CH402 Chemical Engineering Process Design

Class Notes L1

Introduction to Process Design

web site:

https://https://usarmywestpoint.sharepoint.com/sites/cls.ch402/Main%20Page/default.aspx

Classroom and Computer Standards:

The following items will result in a COR:

- Working on anything other than CH402.
- Printing while I am speaking.
- Consuming food of any kind at workstations.
- Chewing gum.
- Sleeping during class.
- Failure to sign out of computers.
- ~~Failure to replace computer floor plates~~.

If you print a document, please either collect it or cancel the print job.

Start > Printers and Scanners > Open queue (for your printer)

Please bring any printer issues to the attention of your instructor.

Please sign out of lab computers (use Ctrl-Alt-Del to sign out).

USMA Chemical Engineering Mission

To prepare commissioned leaders of character who are proficient in applying chemical and engineering principles to solve problems in a complex operational environment.

Published in the USMA Redbook (Part 2 – Disciplinary Offerings)

Chemical Engineering Program Educational Objectives

During a career as commissioned officers in the United States Army and beyond, program graduates:

- Demonstrate effective leadership and chemical engineering expertise.
- Contribute to the solution of infrastructure or operational problems (in a complex operational environment).
- Succeed in graduate school or other advanced study programs.
- Advance their careers through clear and precise technical communication.

Published in the USMA Redbook (Part 2 – Disciplinary Offerings)

Firsties provide input to development of PEOs during the program briefing in January.

Chemical Engineering Student Outcomes

Student Outcome 8

The chemical engineering curriculum closely tracks the topics in the Fundamentals of Engineering Exam

On completion of the chemical engineering program, our graduates demonstrate an ability to understand …

- Chemistry
- Material and energy balances
- Safety and environmental factors.
- Thermodynamics of physical and chemical equilibria
- Heat, mass, and momentum transfer
- Chemical reaction engineering
- Continuous and staged separation processes
- Process dynamics and control
- Modern experimental and computing techniques
- Process design.

Published in the USMA Redbook (Part 2 – Disciplinary Offerings)

Red designates course emphasis; Gray designates minor emphasis

Student Outcomes, cont.

Student Outcomes 1-7

The Chemical Engineering Major contains the student outcomes recommended by ABET.

On completion of the chemical engineering program, our graduates demonstrate an ability to …

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- Communicate effectively with a range of audiences.
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- Design and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
- Acquire and apply new knowledge as needed, using appropriate learning strategies.

Published in the USMA Redbook (Part 2 – Disciplinary Offerings)

Red designates course emphasis; Gray designates minor emphasis

Redbook

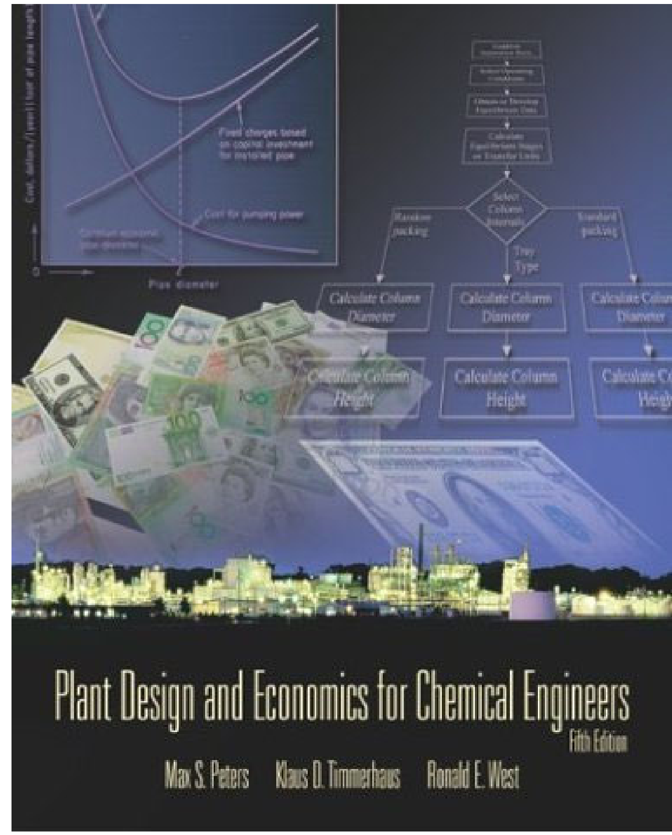
Credit Hours: 3.5 (BS=0, ET=3.5, MA=0)

Prerequisites: CH459, CH485, CH365

Co-requisite: None

Lessons: 40 @ 55 min, 7 @ 120 min

Special Requirements: None



Chapter Coverage

Introduction
Chapter 1

Heat Exchangers
Chapters 14

Fluid Handling
Chapter 12

Design Reports
Chapter 11

Flowsheet Synthesis
Chapter 4

Cost Estimation
Chapter 6

Interest
Chapter 7

Profitability
Chapter 8

Design Project
Independent Study

Assessment

10 Problem Sets @ 25 pts each:	250	13.36%
4 Small Design Probs. @ 50 pts each:	200	10.69%
2 WPRs @ 200 pts each:	400	21.38%
1 Design Report @ 400 pts:	400	21.38%
2 IPRs @ 100 pts each:	200	10.68%
5 Quizzes @ 24 or 25 pts:	121	6.47%
1 Term End Exam @ 300 pts:	300	16.03%
Total:	1871	

All graded assignments are required.

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Overview of Design

Why Engage in Process Design?

Need for a better product…

- Assessment of existing markets.
- Requests or concerns from customers.
- Pressure from competitors.
- Changes in downstream uses of the product.
- Addition of purification steps or reactors
- Relax yield in favor of purity.

Continuous R&D is required, which results in gradual changes in existing production technology.

Need for a better process…

- No further development is possible with existing process.
- No further advances possible with existing raw materials.
- No further advances possible with existing raw materials.
- Changes or maintenance might become too expensive.

Lowering the cost of production…

- Companies always engage in process design continuously with gradual, ad-hoc steps to achieve…
  - Decrease energy consumption.
  - Lower-priced more competitive product.
  - De-bottlenecking (higher yields, increased profits)
- *There is always the possibility of a completely new process with dramatically lower operating costs available to the competition.*

Steps for Process Design

1. Recognize a societal or engineering need
   - Preliminary market analysis
2. Create one or more potential solutions
   - Literature and patent search and preliminary process data
3. Develop preliminary process
   - Determine reactions, separations and operating conditions
   - Environmental, safety and health concerns
4. Assess profitability
5. Obtain required property data with software or experiments
6. Prepare detailed engineering design
   - Base case for economic design
   - Flowsheet
   - Integration and Optimize
   - Controls
   - Sizing
   - Capital cost
7. Reassess economic viability of the process.
8. Review the process for environmental, safety, and health factors
9. Provide a written design report
10. Complete the final design
    - Equipment layout, piping and instrumentation diagrams, bids
11. Procure equipment
12. Provide assistance during construction
13. Assist with start-up and shakedown
14. Initiate production

General Overall CH402 Course Structure

Process design development

Flowsheet development – Chapter 4

Computer-aided design – CHEMCAD

Cost estimation – Chapters 12-15, 6

Profitability analysis – Chapters 7-9

Optimum design – selected examples

Practical Considerations

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Case Study - Sulfur

Example Problem – Sulfur Production

You are asked to design a plant to produce elemental sulfur from natural gas. What exactly do you do? Where do you begin?

Through background research, you find that sulfur comes from two sources:

1. Mining – naturally occurring in volcanic deposits and salt domes (.052 wt% of the earth's crust).
2. Sulfur is also recovered from desulfurization of natural gas and crude oil. In the US, 5% in 1950, 67% in 1996.

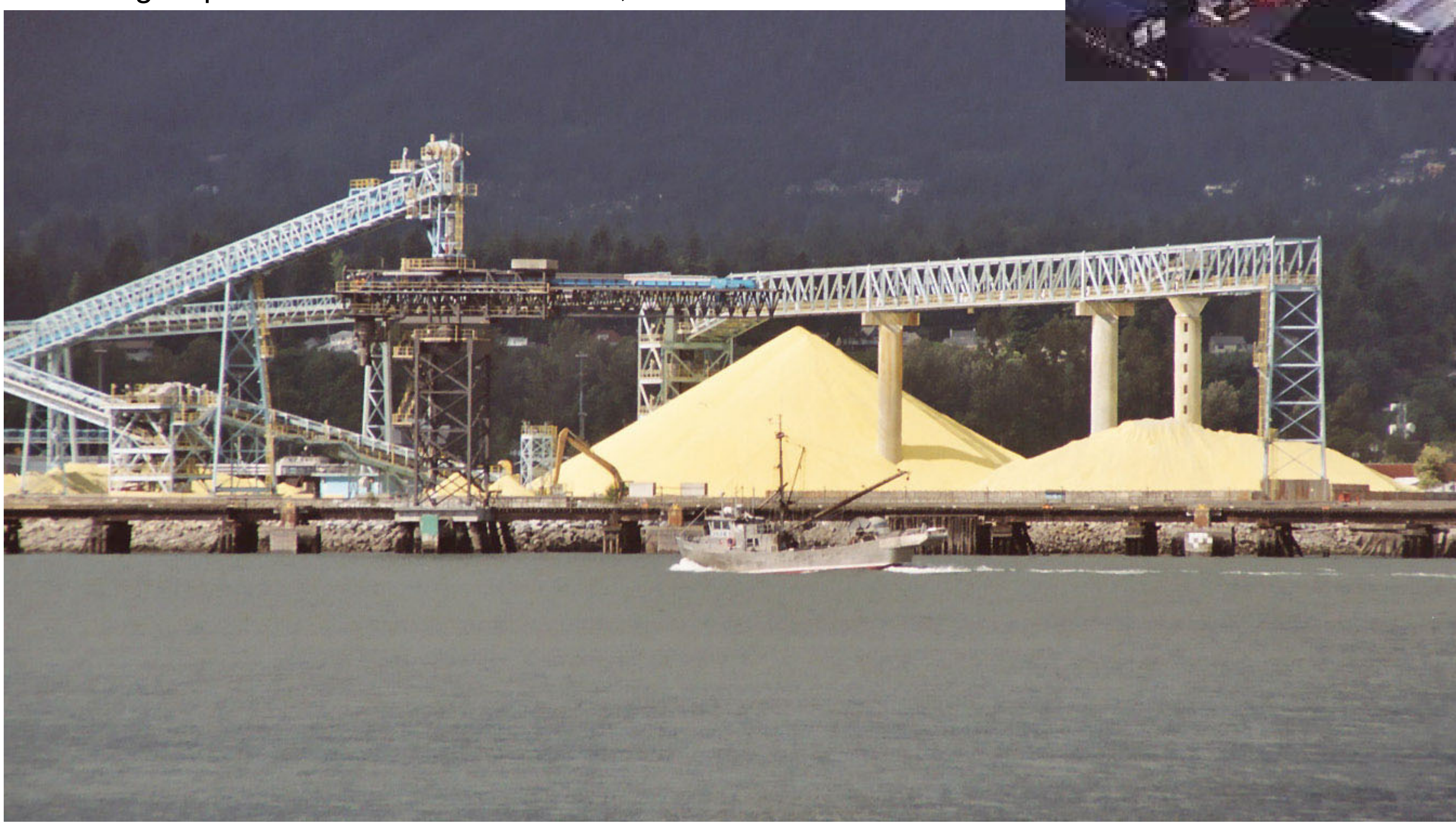
Continue researching the *sulfur process* in sources such as Kirk-Othmer and Wikipedia

Example Problem – Sulfur Production

Wikipedia articles “Sulfur Recovery” and “Natural Gas Processing”

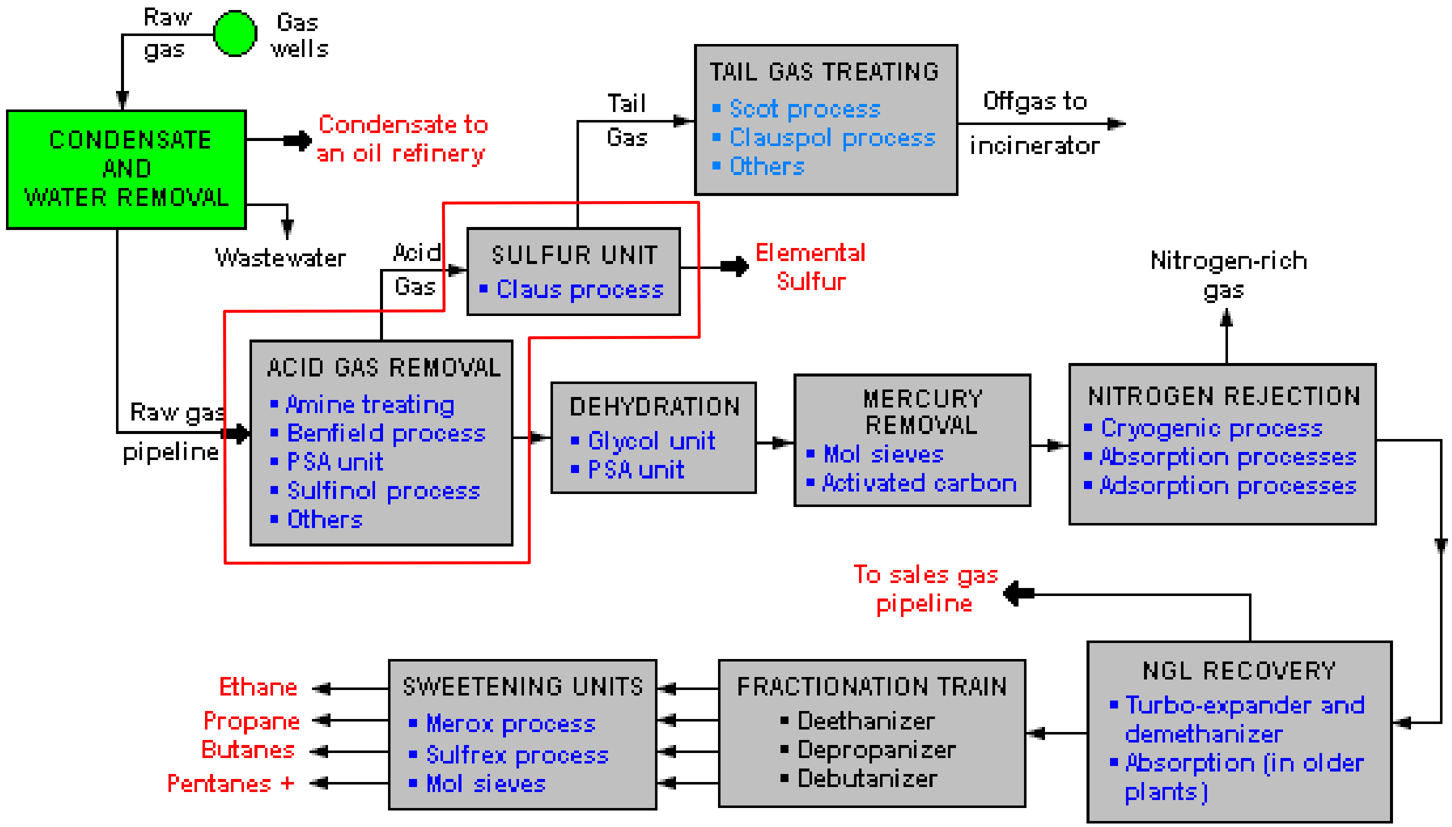
Natural Gas processing plant

Piles of sulfur produced in Alberta by the Claus process awaiting shipment at docks in Vancouver, Canada.



Case Study - Sulfur

Wikipedia “Natural Gas Processing”



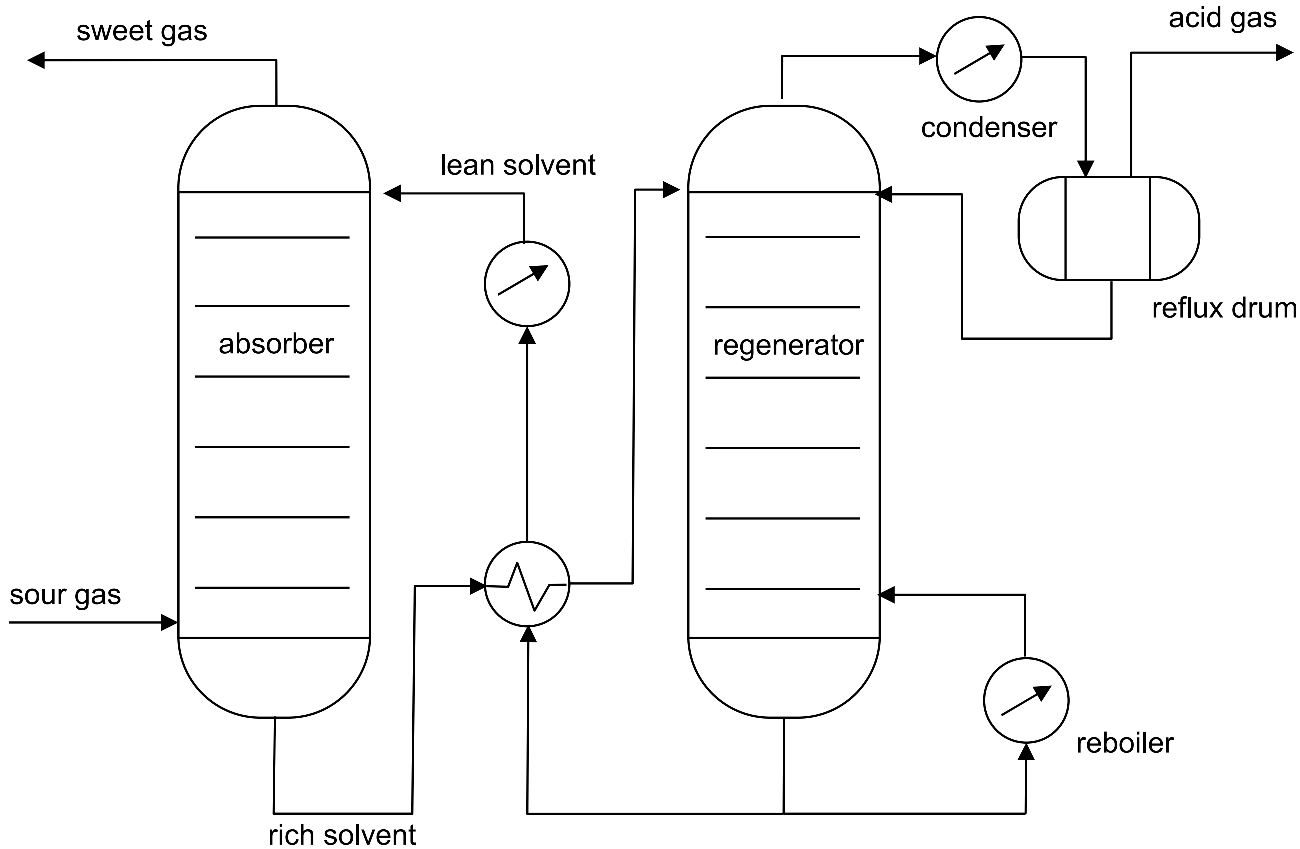
LEGEND:

- Located at gas wells — Located in gas processing plant
- Red Indicates final sales products — Blue Indicates optional unit processes available
- Condensate is also called natural gasoline or casinghead gasoline
- Pentanes + are pentanes plus heavier hydrocarbons and also called natural gasoline
- Acid gases are hydrogen sulfide and carbon dioxide
- Sweetening processes remove mercaptans from the NGL products
- PSA is Pressure Swing Adsorption
- NGL is Natural Gas Liquids

H_2S Processing

Source: Kirk-Othmer Encyclopedia of Chemical Technology

Chemical Absorption using Amines



Acid Gas:
H_2S
CO_2

Sour Gas:
CH_4
H_2S
CO_2

$$RNH_2(aq) + H_2O(l) \rightleftharpoons RNH_3^+(aq) + OH^-(aq)$$

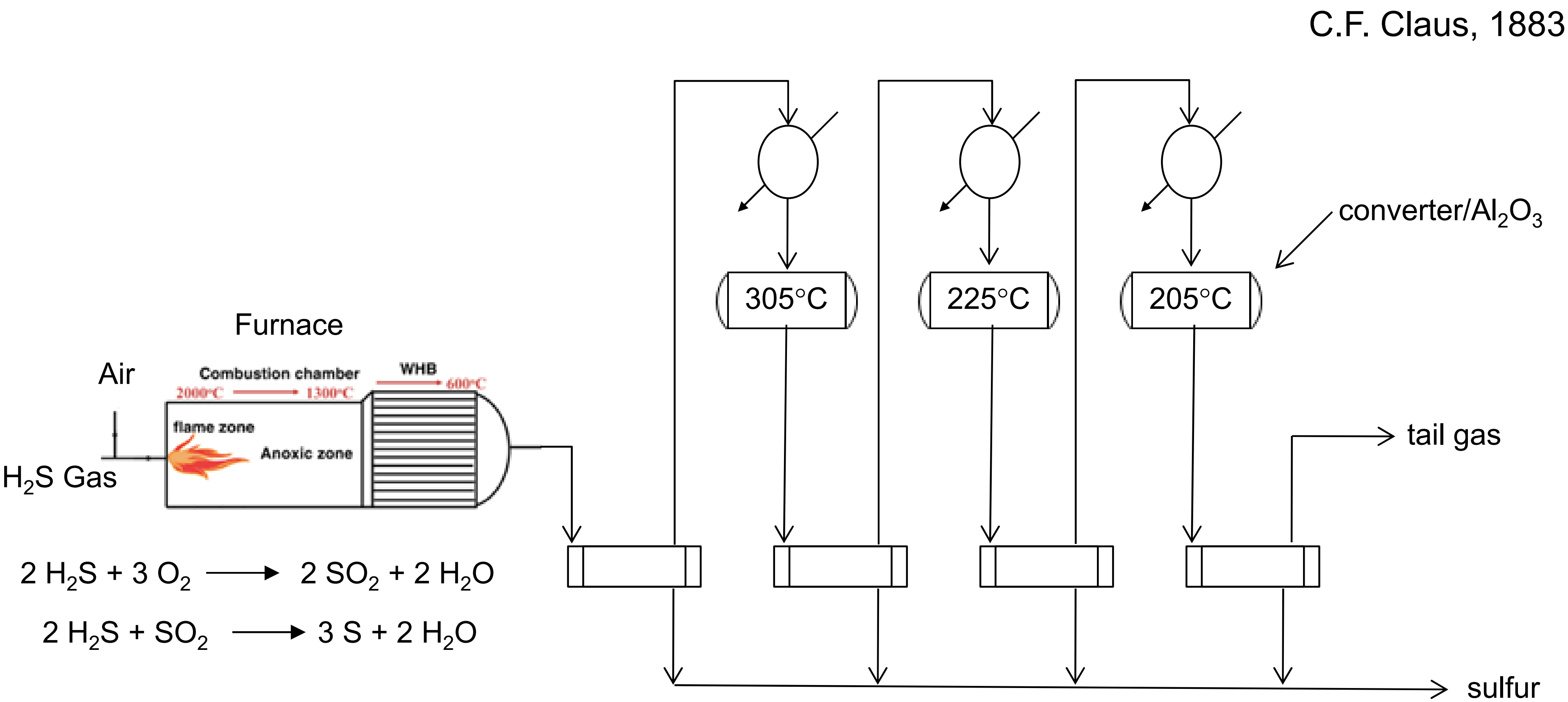
$$RNH_2(aq) + H_2S(aq) \rightleftharpoons RNH_3^+(aq) + SH^-(aq)$$

All reactions are acid-base proton transfer

Kinetics: rapid

Sulfur Production

Claus Reactors, I.G. Farbenindustrie AG, 1930’s



$$2\ H_2S + 3\ O_2 \longrightarrow 2\ SO_2 + 2\ H_2O$$

$$2\ H_2S + SO_2 \longrightarrow 3\ S + 2\ H_2O$$

Source: Kirk-Othmer Encyclopedia of Chemical Technology

Example Problem – Sulfur Production - Summary

The development of a new plant from concept to operational reality often is a complex operation.

Chemical engineers are engaged in

- -design engineering
- -cost engineering
- -process engineering
- -plant engineering
- -research engineering
- -control engineering

Some chemical engineering tasks are:

- -making an economic analysis
- -designing individual pieces of equipment
- -designing processes (or products)
- -designing the physical plant layout (multidisciplinary)
- -supervising plant startup, shake-down, & operations