Energy Analysis Techniques

Engineers India Limited

R&D Division; Sector – 16

Gurgaon – 122 001 (Haryana)

INDIA

Manu Kaushal manu.kaushal@eil.co.in

What is energy conservation?

Three simple ways to save energy

1. By not doing things – e.g. not traveling
2. By doing things at reduced quality – traveling in a two wheeler or may be cycle
3. By doing things as before or better with lower energy use – e.g. using more efficient cars, or combining many trips into one or car pooling

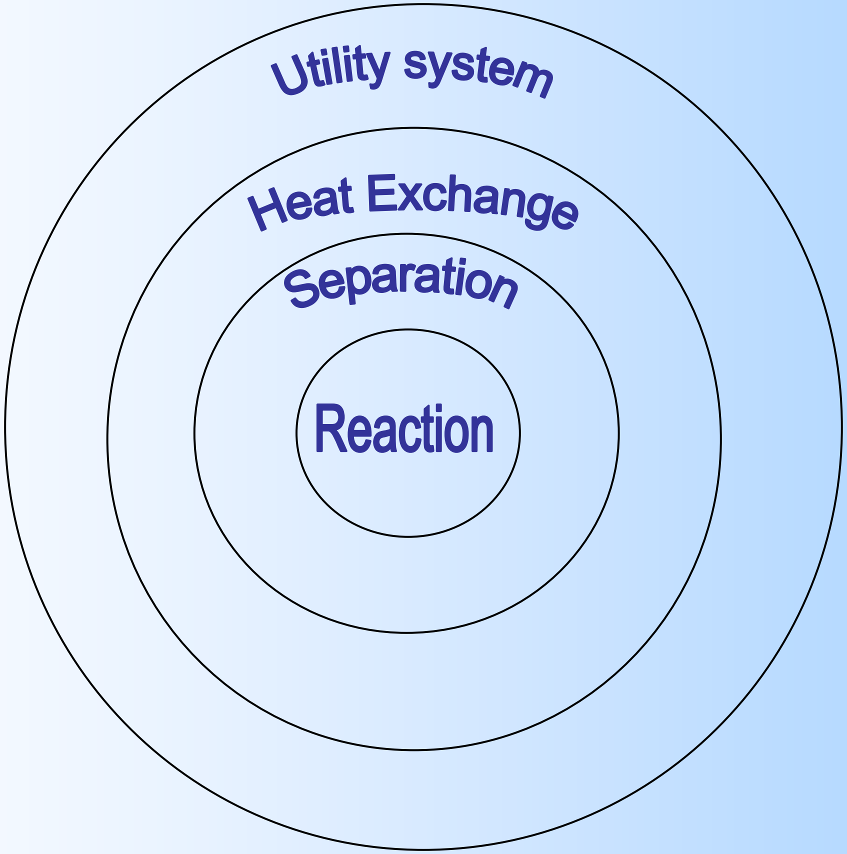
Energy conservation

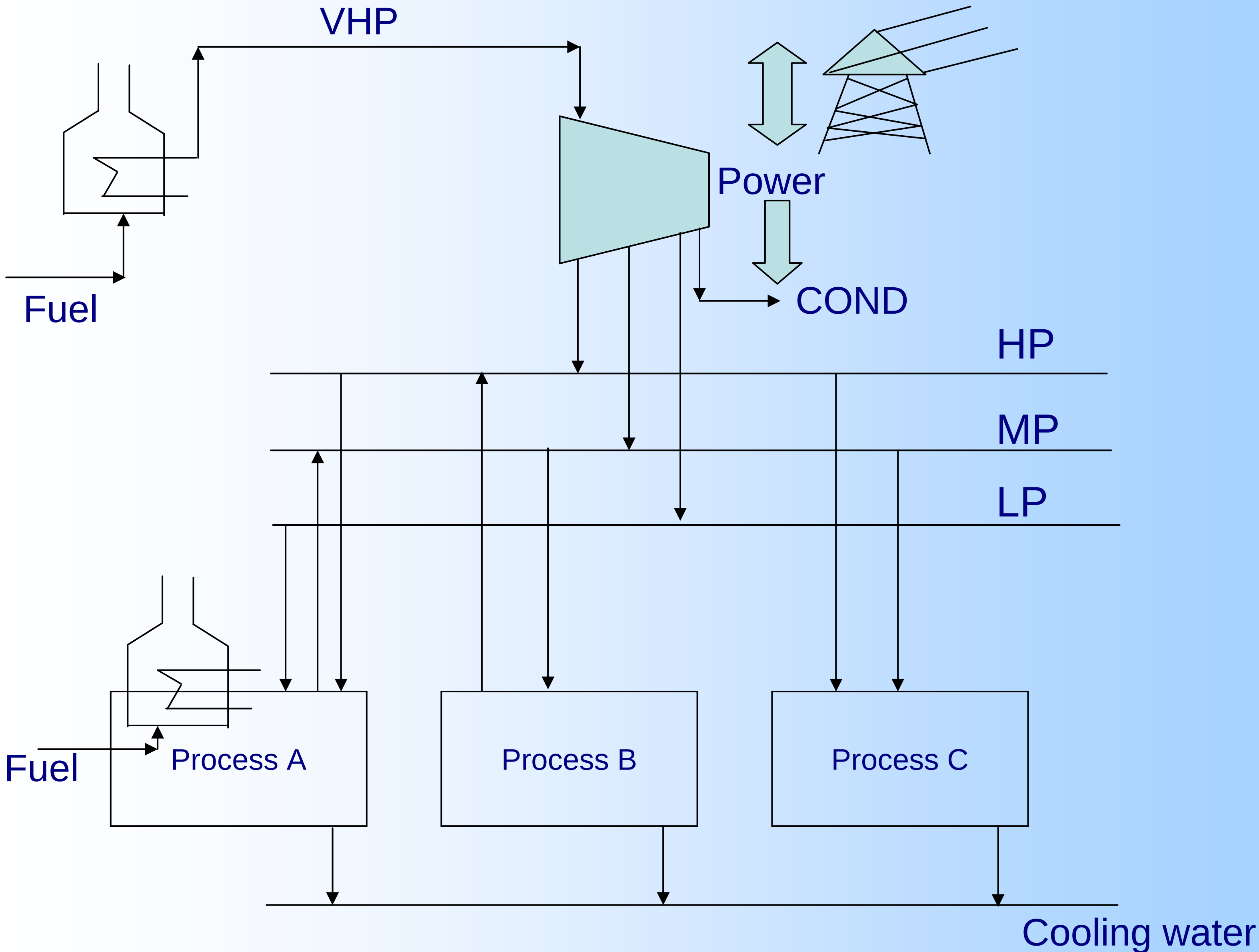
- Realizing the objectives of the operation / action with lower energy or resource consumption without compromising the quality of outcome.

Need for energy conservation

- Limited resources
- Cost competitiveness
- Rising Energy costs
- Global environmental concerns
- Regulatory requirements to reduce emissions

Process




VHP
Power
COND
Fuel
HP
MP
LP
Fuel
Process A
Process B
Process C
Cooling water

A total site

Complex interactions

- Process to Process
  - Intra and inter process both
- Process to utility
- Utility to utility
- Process to process through utility

Approach to energy analysis

- Conventional approach
  - Individual equipment performance
  - Standalone analysis
  - Global impact not considered
- Integrated approach
  - Systems approach accounting for all site interactions
  - Identify potential areas
  - Establish benefits
  - Translate them to global level
  - Target global optimization of energy and resource consumption

Integrated energy analysis - Methodology

- Individual equipment performance analysis
- Process audit
- Utility system analysis
- Integrated system analysis
- Monitoring and targeting

Equipment performance analysis

- Fired heaters
  - Heater efficiency estimation
- Boilers
  - Boiler efficiency estimation
- Compressors
  - Establish polytropic and overall efficiency
- Pumps
  - Establish pump performance & VSD application
- Fin fan coolers
  - Coolers performance & VSD application

Boilers / Fired heaters

- Efficiency estimation by direct and indirect methods
- Indirect method gives better insight towards the losses and helps identifying the potential area
- Efficiency improvement
- Soot deposit, peep holes, dampers

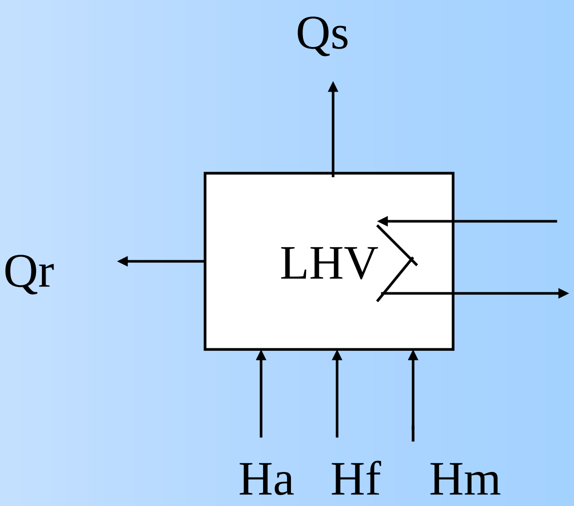
Furnace efficiency

- **THERMAL EFFICIENCY OF HEATER**
  - **LHV : LOWER HEATING VALUE OF THE FUEL**
  - **HM : ENTHALPY OF ATOMISING MEDIA**
  - **HA : ENTHALPY OF AIR ABOVE15.5°C**
  - **HF : ENTHALPY OF FUEL**
  - **QS : HEAT CONTENT OF STACK GASES**
  - **QR : HEAT LOSS FROM HEATER SURFACE**

$$\eta = \frac{\text{Total Heat Absorbed}}{\text{Total Heat Input}} \times 100$$

$$= \frac{\text{Total Heat Input - Total Heat Losses}}{\text{Total Heat Input}} \times 100$$

$$= \frac{LHV + H_a + H_f + H_m - (Q_r + Q_s)}{LHV + H_a + H_f + H_m} \times 100$$



Compressor efficiency

- Establish polytropic efficiency
- Establish overall efficiency
- Real work transferred to fluid
- Fine tune feed suction conditions / inter-cooling / bearing losses / recycle flow

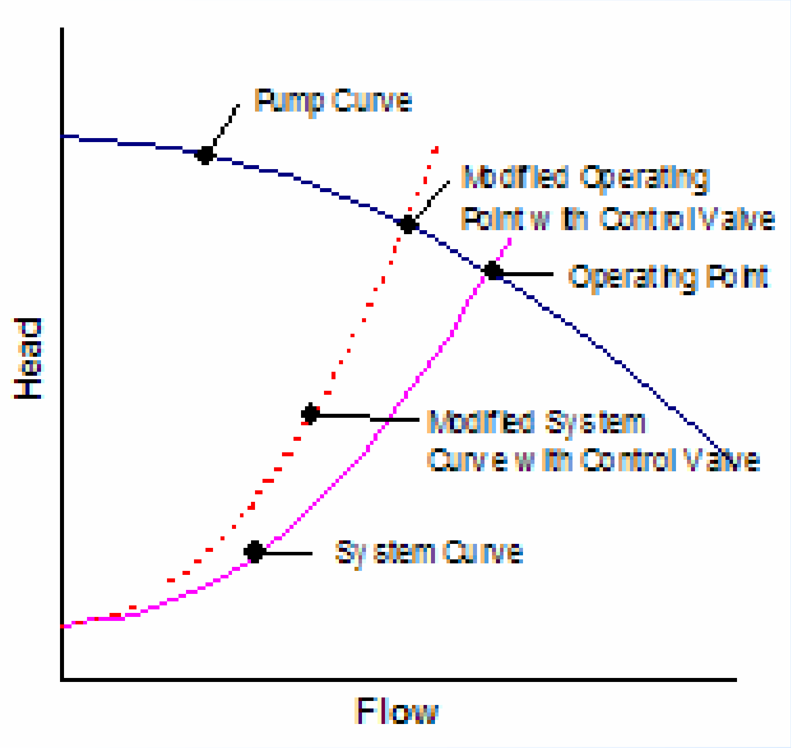
OPERATING DATA				
Stage - I				
	Suction		Discharge	
Pressure, psia	235.6		437	
Temperature, ^oF	96.9		231.8	
Compressibility	1.0003		1.0076	
Flow lb/min	556.54			
Cp/Cv	1.30		1.28	
Cp/Cv (Avg)	1.29			
Stage 1				
Gas composition	**Mole (f) we**	**Mol.Wt**	**Mol.m, w**	
C1	0.089	16.043	1.427827	
C2	0.054	30.07	1.62378	
C3	0.04	44.097	1.76388	
I-C4	0.013	58.123	0.755599	
N-C4	0.015	58.123	0.871845	
I-C5	0.01	72.15	0.7215	
C6+	0.009	86.117	0.775053	
C2H4		28	0	
C3H6		42	0	
C3H4		40	0	
C4H8		56	0	
C4H4		52	0	
H2	0.75	2.016	1.512	
CO		28.01	0	
Air		28.963	0	
CO2	0.015	44.01	0.66015	
N2	0.005	28.013	0.140065	
H2S		34.08	0	
O2		31.999	0	
H2O		18.015	0	
Total	1		10.25	

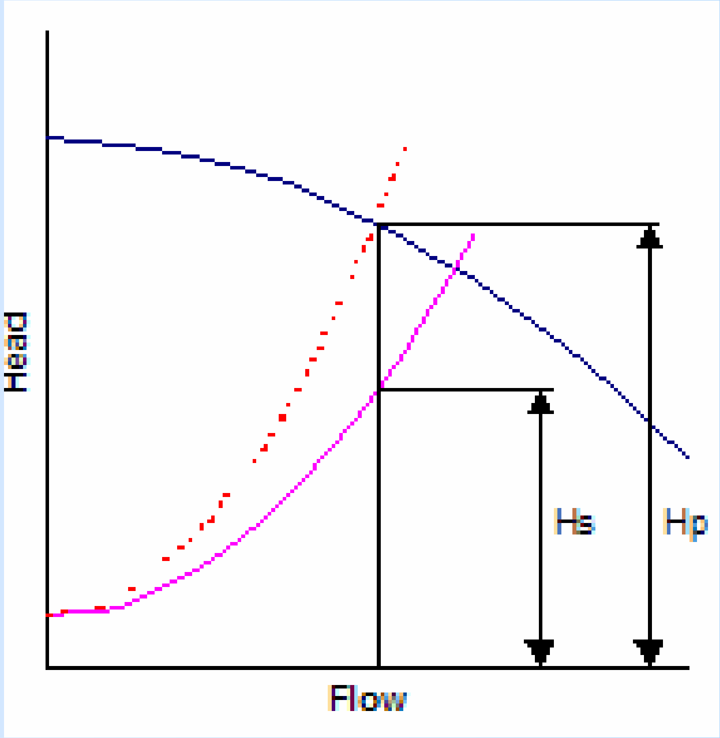
K-201		
Gas Flow	**Stage - I**	
Mol. Wt	10.25	
Wt flow Lb/min	556.54	
Operating parameters		
	Stage - I	
	Suction	Discharge
Temp., ^oR	556.90	691.80
	Stage - I	
Polytropic n	1.541	
cp/cv (Avg)	1.291	
Av. Comp. Factor	1.004	
Head Polytropic, Ft	58133	
BHPp gas	980	
KW Gas	731	
Head J/kg	173784	
Total Gas Power KW	731	
Overall Efficiency %	**55.6**	
Polytropic Efficiency	64.3	
Motor Drive		
Amps	372.4	
Volts	2400	
Power Factor	0.85	
Motor KW	1316	

Pumps

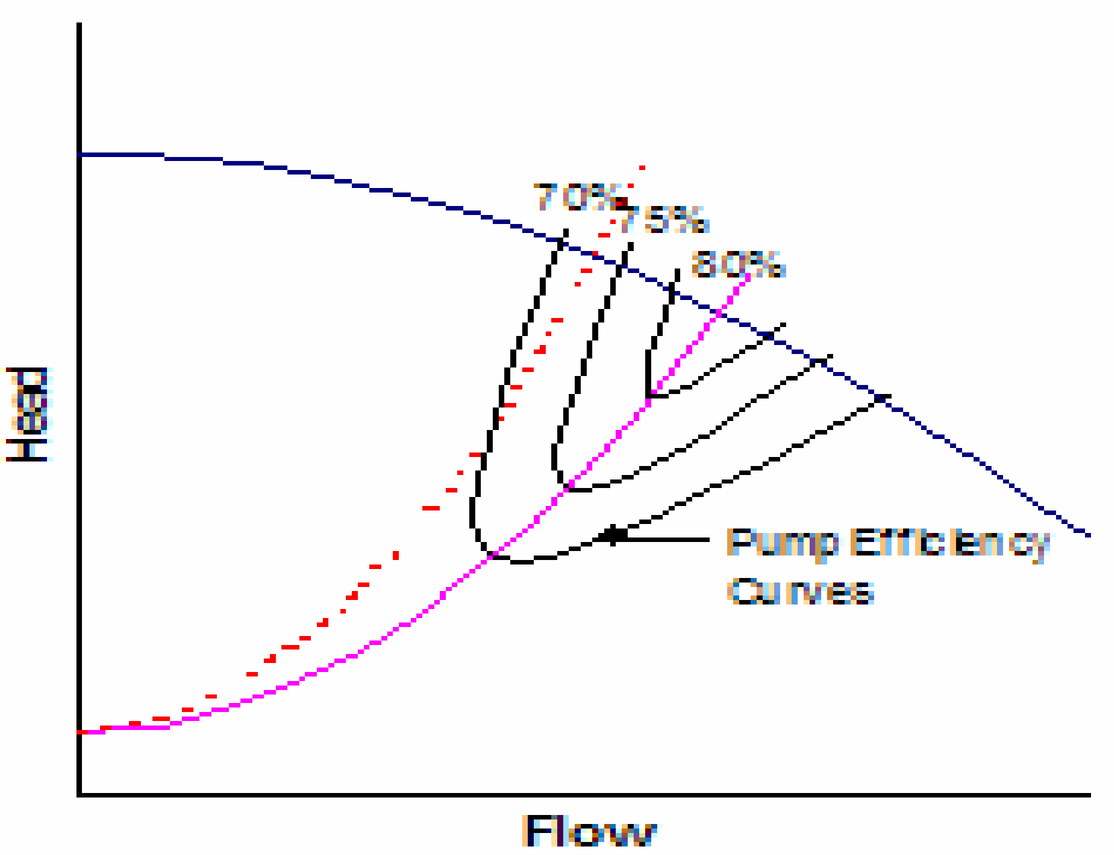
- Establish current performance
- Compare it with design operating point on characteristic curves
- Optimize power consumption by choosing appropriate impeller or through application of VSD

Throttling losses



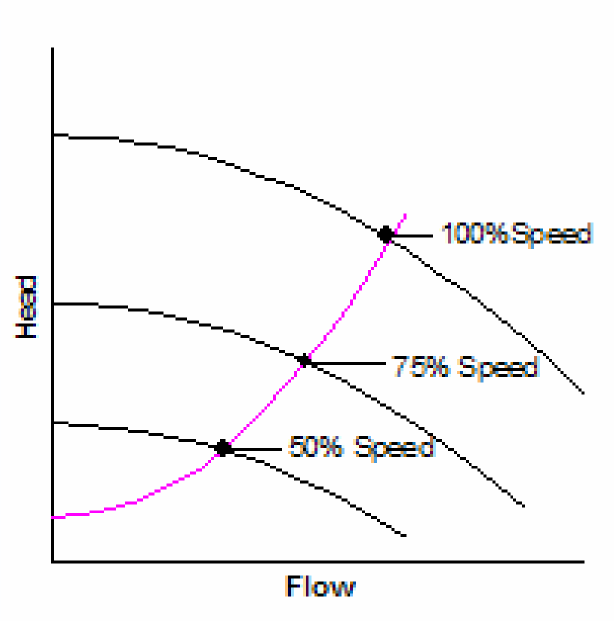


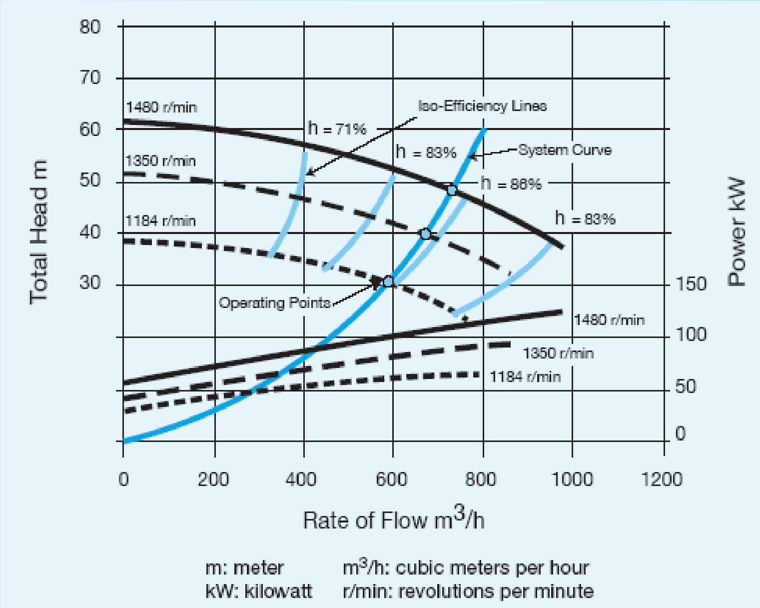
Throttling losses



VSD Application in pumps

- When speed control is employed to control the pump flow the pump curve moves up and down the system curve.
- This ensures just enough energy is supplied to get the desired flow



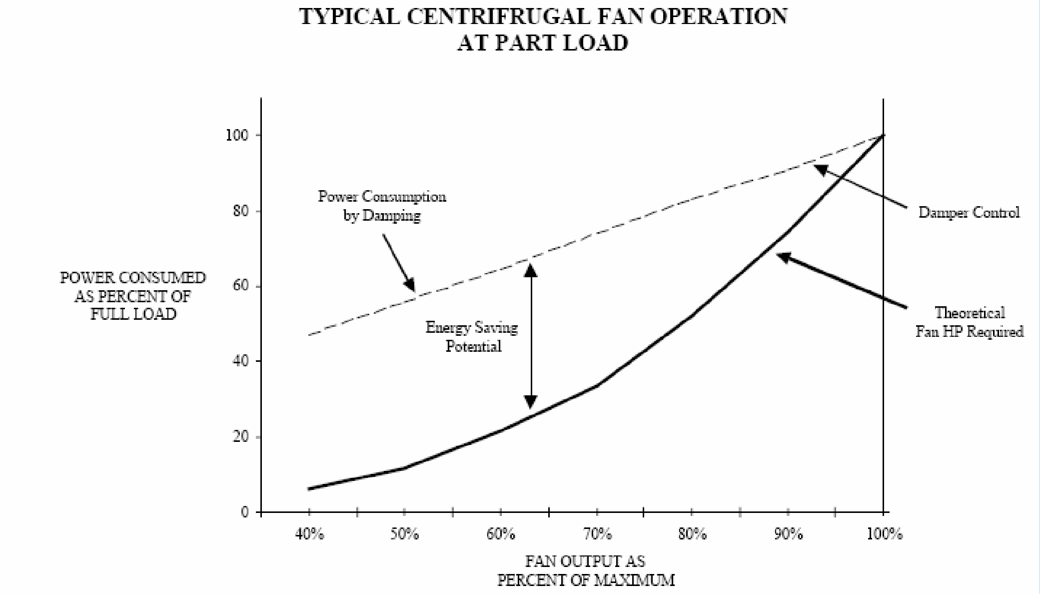


Applications of VSD on fans

- Normally the procedure applied for pumps can be extended for a VSD application on a fan also and the same affinity laws are applicable.
- These correspond to variation in flow requirement by the system.
- For cases where the variation in flow is due to meeting the process requirement at varying utility property due to ambient limitation, process analysis or equipment evaluation might be required

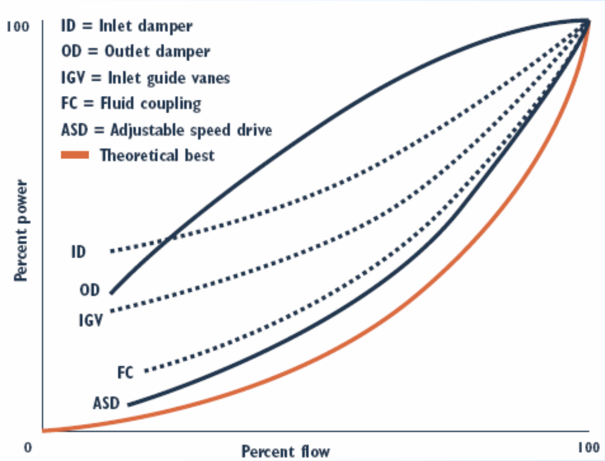
Application of VSD on fans

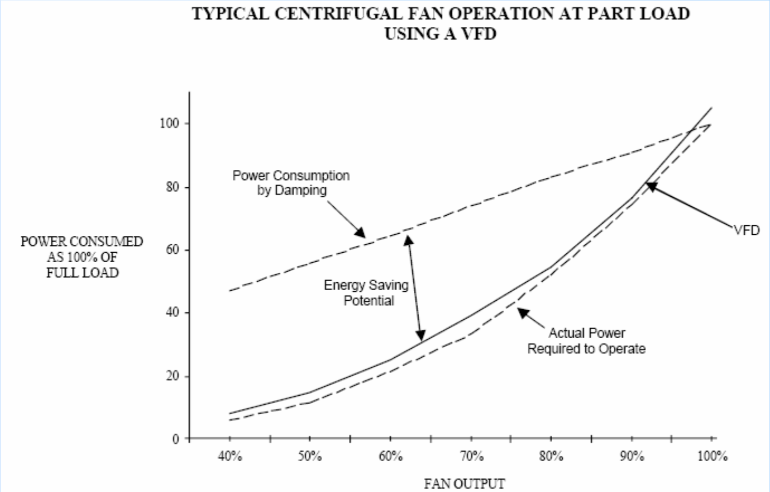
- Flow control through restricting control device such as throttling, damping and recirculating of flow has a direct bearing on the fan/blower energy consumption.
- The energy saving through VSD results from eliminating the damping and moving closer to the theoretical minimum requirement.



VSD POWER SAVING

- The effect of various types of control mechanism on power utilization of fans is depicted below





Fin fan cooler

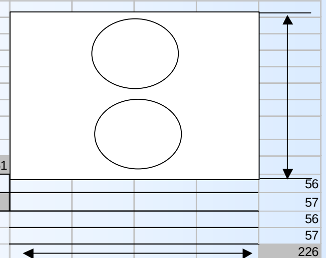
- These are product or process stream cooling exchangers using air as the cooling medium.
- For geographical locations where there is a wide variation of temperature throughout the year and day and night.
  - The flow of air through these exchangers have to be varied to meet the process requirement.
  - In actual for system with multi fans shutting of fans is practiced
  - Other method available is fans with multi pitch control which is adjusted at extreme conditions.

Fin fan coolers

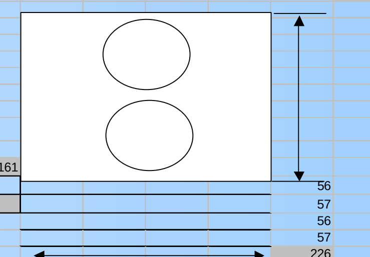
- Rate the current operation
- Study variation in ambient conditions
- Power savings through application of VSD

VSD on fan fin (015-e-263)

Fin Fan Cooler Evaluation			**DESIGN SIMULATION**							
Geometry (Tubes with radial fins)										
No of fans	2									
Air flow	189.5	kg/s					68.7			
Air inlet T	41.1	°C		146.1						
Air Exit T	68.7	°C							65.6	
Cp	0.239	kcal/kg.°C								
Duty	4.50	MMKcal/h	4.50				41.1			
Process f	29.67	kg/s			LMTD	46.0				
Proc Inlet T	146.1	oC			Correction factor determination					
Proc Out T	65.6	oC			K	0.77				
U process	528.0	kcal/h.m².C	528		S	0.26				
Design U bare		kcal/h.m².C			R	2.92				
Types of fins		Extruded			Ft	0.986	One mixed other non mixed			
No of fins/ m		394			U Overall	333.2	kcal/h.m².K		68.2	Btu/hr.ft².°F
Fi OD	mm	57.15			Duty	4.50	MMkcal/h			
Fin Ht	mm	15.88								
Fin thk	mm	0.4064								
Fin spacing	mm	2.54	Summer High Temperature			45	°C			
Tube OD	mm	25.4								
Tube ID	mm	21.8								
Tube L	m	12.2								
Effective L	m	12.2								
Tube pitch	mm	63.5								
Total Finned tubes		306								
Rows		5								
Fin Thc W/m.K		208								
Fan dia	m	3.962								
Air side calculation										
Geometric factors										
Unfinned surface		0.080	m²/m		6161					
Finned surface		1.652	m²/m	ft2	m2					56
Bare external surface		0.080	m²/m	3206	298					57
FAR		0.456	Table - 9.2							56
Effective Fin ht		0.021	m (Tab-9.3)							57
										226
Cooler face area		47.91	m²			62	pitches at	63.5		
Flow area between Tubes		21.83	m²			2 bundle	3937	mm		
Fan Opening area		24.67	m²	47.91456		Effective	3930	mm		
		Dia Based		Total area based		Overall		mm	end elevation	
Air velocity										
Flow rate standard m³/s		154.15	T	15.5	P	1.01E+05				
Flow rate at fans m³/s		167.87	T	41.1	P	1.01E+05				
Standard Vel Bet Tu		7.06	m/s							
Velocity Thru fan openings		3.50	m/s							
Fin Efficiency and coefficient										
Htc to the fins alpha'		56.78	W/m²K							
(me)x(lfe)		0.757								
Fin Efficiency Omega		0.845								
Effective fin side Htc		1048.9	W/m²K		903.4	kcal/h.m².K		185	Btu/hr.ft².°F	
Pressure loss and power consumption										
Bundle loss		15.3	mmWC							
Fan & Plenum loss		0.8	mmWC	Rho based on summer high temp						
Total loss		16.1	mmWC							
Required Fan Power		26.5	KW	35.5	HP					

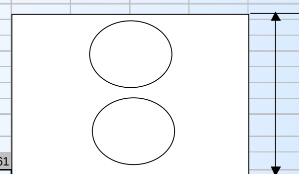


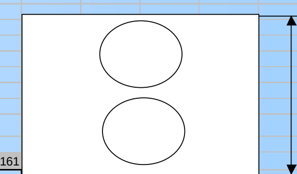
Fin Fan Cooler Evaluation				**CASE-I**							
Geometry (Tubes with radial fins)											
No of fans	2										
Air flow	146.2	kg/s					71.6				
Air inlet T	35.8	°C		146.1							
Air Exit T	71.6	°C							65.6		
Cp	0.239	kcal/kg.°C									
Duty	4.50	MMKcal/h	4.50				35.8				
Process f	29.67	kg/s			LMTD	48.8					
Proc Inlet T	146.1	oC			Correction factor determination						
Proc Out T	65.6	oC			K	0.73					
U process	528.0	kcal/h.m².C	528		S	0.32					
Design U bare		kcal/h.m².C			R	2.25					
Types of fins		Extruded			Ft	0.986	One mixed other non mixed				
No of fins/ m		394			U Overall	314.1	kcal/h.m².K		64.3	Btu/hr.ft².°F	
Fi OD	mm	57.15			Duty	4.50	MMkcal/h				
Fin Ht	mm	15.88									
Fin thk	mm	0.4064									
Fin spacing	mm	2.54	Summer High Temperature			45	°C				
Tube OD	mm	25.4									
Tube ID	mm	21.8									12.192
Tube L	m	12.2									
Effective L	m	12.2									
Tube pitch	mm	63.5									
Total Finned tubes		306									
Rows		5									
Fin Thc W/m.K		208									
Fan dia	m	3.962									
Air side calculation											
Geometric factors											
Unfinned surface		0.080	m²/m		6161						
Finned surface		1.652	m²/m	ft2	m2					56	
Bare external surface		0.080	m²/m	3206	298					57	
FAR		0.456	Table - 9.2							56	
Effective Fin ht		0.021	m (Tab-9.3)							57	
										226	
Cooler face area		47.91	m²			62	pitches at	63.5			
Flow area between Tubes		21.83	m²			2 bundle	3937	mm			
Fan Opening area		24.67	m²	47.91456		Effective	3930	mm			
		Dia Based		Total area based		Overall		mm	end elevation		
Air velocity											
Flow rate standard m³/s		118.94	T	15.5	P	1.01E+05					
Flow rate at fans m³/s		127.34	T	35.8	P	1.01E+05					
Standard Vel Bet Tu		5.45	m/s								
Velocity Thru fan openings		2.66	m/s								
Fin Efficiency and coefficient											
Htc to the fins alpha'		47.59	W/m²K								
(me)x(lfe)		0.693									
Fin Efficiency Omega		0.866									
Effective fin side Htc		899.9	W/m²K		775.1	kcal/h.m².K		159	Btu/hr.ft².°F		0.204813
Pressure loss and power consumption											
Bundle loss		9.7	mmWC								
Fan & Plenum loss		0.5	mmWC	Rho based on summer high temp							
Total loss		10.2	mmWC								
Required Fan Power		12.7	KW	17.0	HP						



Sample calculation sheet

Item	Unit	CASE-II	Unit	CASE-III	Unit
Fin Fan Cooler Evaluation					
Geometry (Tubes with radial fins)					
No of fans		2		2	
Air flow		128.4	kg/s	125.7	kg/s
Air inlet T		32.5	°C	31.9	°C
Air Exit T		73.2	°C	73.5	°C
Cp		0.239	kcal/kg.°C	0.239	kcal/kg.°C
Duty		4.50	MMKcal/h	4.50	MMKcal/h
Process f		29.67	kg/s	29.67	kg/s
Proc Inlet T		146.1	oC	146.1	oC
Proc Out T		65.6	oC	65.6	oC
U process		528.0	kcal/h.m^2.C	528.0	kcal/h.m^2.C
Design U bare			kcal/h.m^2.C		kcal/h.m^2.C
Types of fins		Extruded		Extruded	
No of fins/ m		394		394	
Fi OD	mm	57.15		57.15	
Fin Ht	mm	15.88		15.88	
Fin thk	mm	0.4064		0.4064	
Fin spacing	mm	2.54		2.54	
Tube OD	mm	25.4		25.4	
Tube ID	mm	21.8		21.8	
Tube L	m	12.2		12.2	
Effective L	m	12.2		12.2	
Tube pitch	mm	63.5		63.5	
Total Finned tubes		306		306	
Rows		5		5	
Fin Thc W/m.K		208		208	
Fan dia	m	3.962		3.962	
Diagram temperatures (air out / proc in / proc out / air in)		73.2 / 146.1 / 65.6 / 32.5		73.5 / 146.1 / 65.6 / 31.9	
Duty		4.50		4.50	
U process		528		528	
LMTD		50.4		50.7	
Correction factor determination					
K		0.71		0.70	
S		0.36		0.36	
R		1.98		1.93	
Ft		0.986	One mixed other non mixed	0.986	One mixed other non mixed
U Overall		304.1	kcal/h.m^2.K	302.4	kcal/h.m^2.K
U Overall		62.3	Btu/hr.ft^2.°F	61.9	Btu/hr.ft^2.°F
Duty		4.50	MMkcal/h	4.50	MMkcal/h
Summer High Temperature		45	°C	45	°C
		12.192		12.192	
Air side calculation					
Geometric factors					
Unfinned surface		0.080	m^2/m	0.080	m^2/m
		6161		6161	
Finned surface		1.652	m^2/m	1.652	m^2/m
Bare external surface		0.080	m^2/m	0.080	m^2/m
Area (ft2 / m2)		3206 / 298		3206 / 298	
FAR		0.456	Table - 9.2	0.456	Table - 9.2
Effective Fin ht		0.021	m (Tab-9.3)	0.021	m (Tab-9.3)
Dimensions		56, 57, 56, 57, 226		56, 57, 56, 57, 226	
Cooler face area		47.91	m^2	47.91	m^2
Flow area between Tubes		21.83	m^2	21.83	m^2
Fan Opening area		24.67	m^2	24.67	m^2
		Dia Based		Dia Based	
Total area based		47.91456		47.91456	
62 pitches at		63.5		63.5	
2 bundle		3937	mm	3937	mm
Effective		3930	mm	3930	mm
Overall			mm		mm
		end elevation		end elevation	
Air velocity					
Flow rate standard m^3/s		104.46	T 15.5, P 1.01E+05	102.22	T 15.5, P 1.01E+05
Flow rate at fans m^3/s		110.63	T 32.5, P 1.01E+05	108.05	T 31.9, P 1.01E+05
Standard Vel Bet Tu		4.79	m/s	4.68	m/s
Velocity Thru fan openings		2.31	m/s	2.26	m/s
Fin Efficiency and coefficient					
Htc to the fins alpha'		43.56	W/m^{2}K	42.92	W/m^{2}K
(me)x(lfe)		0.663		0.658	
Fin Efficiency Omega		0.875		0.877	
Effective fin side Htc		832.5	W/m^{2}K	821.7	W/m^{2}K
Effective fin side Htc		717.0	kcal/h.m^2.K	707.7	kcal/h.m^2.K
Effective fin side Htc		147	Btu/hr.ft^2.°F	145	Btu/hr.ft^2.°F
		0.204813		0.204813	
Pressure loss and power consumption					
Bundle loss		7.7	mmWC	7.5	mmWC
Fan & Plenum loss		0.4	mmWC (Rho based on summer high temp)	0.3	mmWC (Rho based on summer high temp)
Total loss		8.1	mmWC	7.8	mmWC
Required Fan Power		8.8	KW	8.3	KW
Required Fan Power		11.8	HP	11.1	HP





Savings in power through VSD on fin fan cooler

ASD Eff	95	%		
No of months	No of Hrs/day	Temp	Power Cons	Total Po Cons
2	24	35.8	28.8	41433
2	24	32.5	19.9	29088
2	24	31.9	18.7	27341
2	24	23.7	9.0	13461
2	24	22.1	8.0	11740
2	24	19.6	6.7	9826
			Total KW/Yr	111324
Actual power Consumption			60.0	
			Total KW/Yr	527037
$/MW	19.36			
			Saving KW/Yr	409853
			Saving $/Y	**7934.76**

- The pay back for such replacement is less than a year however depending on cost of power it may go up to 3 – 3.5 years.

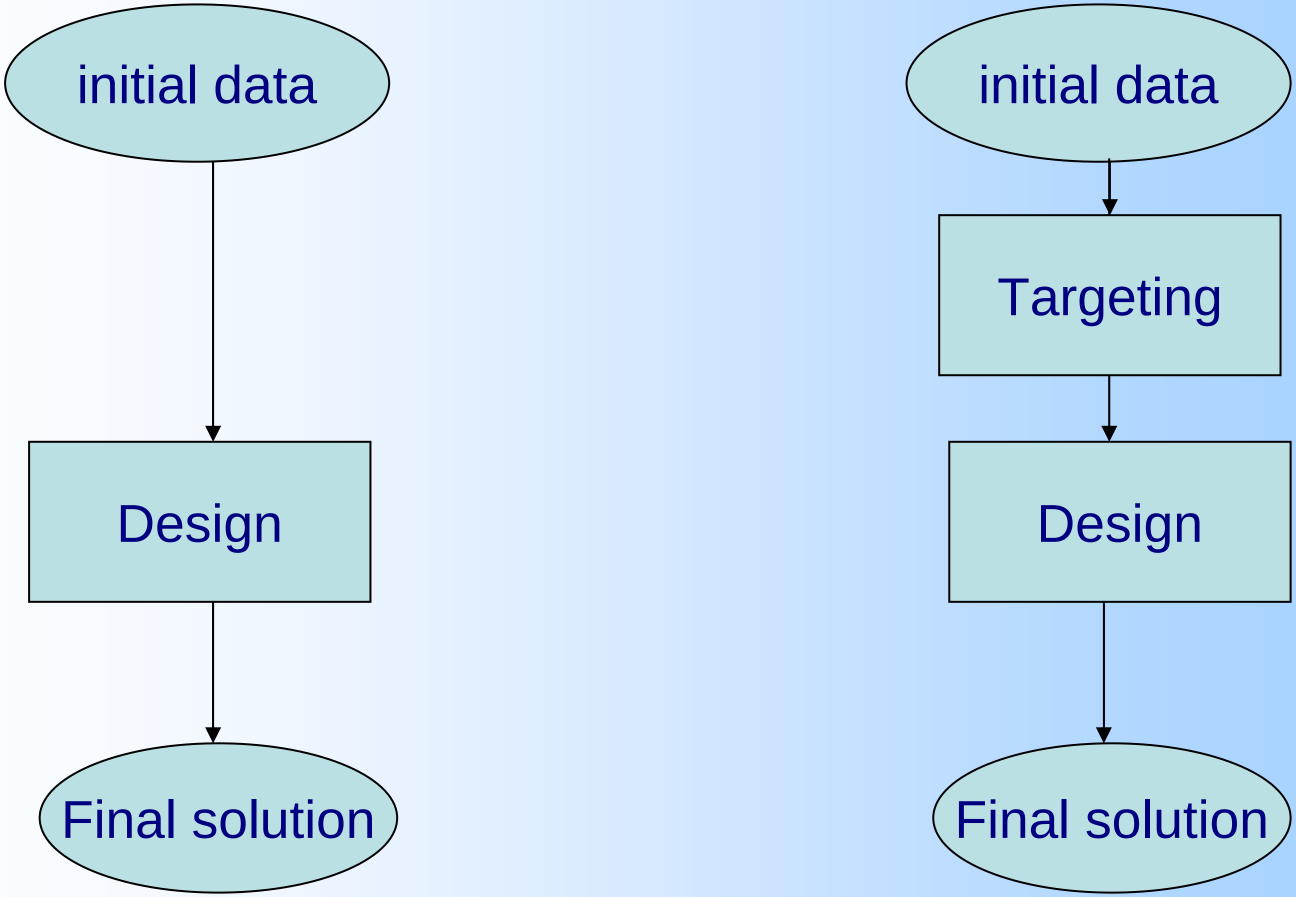
Low level heat recovery

- Explore possibility of recovering low level heat
  - Useful for BFW heating
  - Can be used for vapor absorption chiller to produce cold for refrigeration
  - Trigeneration – combined heat, cooling and power

Process audit

- Pinch technology
  - Heat exchange systems
  - Separation systems
  - Process changes

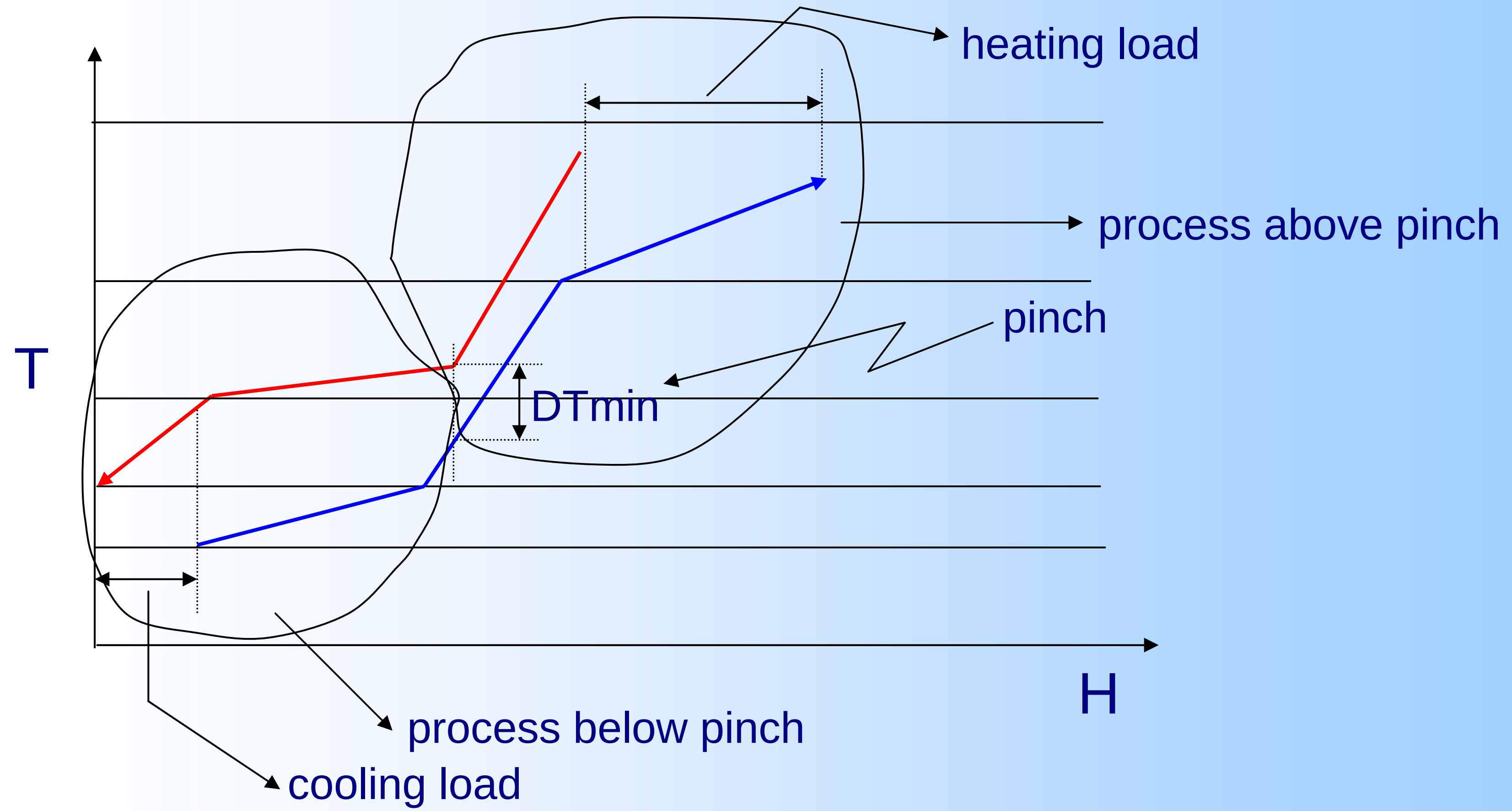
Pinch technology - approach



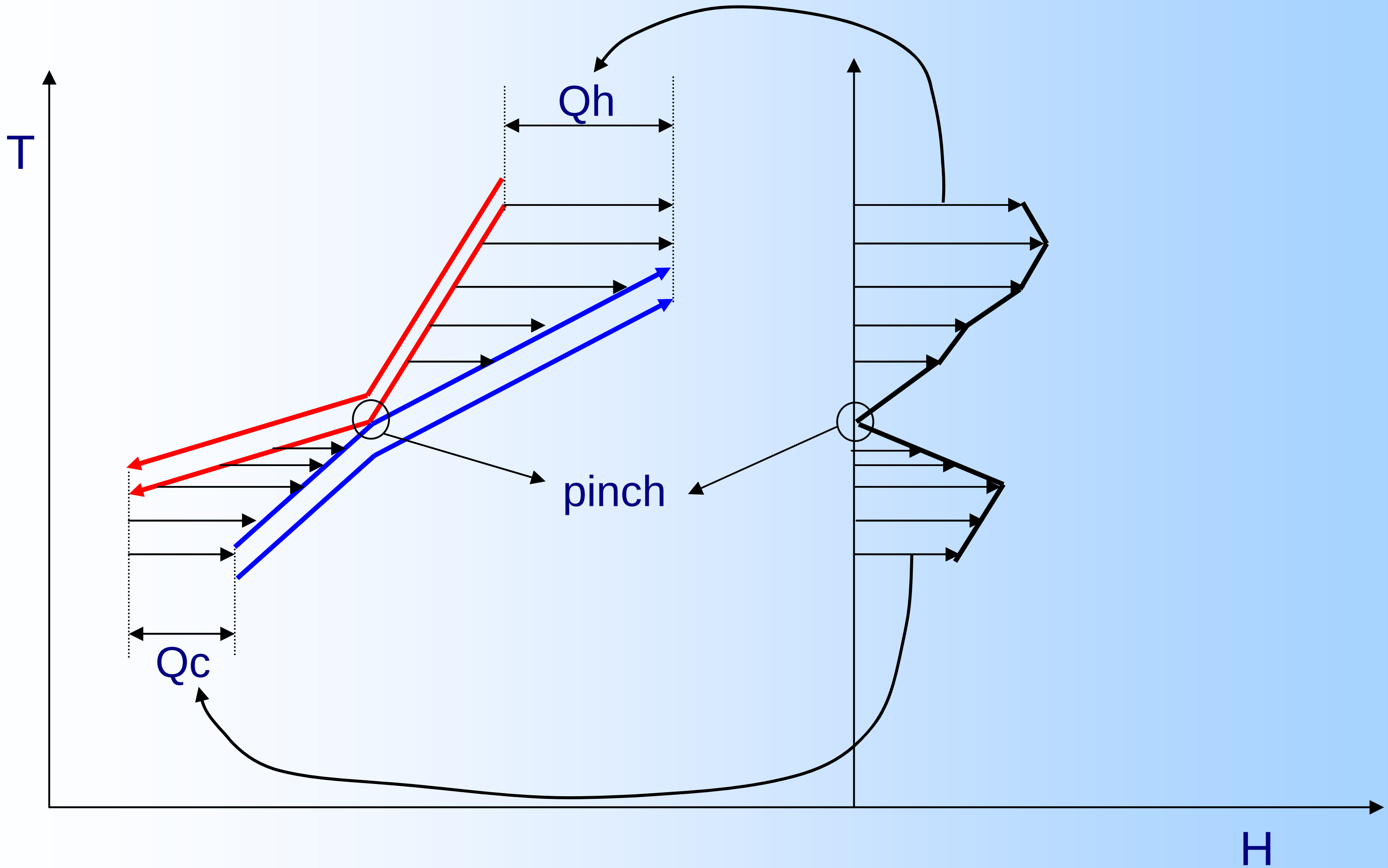
Pinch analysis heat exchange systems

- Collect all heat sources and heat sinks of process
- Represent them on a common platform of resource and driving force
- In heat exchange system it is temp vs enthalpy change diagram, in mass exchange it is conc vs mass change

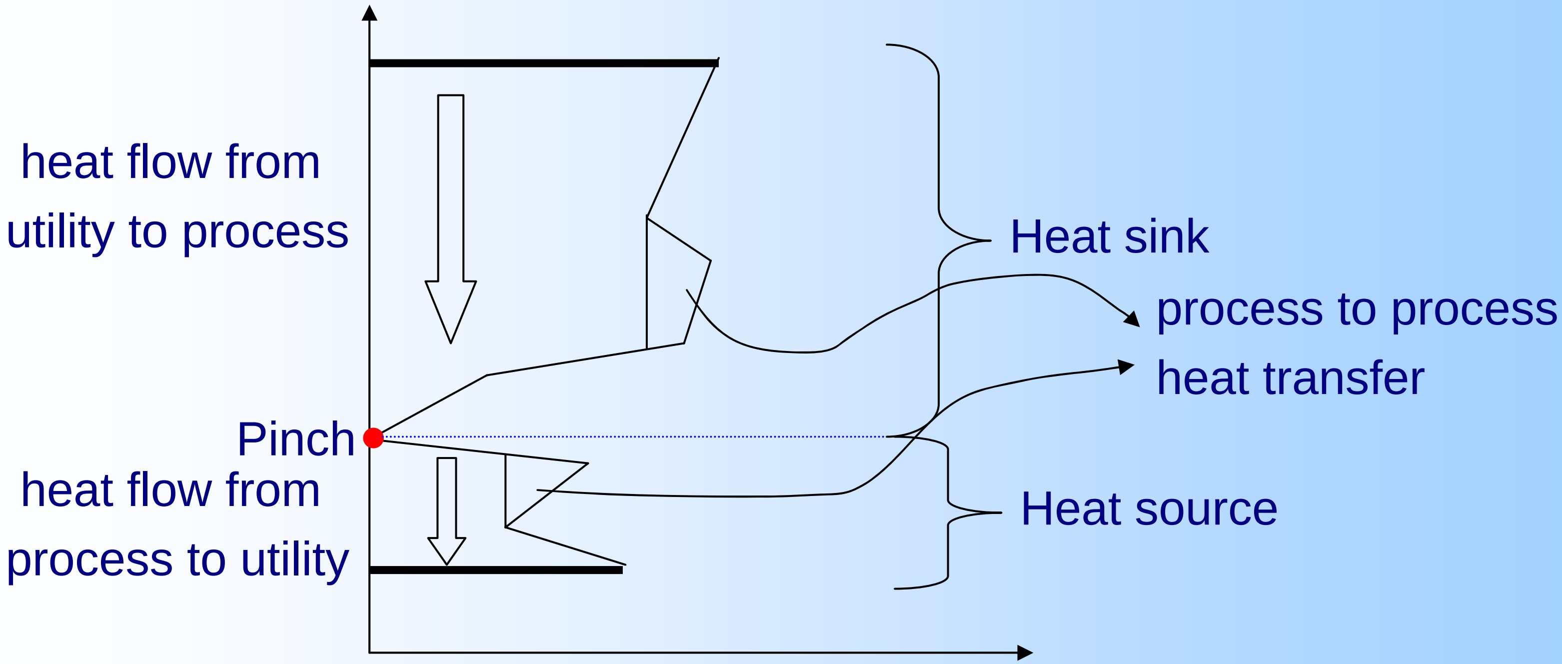
HEN - Composite curves



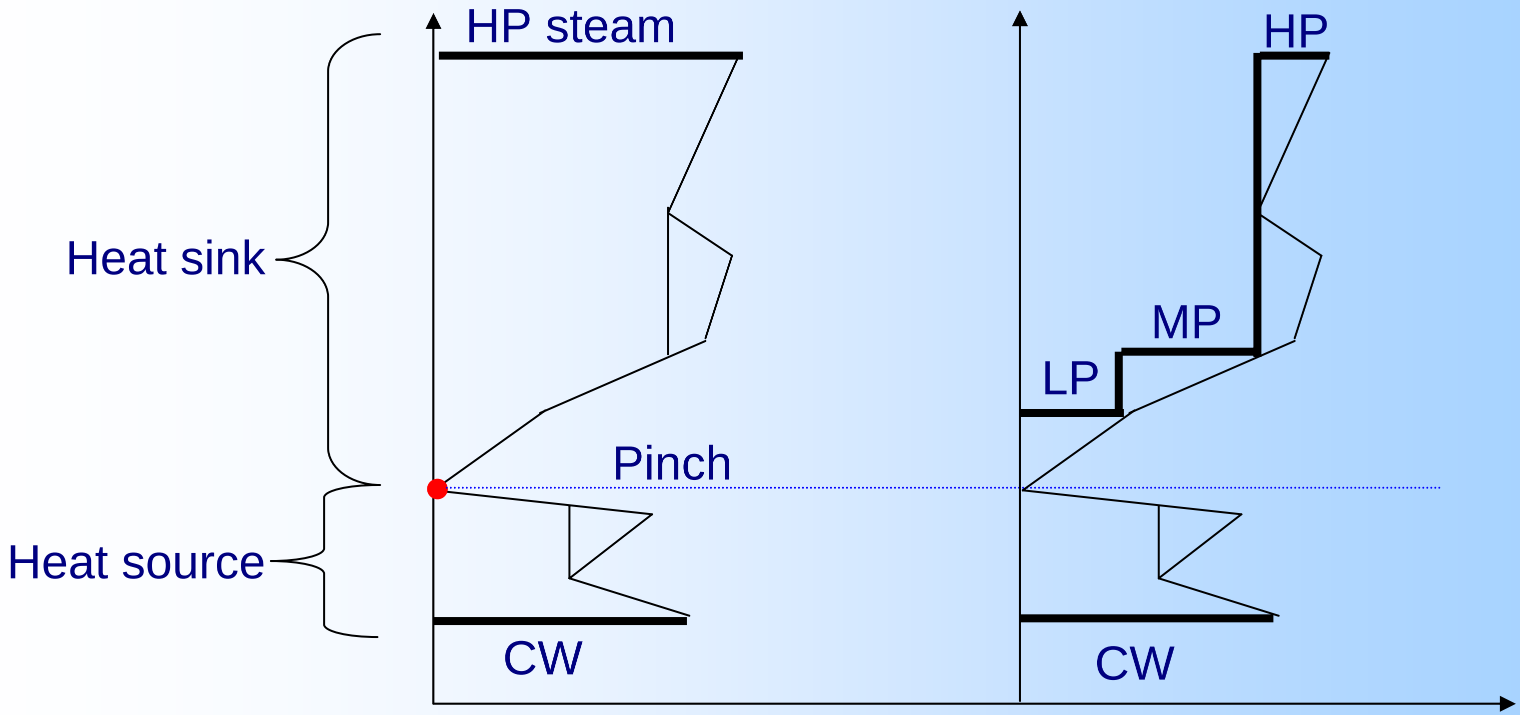
Grand composite curve



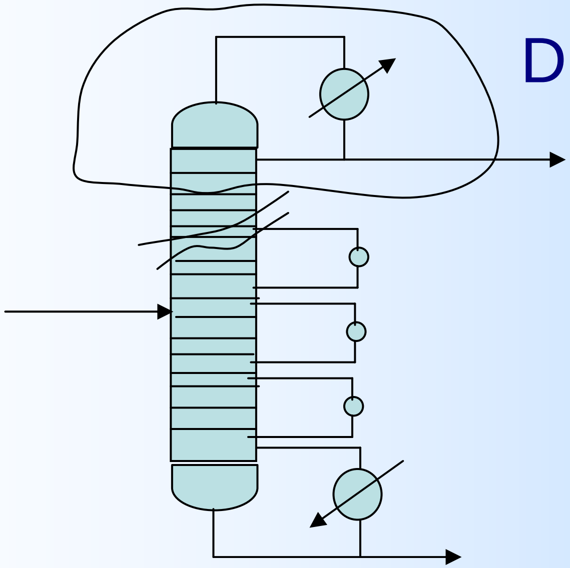
Grand composite curve



Grand composite curve



Separation system – distillation column



D_L, D_H

- Operating line

$$VY_L - LX_L = D_L$$
$$VY_H - LX_H = D_H$$

- Equilibrium line

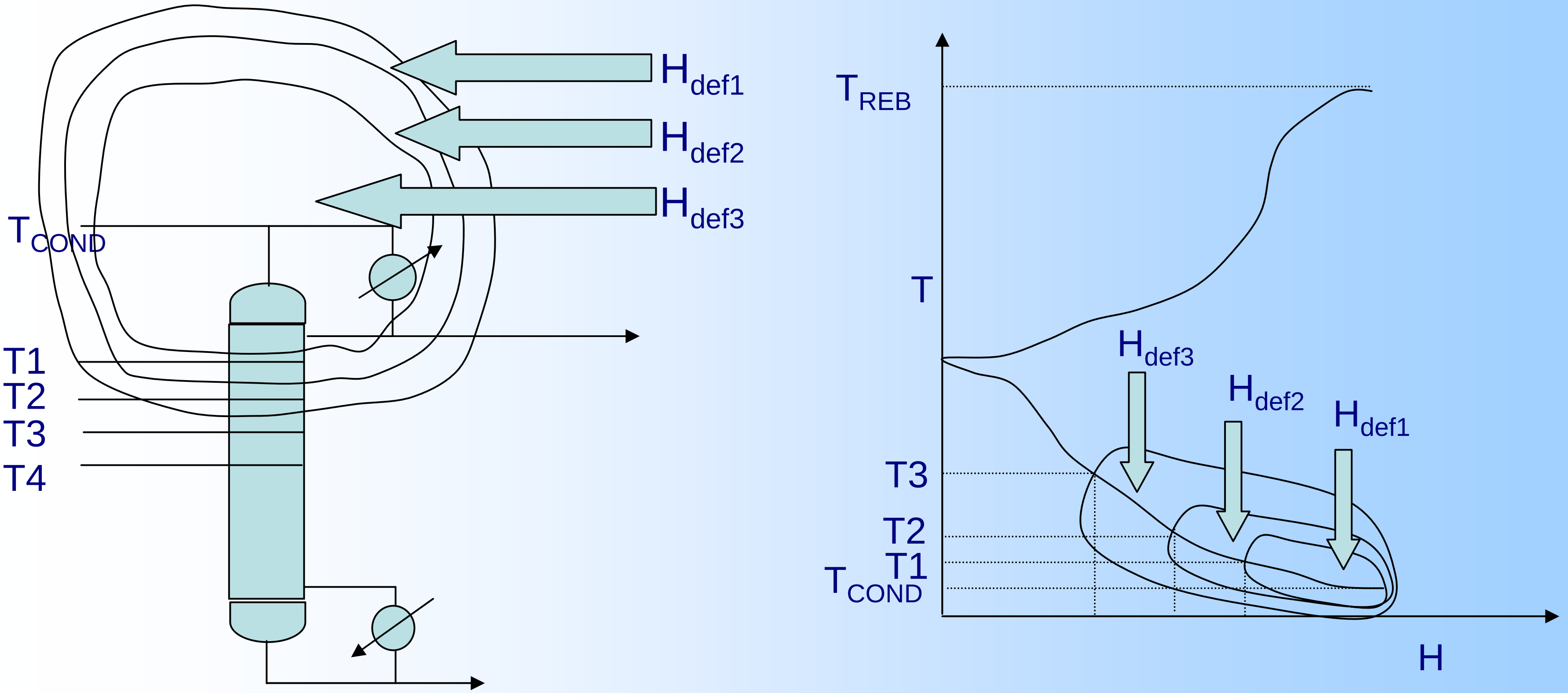
Y_L^*, X_L^*
Y_H^*, X_H^* } From simulation

$$V_{min}Y_L^* - L_{min}X_L^* = D_L$$
$$V_{min}Y_H^* - L_{min}X_H^* = D_H$$

Two simultaneous equations to solve

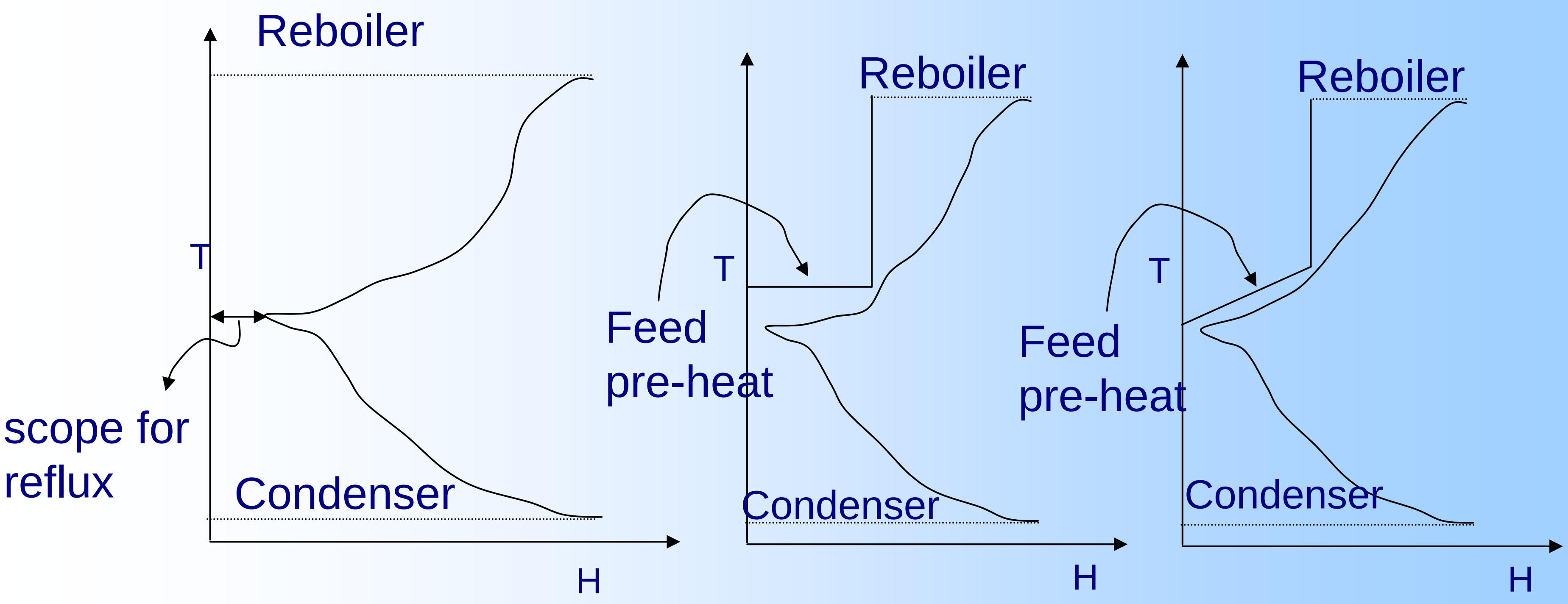
Evaluate V_{min} . L_{min} and enthalpy deficit

Separation system – distillation column



Column temperature – enthalpy profile

Distillation column – Energy analysis



Process changes

- Recycle loops
- Feed variation
- Condenser re-boiler integration
- Heat engine / heat pump placement and sizing
- Multiple feed cases etc

Utility systems

- Utility boilers
  - Efficiency estimations and improvement
  - $F = a+bS+cS^2$
- Steam turbine
  - Performance analysis
- Gas turbines
  - Performance analysis
  - $F=a+bP+cP^2+dT+eT^2$
- HRSG
  - Performance analysis
  - $S= a+bF+cF^2+dT+eT^2$
- Insulation losses
- Steam trap

Steam loss through trap

- Steam as high as 15-20% of leaving a boiler lost via leaking traps
- With best steam trap and proactive steam trap maintenance programme can reduce loss to less than 1%
- A single leaking trap (100psig with 1/8-in. [3mm] orifice) can Squander more than $2000/yr

Steam trap distribution

Total traps by pressure, %	Total traps by pressure/ condensate- load, %
8% 30 kg/cm^2 (g) & above (High-Pressure)	<1% Large condensate load (>1500 kg/h) 1% Medium condensate load (250-1500 kg/h) 7% Small condensate load (< 250kg/h)
12% 7 to 30 kg/cm^2 (g) (Moderate-pressure)	<1% Large condensate load (>1000 kg/h) 2% Medium condensate load (100-1000 kg/h) 10% Small condensate load (< 100kg/h)
80% 2.5 to 7 kg/cm^2 (g) (Low-Pressure)	<1% Large condensate load (>500 kg/h) 2% Medium condensate load (50-500 kg/h) 78% Small condensate load (< 50kg/h)

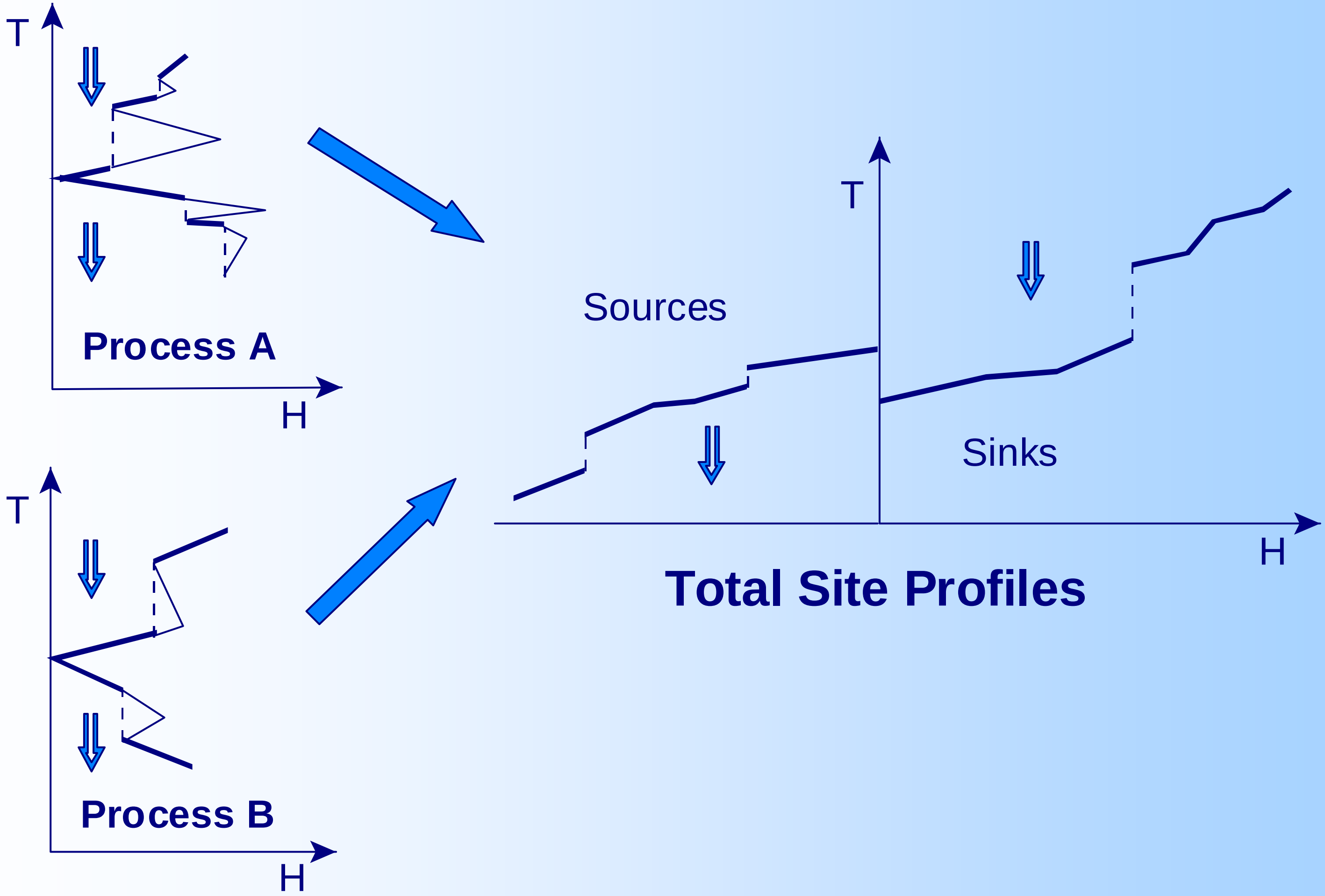
EIL developed steam trap

- Indigenous design
- High reliability
- High energy saving
- Field Trials : 2yrs at R&D pilot plant
- Commercial testing :
  - One year at CPCL, Chennai
  - Six months at IOCL, Mathura
- Performance wise better than other traps
- Zero live steam loss up to 3.5 kg/cm2
- Can save Rs 183 crores every year for refineries having estimated 100,000 traps

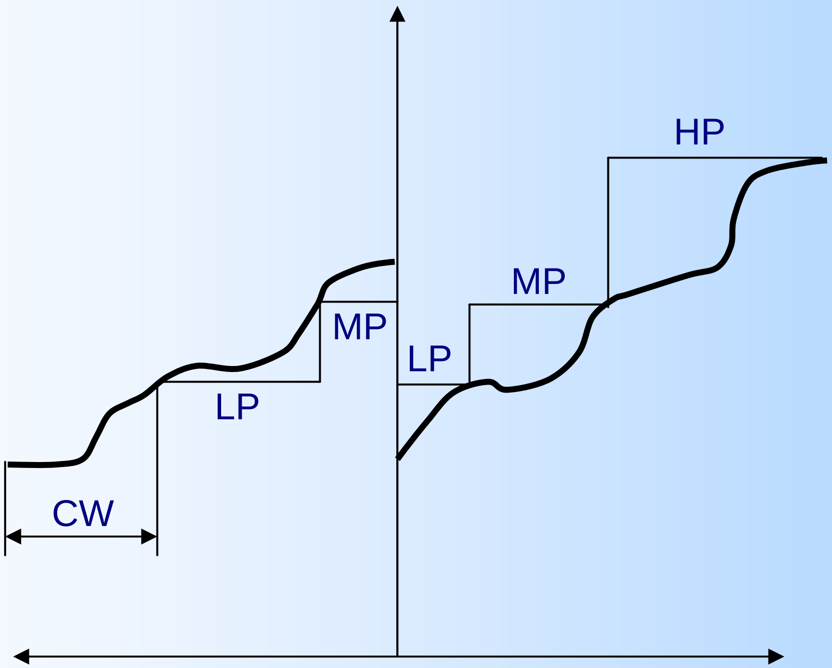
Integrated analysis

- Total site analysis – Pinch approach
  - Utility network – CHP system
  - Optimizing steam mains
  - Cogeneration targeting
  - Path level / top level analysis
  - Hydrogen networks
  - Water and waste water minimization

Total site profiles

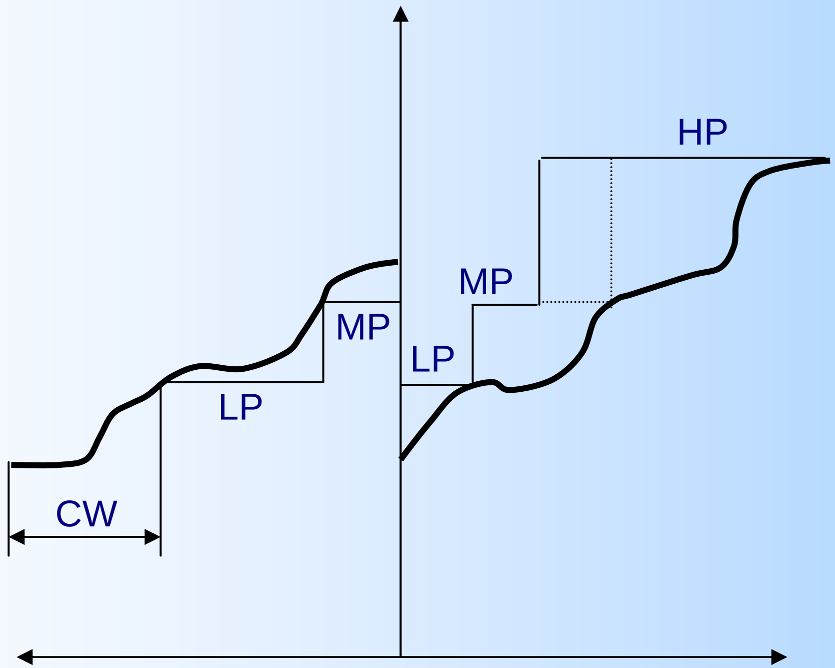


Total site profiles



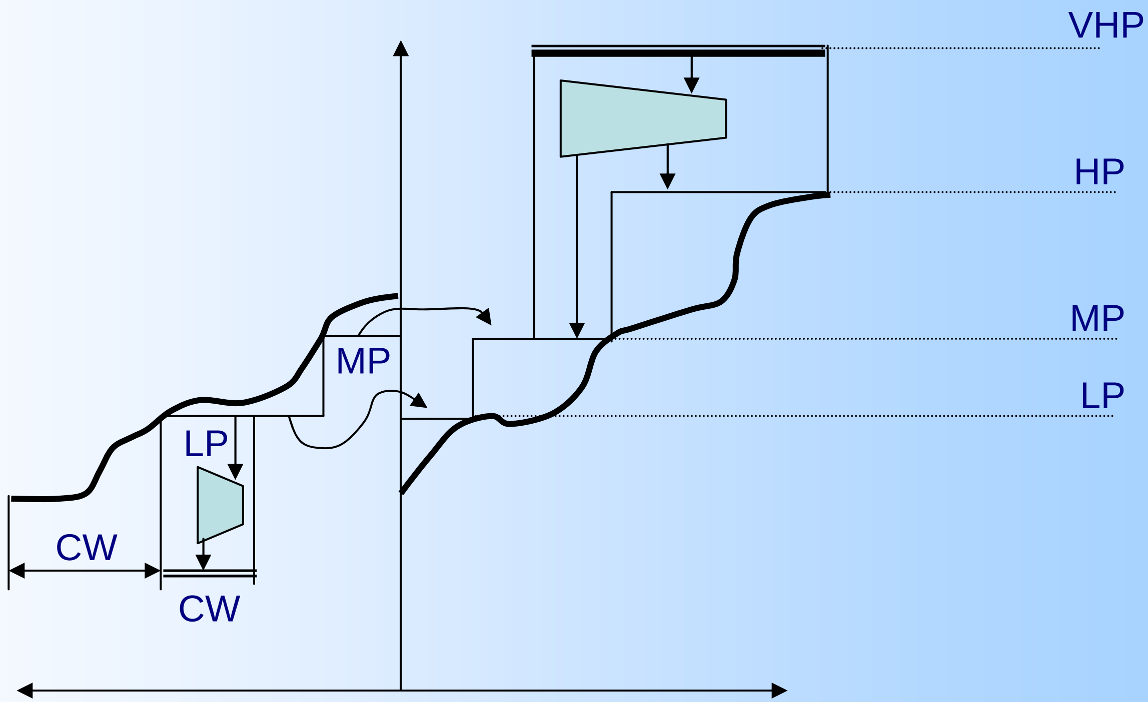
Set targets for steam load

Retrofit – plot existing steam loads



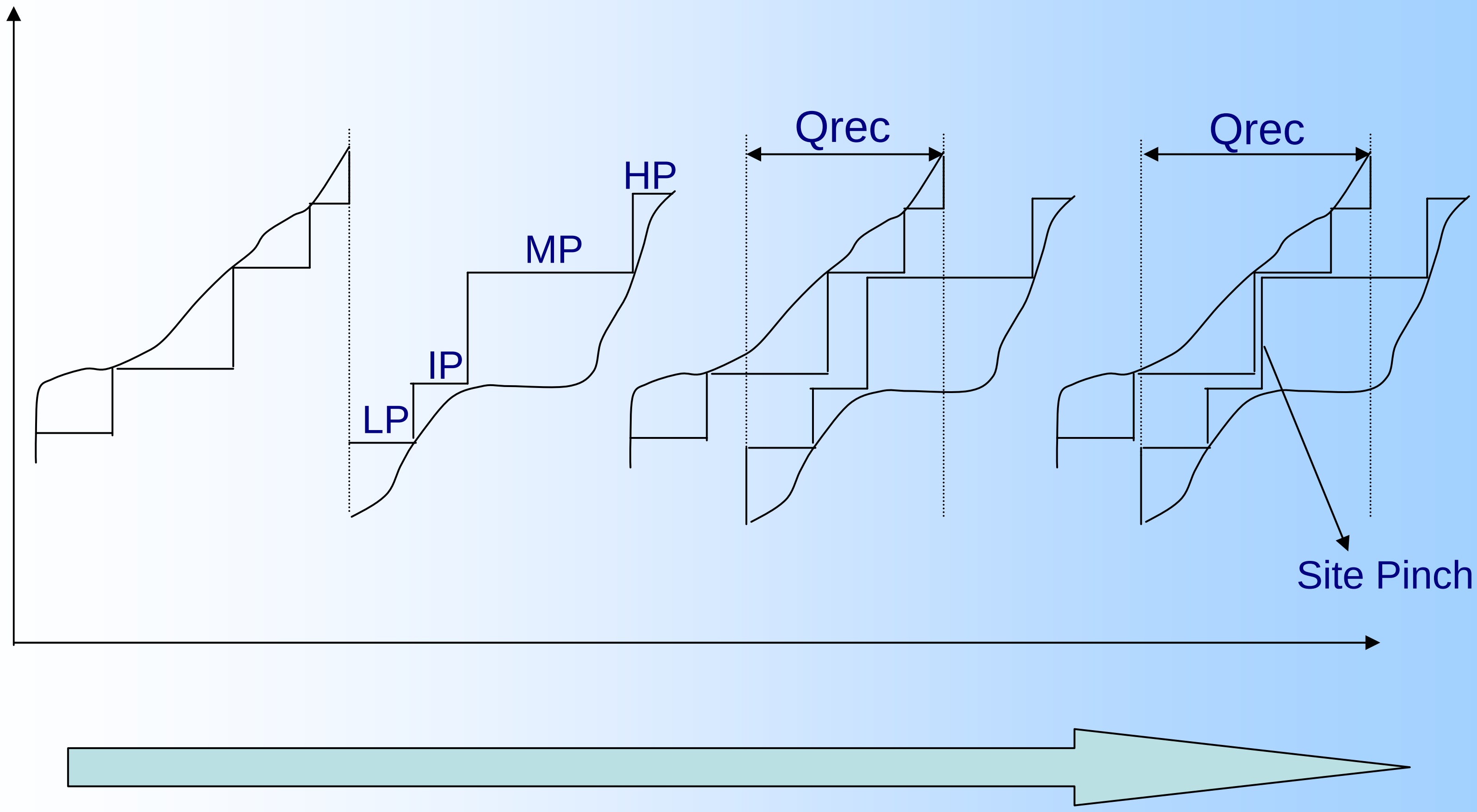
scope for improvement

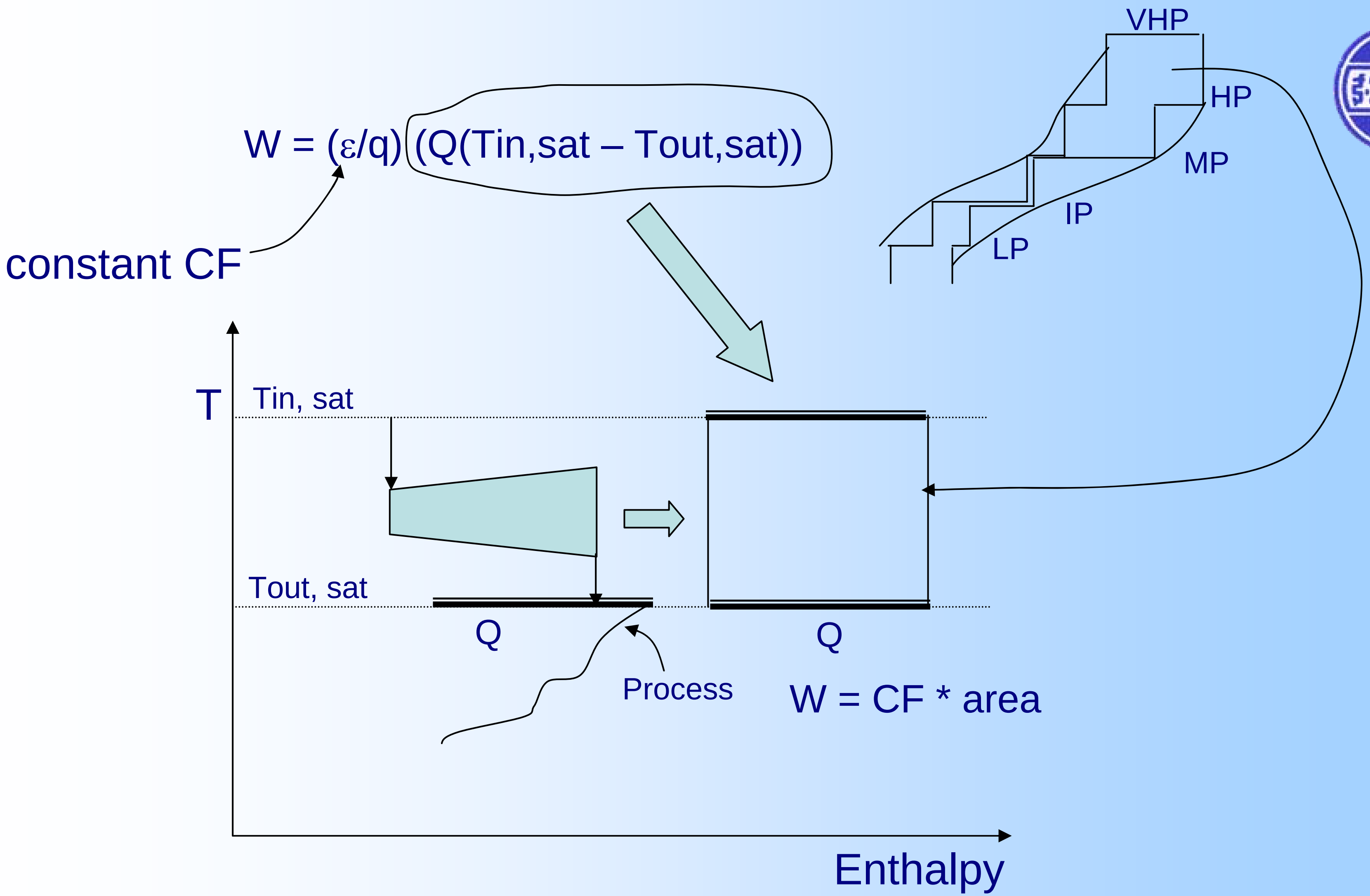
Total site profiles



- Improve total site utility systems
- Plan future infrastructure investment

Procedure

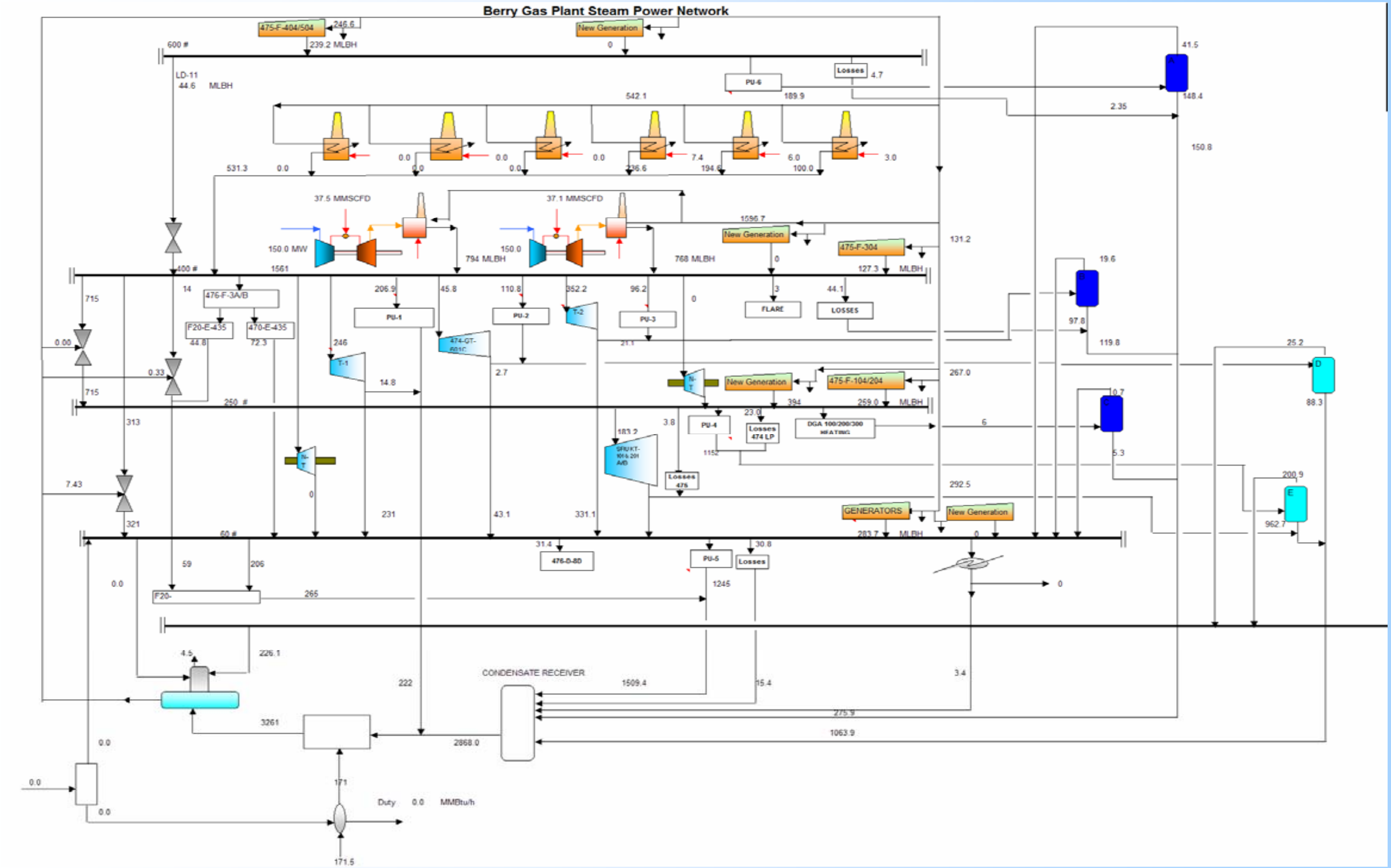



W = (ε/q) (Q(Tin,sat – Tout,sat))
constant CF
VHP
HP
MP
IP
LP
T
Tin, sat
Tout, sat
Q
Q
Process
W = CF * area
Enthalpy

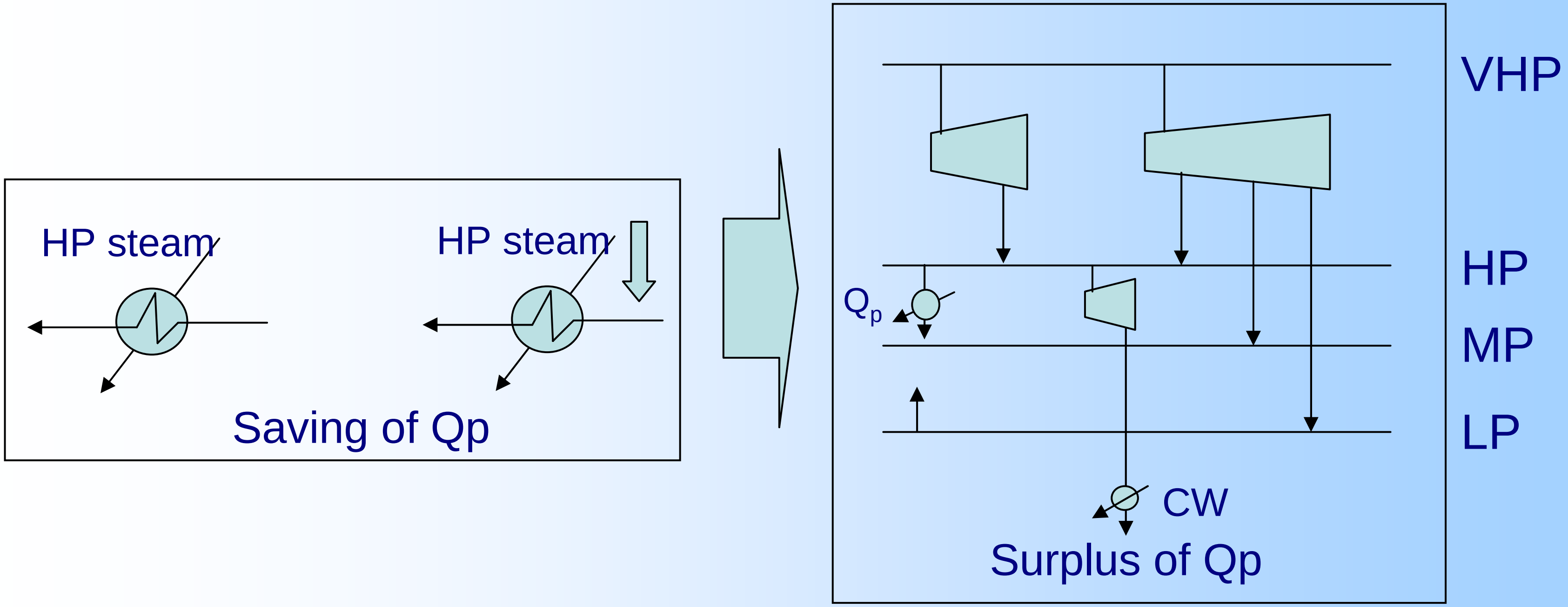
Utility network - CHP

- Understanding interaction between various components of process and utility.
- Identify opportunity for cost reduction through efficiency improvement.
- Identify load shaping strategy
- Evaluating various energy conservation projects for fuel saving by plugging them in the CHP model.

Typical CHP representation

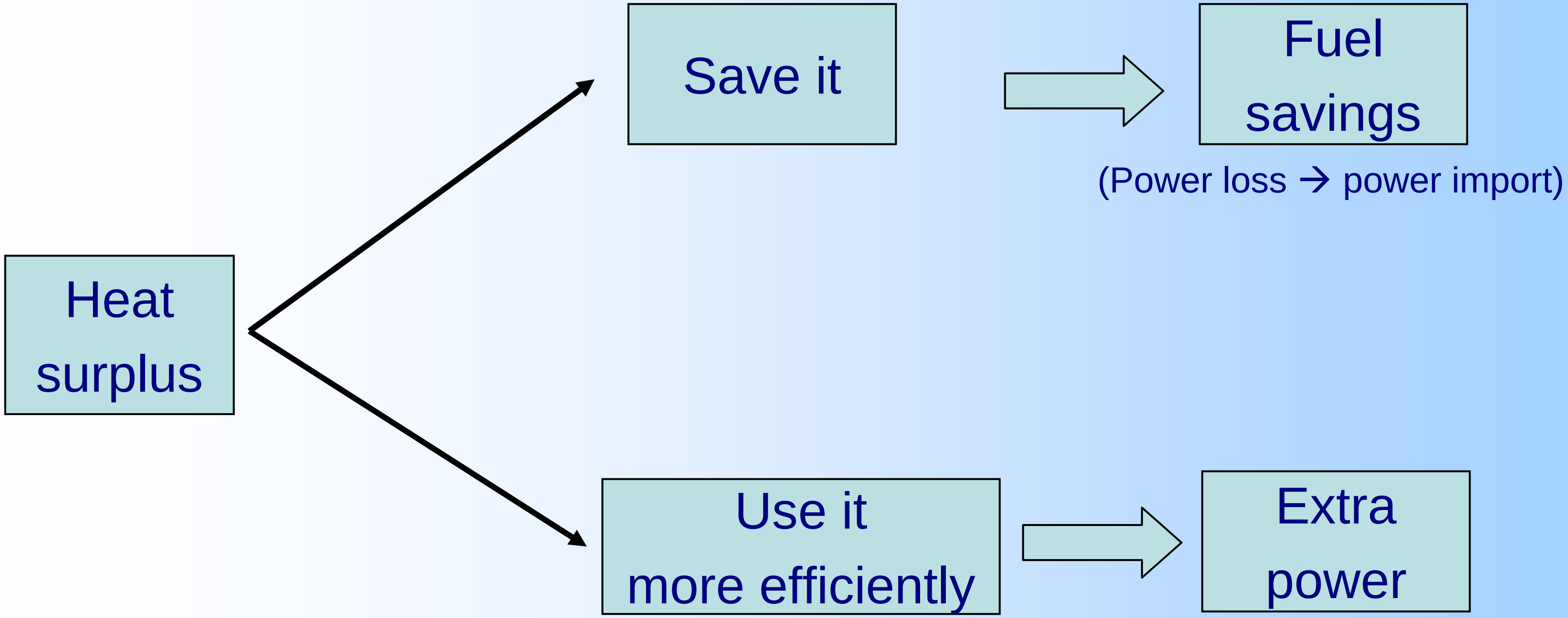


Path level analysis



Implications of energy savings on utility systems

Options for surplus usage



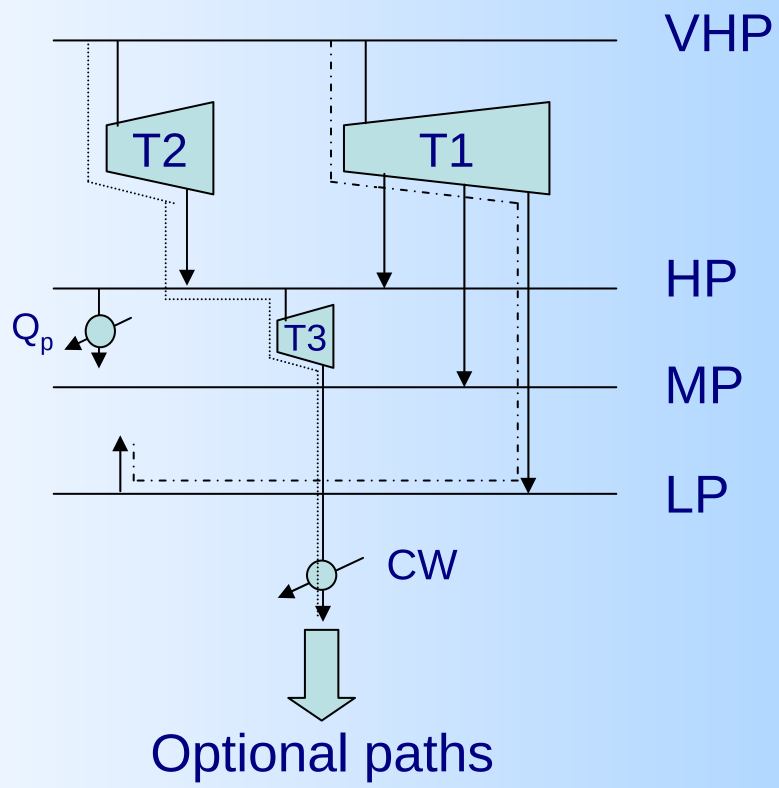
Which option is more economic ?

Implications of surplus Q_p steam at any steam level

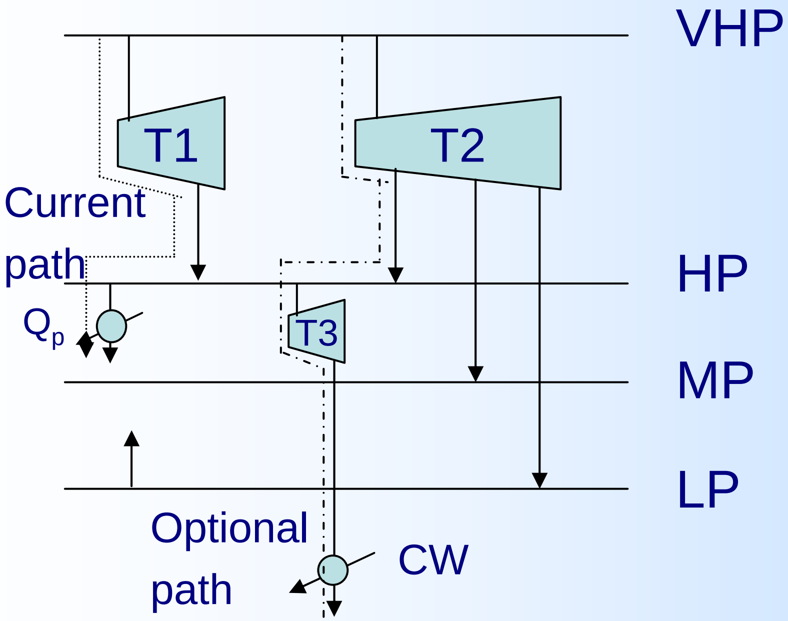
surplus Q_p means surplus VHP

How do we use the surplus more efficiently?

identify heat-flow paths to use surplus steam



Illustration



$\eta_{current} = 0.042$

$\eta_{optional} = 0.359$

$\eta_{import\ power} = 0.24$

$\eta_{current} < \eta_{import\ power} < \eta_{optional}$

- Step 1 Exhaust the optional path by shifting surplus from current path
- Step 2 Convert any other further surplus on current path to fuel savings and import power

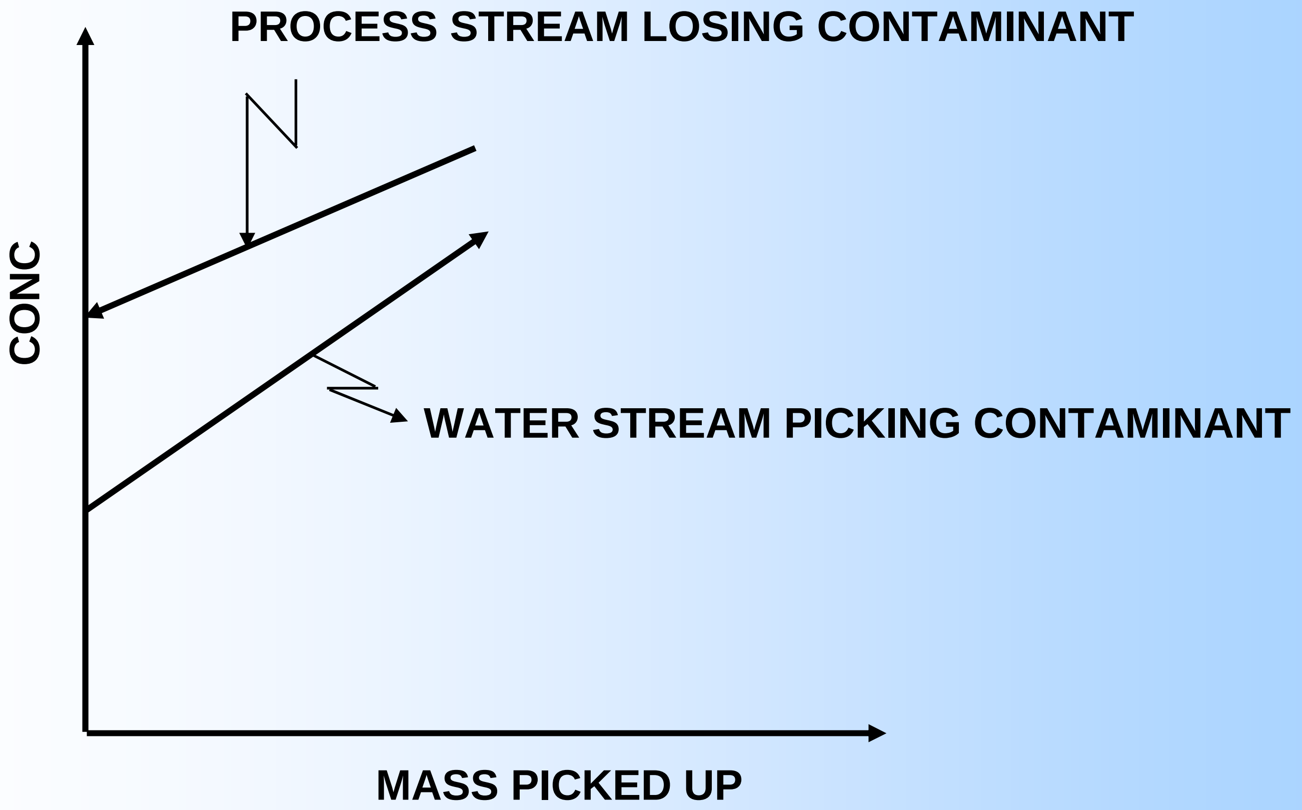
Water and waste water minimization

- General approach
  - Process changes
  - Improved effluent treatment
  - Intra & inter process water reuse / recycle

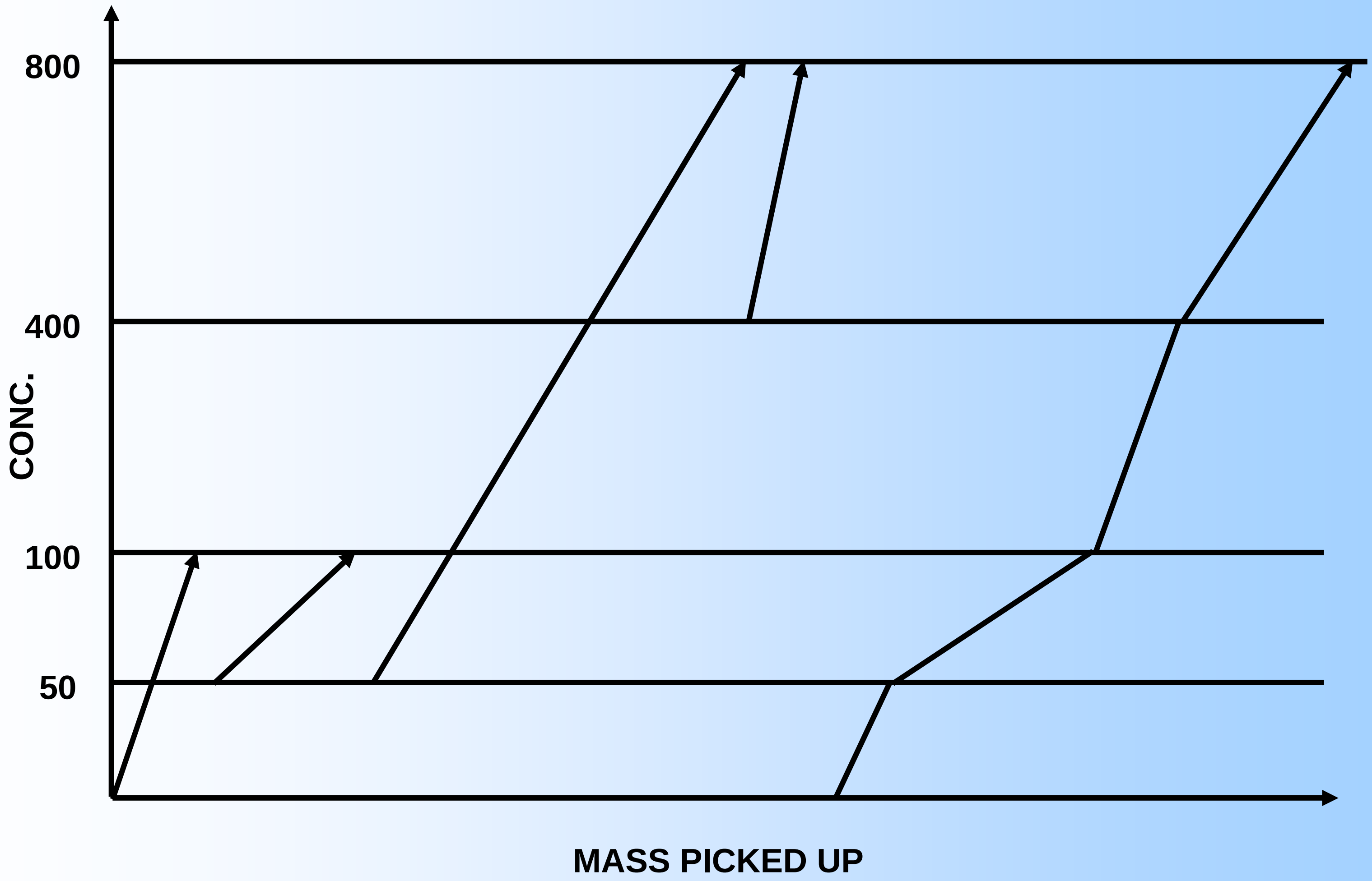
Water pinch analysis

- Waste water is characterized by vol. and load of the contaminant
- Water consuming operations are represented graphically on conc. Vs. mass picked up diagram
- The techniques are well tested for thermal networks and similar principals have been extended for mass exchange networks

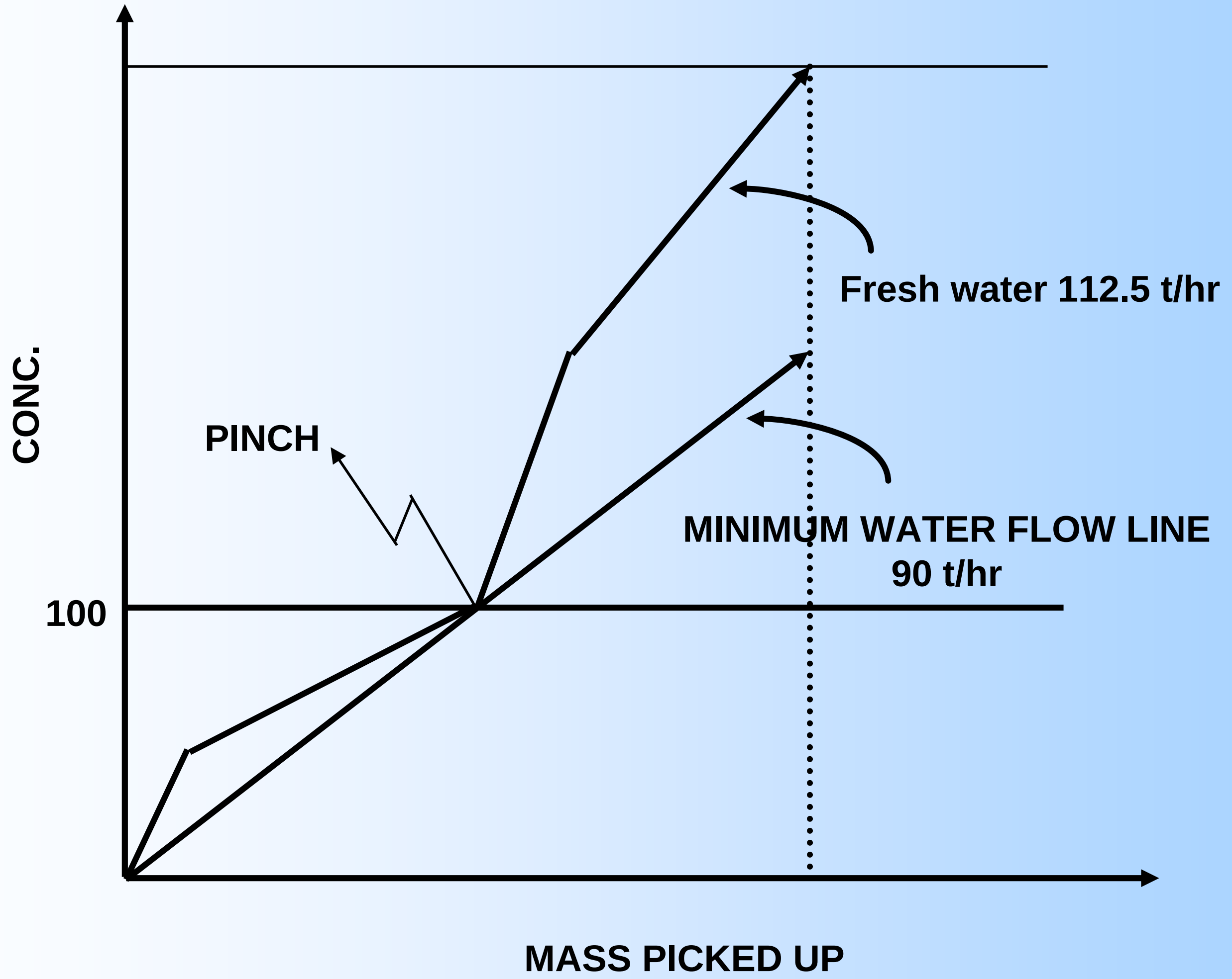
Water consuming operation



Water composite curves



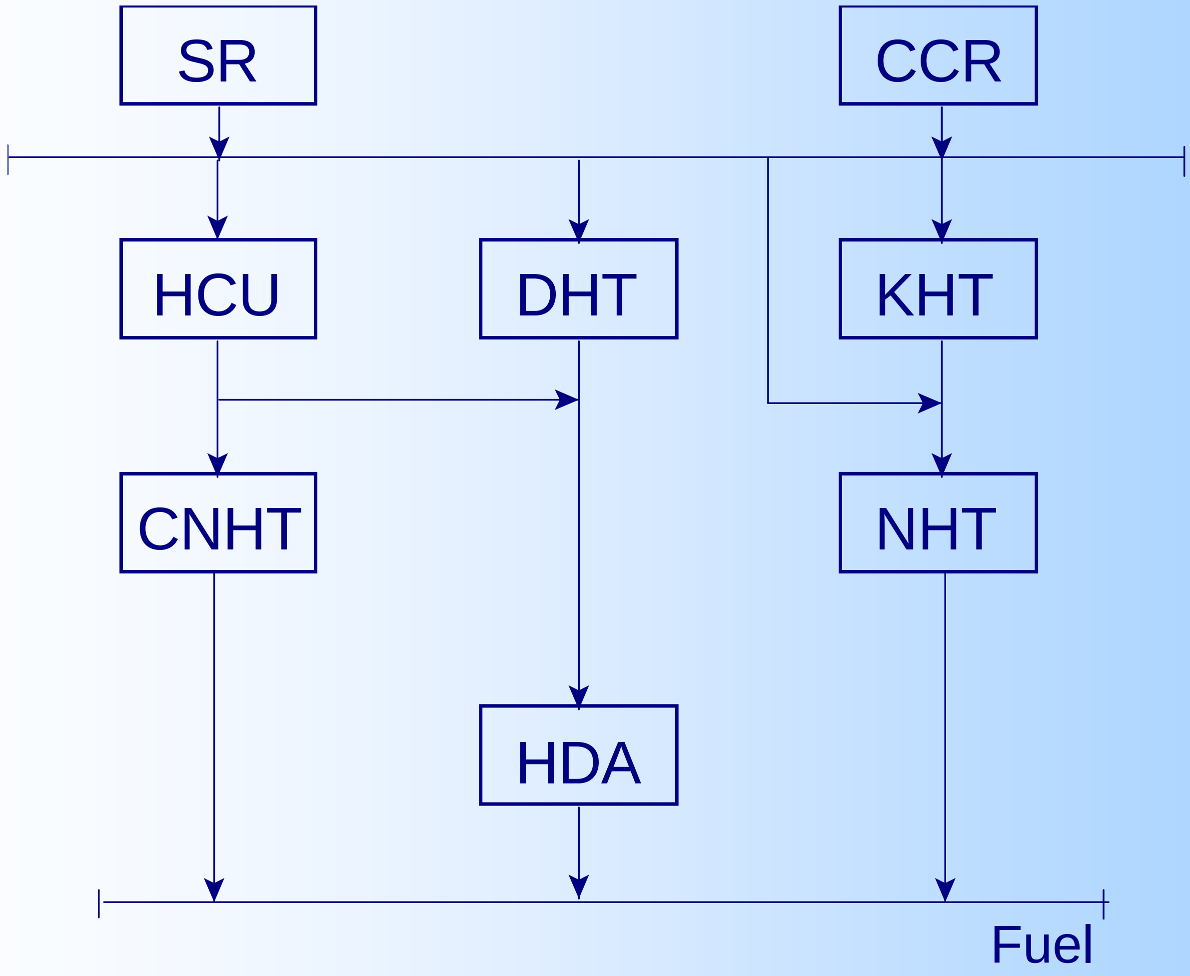
Minimum water targets



Hydrogen management

- Objectives
  - Hydrogen network optimization
  - Hydrogen purification
  - Process modifications
- Hydrogen network
  - Hydrogen consumers
  - Hydrogen producers
  - Purification operations

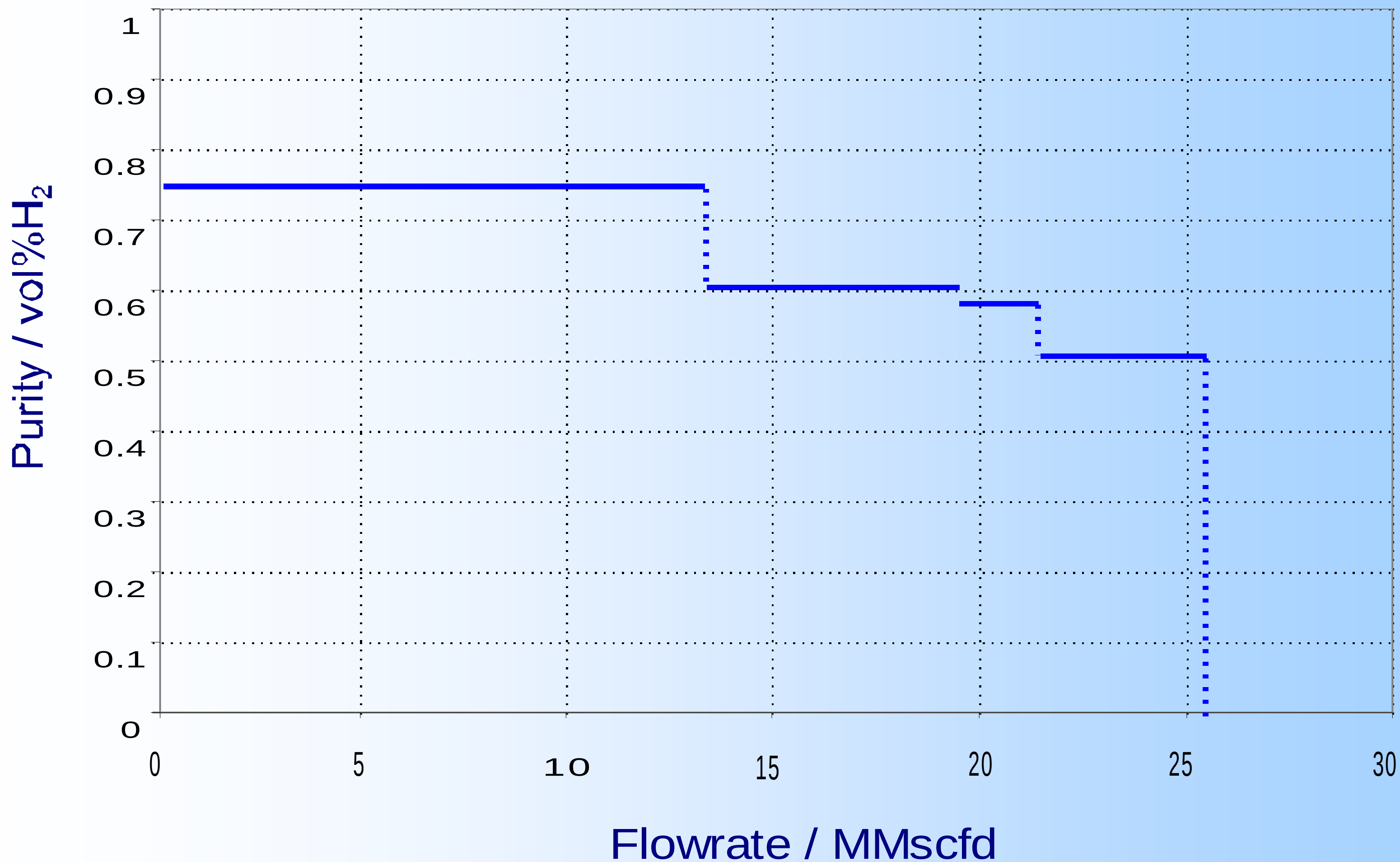
Typical hydrogen distribution system



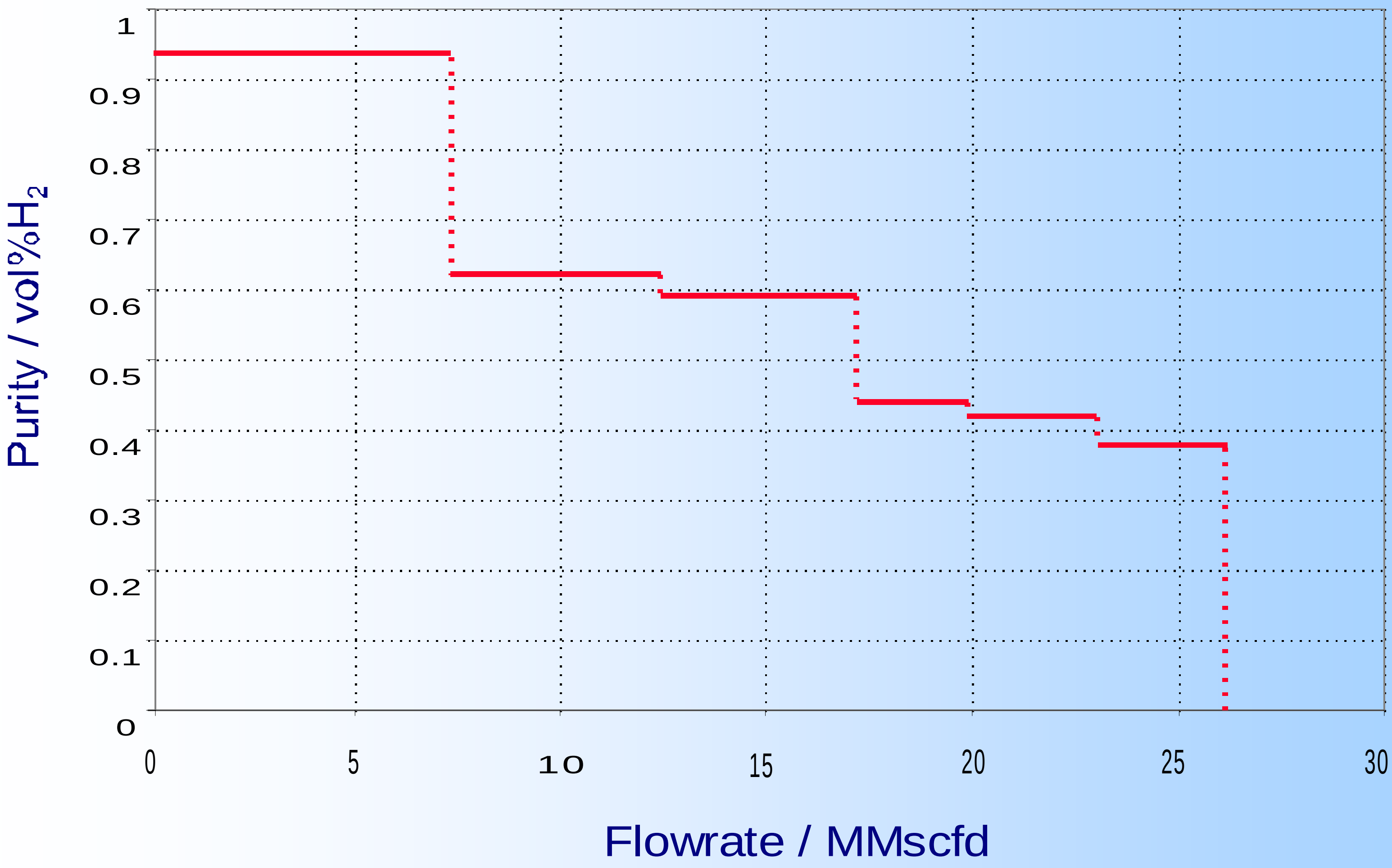
Analysis methodology

- Similar to heat recovery networks
- All sources and sinks of hydrogen are identified
    - sources are SR, CCR, imports etc
    - sinks are hydro-processing units, hydro-cracker etc
- Composites of demand and supply are generated
    - flow rate Vs. purity
- Targets for minimum hydrogen utility are established
- Pinch techniques are used to achieve the targets

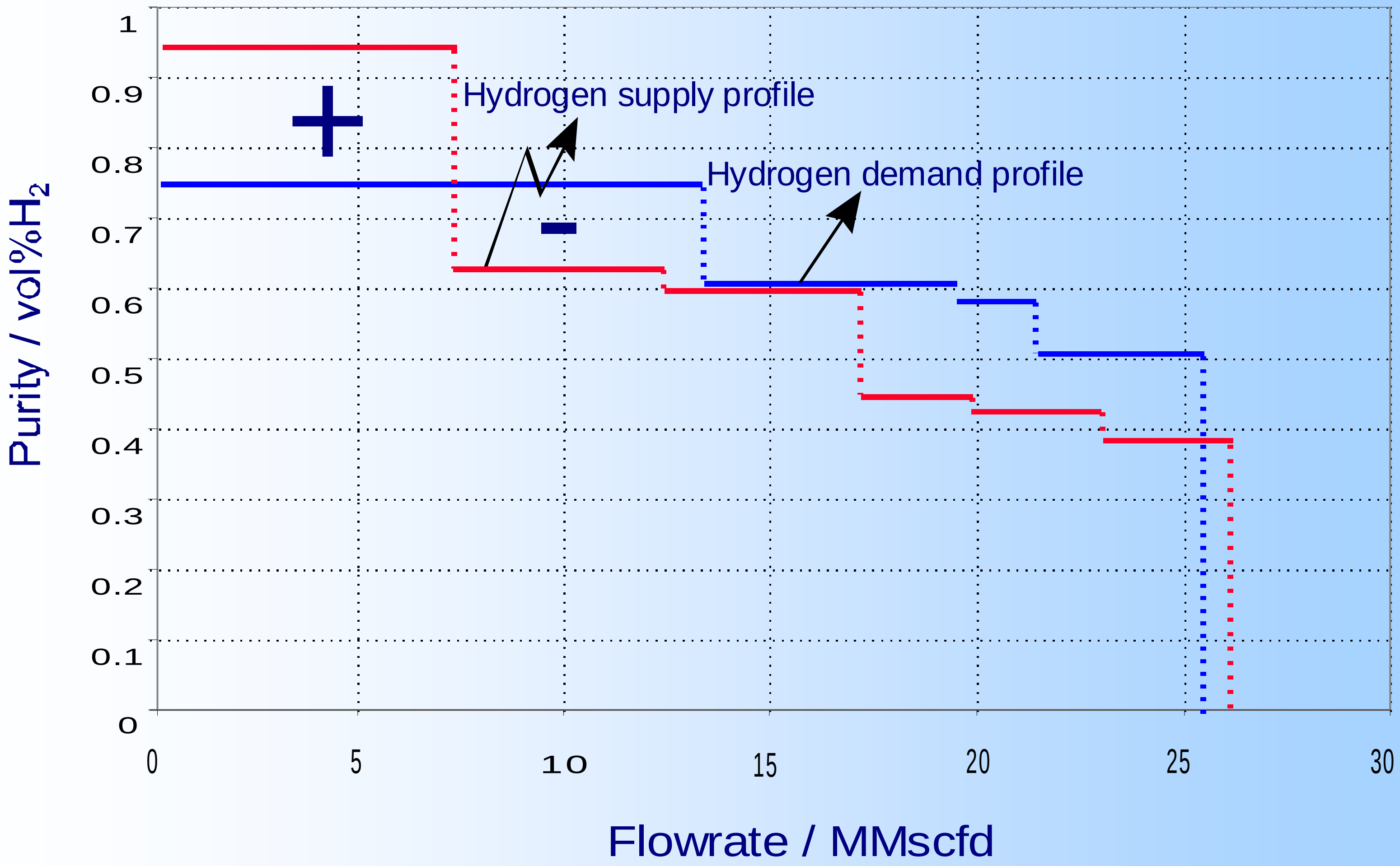
Purity Vs flow rate demand profile



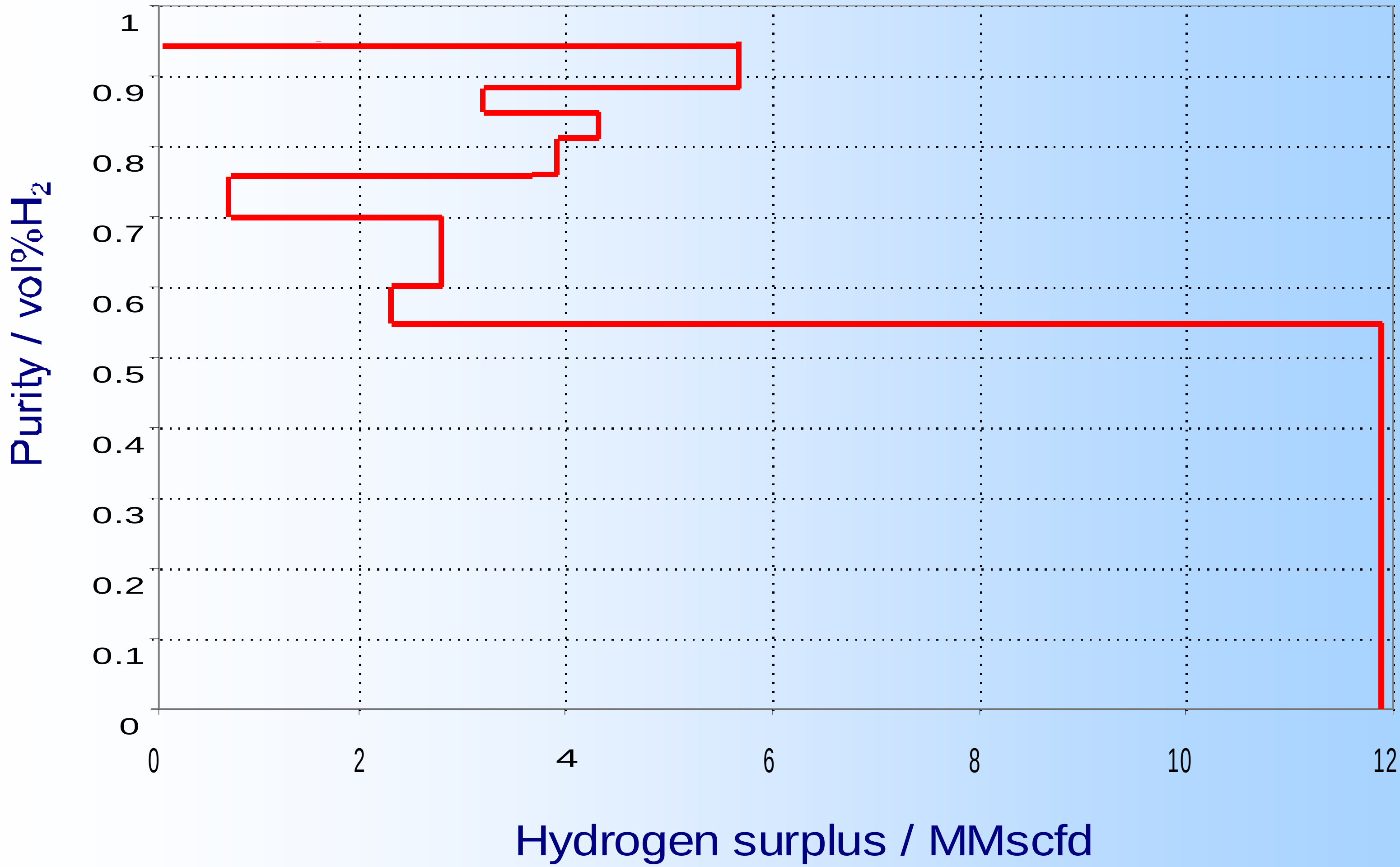
Purity Vs flow rate supply profile



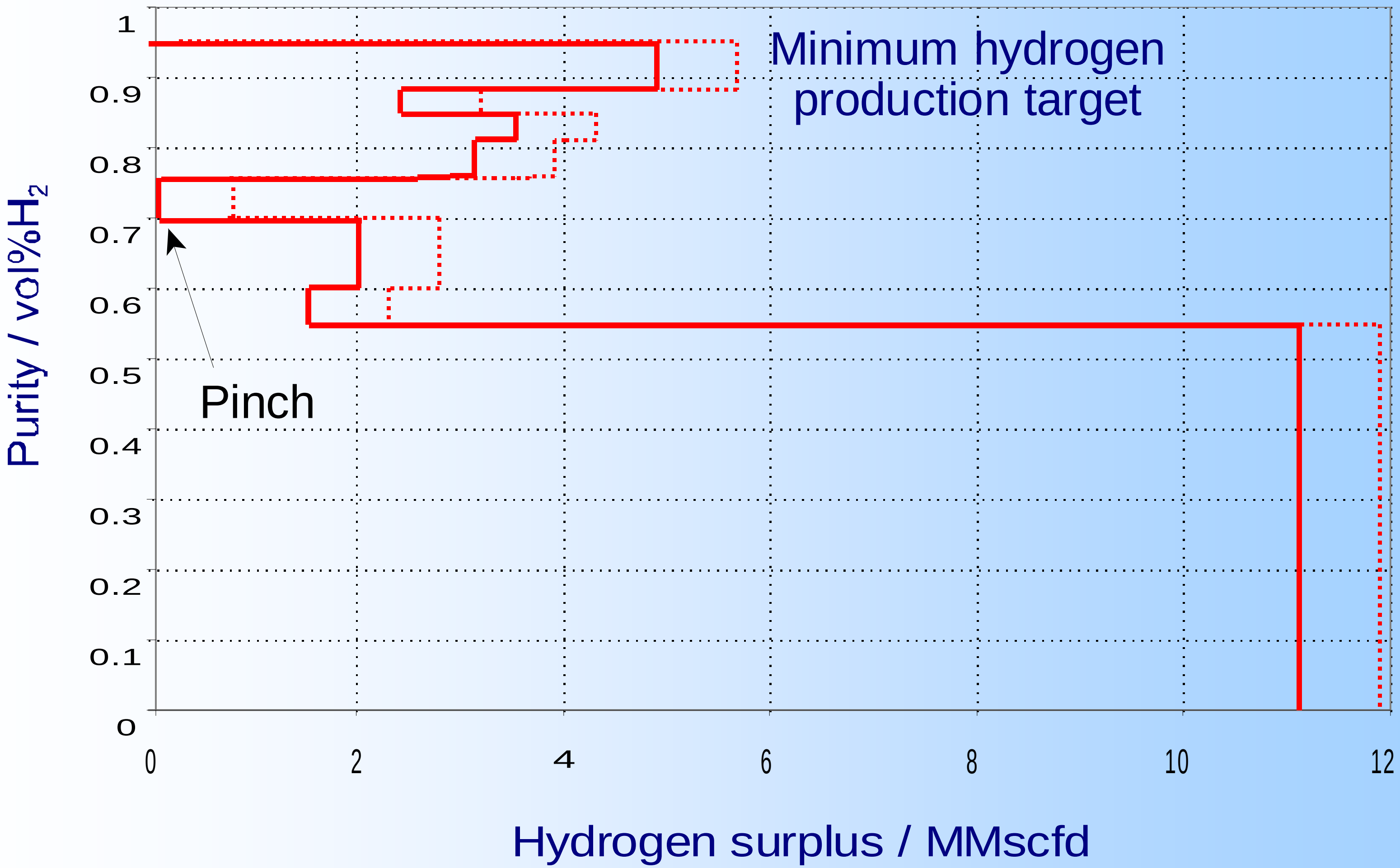
Hydrogen composite curves

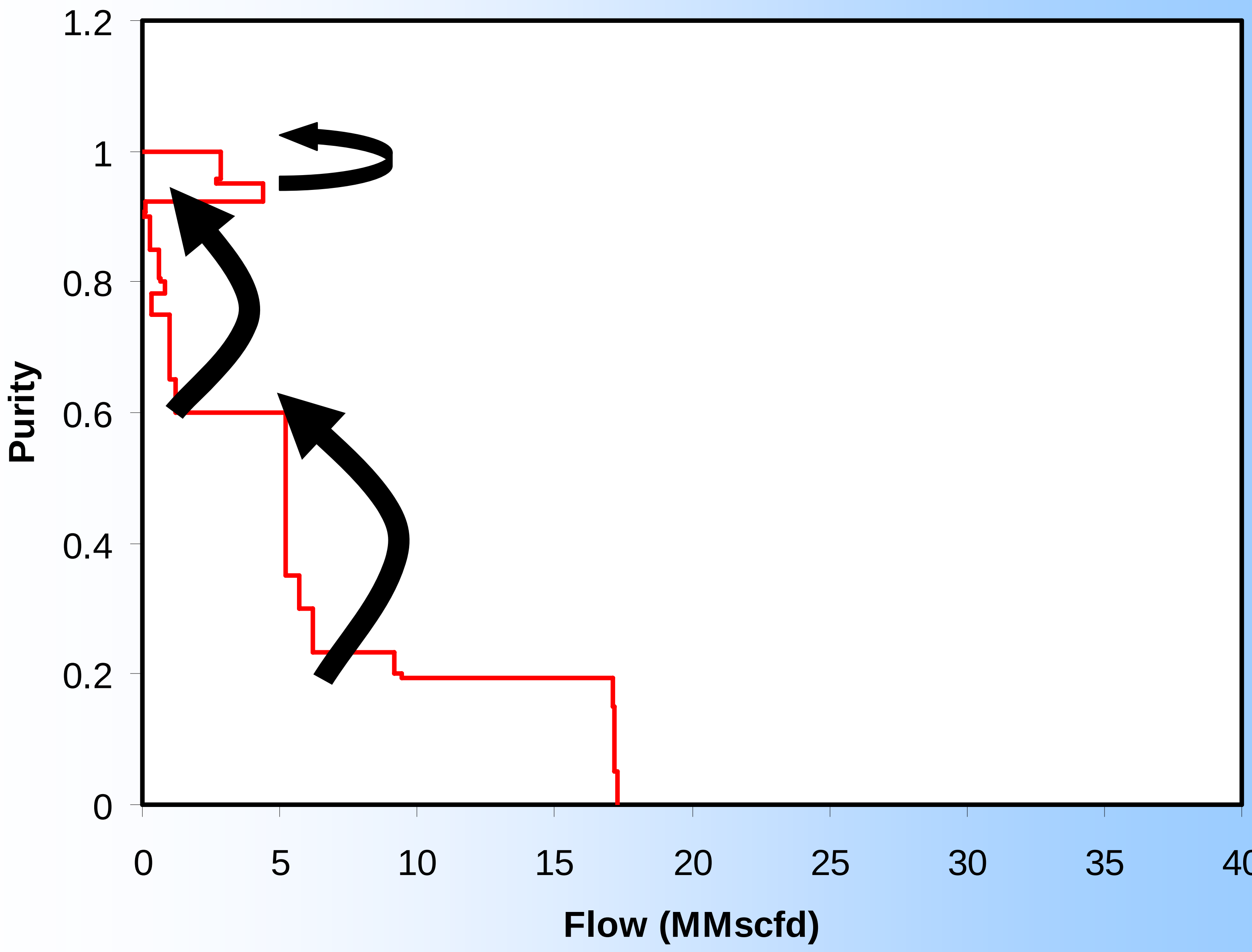


Hydrogen surplus diagram

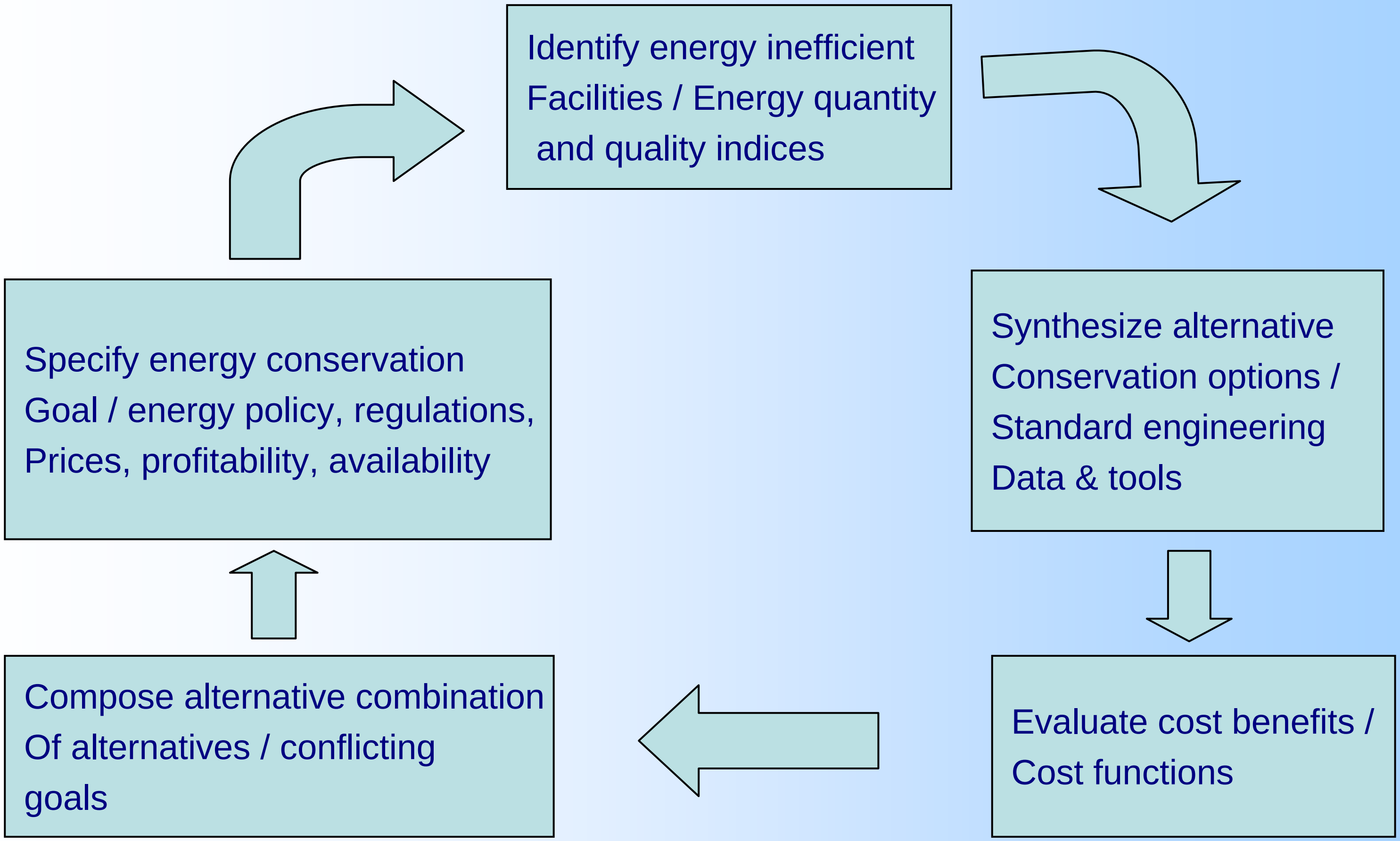


Hydrogen surplus diagram




1.2
1
0.8
0.6
0.4
0.2
0
Purity
0
5
10
15
20
25
30
35
40
Flow (MMscfd)

Comprehensive energy management



ENCON tools at EIL

- In-house developed Excel based tools for:
  - Pump, compressor, fin fan coolers performance
  - VSD applications
  - Fired heater and boiler efficiency estimations
  - CHP model tailor made for specific site
- In-house developed Pinch analysis tools for:
  - HEN design and retrofit
  - Distillation column energy analysis
  - HEN monitoring and targeting
- UMIST suite of softwares for process integration

Conclusion

- Target both resource and energy conservation
- Adopt systems approach of analysis
- It is an ongoing dynamic process
- Update data base, cost functions regularly
- Evaluate every possible opportunity
- Finally.. ENCON is every one's business

Thank you