SRU Thermal Reactor Chemistry & Design

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Company Profile

• Engineering company specialized in process combustion equipment
• Founded in 1919
• ± 75 employees
Goals of the SRU

• Recover elemental sulfur ($S_{2-8}$) from all sulfur species in the feed gases (AAG and/or SWSAG).
• Destruct other harmful components of the feed gases.
• Limit the formation of new harmful substances.

Basically, comply with emissions regulations!
Typical Sulfur Recovery Unit

1. Acid gas comb air flows through the main burner.
2. Fuel gas comb air flows through the 1st line burner.
3. Fuel gas comb air flows through the 2nd line burner.
4. Fuel gas comb air flows through the RGG burner.
5. Fuel gas comb air flows through the incinerator burner.
6. The reaction furnace converts sulfur compounds.
7. The mixing chambers mix the gases and fuel.
8. The catalytic converters reduce sulfur compounds.
9. The reduction reactor further reduces sulfur compounds.
10. The quench chamber cools the gases.
11. The absorber removes any remaining sulfur compounds.
12. The regen process recovers the sulfur.
13. The waste heat recovery section recovers heat.
14. The stack exhausts the gases.
Sulfur Recovery Unit Thermal Stage

- **MAIN BURNER**
- **REACTION FURNACE**
- **WASTE HEAT RECOVERY SECTION**
- **CONDENSER**
- **SULFUR**

- **1st LINE BURNER**
- **MIXING CHAMBER**
- **CATALYTIC CONVERTOR**
- **CONDENSER**
- **SULFUR**

- **2nd LINE BURNER**
- **MIXING CHAMBER**
- **CATALYTIC CONVERTOR**
- **CONDENSER**
- **SULFUR**

- **RGG BURNER**
- **MIXING CHAMBER**
- **REDUCTION REACTOR**
- **QUENCH**
- **ABSORBER**
- **REGEN**

- **INCINERATOR BURNER**
- **INCINERATOR CHAMBER**
- **WASTE HEAT RECOVERY SECTION**
- **STACK**
Thermal Stage Objectives

- 65-70% Sulfur Recovery
- Ammonia Destruction
- Hydrocarbon Destruction
- By-product Conversion
Sulfur formation in the Reaction Furnace

**Claus reaction:**

\[ 2\text{H}_2\text{S} + \text{SO}_2 \rightarrow 1\frac{1}{2}\text{S}_2 + 2\text{H}_2\text{O} \]

- **Acid gas**
- **Hydrogen sulfide (H_2S)**
- **Sulfur dioxide (SO_2)**
- **Sulfur (S)**
- **Water (H_2O)**
Sulfur formation in the Reaction Furnace

**Combustion zone**

- $\text{H}_2\text{S} + \frac{1}{2}\text{O}_2 \rightarrow \text{SO}_2 + \text{H}_2\text{O}$
  - Hydrogen sulfide
  - Oxygen
  - Air
  - Sulfur dioxide
  - Water

**Reaction zone**

- $2\text{H}_2\text{S} + \text{SO}_2 \rightarrow \frac{1}{2}\text{S}_2 + 2\text{H}_2\text{O}$
  - Hydrogen sulfide
  - Sulfur dioxide
  - Sulfur
  - Water
Sulfur formation

Partial \( \text{H}_2\text{S} \) oxidation

\[ \text{H}_2\text{S} + \frac{1}{2}\text{O}_2 \rightarrow \frac{1}{2}\text{H}_2\text{O} + \frac{1}{2}\text{SO}_2 \]

\( \frac{1}{2}\text{H}_2 \) cracking

\[ \text{H}_2\text{S} \rightarrow \text{H}_2 + \frac{1}{2}\text{SO}_2 \]

\( \text{SO}_2 \) reduction

\[ \frac{1}{2}\text{SO}_2 + \text{H}_2 \rightarrow \text{H}_2\text{O} + \frac{1}{2}\text{H}_2\text{S} \]

Acid gas

\[ \text{H}_2\text{S} \]

Water

\[ \text{H}_2\text{O} \]
Ammonia destruction

$\text{NH}_3 + \frac{3}{4}\text{O}_2 \rightarrow \frac{1}{2}\text{N}_2 + 1\frac{1}{2}\text{H}_2\text{O}$
Ammonia destruction

\[ \text{NH}_3 + \frac{3}{4}\text{O}_2 \rightarrow \frac{1}{2}\text{N}_2 + 1\frac{1}{2}\text{H}_2\text{O} \]

**Ammonia conversion**

- **NH\(_3\)**: Ammonia
- **\(\frac{1}{2}\text{N}_2\)**: Nitrogen
- **\(\frac{3}{4}\text{O}_2\)**: Oxygen
- **\(\frac{1}{2}\text{H}_2\text{S}\)**: Hydrogen sulfide
- **\(\frac{1}{2}\text{SO}_2\)**: Sulfur dioxide
- **\(\text{H}_2\text{O}\)**: Water

**H\(_2\text{S}\) oxidation**

- **Air**: Air
- **\(\frac{3}{4}\text{O}_2\)**: Oxygen
- **\(\frac{1}{2}\text{H}_2\text{O}\)**: Water

**Acid gas**
Ammonia destruction

Remaining NH₃ at MRF outlet:
• Expected < 20 ppm
• Guaranteed < 100 ppm

Provided:
• MRF operating temperature > 1300°C (2372°F)
• Residence time > 1 sec
Hydrocarbon destruction

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]
Hydrocarbon destruction

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]

- **CH\(_4\)** conversion
  - **CH\(_4\)**: Methane
  - **CS\(_2\)** conversion
  - **CS\(_2\)**: Carbon disulfide
  - **SO\(_2\)** conversion
  - **SO\(_2\)**: Sulfur dioxide

**Reactants**
- CH\(_4\)
- O\(_2\)
- H\(_2\)S
- H\(_2\)O
- S

**Products**
- CO\(_2\)
- H\(_2\)O
- S

**Oxidation**

4 Oct, 2018
RefComm Valencia
The degree of combustion depends on 3 factors, the three T’s of combustion:

• Temperature
• (Residence) Time
• Turbulence
SRU Temperature

The overall temperature in the main reaction furnace depends on:

• Chemical reactions
  – Heat release and absorption
  – The stoichiometry

• Design conditions (set by process licensor)
  – Pre-heating of the combustion air / acid gas
  – Oxygen enrichment
  – Co-firing of fuel gas
  – Bypassing part of the amine acid gas
SRU Residence Time

Minimum: determined by reaction kinetics
Longer: better destruction of impurities.
The flow pattern determines the shape of the flame, the degree of mixing as well as the flame stability. Mixing is achieved through:

- Burner geometry
  - E.g. physical restrictions, swirlers, constrictions, etc.
- Pressure drop
  - Higher pressure drop = more energy!
- Design principle
  - Pre-mixing vs. diffusion flame principle
Resulting Burner Requirements

• Intense mixing of acid gas and oxygen

• Recirculation of flue gas
LMV Main Burner

- Thermal Shroud
- Air Inlet
- Air Shield
- Refractory Lining
- Lifting Trunnion
- Saddle
- Sliding Plate
- Support Plate Anchor
- Burner Head
- Ignitor Connection
- Fuel Gas Inlet
- Lifting Lug for Gun
- Acid Gas Inlet
- Cover Plate
- Air Register

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LMV Main Burner
LMV Burner Axial Velocity

Contours of Axial Velocity (m/s)

ANSYS FLUENT 12.1 (axi, swirl, pbns, spe, RSM)
Turbulent combustion