.44	1460.39
18	151710.56	100435.31	51275.25	1162.07
19	152523.19	102222.00	50301.19	923.70
20	153340.75	104051.62	49289.12	733.39
21	154163.19	105925.12	48238.06	581.57
22	154990.50	107843.62	47146.87	460.57
23	155822.75	109308.12	46014.62	364.22
24	156660.00	111819.81	44840.19	287.58
25	157502.25	113679.75	43622.50	226.09