IPRO 302 –

Analysis of Water Recovery from Power Plants for Recycling

Final Presentation
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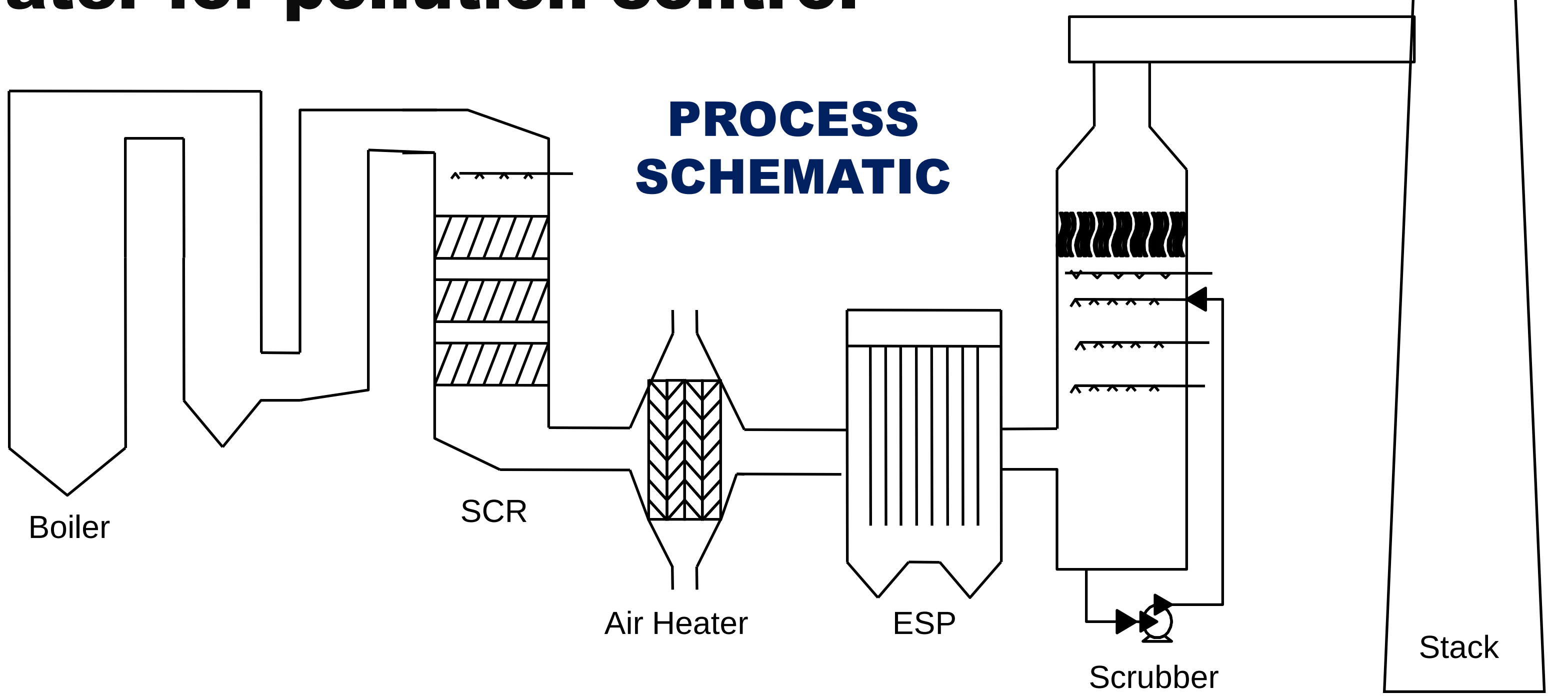
Problem

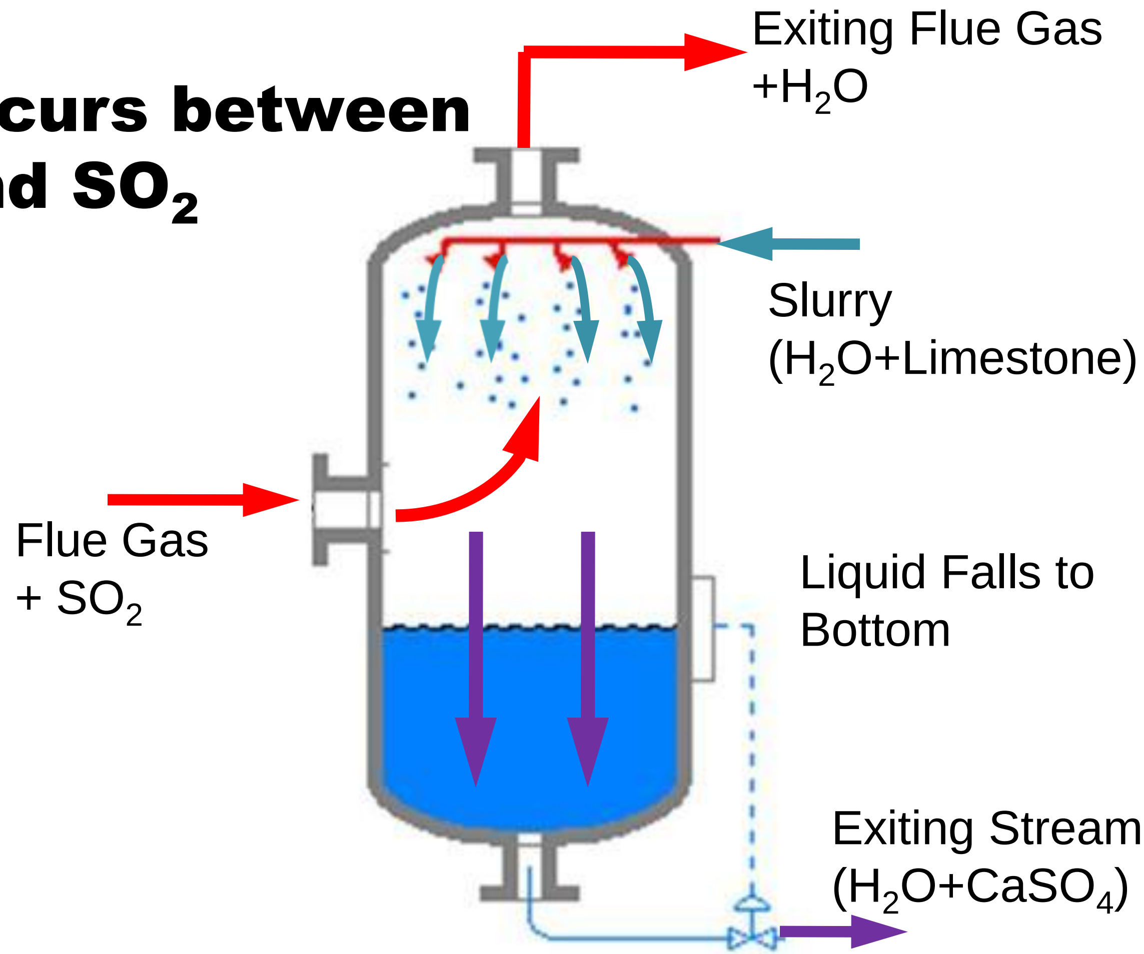
- **Analyze different methods of removing water from flue gas after coal combustion (750 MW plant)**
- **Why? Limited water resources in various locations around the country that require water for pollution control**



SO_2 Pollution Control & Purpose

FGD (Flue Gas Desulfurization)

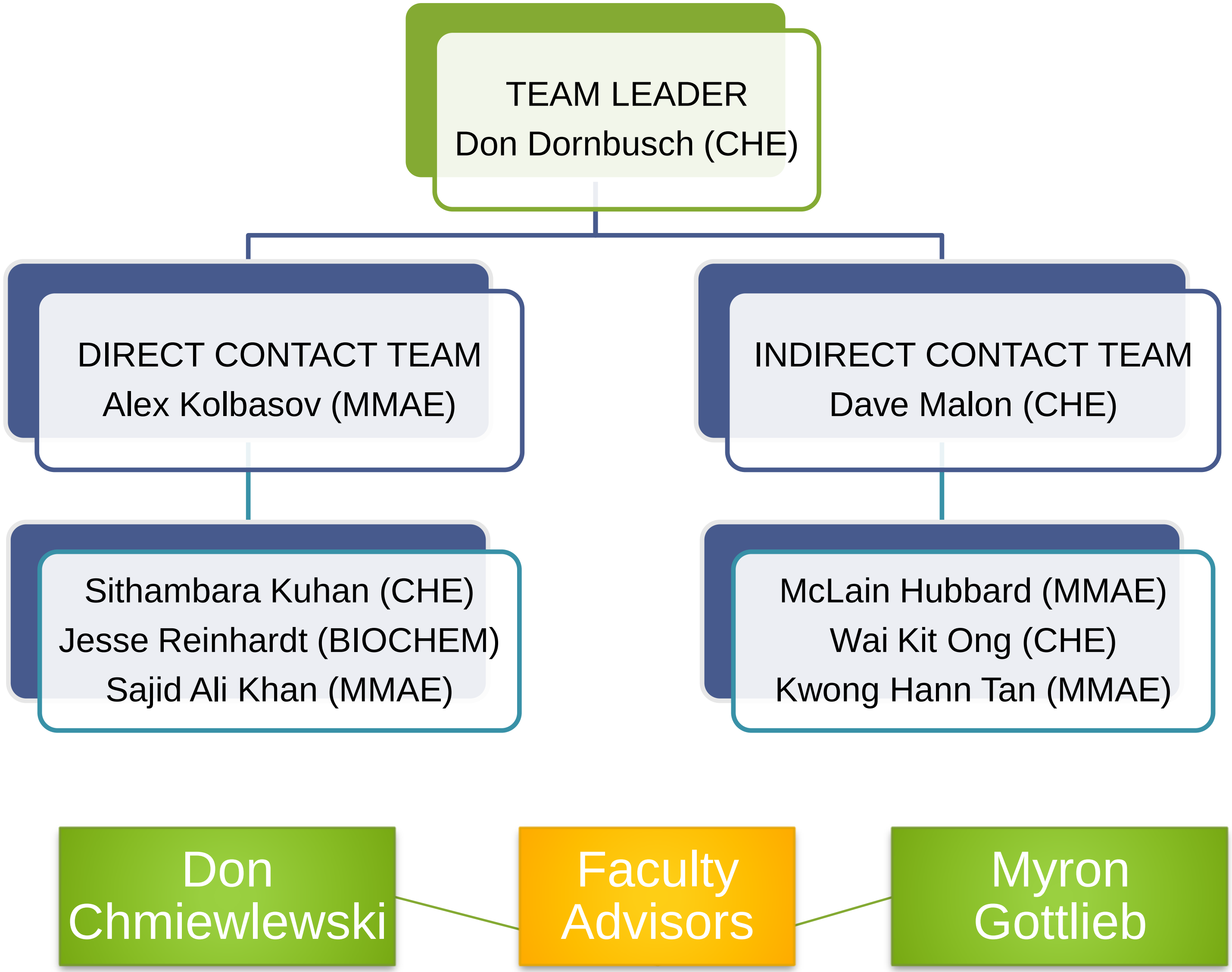
- Reaction occurs between Limestone and SO_2



Objectives

- Analyze and Cost different methods for removing water
- Determine:
  - Rate of H_2O consumption from FGD
  - Amount of H_2O produced for each technology
  - Cost of H_20 produced ($/1000gal H_2O)
  - Quality of water recovered

Organization



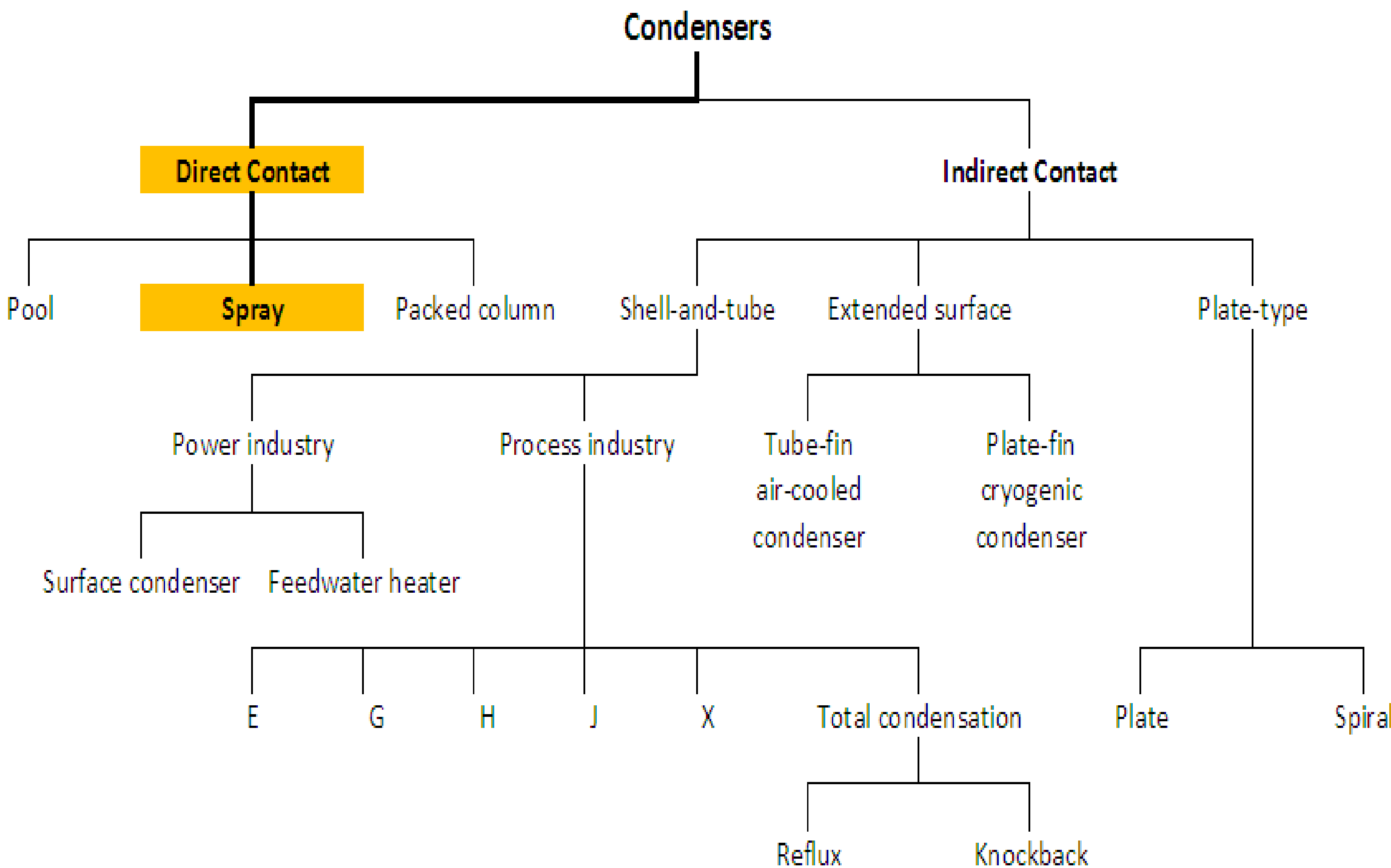
Project Planning

- Establishing common goals
  - Quality of Work
  - Ethical Research
- Team Code of Conduct
  - Honest, Reliable, Respectful
- Project Schedule
  - Dates for Achievements
  - Allow for Adjustments

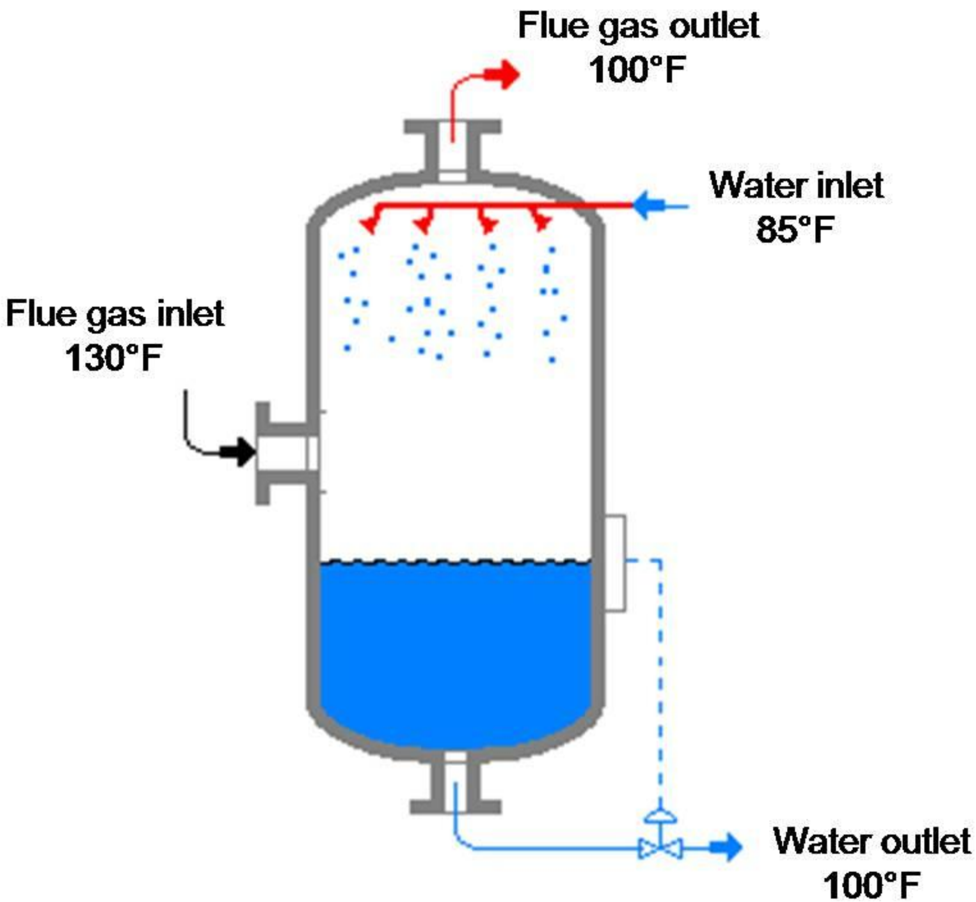
Related Projects

- **Various Separation Techniques**
  - **Desiccant *Siemens***
  - **Spray Towers (Used in FGD)**
  - **Heat Exchanger *US Department of Energy (DOE)***

Direct Contact Team



Spray Tower



- **Advantages**
  - **Simple maintenance**
  - **Low risk of fouling and corrosion**
  - **Low pressure drop**

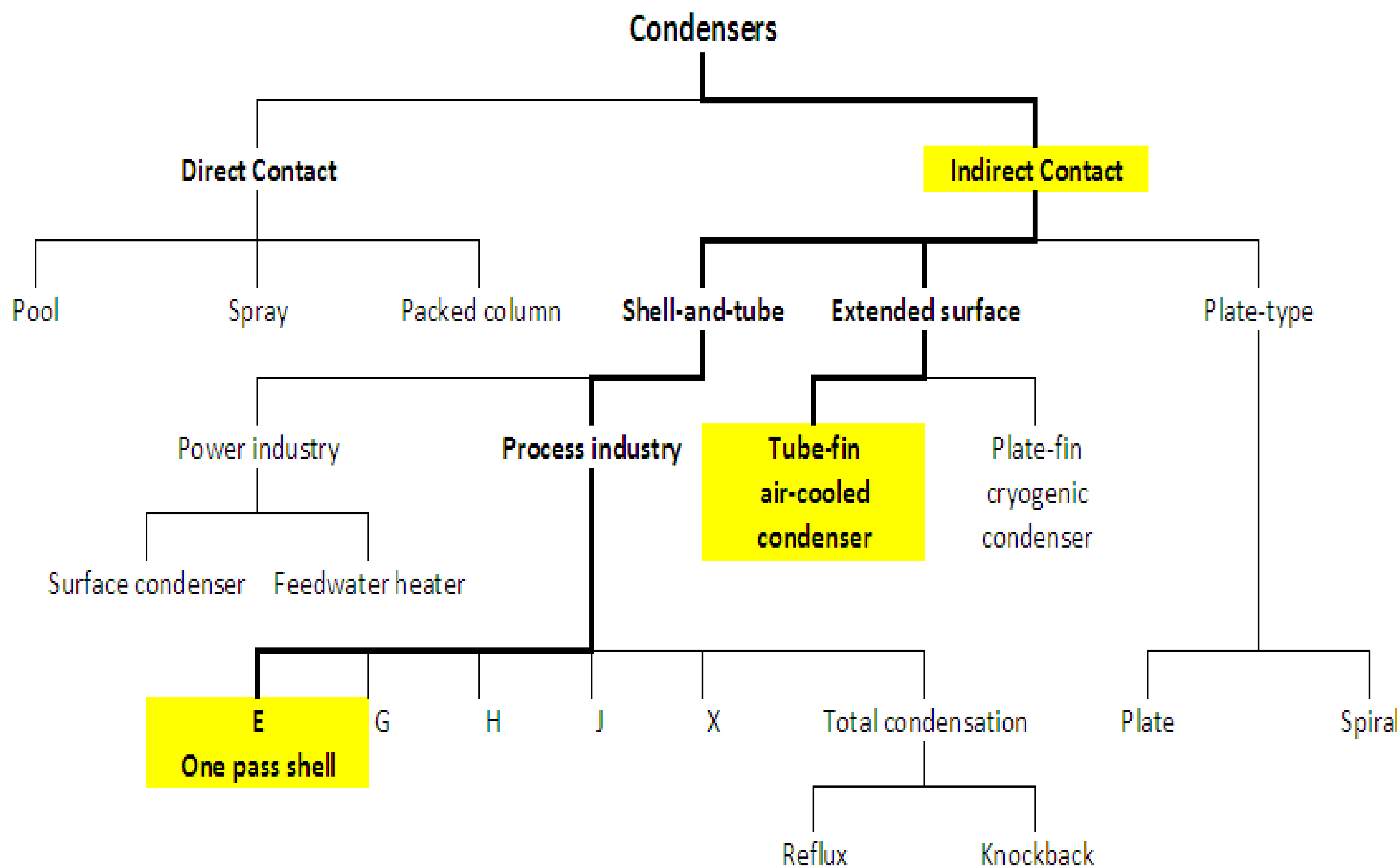
Design Parameters

Part	Parameter	
Tower	Height	7 meters
	Diameter	2 meters
	Primary Material for Construction	Carbon Steel
Nozzles	Type	Flat cone
	Droplet diameter	750 microns
	Operating flow rate	9000 gpm/nozzle
	Operating pressure	470 psi
Pump	Type	Condensate pump
	Total flow rate	90000 gpm
	Power requirements	8995 HP
Cost		
Capital Cost		$218,000
Annual Operating Cost		$3,273,400

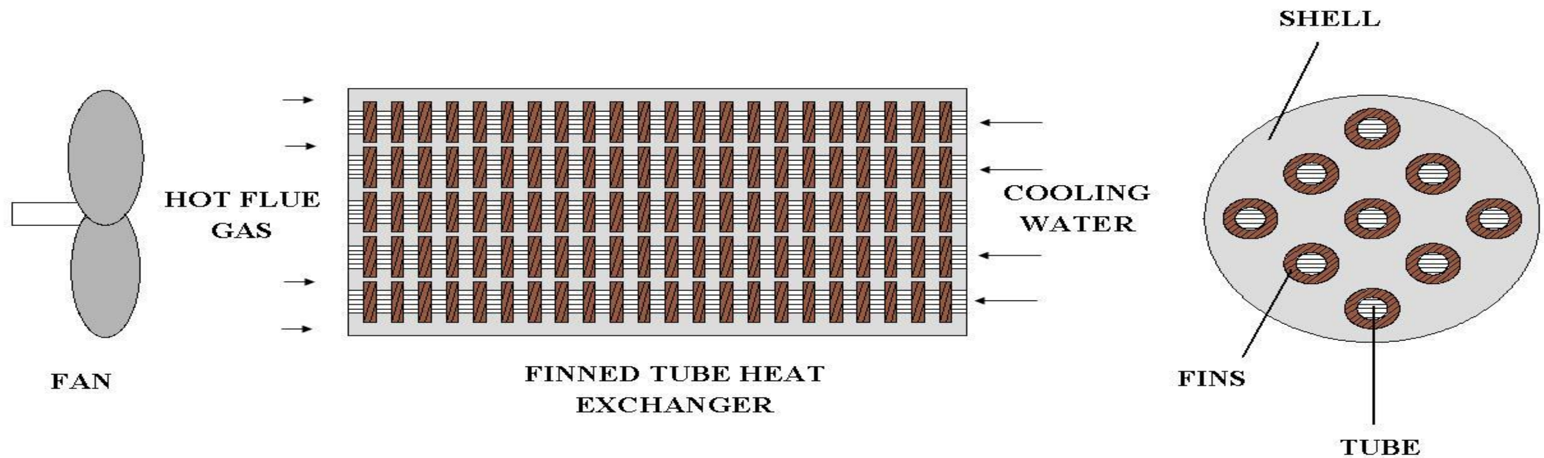
Obstacles

- Wide array of variables
- Lack of literature to compare assumptions
- Use of spray systems for pollution control processes rather than cooling
- Low tolerance to pressure drops

Indirect Contact Team



Compact Shell-and-Tube Heat Exchanger



Counter-flow

Staggered

$$h_i A_i \approx h_o A_o$$

h – Heat transfer coefficient
A – Heat transfer area
i – Tube-side
o – Shell-side

- Large surface-to-volume ratio
- Increased contact with flue gas
- Largest average temperature difference
- Minimized thermal stress
- Overall cost, weight, volume savings

Design

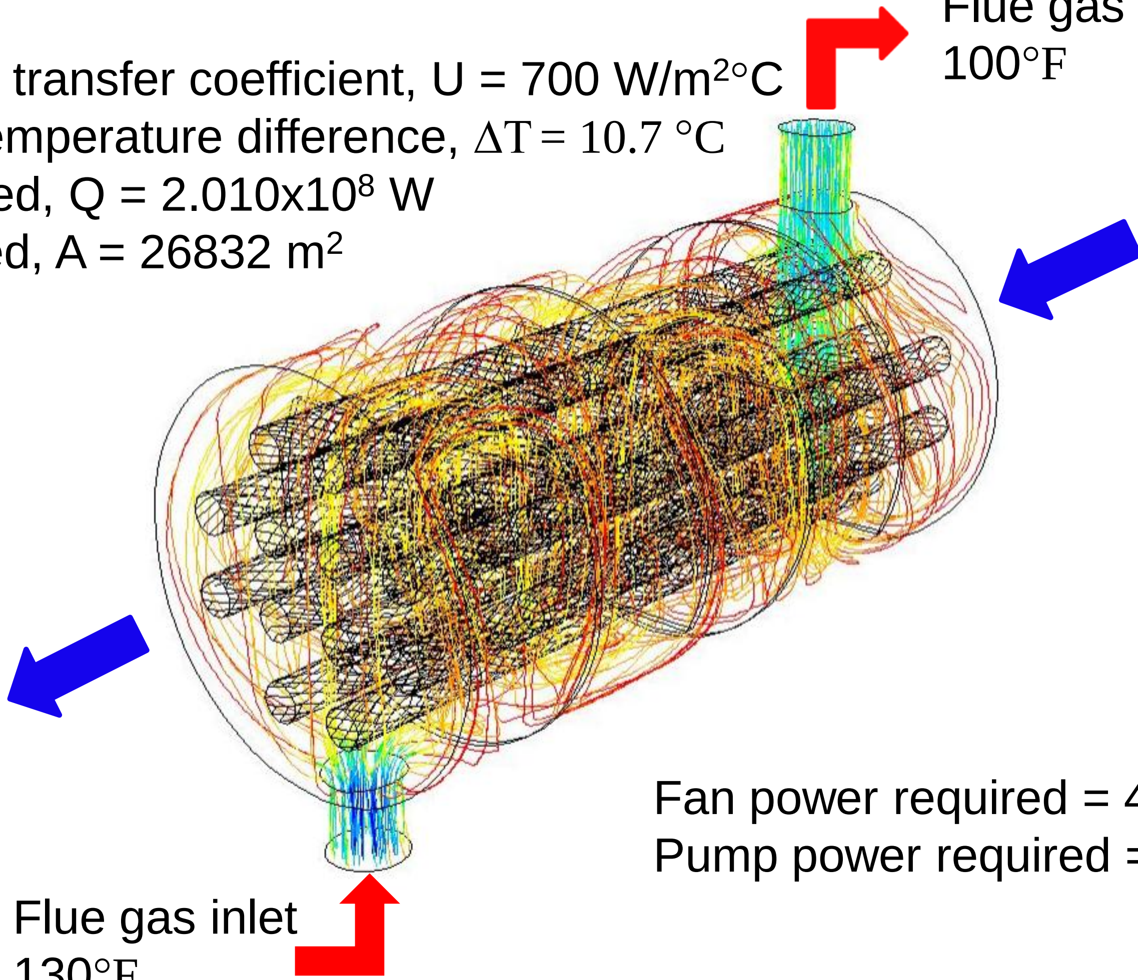
$Q = UA\Delta T$

Overall heat transfer coefficient, $U = 700\ W/m^2\,°C$

Corrected temperature difference, $\Delta T = 10.7\ °C$

Heat removed, $Q = 2.010 \times 10^8\ W$

Area required, $A = 26832\ m^2$



Fan power required = 4320 kW

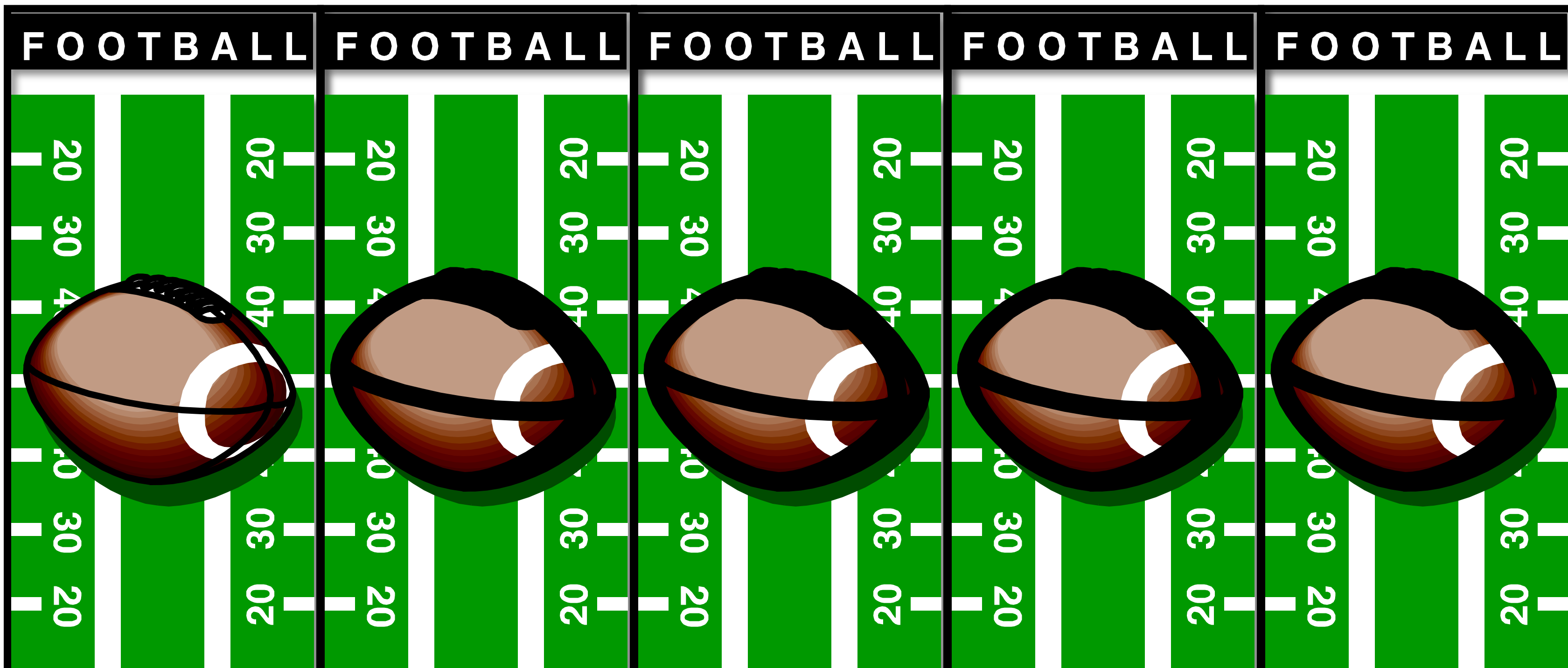
Pump power required = 678 kW

Design Parameters

	Shell-side		Tube-side	
Fluid	Flue Gas		Water	
Total Flow [kg/h]	4,017,500		20,124,000	
Vapor (in/out) [kg/h]	4,017,500	3,750,000	0	0
Liquid (in/out) [kg/h]	0	267,500	20,124,000	20,124,000
Temperature (in/out) [°F]	130	100	85	100
Heat Duty [kJ/h]	7,235,000			
Area [m^2]	26,832			
Capital Cost [US$]	836,939[1]			
Annual Operating Cost [US$]	Fan		Pump	
	2,649,004		415,955	

[1] Corrected 2008 value – CE index 746.4

That’s 5 Football Fields!



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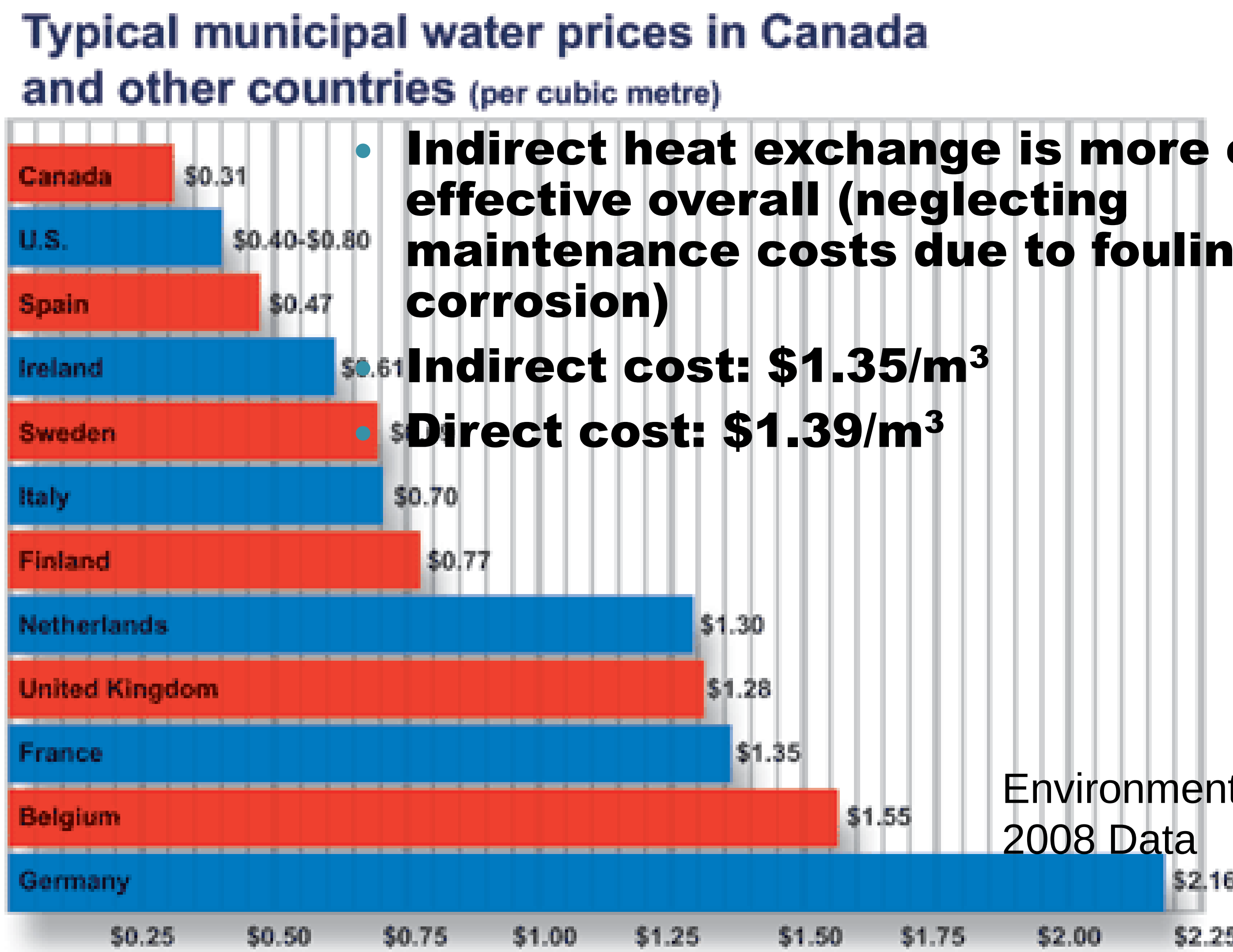
Obstacles

- Heat exchanger information not readily available
- Determining actual overall heat transfer coefficient
- Sizing of heat exchanger
  - Tubes
    - Diameter, thickness, length
  - Fins
    - Thickness, height, number of fins per inch

Results and Recommendations



- **Indirect heat exchange is more cost effective overall (neglecting maintenance costs due to fouling and corrosion)**
- **Indirect cost: $1.35/m^3**
- **Direct cost: $1.39/m^3**

Environment Canada 2008 Data

Economics

Cost	Direct Contact (US$)	Indirect Contact (US$)
Capital Cost	218,000	836,939
Operational Cost	3,273,400	3,064,959
Annualized Cost	3,299,500	3,165,392
Cost per 1000 Gallons H_2O Recovered	5.28	5.10

Quality of Water Recovered

Temperature = 85 °F

Pressure = 1 atm

Component	Mass Flows (kg/h)	Mass Percent (%)
Water	268,000	99.67
Oxygen	854.72	0.32
Carbon Dioxide	28.144	0.01
Nitrogen	2.8981	0.00
Sulfur Dioxide	0.1782	0.00
Chlorine	0.00265	0.00
Argon	0.000462	0.00
Total	268,406	100

Ethical Issues

- **Concerns**
  - **Environmental impact**
  - **Economics & Resource management**
  - **Societal impact**
  - **Sponsor's needs**
- **Responsibilities**
  - **Intra-group**
  - **Inter-communal**

Conclusions

- **Was enough water produced for FGD?**

  YES

- **Was the price competitive?**

  NO

Feasible?

- **Only under restrictive circumstances**

  (ex. scarce resources)

Recommendations

- **Analyze other technologies**
- **Only apply one of our methods when resources are scarce.**

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Questions/Comments?

References

- [1] **U.S. Department of Energy. http://www.energy.gov/energysources/coal.htm. *Last Reviewed: 10/19/2007.***
- **Principles of Flue Gas Water Recovery Systems. © Siemens AG 2005.**
- **Recovery of Water from Boiler Flue Gas. US Department of Energy. ©11/2006.**
- Seider, Warren D., J. D. Seader, and Daniel R. Lewin. Product and Process Design Principles : Synthesis, Analysis, and Evaluation. 2nd ed. San Francisco: Pfeiffer, 2003.
- Singh, Jasbir. Heat Transfer Fluids and Systems for Process and Energy Applications. Danbury: Marcel Dekker Incorporated, 1985.

CE Index

Economic Indicators

2008 2007

DOWNLOAD THE *CEPCI* TWO WEEKS SOONER AT *WWW.CHE.COM/PCI*

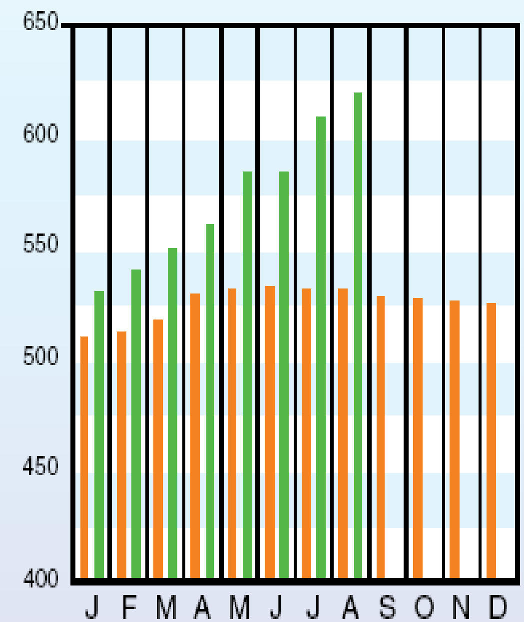
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)

	Aug.'08 Prelim.	Jul.'08 Final	Aug.'07 Final
***CE* INDEX**	619.3	608.8	531.5
Equipment	761.0	746.4	632.9
Heat exchangers & tanks	784.2	760.1	602.9
Process machinery	680.6	669.5	601.5
Pipe, valves & fittings	881.5	875.5	747.4
Process instruments	457.8	459.0	428.6
Pumps & compressors	872.9	869.9	836.1
Electrical equipment	468.1	468.2	434.5
Structural supports & misc	843.9	815.8	669.9
Construction labor	325.1	322.1	317.4
Buildings	529.7	521.5	478.6
Engineering & supervision	352.3	352.9	356.4

Annual Index:

2000 = 394.1
2001 = 394.3
2002 = 395.6
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4



Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics

Project Sponsor:

Sargent & Lundy LLC

Informational Resources:

MATLAB SIMULINK

aspentech

Mc Graw Hill

Environment Canada

TEMA
TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION

Calculations