Sulfur Recovery Facilities Turnaround Execution

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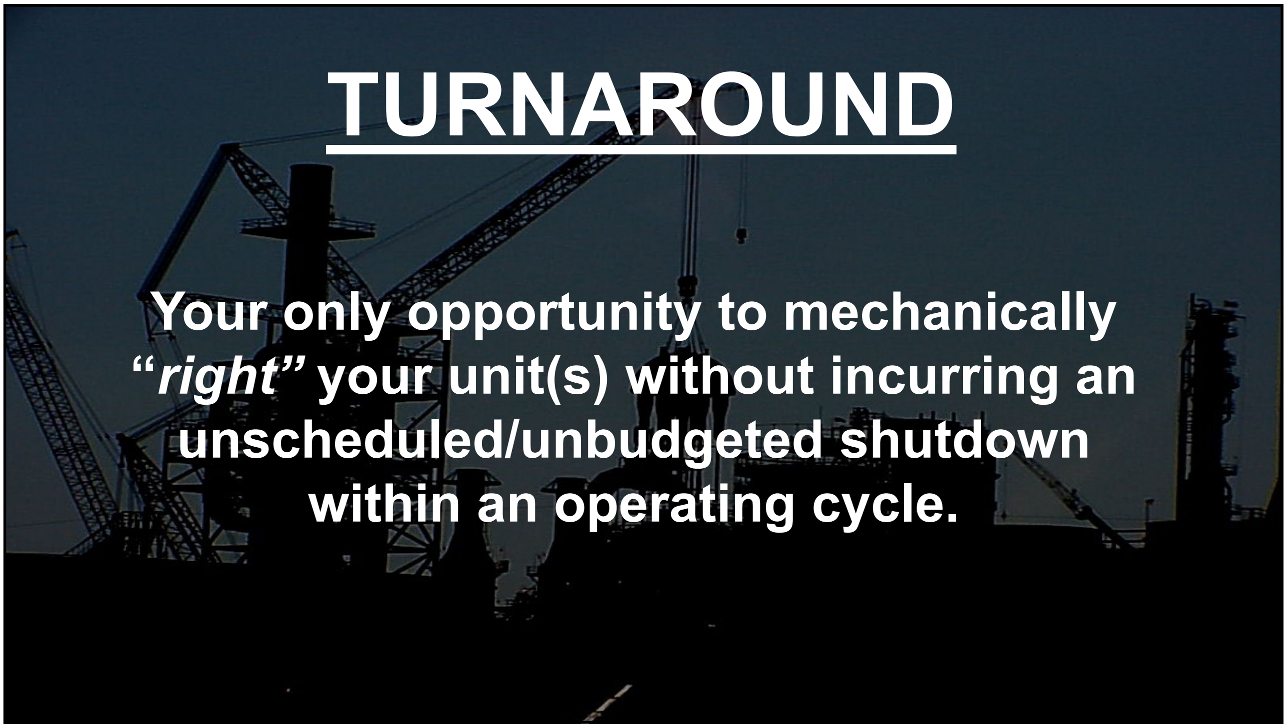

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Turnaround – Why do we take them?

Driven by the need to take a unit shutdown

- Regulatory requirements:
  - Boiler inspections
  - PSM mechanical integrity
- Unstainable production capacity loss:
  - Process related (catalyst life and fouling)
  - Mechanical deterioration (or failure)
- Environmental limitation or off-spec products:
  - Process related (catalyst life and fouling)
  - Mechanical failure
- Shutdown co-alignment
- Other?

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Turnaround Myth #1
(wrong philosophy)

Turnarounds are the sole responsibility of the Maintenance Department:

- Solely scoped and planned by Maintenance
- Solely managed and executed by Maintenance
- Operations clears & cools the units then hands them off to Maintenance and waits for them to give the units back

WRONG!

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The Right Attitude
(correct philosophy)

A well planned, executed and successful turnaround only results from a ***JOINT*** effort between Operations, Maintenance and Engineering:

- Jointly create a scope and plan
- A cohesive execution (no us vs. them)
- Operations personnel should inspect every piece of equipment along with Maintenance & Engineering
- Work acceptance is a joint decision
- Unit ownership does not change hands – Maintenance leadership works side-by-side with Operations leadership

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Turnaround Myth #2

OCIR (open, clean, inspect and repair) of everything is a given:

- Only after a very scrutinized analysis were scope items removed
- A bygone practice of the past!

Today's Practice

Starting scope ***should*** be a blank sheet:

- Every task item must be justified – emulating a "zero-based" budget
- No *"sacred cows"*
- The burden of approval falls onto the Operations Manager:
  - The "process" representative ***must*** quantify all the things wrong with the process
  - The "process" representative ***should*** be tasked with developing the justifications

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Turnaround Objectives

- Address the Process Issues:
  - Combustion problems
  - Catalyst reactivity loss and pressure drop
  - Fouled exchangers and process lines
  - Safety equipment re-certification/refurbishment
- Address Known Mechanical Problems:
  - Damaged burners
  - Non-spared or rate limiting rotating equipment
  - Thin/pitted piping and vessel walls
  - Critical and/or non-by passable controllers
  - Leaking exchangers
  - Refractory: cracks, loose bricks, skin hot spots, failed castable, etc.

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Turnaround Objectives

- Complete Necessary Inspections:
  - Complete assessment of known failures
  - Find unknown mechanical problems:
    - Assess for immediate repair
    - Accumulate data for future repair/replacement
  - Required Boiler Inspections
  - U.S. Players: meet compliance with OSHA 29 CFR 1910.119 Paragraph (J) Mechanical Integrity
  - Canadian Players = Province Boiler Code Associations:
    - Alberta = Alberta Boilers Safety Association
- Install Upgrades and Replacements that require a Shutdown

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Texas Boiler Inspection Requirements

(Health and Safety Code Title 9 Chapter 755)

Exchanger Type	Texas Classification	Inspection Interval	
		Internal*	External
Claus Thermal Reactor WHB (600# or lower)	Unfired Steam Boiler	**7 years**	1 year
Claus Condenser (50# or lower)	Process Steam Generator	12 years**	1 year
TGU WHB (50#)	Process Steam Generator	12 years**	1 year
Thermal Oxidizer WHB (600# or lower)	Unfired Steam Boiler	**7 years**	1 year

*24-month extension is feasible with Executive Director approval **If commissioned after 1/1/1970; prior units are 10-year intervals

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Turnaround Goals

- Complete the shutdown, mechanical work and start-up safely and without equipment damage:
  - Nobody gets hurt!
  - Minimize overall environmental impact
  - Complete the work within the available window or minimize down time
  - Complete at or below budget
  - Collect as much data as time and economics allow (regulatory required data must be collected!)
  - Return the unit(s) to an ***acceptable*** operating condition

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Turnaround Planning Considerations

- **Scope out Projects**
- **Scope out Maintenance:**
  - Work Plan (punch list of activities)
  - Personnel Requirements
  - Inspection Plan
  - Required Tools & Lifting Equipment
  - Elevated Work Plan (scaffolding/man lifts)
  - Required Safety Equipment
  - Machinery, Vessel and Piping Lifting Strategy
  - Outside Plant Repair Export and Return Plan
- **Operations Personnel Requirements** **(Operators & Supervision)**
- **Shutdown/Cool Down Plan**
- **Clearing, Purging and Degassing**
- **Management of Change (MOC)**
- **Materials Availability Analysis**
- **Materials Delivery Strategy**
- **Lock out/Tag out Strategy**
- **Isolation and Blinding (energy/process)**
- **Safe Work and Confined Space Preparation and Permitting**
- **Asbestos Abatement Plan** **(older units)**
- **Vessel Opening and Cleaning**
- **Demolition Plan (if applicable)**
- **Catalyst Handling**
- **Required Chemicals Delivery**
- **Quality Control Management Plan**
- **Waste Disposal Plan**
- **Technical Support Scheduling**
- **Housekeeping Plan**
- **Transportation and Staging Plan**
- **Equipment Closure, Un-blinding and Unlocking Plan**
- **Start-up Plan**

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Shutdown Plan Issues

- Clearly defined & accurate load shedding plan:
  - Make sure you can get the units offline on time
  - Especially important when SRU is critical path
- Sour Water containment plan:
  - Can remaining SW acid gas be processed?
  - Can water be contained when SWS is down?
  - Don't forget added volume from T/A flushes!
- Plan to overcome possible high amine loading
- Amine containment plan:
  - Temporary storage of amine drained from vessels & piping requiring work

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Turnaround Planning

- Formulate all plans into a "Master Plan":
  - Pre-T/A preparation plan
  - Shutdown and clearing plan (+ any chemical cleaning)
  - Mechanical activities plan
  - Catalyst handling plan (unloading and loading)
  - Projects installation plan
  - Sign-off and equipment closure plan
  - Start-up plan
- Determine <u>Who</u> does <u>What</u> and <u>When</u>:
  - Operations
  - Maintenance
  - Purchasing
  - Health, Safety and Environmental
  - Engineering
  - Inspection
  - Accounting
  - Others

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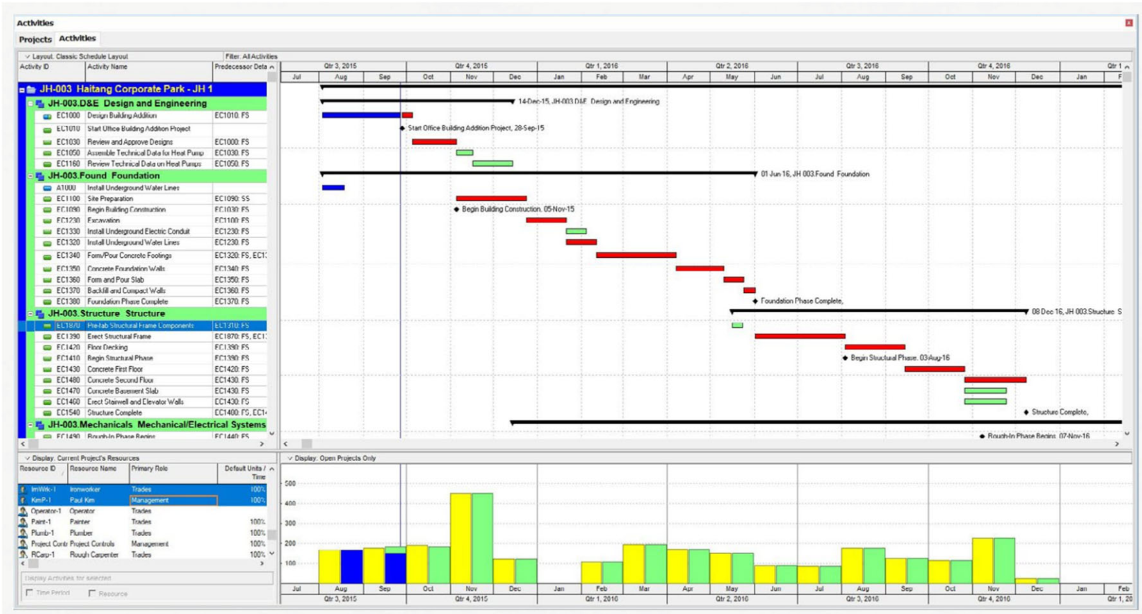
Create a Timeline that has clear Milestones to track progress (Primavera P-6 is the predominate industry tool)



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Your Role (as the Process Engineer/Specialist)

- Complete the necessary assessments for the **justifications**:
  - To inspect (and repair) tower and vessel internals
  - To change catalyst
  - To repair burners
  - To clean heat exchangers
  - To prepare for possible refractory damage
  - To repair/rebuild any control valves and instruments
  - To have any unspared rotating equipment repaired/rebuilt
  - That process conditions are (or have been) present that may be contributing to equipment integrity issues:
    - Corrosive/erosive environments
    - Flow restrictions and excessive flows
    - Over temperature (ongoing or event based)
    - Over pressure events
    - Service changes resulting in materials mis-matches

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Your Role (as the Process Engineer/Specialist)

Towers

- Understand the PSM inspection cycle – is the tower scheduled to be open?
- Improved methods of external vessel integrity monitoring are minimizing the "it's going to be opened anyway" concept for many vessels:
  - Burden is on "process" to justify entry
- Conduct thermal scans of amine absorbers/contactors:
  - Is the absorption profile where you would expect it?
- Track rate-based SWS product NH_3 levels, indicator of upper tray problems
- Order timely tower gamma scans:
  - Essential for scoping internal inspection when not scheduled for entry:
    - Burden is on "process" to justify
    - Provides justification to pre-order tray/packing parts

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Your Role (as the Process Engineer/Specialist)

Drums and Vessels

- Make sure you have an accurate assessment of hydrocarbon levels on the various separators:
  - Applicable to Rich Amine and Sour Water Separator and may apply to KO drums with a hydrocarbon weir
  - Key for understanding if weir plate damage is present
  - Excessive and constant "rumbling" or "slushing" sounds may indicate that the Stilling Well is damaged
  - Growing rag layer in a sour water separator can be an indication of packing fouling reducing effective surface area

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Your Role (as the Process Engineer/Specialist)

Burners (Claus main burner and reheaters, RGG and Incinerator)

- Predetermine (as much as possible) needed burner maintenance
- Make regular flame observations (photo document if possible):
  - Look for abnormal flame pattern changes
  - Look for liquids dispensing and flame color changes
  - Look for refractory flame impingement and burner “back-burn”
  - Note changes with vibrations and unusual noises
- Ensure that burner/ignitor replacement parts are readily available:
  - Most of the industry’s specialty burner spare parts are long-lead items
- Note: during the outage, inspect the burner metal component integrity:
  - Metal loss and internal damage
  - Measure tolerances

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Your Role (as the Process Engineer/Specialist)

Catalyst Changes

- The “act” of changing catalyst has become extremely costly:
  - Especially true if inert extraction is required or dictated
  - Many locations are no longer allowed to passivate Claus catalyst for environmental reasons
  - “Wet extraction” being deployed as an inert extraction substitute
- Improved methods of external vessel integrity monitoring have created opportunity to avoid catalyst removal
  - Non-destructive methods measure wall thickness even with refractory present
- Hydrogenation catalyst for TGUs have always been costly due to the semi-precious metals used (cobalt and molybdenum)
- Titania costs vs. alumina driving up Claus catalyst costs

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Your Role (as the Process Engineer/Specialist)

Catalyst Changes (continued)

- Ongoing catalyst performance monitoring:
  - Conversion is monitored as a function of ΔT across the bed
  - Monitor ΔP properly corrected for variable flow
  - Look for channeling in the bed
  - How many relights and or stand-by firings have occurred:
    - How good is your burner(s)?
    - How clean is your fuel gas?
- You will be expected to justify catalyst changes:
  - A “cycle skip” for Claus catalyst is feasible (maybe longer?):
    - Unit and run-length specific – case-by-case analysis required
  - TGU catalysts properly operated (off-ratio operation) with ΔP safeguarding can achieve many cycles:
    - 17+ years has been achieved

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Your Role (as the Process Engineer/Specialist)

Refractory

- Preparing for possible refractory damage:
  - Thermally scan vessel eternal surfaces to find “hot spots”
  - Identify excessive number of thermal cycles or excursion
  - Look for “pressure excursions” that may have knocked off refractory
  - Visually monitor burner/fire box view ports – have photo history!
- Pinpointing problem spot locations more precisely increases the odds for the correct refractory materials to be pre-ordered:
  - Specialty shapes have long-lead times – avoids excessive “field shaping” that adds repair time
  - Getting the correct “hot face” brick formulations to prevent melting/spalling
  - Getting the correct thermal properties of the insulating materials

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Your Role (as the Process Engineer/Specialist)

Un-spared Equipment

- Justifications to repair/rebuild control valves and instruments:
  - Most instrumentation and control valves are set up to be serviced without a unit shutdown
  - Often leave the process at risk for upsets and sub-optimized operation
  - Some instruments are *process critical* to prevent catalyst damage, severe rapid corrosion or fouling
  - Don't assume the turnaround team (or even the OPS Manager) understands this
- Make the process optimization case:
  - To have any unspared rotating equipment repaired/rebuilt
  - Load-shared blowers that result in rate cuts
- Ask about Relief Device schedules – don't assume!

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Your Role (as the Process Engineer/Specialist)

Heat Exchangers

- Have ongoing heat exchanger performance tracking:
  - Heat exchange efficiency
  - Pressure drop
  - Monitor Δ air temperature across finfans
  - Look for heat load changes at the cooling tower
  - Monitor cooling water cooler *water-side* exit temperatures
- Reboiler performance:
  - Monitor steam consumption per volume fluid processed (ratio)
  - Monitor tower OVHD temperature
  - Is the reboiler compensating for the feed/effluent exchanger performance?

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Your Role (as the Process Engineer/Specialist)

Waste Heat Steam Generators (WHSG)

- Short-duration boiler inspection driven outages will need cleaning scope justified
- Monitor for subtle changes in the steam-water balance
  - Signs of potential leaks for low pressure units
- Conduct rate-based outlet temperature monitoring:
  - Signs of tube fouling
- Look for boiler feed water (BFW) quality events:
  - May indicate water side fouling
- Look for excess heat flux areas (especially O_2 enriched units):
  - Tube integrity monitoring
  - Tube sheet/tube front excessive film boiling monitoring

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Your Role (as the Process Engineer/Specialist)

All Heat Exchangers

- Identify any potential process conditions that may have contributed to tube integrity issues so that ***proper*** inspection is conducted:
  - High heat flux areas
  - Corrosion potential
    - Don't forget corrosion under-insulation (CUI) potential
    - Don't forget under-deposit corrosion potential
- Highly suggest demanding *"first run"* baseline integrity inspections
- Tip: Horizontal process tube-side WHSG and Condensers:
  - If exposed to atmosphere, they MUST be neutralized ASAP!
  - Hydro-blasted with soda ash solution is best
  - Note: you will likely need to justify this scope item…

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Thermal Reactor WHSG Case Study

- Both Unit #1 and Unit #2 are 410 LTPD 4-stage Claus units with O_2E capability up to 45% O_2
- Unit #1 and Unit #2 are mirror-image identical units with only minor "lessons-learned" changes incorporated into Unit #2 from Unit #1 construction
- Identical burner technology and identical equipment fabricator
- Both units were "foundation up" total replacement expansions:
  - Unit #1 commissioned 11/15/2011, first T/A October 2018 (6.8 yr run)
  - Unit #2 commissioned 11/5/2012, first T/A May 2021 (8.5 yr run)
- Both TR WHSGs underwent tube Remote Field Eddy Current Testing (REFT) during their first T/As:
  - Unit #1 had pattern testing of 82 of 358 tubes (~22%)
  - Unit #2 had all 358 tubes tested

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Thermal Reactor WHSG Case Study

Unit #1 Operating Data

Period (Days)	= 2491
Operating Days (Days)	= 2432
Average O_2	= 24.28%
O_2E Days	= 895 (36.8%)
High O_2E Days (O_2 >28%)	= 661 (27.2%)
Ultra High O_2E Days (O_2 >32%)	= 349 (14.4%)
High Heat Flux Days (Q" > 50,000 BTU/h-ft^2)	= 928 (38.2%)
Ultra High Heat Flux Days (Q" > 70,000 BTU/h-ft^2)	= 131 (5.4%)

Unit #2 Operating Data

Period (Days)	= 3108
Operating Days (Days)	= 3043
Average O_2	= 24.81%
O_2E Days	= 1257 (41.3%)
High O_2E Days (O_2 >28%)	= 971 (31.9%)
Ultra High O_2E Days (O_2 >32%)	= 516 (17.0%)
High Heat Flux Days (Q" > 50,000 BTU/h-ft^2)	= 1295 (42.6%)
Ultra High Heat Flux Days (Q" > 70,000 BTU/h-ft^2)	= 147 (4.8%)

- Overall operating severity was essentially the same with the principal difference that Unit #2 ran 1.3 yrs longer for the interval

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Thermal Reactor WHSG Case Study - Conclusions

- Unit #1 had no appreciable tube wall loss concerns
- Unit #2 had ~20% of the tubes with long-term impacting “front-end” tube wall loss > 20% (6.6% of the tubes >30% wall loss)
- Conclusions:
  - Process data analysis doesn’t necessarily provide a clear picture for predicting possible equipment integrity problems
  - Identical (near identical) equipment doesn’t always perform the same
  - A hydro-pressure test would not provide indication of a progressing integrity issue
  - Only a proper tube thickness rigorous inspection will provide true understanding of equipment integrity life
  - Capturing a first cycle inspection is key for “base-lining” equipment long-term reliability performance

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Your Role (as the Process Engineer/Specialist)

Identify/Recommend/Justify Upgrades

- Make the pitch for equipment upgrades early:
  - Three years in advance (two at the very minimum)
  - Tag it back to (in the following order of priority):
    1. Process/occupational safety
    2. Environmental Improvement
    3. Economic loss prevention
    4. Efficiency Improvement
- Best investment advice:
  - Get good burners and/or clean with consistent heating value fuel sources
  - Replace seal legs with above ground sealing devices
  - Properly designed and sized amine and sour water hydrocarbon protection
  - Choose proper tube to tubesheet bonding method for the service severity!

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Your Role (as the Process Engineer/Specialist)

During the Turnaround

- Key role in shutdown plan
  - Either generate or review/approve
- Take the lead on chemical cleaning activities
  - Ensure the chemistry is compatible and will achieve objectives
  - Establish the flow plan and cleaning circuits
  - Complete the management of change (MOC) needed
- Inspect, inspect, inspect…
  - You should put your eyes on every piece of equipment before closure
    - Typically, one of the required signature on the closure forms
  - Look for aspects that will impact run-cycle unit performance
- Key role in start up plan
  - Again, either generate or review/approve

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For additional reference material:

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About the author:

Philip J. Oberbroeckling, P.E. is currently the Technology Integration Manager responsible for the new processing technology integration of the future sustainability projects into the LyondellBasell Houston Refinery site. Over Philip's 35-year career he has held numerous engineering and management positions in Technical, HSES, and Operations including a 5-year tenure as the Operations Superintendent of the Houston Refinery Sulfur Recovery Complex (SRC), the Chief Engineer for the Houston SRC 2011-2013 Rebuild and Expansion Project, Technical Consultant to the Berre France Refinery Tail Gas Unit Project and the Process Technical Manager for the entire Houston Refinery. Before LyondellBasell, Philip held engineering positions for five years with Conoco Inc. at their Ponca City, OK engineering offices and at their oil refinery in Billings, MT. Philip holds a Bachelor of Science degree in Chemical Engineering from Iowa State University and is a registered Professional Engineer in Montana and Texas. Philip has participated in 25 turnaround events in his career covering hundreds of refinery process units and authored 44 conference papers and presentations on sulfur recovery and oil refining topics. Philip is a member of the Brimstone Sulfur Recovery Symposium Technical Advisory Committee, was a charter member and Task-Group Chairman for the API 565 Standards Committee on SRU Thermal Reactors until its publishing in 2022, a member of the Amine Best Practices Group, a member of the AIChE and he is the Founder, President, and member of the Mr./Ms. Sulfur Club.

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