ارامكو السعودية
Saudi Aramco

Detailed Energy Assessment at Oil Refinery: Tools and Results

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Synopsis

- First Time Pinch Analysis was applied in SA Refinery (2003)
- Expected Savings ~ 10-15% of Baseline Energy Cost
- Actual Savings Identified ≈ 37% (despite low fuel/power costs)

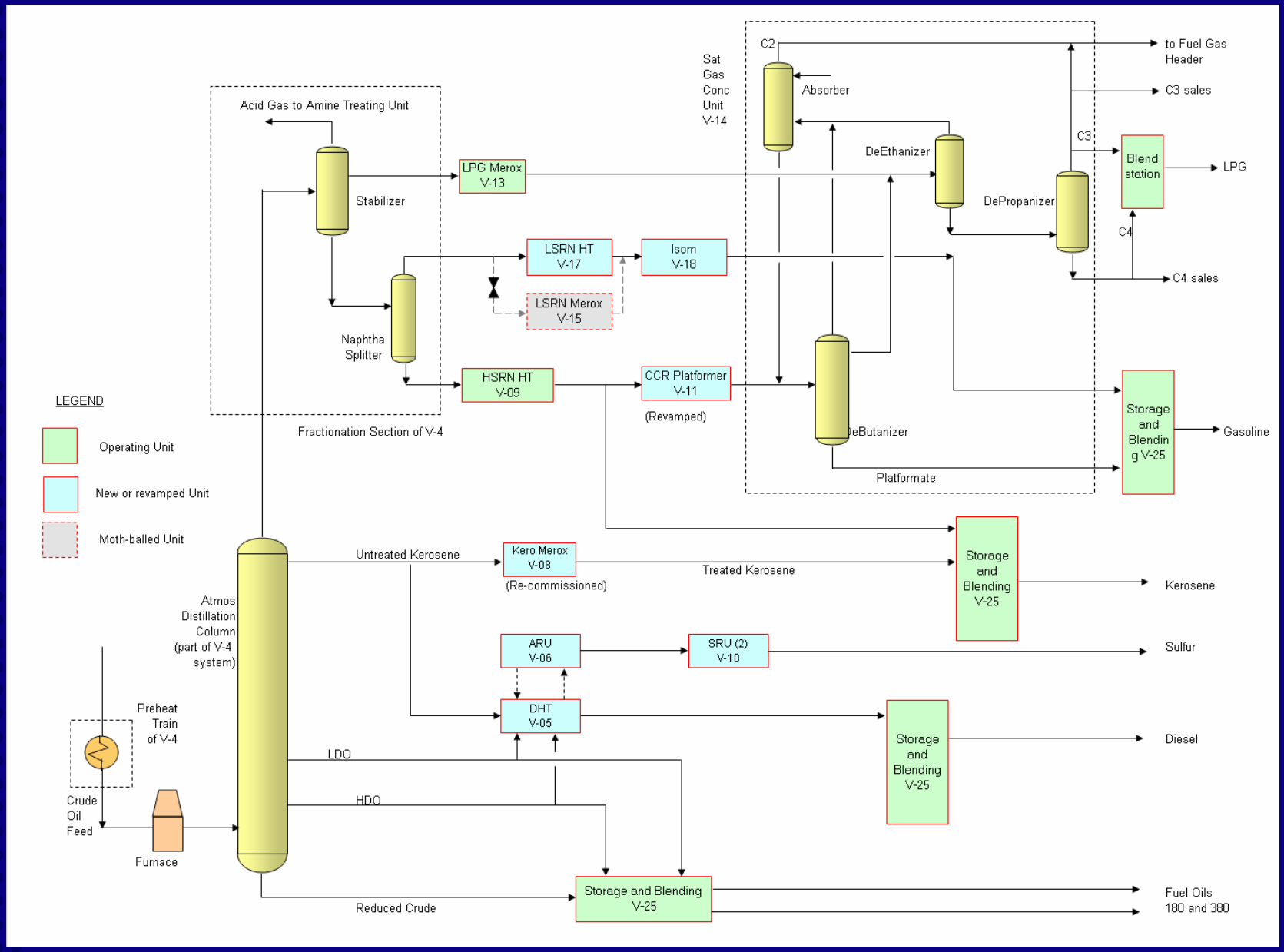
Introduction

- SA management adopted Energy Policy in 2000 with the goal of 50% reduction in corporate energy index over 10 years
- Energy Systems Unit was established to help plants w.r.t. technology transfer

Scope of Work

- Fuel Savings via Heat Recovery optimization (using Pinch Analysis)
- Power Reduction via ASDs
- Optimization of Combined Heat & Power (CHP) design and operation
- Development and deployment of on-line Energy Indices (Solomon EII)

Simplified Refinery schematic, 2006



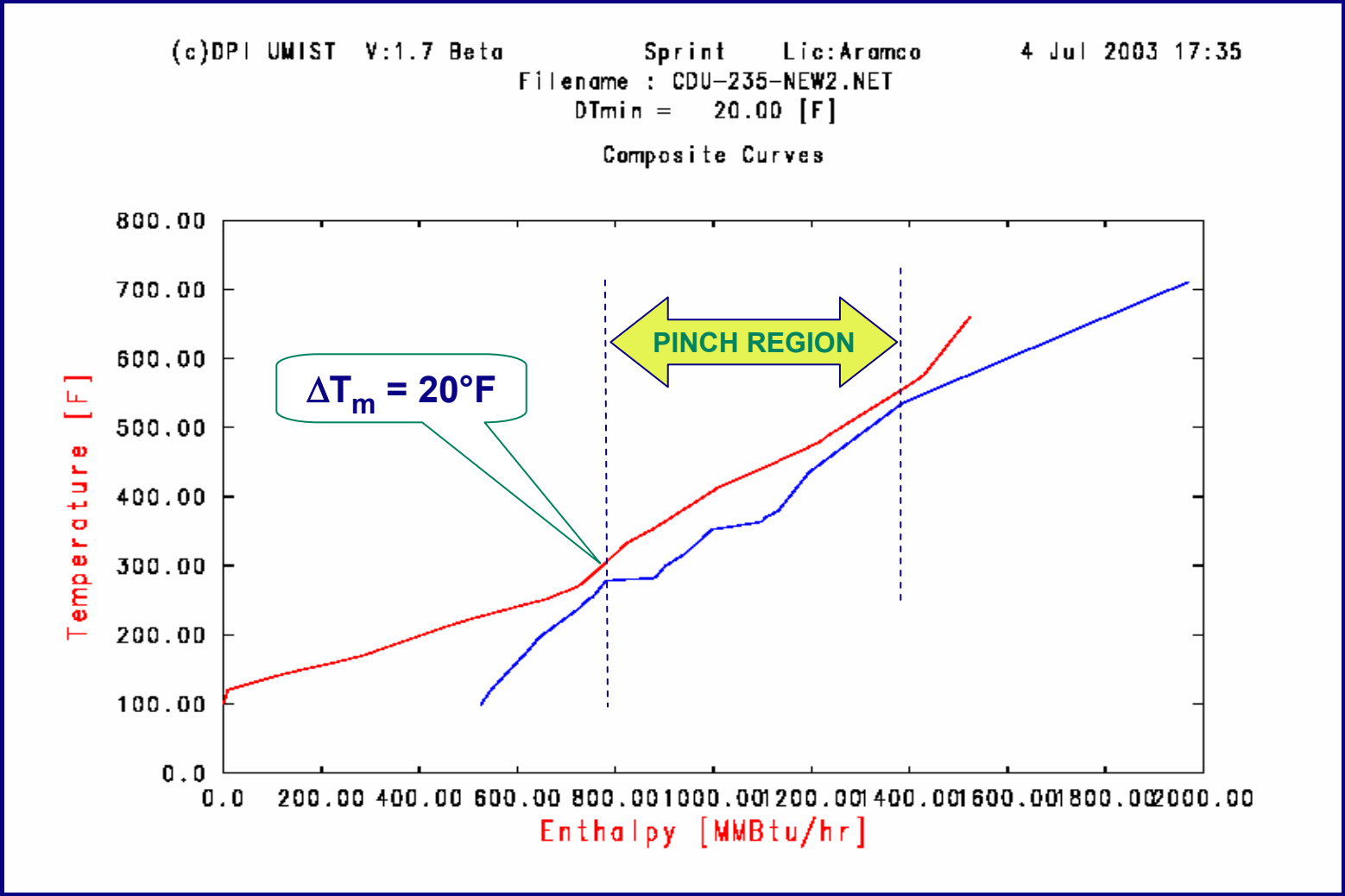
Pinch Analysis - Scope

- Overall Plant Energy Balance
- Thermal Targets and HEN design for:
  - CDU (retrofit)
  - HSRN hydrotreater (retrofit)
  - DHT complex (new)
  - CCR (revamp)
  - LSRN hydrotreater and Isomerization (new)

Pinch Analysis – Procedure

- Prepare reconciled HMB from RIS for existing units (using Data Recon s/w package)
- Confirm HMB with PMT for new units
- Develop proposed new HEN designs
- Discuss with refinery/FPD/PMT for agreement
- HX sizing
- Capital cost estimating
- Project feasibility analysis
- Report preparation

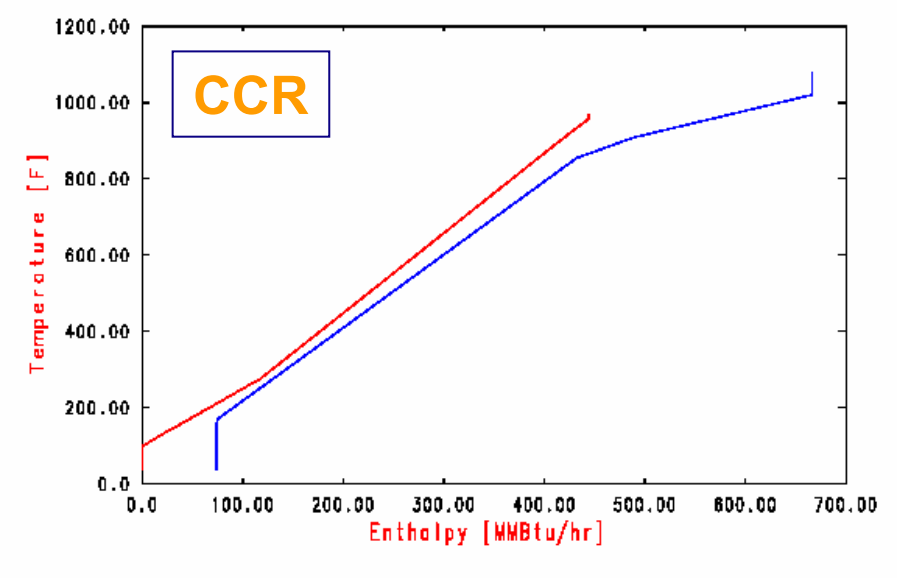
Composite Curves – CDU

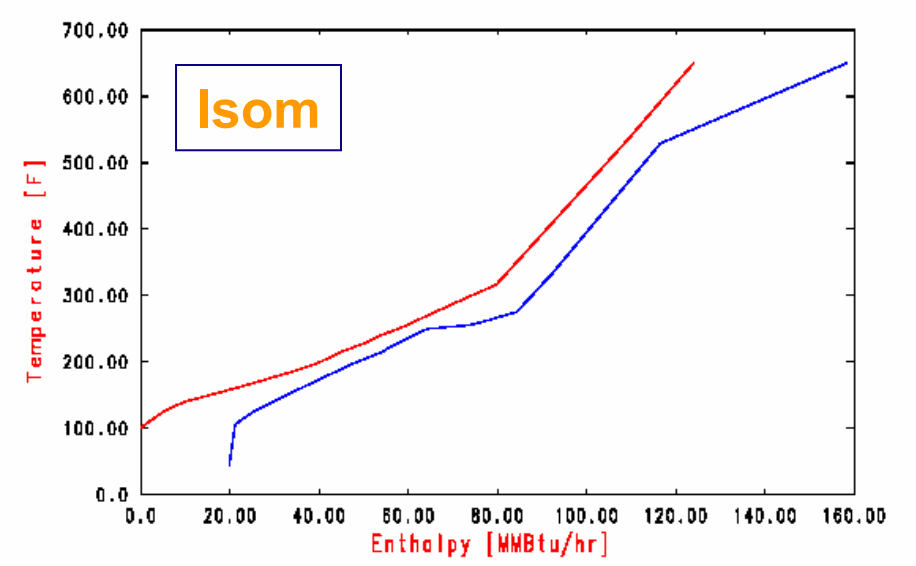


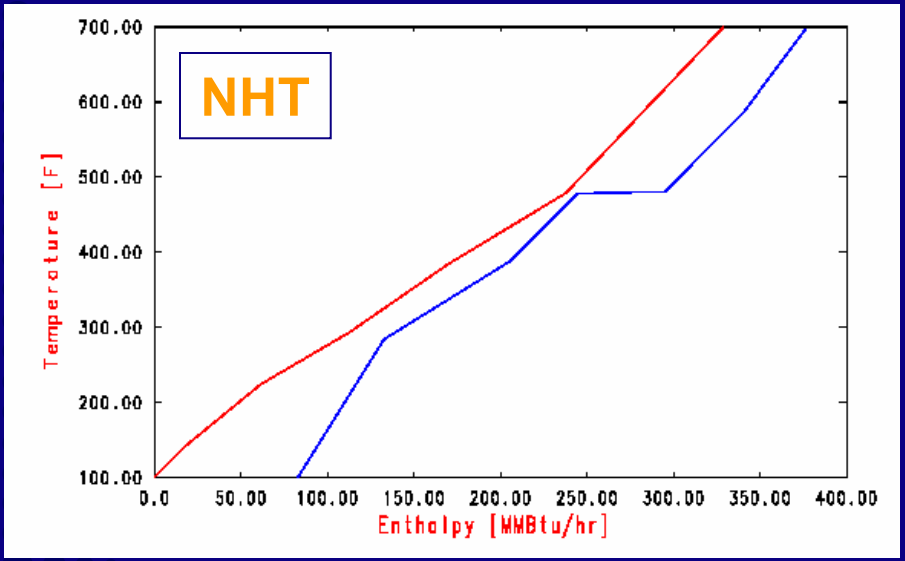
Target Savings – CDU (details)

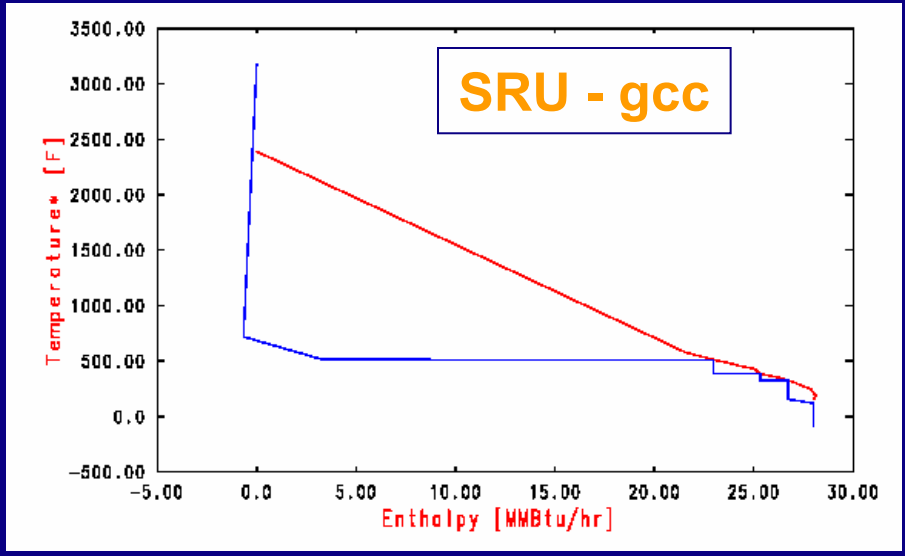
ΔT = 20°F	Actual	Pinch	Savings Potential		
	PFD	Target	MMBtu/h	%	K$/yr
Total heating duty	581.7	502.9	78.8	13.5	
Total cooling duty	661.4	581.8	79.6	12.0	
Fuel supplied	684.4	591.6	92.7	13.5	973.7
Steam	0.0	0.0	0.0	100.0	0.0
60 Steam Gen	0.0	0.0	0.0	100.0	0.0
Air cooling	523.7	573.0	-49.3	-9.4	-53.9
Sea Water cooling	137.7	8.8	128.9	93.6	909.5
					1829.3
Energy Cost, K$/yr	8729	6900		21.0	1829

Composite Curves for others …









Overall Thermal Energy Targets

				Actual Energy Consumption			Target Energy Consumption				
		Normal	Optimum	Heating	Cooling	Cost	Heating	Cooling	Cost	Savings Potential	
Unit No.	Name	feed rate	DT, °F	MMBtu/h	MMBtu/h	K$/yr	MMBtu/h	MMBtu/h	K$/yr	K$/yr	%
V-04	CDU	235 MBD	20	581.7	661.4	8729	502.9	581.8	6900	1829	21.0
V-09	Heavy NHT	37 MBD	16	85.1	120.9	1332	49.3	85.1	468	864	64.8
V-05	DHT + ARU	95 MBD	24	255.2	347.8	4523	162.3	254.9	2369	2154	47.6
V-10	SRU (2 trains)	190 TPD	40	10.4	65.0	-771	1.8	56.4	-1013	242	31.4
V-11	CCR (revamp)	47 MBD	24	265.0	116.4	3645	222.4	73.8	3012	633	17.4
V17, 18	LSRN ht+isom	12 MBD	18	59.9	45.3	958	34.3	19.8	528	430	44.9
V-32	Utilities (CHP)	future	n/a							0	0.0
				1257.4	1356.8	18417	973.0	1071.8	12264	6152.5	33.4

Blue = New Unit
Purple = Revamped Unit
Black = Existing Unit

SURPRISE ! Significant Cost Savings Potential even in new licensed processes !!

HEN simulation – CDU (1/3)

		E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9
Name / Service		Crude vs Naphtha P/A	Crude vs Kero	Crude vs LDO Product	Crude vs No 1 LDO P/A	Crude vs No 2 LDO P/A	Crude vs HDO Product	Crude vs Cold Red. Crude	Crude vs HDO P/A	Crude vs Hot Red. Crude
No. of shells/coils		8	2	4	4	4	2	16	4	8
	series	2	1	2	2	2	1	4	2	4
	parallel	4	2	2	2	2	2	4	2	2
Area per shell, ft2		4078	4530	4821	4327	4327	4004	3197	4714	5072
Total area, ft2		32624	9060	19282	17308	17308	8008	51149	18858	40579
Max duty, MMBtu/h										
Hot stream										
Description		Heavy Naphtha P/A	Kero Prod	LDO Prod	LDO PA 1	LDO PA 2	HDO Prod	Cold Red. Crude	HDO PA 1	Hot Red. Crude
Flow	tag no.									
	mean - μ	480.4	152.9	178.4	200.8	280.3	48.2	308	319.6	307.8
	std dev - σ									
	units	m3/h	m3/h	m3/h	m3/h	m3/h	m3/h	m3/h	m3/h	m3/h
	conversion	1.338	1.415	1.454	1.415	1.415	1.314	1.737	1.282	1.309
	Klb/h meas	643	216	259	284	397	63	535	410	403
	Klb/h used	1810	212	558	262	393	414	1174	584	1174
	phase	liquid	liquid	liquid	liquid	liquid	liquid	liquid	liquid	liquid
	HHV, Btu/lb									
	furnace eff									
Specific gravity		0.660	0.717	0.792	0.789	0.789	0.859	0.949	0.855	0.949
Liquid density, g/cc		0.607	0.642	0.660	0.642	0.642	0.596	0.788	0.582	0.594
Temp In	tag no.									
°C	mean - μ	149.0	173.0	226.2	239.7	239.7	316.4	227.7	324.2	353.6
	std dev - σ									
	deg F	300	343	439	463	463	602	442	616	668
Enthalpy, Btu/lb		156	186	246	261	261	350	251	359	389
Temp Out	tag no.									
°C	mean - μ	71.2	85.1	88.4	116.2	136.4	154.4	173.2	188.1	227.8
	std dev - σ									
	deg F	160	185	191	241	278	310	344	371	442
Enthalpy, Btu/lb		75	92	96	126	148	171	191	208	251
Specific heat, Btu/lb-F		0.583	0.597	0.605	0.605	0.605	0.614	0.612	0.614	0.612
X = (T1+T2)/200, F		2.30	2.64	3.15	3.52	3.70	4.56	3.93	4.93	5.55
film h, Btu/ft2-h-F		120	121	104	108	109	93	51	94	63
Duty	MMBtu/h	147.9	20.0	83.7	35.2	44.20	74.2	70.5	87.9	162.7

HEN simulation – CDU (2/3)

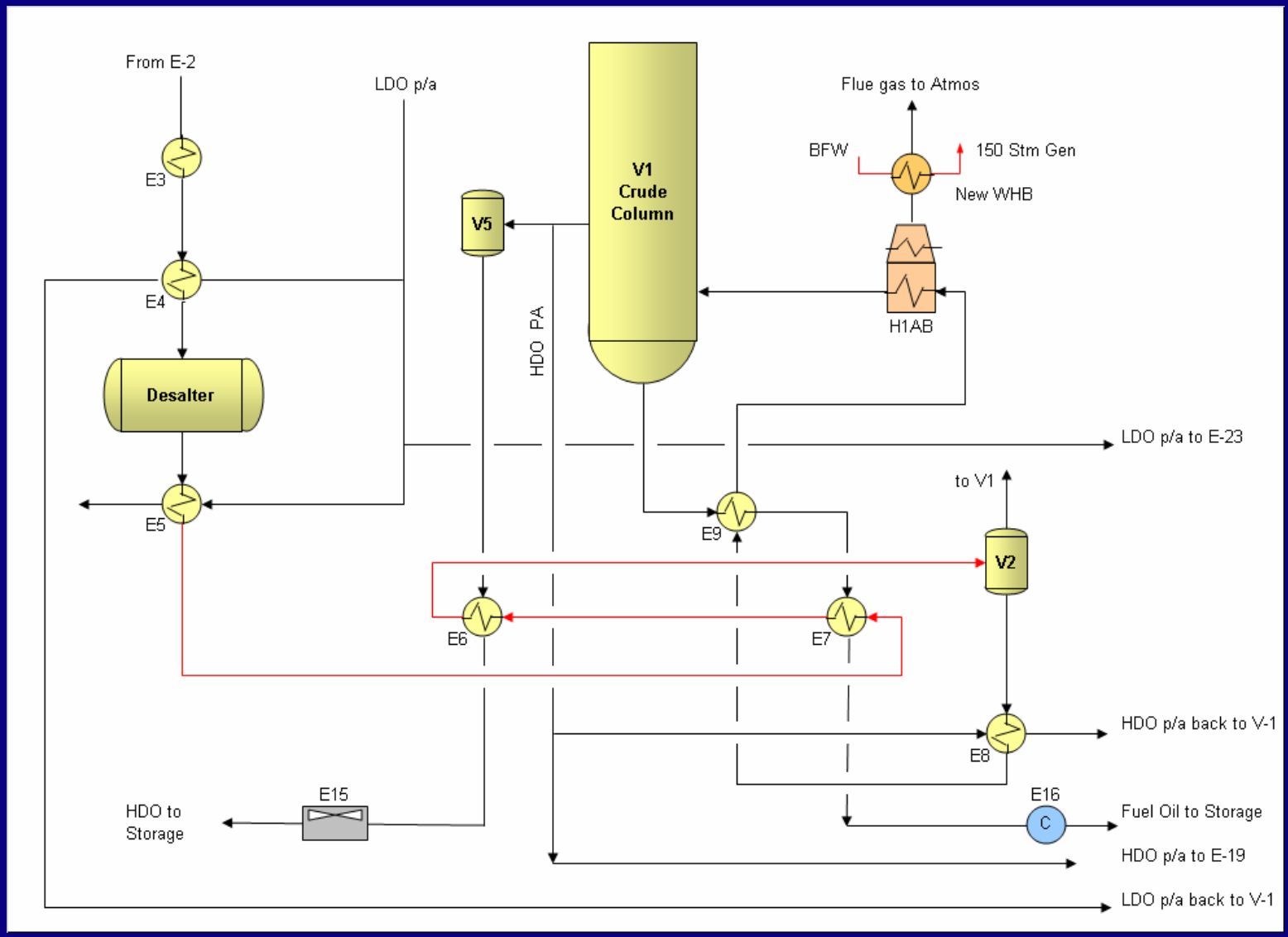
		E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8
Name / Service		Crude vs Naphtha P/A	Crude vs Kero	Crude vs LDO Product	Crude vs No 1 LDO P/A	Crude vs No 2 LDO P/A	Crude vs HDO Product	Crude vs Cold Red. Crude	Crude vs HDO P/A
Cold stream									
Description		Crude Oil Feed	Crude Oil Feed	Crude Oil Feed	Crude Oil Feed	DS Crude Oil Feed	DS Crude Oil Feed	DS Crude Oil Feed	DS Crude Oil from flash drum
Flow	tag no.								
	mean - μ	1569	1569	1569	1569	1569	1569	1569	1427
	std dev - σ								
	units	m3/h	m3/h	m3/h	m3/h	m3/h	m3/min	m3/min	m3/h
	conversion	1.784	1.759	1.751	1.712	1.695	1.670	1.625	1.627
	Klb/h meas	2799	2799	2799	2799	2799	2799	2799	2322
	Klb/h used	2803	2803	2803	2803	2803	2803	2803	2663
	phase	liquid	liquid	liquid	liquid	liquid	liquid	liquid	liquid
Specific gravity		0.816	0.816	0.816	0.816	0.816	0.816	0.816	0.833
Liquid density, g/cc		0.809	0.798	0.794	0.777	0.769	0.758	0.738	0.738
Temp In	tag no.								
°C	mean - μ	43.5	71.1	79.0	111.0	123.0	139.0	165.0	181.4
	std dev - σ								
	deg F	110.3	160.0	174.2	231.8	253.4	282.2	329.0	358.5
Enthalpy, Btu/lb		36.0	60.2	67.4	97.2	108.8	124.6	151.0	168.1
Temp Out	tag no.								
°C	mean - μ	102.0	79.0	111.0	124.0	139.0	165.0	187.0	212.0
	std dev - σ								
	deg F	215.6	174.2	231.8	255.2	282.2	329.0	368.6	413.6
Enthalpy, Btu/lb		88.7	67.4	97.2	109.8	124.6	151.0	174.1	201.2
Sp heat, Btu/lb-F		0.501	0.502	0.518	0.536	0.547	0.564	0.583	0.600
X = (T1+T2)/200, F		1.63	1.67	2.03	2.44	2.68	3.06	3.49	3.86
film h, Btu/ft2-h-F		68.6	69.6	77.5	84.9	88.5	92.9	96.0	97.2
Duty	MMBtu/h	147.7	20.0	83.7	35.2	44.2	74.0	64.7	88.0

HEN simulation – CDU (3/3)

	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8
Name / Service	Crude vs Naphtha P/A	Crude vs Kero	Crude vs LDO Product	Crude vs No 1 LDO P/A	Crude vs No 2 LDO P/A	Crude vs HDO Product	Crude vs Cold Red. Crude	Crude vs HDO P/A
Exchanger								
Avg Duty, MMBtu/h	147.8	20.0	83.7	35.2	44.2	74.1	67.6	87.9
Error in Q,%	0.1%	0.1%	0.0%	0.1%	0.0%	0.2%	8.5%	0.1%
Hot end DT approach	84.6	169.2	207.4	208.3	181.3	272.5	73.3	201.96
Cold end DT approach	49.86	25.2	16.92	9.36	24.12	27.72	14.76	12.06
Avg temp approach	67.2	97.2	112.1	108.8	102.7	150.1	44.0	107.01
No. of HTU (approx)	2.1	1.6	2.2	2.0	1.8	1.9	2.2	2.3
LMTD, deg F	65.7	75.6	76.0	64.1	77.9	107.1	36.5	67.4
Correction factor, Ft	1	0.8	0.8	1	1	0.8	1	0.8
Corrected MTD, F	65.7	60.5	60.8	64.1	77.9	85.7	36.5	53.9
Actual U, Btu/ft2-h-F	68.9	36.5	71.4	31.7	32.8	108.0	36.2	86.5
Design U	43.6	44.1	44.5	47.5	48.9	46.3	33.2	47.8
% Error in U	46%	-19%	48%	-41%	-40%	87%	9%	60%
Design A (for new HX)	51542	7501	30950	11569	11605	18654	55812	34125
Type of HX	S&T	S&T	S&T	S&T	S&T	S&T	S&T	S&T
a	13000	13000	13000	13000	13000	13000	13000	13000
b	465	465	465	465	465	465	465	465
n	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Cap Cost, K$	731	143	414	235	235	237	1006	438
Installation factor	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Installed new cost, K$	1681	328	951	540	541	545	2315	1007
Retrofit cost, K$	0	0	0	0	0	0	0	0

Errors must be reconciled before optimization

Proposed retrofit – CDU



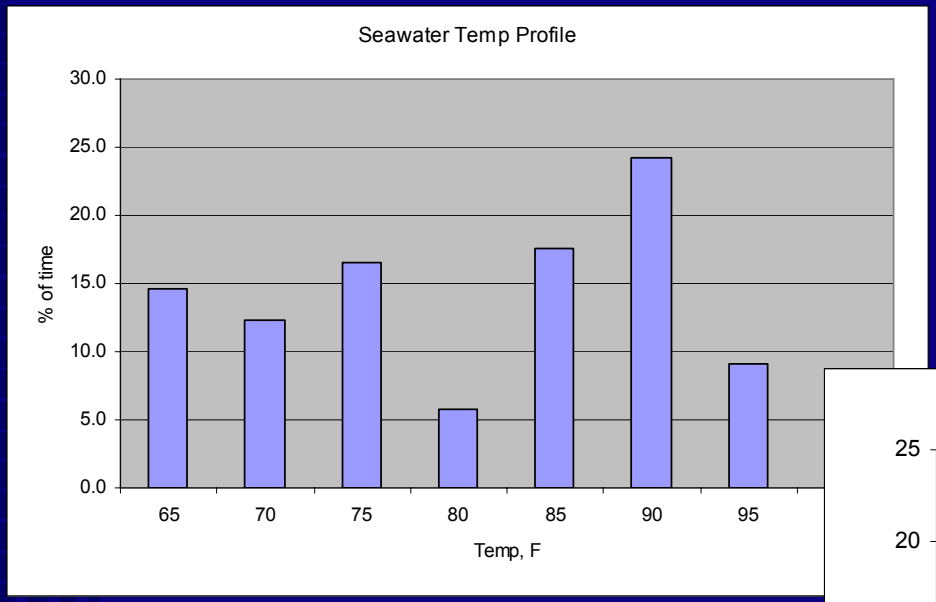
Estd Op Cost Savings – CDU

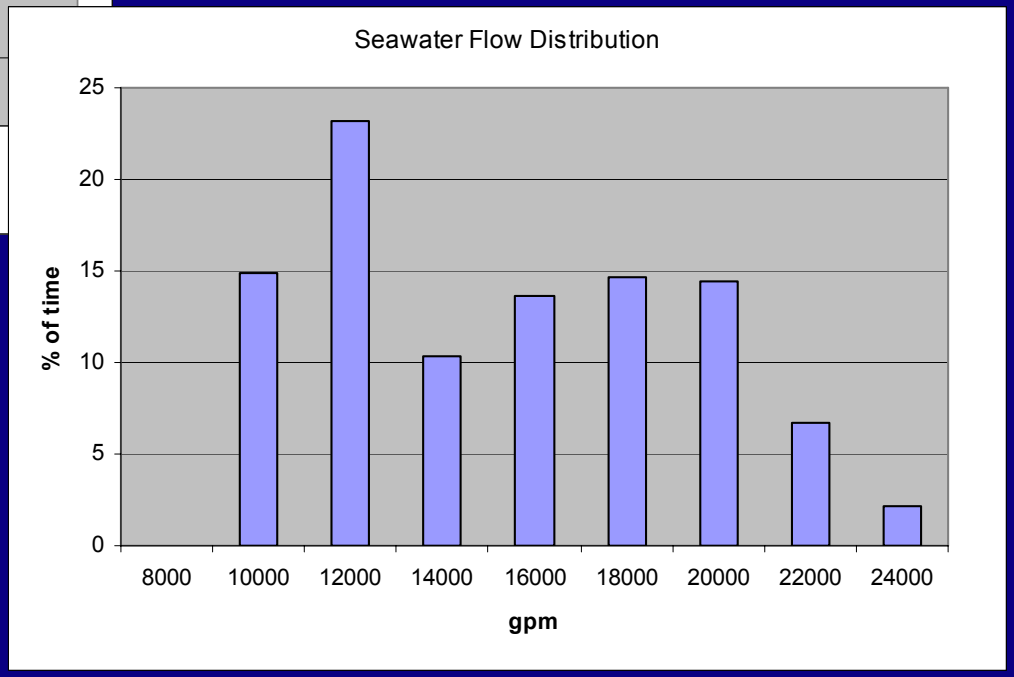
Energy Savings							
		MMBtu/h	$/MMBtu	$/hr	h/yr	K$/yr	
Fuel gas or oil		20.1	1.25	25.1	8400	211	
	psig	Klb/h	$/Klb	$/hr	h/yr	K$/yr	
HP steam	625	0	2.72	0	8400	0	
MP steam	150	37.2	2.48	92.2	8400	774	
LP steam	50	0	2.46	0	8400	0	
Condensate	15	-37.9	0.90	-34.1	8400	-287	
	temp, F	MMBtu/h	$/MMBtu				
Air cooling	100	-112.8	0.09	-10.2	8400	-85	
cooling water	86	35.3	0.27	9.5	8400	80	
freon refg	20	0	2.74	0	8400	0	
		kw	$/kwh	$/hr	h/yr	K$/yr	
Elec power usage Δ			0.0267	0	8400	0	
Elec power generation Δ		0	0.024	0	8400	0	
Operation and Maintenance Cost, etc				3	% of TIC	9	K$/yr
				Total savings (net)		685	K$/yr

37% of New Des

Est. Cap Cost = $300 K, Simple Payback < 6 months

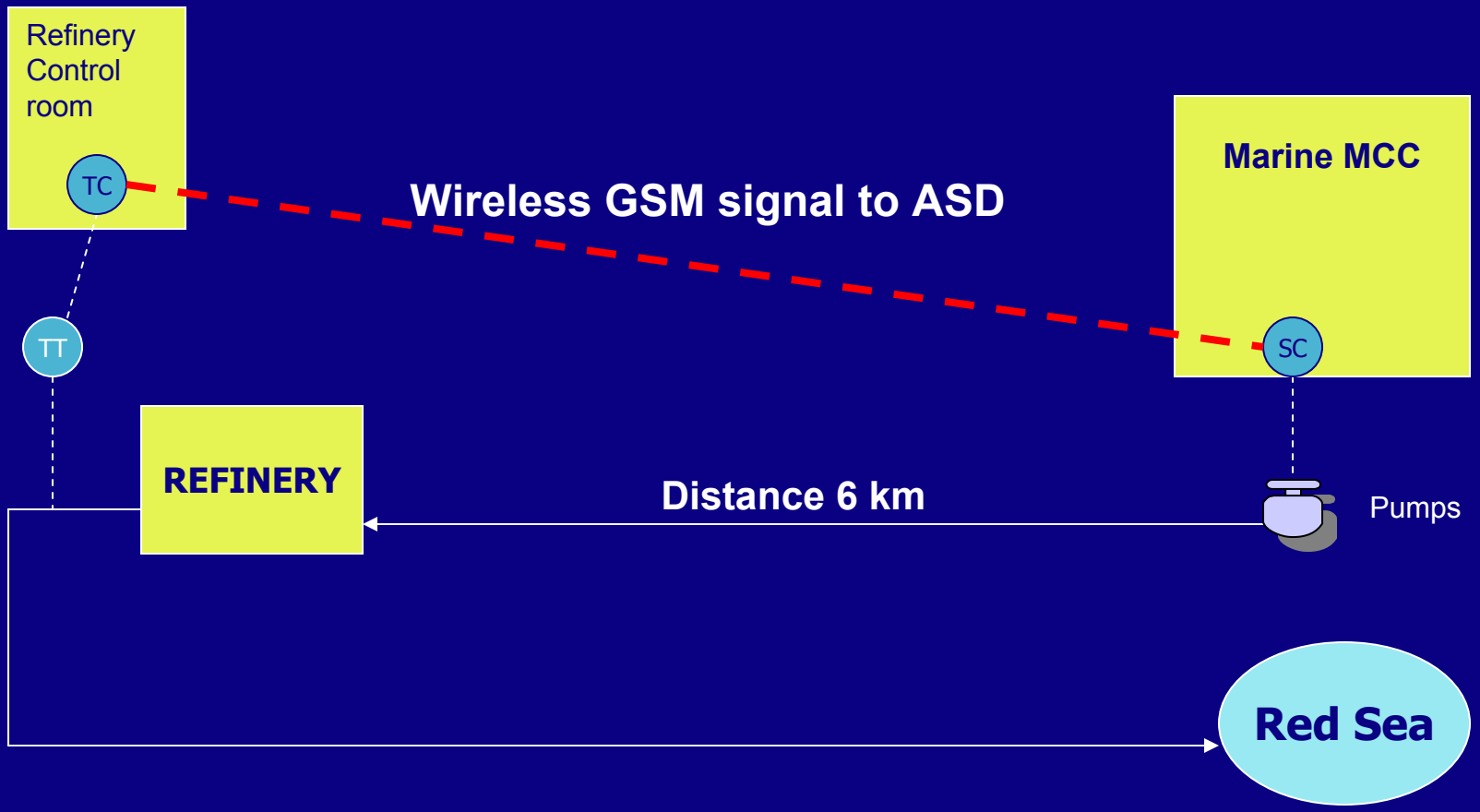
Power Conservation (ASD for Seawater Circulation Pumps)





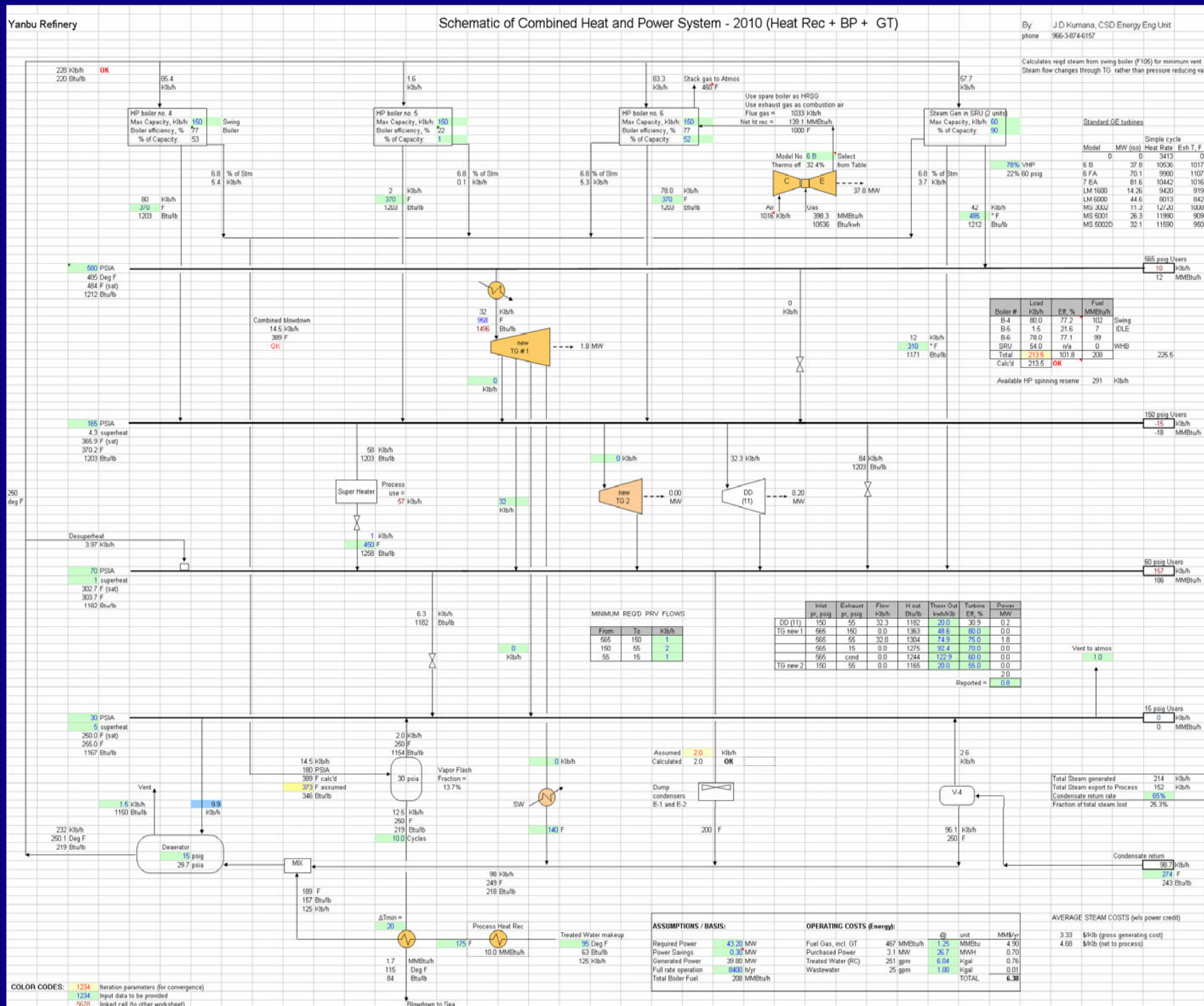
ASDs are a good option when there is significant flow or ΔP variation

Proposed ASD Retrofit



Savings = $90K/yr, Cap cost = $200K

CHP System Optimization



Summary and Status Report

- 35 projects were identified & evaluated
- 6 were accepted by Plant Mgmt
- Savings potential = $9.7 MM/yr (35%) for Cap Cost of $41 MM
- Implemented savings = $0.5 MM/yr
- Rest delayed for political or legal reasons

Thank You