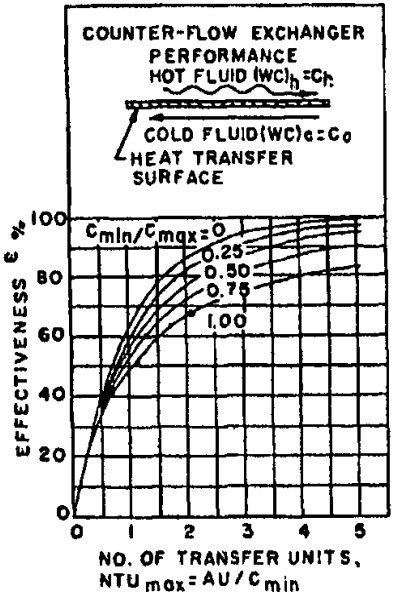
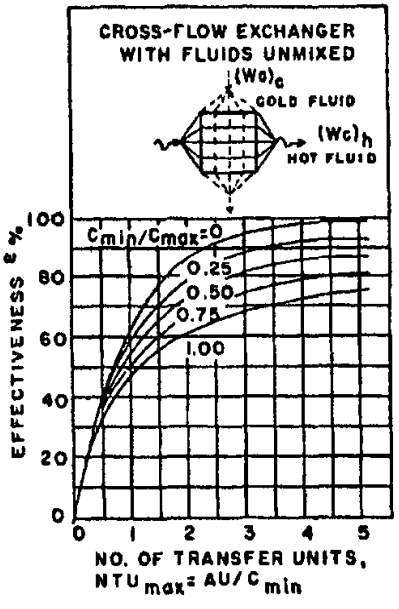
Textbook Effectiveness Curves For Constant Heat Transfer Coefficient (U)
NOTE: GFX's "U" Varies With Flow Rate





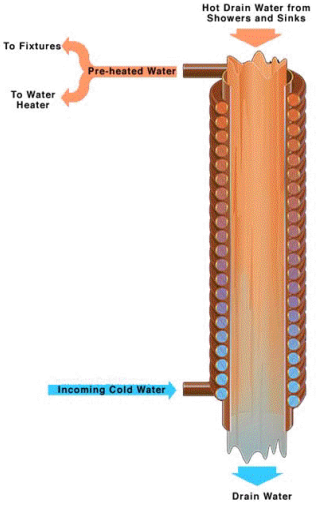


Fig. 19-11. Heat exchanger performance characteristics (from *Gas Turbine Plant Heat Exchangers* by Kays, London, and Johnson, New York, *ASME*, 1951.)

Capacity rates, C_{max} and C_{min}:

C_{max} is the larger of $w_h c_{ph}$ and $w_c c_{pc}$

C_{min} is the smaller of $w_h c_{ph}$ and $w_c c_{pc}$

Effectiveness of the exchanger, ϵ, is the ratio of the actual heat transferred, to the maximum heat transfer permitted by the Second Law (i.e., when one fluid leaves at the entering temperature of the other fluid).

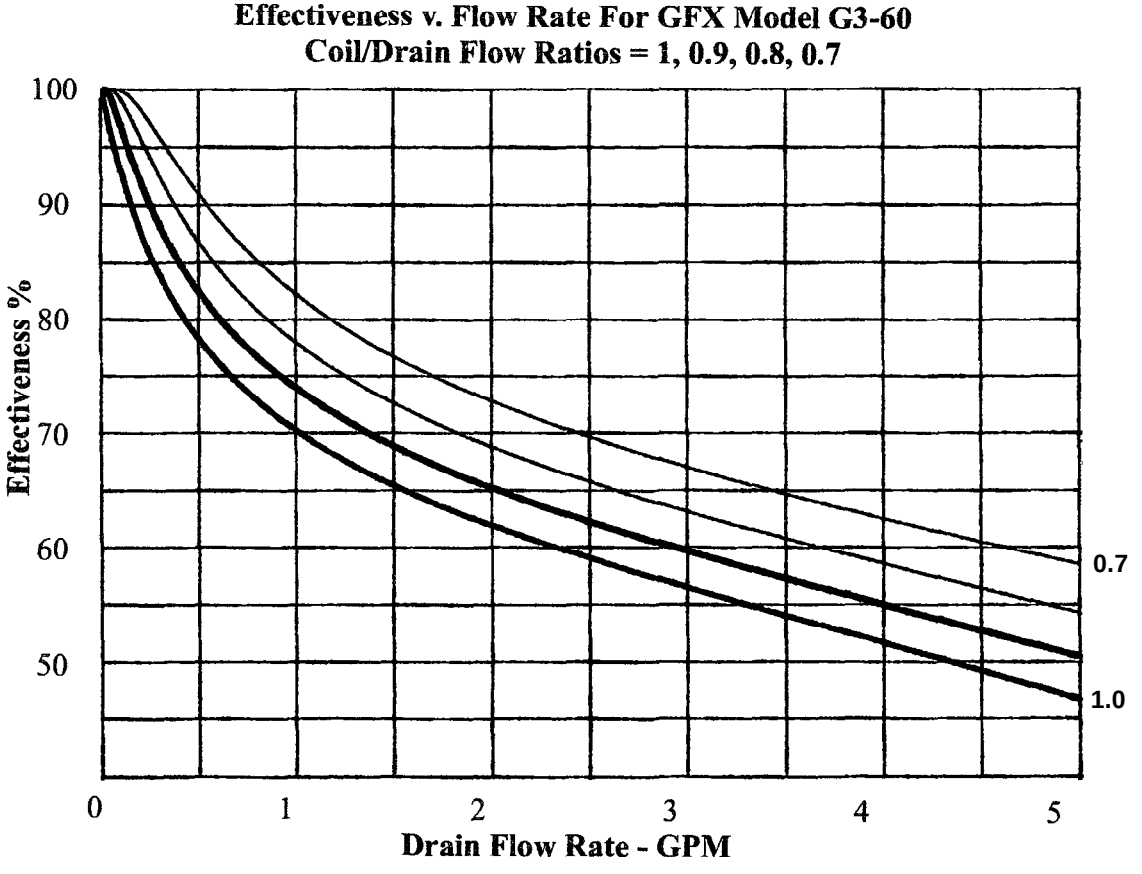
$$\epsilon = \frac{w_h c_{ph}\,(t_{h1} - t_{h2})}{C_{min}\,(t_{h1} - t_{c1})} = \frac{w_c c_{pc}\,(t_{c2} - t_{c1})}{C_{min}\,(t_{h1} - t_{c1})}$$

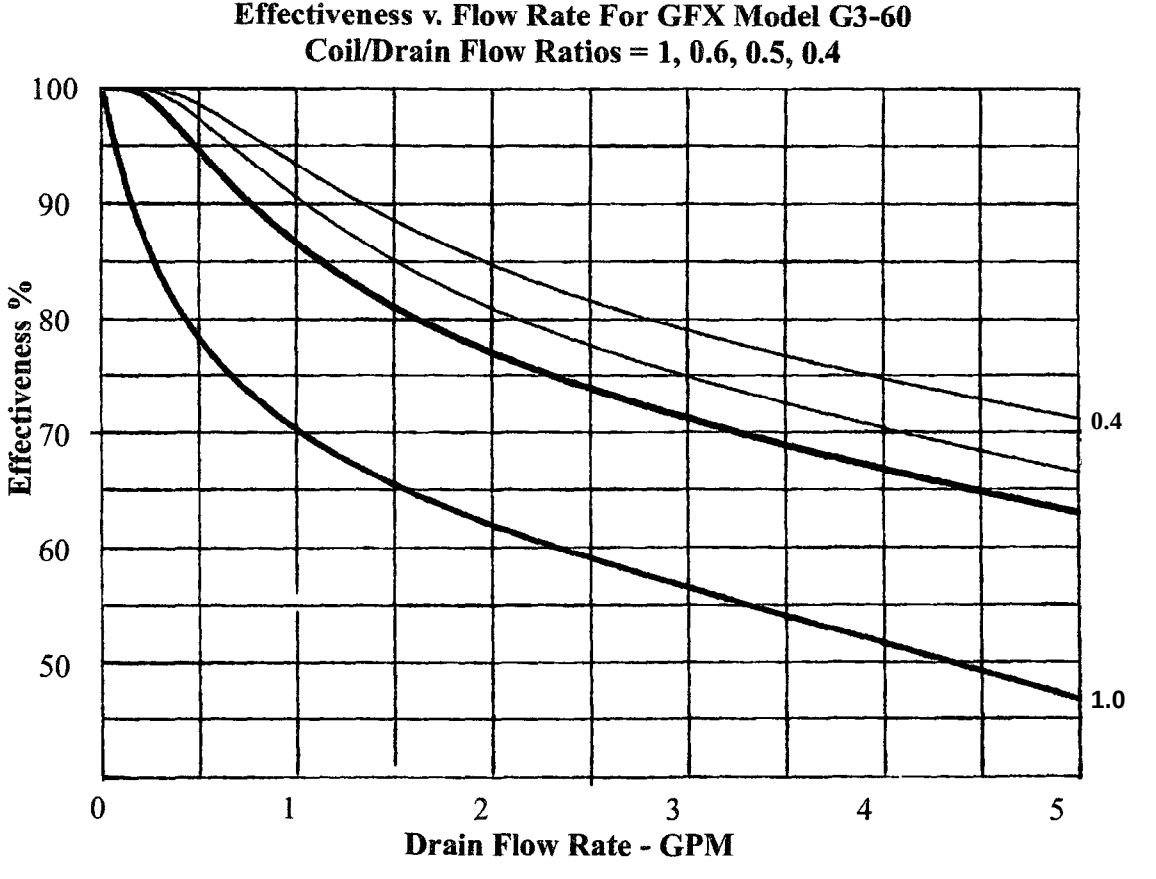
Number of transfer units, NTU, is the ratio of heat exchange capacity per degree temperature difference, to fluid stream heat capacity per degree temperature change. It is a measure of the relation between installed capacity and load.

$$\text{NTU} = AU/C_{min}$$

where A is the heat exchanger surface, and U is the corresponding overall coefficient.

The plots show that as NTU (or installed capacity/load) is increased the effectiveness increases, but at a decreasing rate. The plots can be used in the design of an exchanger, since with given fluid stream characteristics they show how much AU is required to obtain any specified effectiveness. They also reveal clearly the diminishing returns as AU is increased.


Effectiveness v. Flow Rate For GFX Model G3-60
Coil/Drain Flow Ratios = 1, 0.9, 0.8, 0.7
100
90
80
70
60
50
Effectiveness %
0
1
2
3
4
5
Drain Flow Rate - GPM
0.7
1.0


Effectiveness v. Flow Rate For GFX Model G3-60
Coil/Drain Flow Ratios = 1, 0.6, 0.5, 0.4
100
90
80
70
60
50
Effectiveness %
0.4
1.0
0
1
2
3
4
5
Drain Flow Rate - GPM

Equal Flow Btuh Savings

G3-60

EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	34,584	37,182	39,559	43,756	47,342	50,444	53,152	55,538
45	31,440	33,802	35,963	39,778	43,039	45,858	48,320	50,489
50	28,296	30,422	32,367	35,800	38,735	41,272	43,488	45,440
55	25,152	27,042	28,770	31,822	34,431	36,687	38,656	40,391
60	22,008	23,661	25,174	27,844	30,127	32,101	33,824	35,342
65	18,864	20,281	21,578	23,867	25,823	27,515	28,992	30,293
70	15,720	16,901	17,981	19,889	21,519	22,929	24,160	25,244
75	12,576	13,521	14,385	15,911	17,215	18,343	19,328	20,196

Note: 1 kW = 3413 Btuh

S3-60

EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	32,423	35,050	37,458	41,712	45,349	48,490	51,228	53,635
45	29,475	31,864	34,053	37,920	41,226	44,081	46,571	48,759
50	26,528	28,677	30,647	34,128	37,103	39,673	41,914	43,883
55	23,580	25,491	27,242	30,336	32,981	35,265	37,256	39,007
60	20,633	22,305	23,837	26,544	28,858	30,857	32,599	34,131
65	17,685	19,118	20,432	22,752	24,736	26,449	27,942	29,255
70	14,738	15,932	17,026	18,960	20,613	22,041	23,285	24,379
75	11,790	12,745	13,621	15,168	16,490	17,633	18,628	19,504

Basis: 120F from water heater, 105F mix at shower head, 95F drain water

Preheat Water Heater Only

Btuh Recovered

G3-60								
EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	32,104	34,641	36,977	41,129	44,711	47,831	50,573	53,003
45	29,000	31,303	33,423	37,196	40,451	43,289	45,785	47,997
50	25,905	27,973	29,878	33,270	36,200	38,756	41,004	42,999
55	22,818	24,653	26,343	29,355	31,959	34,232	36,234	38,010
60	19,745	21,345	22,821	25,454	27,732	29,722	31,477	33,035
65	16,689	18,056	19,318	21,571	23,523	25,231	26,738	28,077
70	13,659	14,793	15,840	17,714	19,340	20,765	22,024	23,144
75	10,666	11,567	12,401	13,896	15,197	16,338	17,349	18,249
S3-60								
EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	29,845	32,416	34,787	39,009	42,651	45,822	48,604	51,065
45	26,944	29,277	31,430	35,265	38,576	41,460	43,993	46,233
50	24,051	26,146	28,081	31,530	34,509	37,107	39,389	41,410
55	21,169	23,027	24,742	27,805	30,454	32,764	34,797	36,596
60	18,301	19,921	21,419	24,095	26,412	28,436	30,217	31,796
65	15,452	16,835	18,115	20,404	22,390	24,127	25,657	27,015
70	12,630	13,776	14,838	16,741	18,395	19,844	21,123	22,259
75	9,847	10,757	11,601	13,118	14,441	15,601	16,627	17,540

GPM Coil Flow

G3-60 & S3-60								
EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	1.625	1.828	2.031	2.438	2.844	3.250	3.656	4.063
45	1.600	1.800	2.000	2.400	2.800	3.200	3.600	4.000
50	1.571	1.768	1.964	2.357	2.750	3.143	3.536	3.929
55	1.538	1.731	1.923	2.308	2.692	3.077	3.462	3.846
60	1.500	1.688	1.875	2.250	2.625	3.000	3.375	3.750
65	1.455	1.636	1.818	2.182	2.545	2.909	3.273	3.636
70	1.400	1.575	1.750	2.100	2.450	2.800	3.150	3.500
75	1.333	1.500	1.667	2.000	2.333	2.667	3.000	3.333

Preheat Shower Water Only

Btuh Recovered

G3-60								
EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	24,507	26,389	28,130	31,243	33,971	36,394	38,564	40,530
45	22,447	24,188	25,795	28,669	31,192	33,421	35,431	37,241
50	20,367	21,957	23,425	26,060	28,366	30,411	32,249	33,903
55	18,260	19,693	21,026	23,408	25,495	27,348	29,007	30,510
60	16,122	17,402	18,587	20,715	22,577	24,231	25,709	27,041
65	13,954	15,075	16,109	17,974	19,600	21,046	22,342	23,510
70	11,749	12,702	13,587	15,174	16,563	17,796	18,897	19,891
75	9,505	10,287	11,013	12,312	13,455	14,462	15,364	16,175
S3-60								
EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	21,129	23,124	24,971	28,295	31,194	33,764	36,061	38,134
45	19,443	21,278	22,976	26,031	28,705	31,075	33,187	35,094
50	17,726	19,398	20,944	23,728	26,173	28,331	30,258	31,998
55	15,972	17,479	18,872	21,380	23,579	25,529	27,263	28,832
60	14,177	15,512	16,753	18,983	20,936	22,664	24,209	25,598
65	12,336	13,499	14,578	16,522	18,223	19,730	21,080	22,289
70	10,448	11,435	12,349	13,998	15,444	16,723	17,866	18,893
75	8,504	9,307	10,053	11,399	12,581	13,624	14,556	15,392

GPM Coil Flow

G3-60								
EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	0.988	1.082	1.172	1.344	1.506	1.660	1.808	1.951
45	0.999	1.095	1.188	1.365	1.532	1.691	1.845	1.993
50	1.011	1.110	1.205	1.388	1.561	1.726	1.886	2.040
55	1.024	1.125	1.224	1.413	1.592	1.765	1.931	2.093
60	1.038	1.143	1.245	1.441	1.628	1.808	1.982	2.151
65	1.053	1.162	1.268	1.472	1.667	1.856	2.040	2.219
70	1.070	1.183	1.294	1.507	1.713	1.912	2.106	2.296
75	1.089	1.207	1.323	1.547	1.765	1.976	2.183	2.385
S3-60								
EWT/GPM	2	2.25	2.5	3	3.5	4	4.5	5
40	0.903	1.000	1.093	1.270	1.436	1.594	1.745	1.891
45	0.918	1.017	1.113	1.294	1.465	1.629	1.785	1.936
50	0.935	1.036	1.134	1.321	1.498	1.667	1.829	1.986
55	0.953	1.057	1.158	1.350	1.533	1.709	1.877	2.041
60	0.973	1.080	1.184	1.383	1.573	1.755	1.932	2.103
65	0.994	1.105	1.212	1.419	1.617	1.808	1.994	2.174
70	1.018	1.133	1.244	1.460	1.668	1.869	2.065	2.256
75	1.045	1.164	1.280	1.506	1.726	1.939	2.147	2.350

Basis: 120F from water heater, 105F mix at shower head, 95F drain water

Laundry Performance Table

Model	GPM*	Cold Water EWT (F)	Cold Water LWT (F)	Hot Water EWT (F)	Hot Water LWT (F)	Heat Trans Btuh	Cold Water Pres. Drop
P4-60	5	55	80.2	95	69.8	63,110	12.4
P4-60	5	60	82.1	95	72.9	55,220	12.4
P4-60	5	65	83.9	95	76.1	47,332	12.4
P4-60	5	70	85.8	95	79.2	39,444	12.4
P4-60	5	75	87.6	95	82.4	31,554	12.4

* Basis: 5 GPM cold and 5 GPM pit water at 95F avg. temperature

Laundry Performance Table

Model	GPM*	Cold EWT (F)	Cold LWT (F)	Hot W EWT (F)	Hot W LWT (F)	Heat Trans Btuh	Cold Water Pres. Drop
PS4-60	10	55	72.7	95	77.3	88,590	6.5
PS4-60	10	60	77.5	95	79.5	77,548	6.5
PS4-60	10	65	78.3	95	81.7	66,506	6.5
PS4-60	10	70	81.1	95	84.0	55,464	6.5
PS4-60	10	75	83.9	95	86.1	44,294	6.5

* Basis: 10 GPM cold and 10 GPM pit water at 95F avg. temperature

Laundry Performance Table

Model	GPM*	Cold Water EWT (F)	Cold Water LWT (F)	Hot Water EWT (F)	Hot Water LWT (F)	Heat Trans Btuh	Cold Water Pres. Drop
M2P4-60	10	55	80.2	95	69.8	126,220	12.4
M2P4-60	10	60	82.1	95	72.9	110,440	12.4
M2P4-60	10	65	83.9	95	76.1	94,664	12.4
M2P4-60	10	70	85.8	95	79.2	78,888	12.4
M2P4-60	10	75	87.6	95	82.4	63,108	12.4

* Basis: 10 GPM cold and 10 GPM pit water at 95F avg. temperature

[10/27/98]

Average Operating Parameters For NY Laundry

[*Very Cold Water From Lake Erie @ 30ºF to 55ºF*]

Parameter	***Existing Luddell System*** [4-Pass Shell & Tube HX]	***GFX*** [2 1/2 Tier Falling-Film HX]
Heat Recovery Efficiency	30%	**80%**[1]
Effectiveness of Heat Exchanger [HX]	66.7%	**80%**
Wastewater Into HX	120ºF @ 75,000 gpd *[ÄTmax = 75º]*	Same
Wastewater Out of HX	90ºF @ 75,000 gpd *[ÄT=25º]*	**60ºF** @ 75,000 gpd ***[ÄT=60º]***
Cold In @ 7% Drag-Out Loss	45ºF @ 48,750 gpd	45ºF @ **80,000** gpd
Tepid Out	95ºF @ 48,750 gpd *[ÄT=50º]*	**101ºF @ 80,000 gpd** ***[ÄT=56º]***
Value of Wastewater Into HX @ $4.40/Million Btu	$206/day @ 100% *W/Htr. Eff.* $228/day @ 90% ” $380/day @ 60% ”	Same
Value of Wastewater Out of HX [To Sewer]	$144/day @ 100% ” $160/day @ 90% ” $266/day @ 60% ”	$**41**/day @ 100% W/H Eff. $**46**/day @ 90% ” $**76**/day @ 60% ”
Savings	$ 62/day @ 100% ” $ 68/day @ 90% ” $114/day @ 60% ”	$**165**/day @ 100% ” $**182**/day @ 90% ” $**304**/day @ 60% ”
Annual Savings 5 days/week 52 weeks/year	$16,120 @ 100% ” $17,680 @ 90% ” $29,640@ 60% ”	$**42,900** @ 100% ” $**47,320** @ 90% ” $**79,040** @ 60% ”

System Changes With GFX

1. Rinse with tepid water @ 101ºF if possible. [The cooler the rinse, the less the savings.]
2. Pump directly from first tank without filtering.
3. No back-flushing.
4. Preheat all incoming cold water, or as much as practical.
5. Dramatic drop in boiler load when incoming water drops to 30ºF.
6. Use 2/12 Tier Cooling-Wall, 32 Columns. [HX Height: 12', Array With: 12' x 41/2"]
   See: http://oikos.com/gfx/coolingwall.html &
   http://oikos.com/gfx/applications.html
7. Budget Estimate For Falling-Film HX's: 60 Model G3-60 & 33 Model G3-30 = **$22,400.**
8. Fittings + PVC Manifold: Under $2000 [If wall mounted]
9. Use Existing Pumps.
10. Labor, Instrumentation & Monitoring: T.B.D.

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[1] GFX's efficiency will drop to about **60%** if just boiler-feed water is preheated; with full-cold water being used for tempering & rinsing as in the existing system. [Note: Drag-out loss, which is low because of high-spin rate washers, can approach 20% with some washing & dye machines.]

Dishwasher Performance Table

Model	GPM*	Cold Water EWT (F)	Cold Water LWT (F)	Hot Water EWT (F)	Hot Water LWT (F)	Heat Trans Btuh	Cold Water Pres. Drop
P3-60	4	55	101.3	130	83.7	92,586	6.8
P3-60	4	60	103.2	130	86.8	86,414	6.8
P3-60	4	65	105.1	130	89.9	80,241	6.8
P3-60	4	70	107.0	130	93.0	74,069	6.8
P3-60	4	75	108.9	130	96.1	67,896	6.8

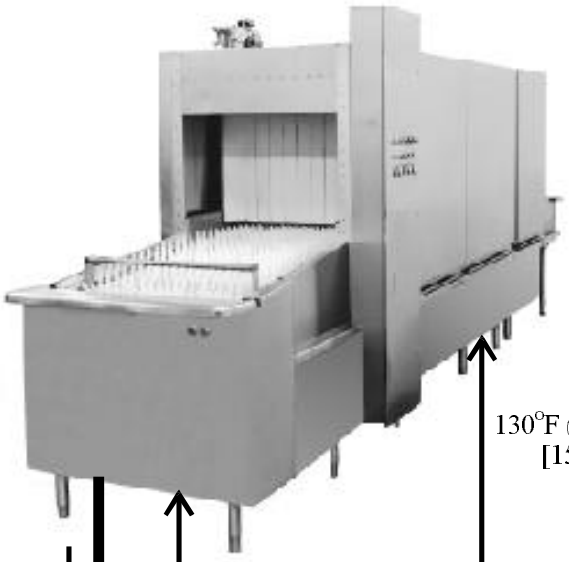
* Basis: 4 GPM cold and 4 GPM waste water at 130F avg. temperature

Dishwasher Performance Table

Model	GPM*	Cold EWT (F)	Cold LWT (F)	Hot W EWT (F)	Hot W LWT (F)	Heat Trans Btuh	Cold Water Pres. Drop
P4-60	4	55	106.0	130	79.0	102,037	9.0
P4-60	4	60	107.6	130	82.4	95,234	9.0
P4-60	4	65	109.2	130	85.8	88,432	9.0
P4-60	4	70	110.8	130	89.2	81,629	9.0
P4-60	4	75	112.4	130	92.6	74,827	9.0

* Basis: 4 GPM cold and 4 GPM waste water at 130F avg. temperature

Case Study: *DHR Energy & Demand Savings Estimates For Flight-Type Commercial Dishwasher Operating In Our Lady of Consolation Nursing Home*



Hobart FT900
Flight-Type Conveyer Dishwasher
Pre-, Wash-, Rinse-, Final-Rinse-
Temperatures: 130/140/160/180°F

130°F @ 1.26 gpm
[15.8 kW]

Model M2P4-60 GFX
DHR Efficiency Ratings:
79% @ 4.5 GPM
72% @ 6.5 GPM

Winter Reach: 26°F
@ 72% Balanced Effectiveness
6 psi Pressure Drop
112°F@ 64.5 kW
6.5 gpm

180°F @ 5.24 gpm
Final Rinse
[105 kW]

Tankless W/H
36 kW Electric
123 kBtu/hr Gas

Tankless W/H
18 kW Electric
61 kBtu/hr Gas

Drainwater
138°F @ 6.5 gpm

Run-Dry
Centrifugal-Pump With
Clog-Resistant Impeller
Grainger [TEEL] #3P577
Self-Priming to 20 Feet

Strainer

City Water
45°F Winter
(55°F Avg)

71°F Winter
78°F Avg.
85°F Summer
To Grease Trap

Average Fuel Savings

@ 7 Hours Per Day Operation
Tankless All-Electric @ 100% Conversion
No Distribution Loss: 147,000 kWh/yr

Gas Storage Water Heating
@ 40% Conversion/Distribution Efficiency
1.26 Billion Btu = 12,600 Therm

Water Heater's Load Reduction

Winter: 64.4 kW = 220 kBtu/hr
Summer: 50.6 kW = 172 kBtu/hr
Average: 57.5 kW = 196 kBtu/hr

GFX CASE STUDY

Commercial Dishwasher

Application: Twenty gas water heaters (GWH) supply 150 degree F water @ 4 gpm to twenty flight-type, conveyor "dishwashers" used to remove mold release from injection molded plastic parts. Each parts washer requires an average of 2 GPM of 150 degree F water, 24 hours/day, 5 days/week.

Water Heater: Rheem Vanguard Model 6E743A, 199,900 Btu/hr input, 183 GPH @ 110 degree F rise, 170,000 Btu/hr output; 85% conversion efficiency .

Problem Eliminated By GFX: Heat exchanger fouling from mold release in drainwater.

Problem Reduced By GFX Model P3-60: Poor GWH recovery as supply water cools and they age.

Without GFX

	68F Cold Supply	**45F Cold Supply**
Process Energy Demand:	19.68 Therm/day	25.20 Therm/day
GWH Load [See Notes]	19.68 Therm/day	25.20 Therm/day
Input Energy Demand:	23.15 Therm/day	29.65 Therm/day
Input Heat Demand @ 4gpm:	1.929 Therm/hr	2.471 Therm/hr
Drainwater Heat:	14.88 Therm/day	20.40 Therm/day

With GFX Model P3-60

Process Energy Demand:	19.68 Therm/day	25.20 Therm/day
Measured GFX-Performance:	Drain - 39F drop [130/ 91]	53.6F drop
	Coil - 39F rise [68/107]	53.6F rise
Measured Recycling Efficiency:	63%	63%
Heat Recovered:	9.36 Therm/day	12.85 Therm/day
GWH Load:	10.32 Therm/day	12.35 Therm/day
Input Energy Demand:	12.14 Therm/day	14.53 Therm/day
Input Heat Demand @ 4gpm:	1.012 Therm/hr	1.211 Therm/hr
Energy Savings:	47.6%	51.0%
Demand Savings:	47.6%	51.0%
Net Savings For 20 P3-60's:	48,672 Therm/yr	66,820 Therm/yr

NOTE 1: Distribution & Standby Loss Neglected
NOTE 2: 1 Therm = 100,000 Btu = 29.3 kWh
*GFX Measurements , Courtesy of Jason Blankenship, MERAMEC Group.

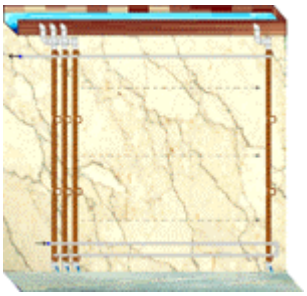
Return to GFX Home Page

Cold Side Pressure Drop

GPM	G3-60	S3-60	P3-60	G4-60	S4-60	P4-60	PS4-60	M2P4-60
0.5	2.2	0.3		2.9	0.4			
1	3.6	0.5	2.2	4.8	0.7	2.9		
1.5	5.2	0.8	2.9	6.9	1.1	3.8		
2	6.8	1.2	3.6	9.0	1.6	4.8	0.7	2.9
2.25	7.9	1.3	4.0	10.4	1.7	5.3	0.8	3.1
2.5	9.4	1.5	4.4	12.4	2.0	5.8	1.0	3.4
3	12.6	1.9	5.2	16.6	2.5	6.9	1.1	3.8
3.5	15.8	2.6	6.0	20.9	3.4	7.9	1.4	4.3
4	19.8	2.6	6.8	26.1	3.4	9.0	1.6	4.8
5	34.0	4.9	9.4	44.9	6.5	12.4	2.2	5.8
6		7.7			10.2		2.5	6.9
7		10.5			13.9		3.0	8.0
8		13.6			18.0		3.4	9.0
9		16.3			21.5		5.0	10.7
10		19.3			25.5		6.5	12.4

GFX Applications

(From: www.oikos.com/gfx/applications.html)



Larger version (149K)

Industrial

GFX Cooling-Walls offer ultra-high recycling efficiency, with inherent risk-management, because GFX's lack of internal welds eliminates cross-contamination problems caused by internal weld-failures and tube leaks common to shell and tube heat exchangers. By eliminating cross-contamination issues, an ESCO can guarantee big energy-savings, with safe and reliable performance. For example, a Textile Dye Plant consuming 1000 gpm of fresh water and producing 800 gpm of hot/smelly effluent could utilize a GFX Cooling-Wall comprised of 285 columns (15-feet tall) to cost-effectively recycle up to 85% of the waste heat carried to settling ponds where evaporation occurs to add to air pollution already created by the plant's stack emissions. The toll of heating one million gallons of water per day from 55 to 140 degrees F is about: 709 mmBtu (208,000 kWh) --- $3,545 @ $5/mmBtu to $10,400 @ $0.05/kWh --- 40 to 230 tons of CO2 & 1.4 to 8 tons of NOx emissions, depending upon the source of energy. Recycling 85% of the effluent's heat could lower peak boiler loading from 45 to 14 mmBtu/hr; dramatically reducing stack emissions and the stench from settling ponds because cool effluent evaporates more slowly. Here are several detailed examples.

GFX Case Study: Commercial Dishwasher

GFX "Cooling Walls"

Commercial/Industrial

GFX Cooling-Wall	Column Flow Rate Range (gpm)	Recycling Efficiency Range	Coil Pressure Drop Range (psi)	List Price per Column [Model F-601]	Approximate Hieght with Upper Manifold
Single-Tier	2.25 to 3.00	60% to 56%	8 to 14	$260	7'
Double-Tier	2.25 to 3.00	75% to 72%	16 to 28	$520	12'
Triple-Tier	2.25 to 3.00	82% to 79%	24 to 42	$780	17'

Performance Example

Textile Dye Plant Application: 275 Column GFX Cooling-Wall
Preheated Flow Rate: 1000 gpm input @ 60 degrees F Avg. [range: 50 to 86 degrees F]
Effluent Flow Rate: 800 gpm @ 140 degrees F [20% drag out loss]
Cost of Energy $3.46/mmBtu = 34.6¢/Therm = 1.18¢ / kWh - Thermal

GFX Cooling-Wall	Recycling Efficiency Range	Annual Savings	Preheat Water Temperature (degrees F)	Peak Effluent Temperature (degrees F)	Peak Boiler Load (mmBtu/hr [kW])
No Recycling	N/A	($797,000)	N/A	140	45 [13,000]
Single-Tier	62%	$494,000	95 to 113	106	22 [6400]
Double-Tier	79%	$630,000	107 to 120	97	17 [5000]
Triple-Tier	86%	$685,000	112 to 123	94	14 [4100]

Other "Cooling-Wall" Applications

Boiler Load Reduction for Equal Flow Case
Tabulated in kW-Thermal per GFX Column
[Cold Water Range T_{cold} =40 deg F to 55 deg F]

GFX Cooling-Wall	Gang Showers & Beauty Shops (Tdrain = 95^{o}F)	Laundries & Textile Mills (Tdrain = 140^{o}F)	Commercial Dishwashing (Tdrain = 175^{o}F)	Steam Condensate (Tdrain = 212^{o}F)
Single-Tier	11 to 8	19 to 16	27 to 24	34.4 to 31.4
Double-Tier	13.8 to 10	23.8 to 20	33.8 to 30	43 to 39.3
Triple-Tier	15 to 10.9	26 to 21.9	36.9 to 32.8	47 to 43.1