WHITE PAPER / **RISK AND TECHNOLOGY REVIEW**

UNDERSTANDING THE REFINERY RISK AND TECHNOLOGY REVIEW REGULATION

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The Environmental Protection Agency's Refinery Risk and Technology Review regulation imposes complex requirements on refineries across the U.S. Attaining compliance in the time allotted can be difficult, but gaining a full understanding of the rules and how they affect your operations is the first step.

CONTENTS

FIGURES

1.0 FINAL RULEMAKING OVERVIEW

Many refiners struggle to understand the impacts of the new Risk and Technology Review (RTR) air quality rulemaking by the U.S. EPA because of a convergence of factors: the regulated processes and the RTR requirements are complex, the potential impacts are severe, and time to comply is short. The EPA's Fact Sheet[1] states that the RTR rulemaking

> *... will further control toxic air emissions from petroleum refineries and provide important information about refinery emissions to the public and neighboring communities. This rule will virtually eliminate smoking flare emissions and upset emission events, and for the first time in a national regulation require refineries to monitor emissions at key emission sources within their facilities and around their fence lines.*

1.1 SCOPE OF IMPACTS

Almost every U.S. refinery is affected by the RTR rulemaking. The scope of RTR impacts is broken down below.

1.1.1 REGULATED POLLUTANTS

The RTR rulemaking includes new and updated requirements that regulate multiple air quality pollutants associated with the refining industry. RTR pollutants are classified as follows:

- Hazardous Air Pollutants (HAP) include 187 regulated substances,[2] which are explicitly identified either by chemical name (e.g., benzene), chemical group (e.g., mercury compounds) or a similar technical basis. HAP can be further classified as follows:
  - Organic HAP such as benzene, toluene, xylenes, formaldehyde and hexane are mostly included with crude feed or generated within refinery processes.
  - Metallic HAP, such as nickel, chromium and mercury, are mostly from process unit catalysts or included with crude feed.
  - Other inorganic HAP, such as hydrochloric acid and cyanide compounds, are mostly generated within refinery processes or included with purchased materials.
- Criteria Pollutants include volatile organic compounds (VOC), nitrogen oxide compounds (NO_X), carbon monoxide (CO), sulfur dioxide (SO_2), sulfur oxides (SO_X) and particulate matter (PM). Most NO_X, CO, SO_2/SO_X and PM emissions affected by RTR requirements are associated with combustion processes within the refinery. Regulated VOCs are associated with almost every emission source type and process affected by the RTR rulemaking.
- Other Compounds are addressed in the RTR rules or mentioned in associated EPA documents. For example, some RTR requirements require testing or continuous measurement of hydrogen sulfide (H_2S) and total reduced sulfur (TRS) either as emitted pollutants or as precursors of regulated SO_2 emissions. Also, EPA's RTR documents include statements about carbon dioxide (CO_2) and other greenhouse gas (GHG) compound emissions, but the RTR rules do not explicitly regulate any compounds as GHG pollutants.

1.1.2 AFFECTED REFINERIES

For an individual affected refinery, the extent of RTR requirements depends on whether the refinery is classified as a major source of HAP. A HAP major source has the potential to emit more than 10 short tons per year (tpy) of any one HAP compound or more than 25 tpy of all HAP compounds combined. The EPA RTR Fact Sheet includes EPA's estimate that 142 U.S. refineries will be regulated as major sources of HAP. These 142 HAP major source refineries are potentially subject to all RTR requirements. The EPA also estimated seven U.S. refinery area sources (i.e., not major sources) of HAP, which are only potentially subject to a subset of the RTR requirements. These EPA estimates were based on information that EPA collected from refineries in 2011, and several new refineries started operating after 2011.

1.1.3 AFFECTED UNITS

Within an affected refinery, RTR requirements can apply to multiple units, components and systems, including the following: flares, fluidized catalytic cracking unit (FCCU) regenerator vents, delayed coker vents, catalytic reforming unit vents, sulfur recovery unit (SRU) emissions, storage tanks, atmospheric pressure relief devices, analyzer vents, and marine vessel loading. Also, the RTR removed lenience that had existed under startup, shutdown and malfunction (SSM) exemptions. Removing these SSM exemptions can have collateral impacts on refinery units or systems (such as SRUs), which can only be determined after a site-specific evaluation of SSM scenarios.

1.2 RULE FRAMEWORK

The RTR is not a new rule. It is a matrix of coordinated updates to five existing EPA air quality rules for refineries. The five affected rules are all promulgated under Code of Federal Regulations, Title 40, Parts 60 and 63 (i.e., 40 CFR 60 and 63). Each of these five refinery air rules applies to specified pollutants and emission sources:

- Subpart CC of 40 CFR 63 Maximum Achievable Control Technology (MACT) rules regulates organic HAP emissions from miscellaneous process vents (typically routed to flare), wastewater systems, storage tanks, loading racks, fugitive piping leaks, and cooling water system leaks. Subpart CC is also known as Refinery MACT 1.
- Subpart UUU of 40 CFR 63 regulates organic and inorganic HAP from major process vents including SRU tail gas, FCCU regenerators, catalytic reformer regenerators and delayed cokers. Subpart UUU is also known as Refinery MACT 2.
- Subpart Y of 40 CFR 63 regulates organic HAP from marine vessel loading.
- Subpart Ja of 40 CFR 60 New Source Performance Standard (NSPS) regulates criteria pollutants NO_X, CO and SO_2 from flares, fuel gas combustion, and SRU and FCCU regenerators.
- Subpart J of 40 CFR 60 is similar to (but older than) NSPS Subpart Ja.

Most refineries have established programs and pollution control systems for compliance with the pre-RTR versions of these RTR rules.

1.3 RETROSPECTIVE RULEMAKING CONSIDERATIONS

Following are selected events in the development of the RTR and the five RTR rules:

- **1970** — NSPS program implemented under Clean Air Act (CAA) section 111(b).
- **March 8, 1974** — NSPS J issued as final.
- **March 8, 1995** — MACT Y issued as final. One revision was made with the final pre-RTR version issued on April 21, 2011.
- **Aug. 18, 1995** — MACT CC issued as final. Multiple corrections and revisions issued over an 18-year period until the final pre-RTR version issued on June 20, 2013.
- **April 11, 2002** — MACT UUU issued as final. Final pre-RTR version issued on Feb. 9, 2005.
- **June 24, 2008** — NSPS Ja and NSPS J updates issued as final. Selected requirements of NSPS Ja and NSPS J updates were stayed (i.e., not effective) from July 28, 2008, until Sept. 12, 2012. Final pre-RTR version issued on Dec. 19, 2013.
- **June 30, 2014** — RTR rulemaking published as draft. The EPA received many comments.
- **Dec. 1, 2015** — RTR rulemaking published as final with EPA's responses to comments.
- **Jan. 30, 2016** — RTR rulemaking became effective as per published Dec. 2, 2015, final version.
- **Feb. 9, 2016** — RTR updates proposed to correct and clarify the final rule and requested comments.

The above series of rulemaking events illustrates the complex history of revisions and corrections for the five rules that are revised again by the RTR. Many more individual revisions, corrections and other rule changes are not included in the above series.

The final RTR requirements may be revised even after the proposed Feb. 9, 2016, updates are finalized. The flexibility to respond to future potential RTR changes is an important component of compliance planning; however, relevant EPA rulemaking precedents and the 20-month RTR promulgation process suggest that these RTR requirements and compliance deadlines are likely to remain effective with relatively limited changes.

1.4 REGULATED EMISSIONS TRENDS AND DISTRIBUTION

As discussed above, the RTR rulemaking is only the latest round of EPA air quality regulatory changes that have focused on the refining sector over the past several decades. These regulatory changes combined with EPA consent decrees, local air pollution rules and other factors that probably influenced historical refinery emission trends. One study[3] commissioned by the American Fuel and Petrochemical Manufacturers (AFPM) concluded that the U.S. refining industry has reduced aggregated emissions while increasing productivity from 1990 through 2013. This study included the following key conclusions for the aggregate refining industry for the 26-year period preceding the RTR rulemaking:

1. Total reported HAP emissions decreased by 66 percent,
2. Total reported criteria pollutant emissions decreased by 91 percent for SO_2, 67 percent for NO_X, 69 percent for VOC and 46 percent for fine particulate matter (i.e., particulates less than 10 μm in diameter).
3. Total reported crude throughput increased by 14 percent.

This study concluded that the U.S. refining industry in aggregate dramatically reduced emission of RTR-regulated pollutants while increasing productivity in the 26 years leading up to the RTR rulemaking. The RTR's focus on source types within refineries is another interesting contextual consideration. Figure 1 shows the EPA's breakdown of 2014 refinery HAP emissions by source type. The HAP emission requirements in the RTR rulemaking are found in MACT Y, MACT CC and MACT UUU. The RTR changes for these three MACT rules are focused on flares, FCCUs, storage, equipment leaks and presumably some of the miscellaneous HAP sources in Figure 1.

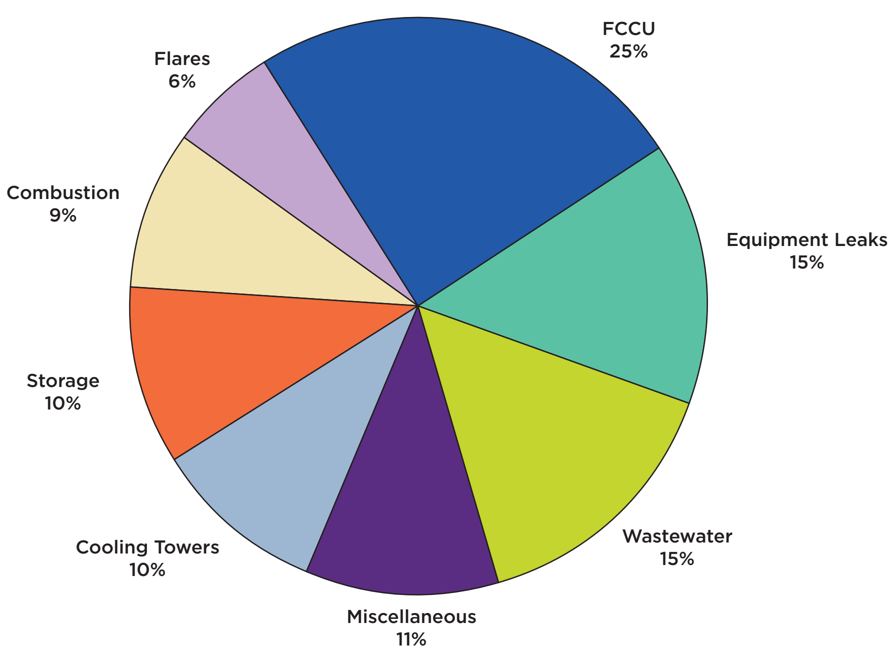

FIGURE 1: *Refinery HAP emissions source breakdown. Source: EPA 2014.*

1.5 COMPLIANCE DEADLINES

New and reconstructed sources that commence construction after June 30, 2014, must comply with all requirements when started up. For existing refinery sources, compliance is required as expeditiously as practical[4] but not later than the below dates:

- **Startup/Shutdown/Malfunction** — exemptions under MACT CC and MACT UUU are immediately eliminated and replaced, e.g., by new general duty requirements and (by Aug. 1, 2017) new unit-specific startup/shutdown limits
- **Marine vessel loading** — implement submerged filling immediately for all vessels
- **Storage tank standards** — implement by April 29, 2016 (can request more time)
- **FCC emissions testing** — new tests/frequency with first new tests by Aug. 1, 2017
- **Benzene fence line monitoring** — start by Jan. 30, 2018
- **All other requirements** — comply by Jan. 30, 2019

1.6 COMPLIANCE COSTS

The RTR requirements will involve high initial compliance costs for some refiners. The EPA estimated typical initial compliance implementation cost of $2 million per refinery across about 142 refineries in the U.S.[5] The American Petroleum Institute estimated typical implementation cost to be $8 million per refinery, but these estimates were developed before the RTR was finalized. Preliminary feedback from refining industry sources indicates that compliance implementation costs will be distributed unevenly. Some refineries already meet many of the RTR requirements, especially those refineries in ozone non-attainment areas and those under EPA consent decrees and similar compliance agreements. Other refineries may determine that site-specific compliance costs are much higher than is typical. Most costs will occur in 2016, 2017 and 2018 to meet compliance deadlines discussed above.

2.0 RECOMMENDED APPROACH TO SUCCESS

In the midst of unprecedented energy market and feedstock changes, refiners now face an entirely different set of challenges posed by the EPA's RTR rulemaking. The RTR challenges each refiner to evaluate each targeted unit, identify potential compliance gaps under an updated regulatory framework and then engineer, procure and construct complex projects to achieve compliance within three years. Some potential solutions may require complex permitting between the initial design phase and start of construction. Successful compliance solutions must also reflect the full range of potential operating envelopes to meet the dynamic new business and regulatory environment.

2.1 COMPLIANCE TEAM

A purpose-built RTR compliance team is recommended to meet the many challenges of RTR compliance implementation. The RTR team should represent all affected refinery departments: management, engineering, operations, maintenance and environmental. Following are several recommended characteristics and objectives for the RTR team:

1. **Representative Membership** — Include members who represent all affected refinery departments such as management, engineering, operations, maintenance and environmental
2. **Clear Purpose** — Team should be empowered and expected to achieve RTR compliance implementation success. Compliance success will involve assessing RTR impacts, identifying compliance options, developing cost estimates and initiating compliance projects/changes for appropriate departments to implement.
3. **Authority** — Team or selected team members should have authority (or have clear steps established to get approval) to engage support from plant personnel, plant resources and outside support as needed to achieve compliance success.

4. **Urgency** — Compliance success will depend on tracking multiple parallel compliance efforts to meet compliance schedules. Some compliance projects and changes will need to be coordinated with turnaround plans and other project plans. The team will need a strong emphasis on scheduling with flexibility to adjust for unplanned events while staying on track.

5. **Resources** — The team is likely to need many types of support including cost estimation, project scheduling, technology expertise, design, procurement, construction and permitting. Any resource constraints should be identified and addressed with corporate or consulting support.

6. **Communication** — The team should distribute regular reports to inform team members, other refinery managers and corporate stakeholders of RTR progress and issues.

2.2 COMPLIANCE ROADMAP

Achieving RTR compliance will involve a challenging journey for many refiners. A compliance roadmap is an early critical step for each refinery because it charts the compliance implementation course by aligning stakeholders, setting the schedule, identifying the risks and defining the strategy for success. An RTR compliance roadmap is a site-specific plan to set milestones, chart the course, and address multiple objectives, including the following:

1. Guide team by defining responsibilities for compliance experts, engineers, operations, refinery management and other groups to collaborate.

2. Identify options following an integrated analysis of compliance solution options with associated timelines, costs, risks and collateral impacts to inform decisions. Options to evaluate should include execution strategies as well as technical compliance solution options. For example, engineer-procure-construct (EPC) project execution can support faster completion of compliance projects or integration with other projects.

3. Evaluate resources by identifying what resources are needed and when, mapping individual responsibilities, and characterizing any potential constraints in supply chain or resource demands.

4. Plan processes recognizing that some RTR projects require air permits, agency approvals or other processes that are not under refinery control, but still need to be accommodated in the compliance schedule.

5. Establish schedule to reflect individual compliance steps with milestones and uncertainties identified to facilitate actual progress tracking. Any other projects or plant shutdown/turnaround plans need to be reflected.

There is no single playbook for success, as the RTR requirements require case-by-case evaluations and unique compliance solutions. A refinery-specific evaluation is necessary to build a compliance roadmap.

3.0 DISTRIBUTED EQUIPMENT IMPACTS

This section discusses MACT CC and MACT UUU RTR requirements that are distributed across an affected refinery. Understanding these distributed RTR requirements is important to understanding the context of the more unit-specific RTR requirements discussed in Sections 4 through 9. These distributed RTR requirements are associated with reducing organic HAP emissions.

3.1 STARTUP, SHUTDOWN AND MALFUNCTION (SSM) EMISSIONS

The RTR rulemaking includes a new EPA regulatory approach to SSM emissions in MACT CC and MACT UUU. SSM emissions occur during startup, shutdown or malfunction of the unit or associated air pollution control equipment. Emissions have typically been designated as SSM when they do not comply with emissions limits or other requirements for normal operation of the unit. Under the pre-RTR rule versions of MACT CC and MACT UUU, the SSM emissions were considered exempt from normal requirements to the extent that the refinery minimized emissions, followed a written SSM Plan and complied with other SSM requirements. The RTR rulemaking eliminates the old SSM exemptions and SSM Plan requirements under MACT CC and MACT UUU.

The post-RTR versions of MACT CC and MACT UUU require each refinery to meet new emission limits that apply specifically to startup and shutdown periods (and hot standby periods for FCCUs). Unit-specific SSM limits and requirements are discussed each unit in Sections 4 through 9. In general, refineries are required to comply with the new unit-specific SSM limits by Aug. 1, 2017. Refineries are required to comply with the MACT CC and MACT UUU general duty emission standards until Aug. 1, 2017, or until the refinery meets the new unit-specific SSM limits, whichever occurs first. The general duty emission standards in MACT CC and MACT UUU require refineries to operate and maintain any affected source, including associated air pollution control equipment and monitoring equipment, in a manner consistent with safety and good air pollution control practices for minimizing emissions.[6]

The post-RTR versions of MACT CC and MACT UUU do not include emissions limits or requirements for compliance specifically during malfunction events; however, the post-RTR rules make clear that periodic emissions associated with malfunction events are regulated by MACT CC and MACT UUU. It is not clear whether refineries may presume compliance by following the general duty requirements during malfunction events.

The RTR does not fundamentally change requirements for SSM emissions under the NSPS J and NSPS Ja rules. Consistent with the pre-RTR version of these NSPS rules, the post-RTR rules continue to regulate SSM emissions under general exemptions in NSPS Subpart A.[7] In general, NSPS A establishes conditional SSM exemptions to the extent that the refinery minimizes emissions and complies with other requirements during the SSM periods. However, the RTR does add new NSPS Ja startup- and shutdown-related requirements for SRUs as discussed in Section 9.

3.2 ATMOSPHERIC PRESSURE RELIEF DEVICES

The post-RTR version of MACT CC includes new requirements for each regulated pressure relief device (PRD) that would vent to atmosphere.[8] These MACT CC requirements do not apply to all PRDs. For example, a PRD is only regulated if it is in organic HAP gas or vapor service (e.g., at least 5 percent organic HAP by weight, but other factors are also considered).[9] MACT CC includes several options to exempt specific PRDs from most of these requirements based on various technical factors.[10] Atmospheric PRDs that cannot be exempted are subject to several new requirements summarized as follows:

1. Use a hand-held organic vapor analyzer (EPA Method 21) to check for leaks, both on a routine basis and after any opening of that PRD. These are similar to pre-RTR fugitive equipment leak detection and repair (LDAR) program requirements, but some LDAR program updates may be needed.

2. Each PRD must have instrumentation to detect any pressure release, provide immediate operator notification and record start/stop time for the release. For example, the required instrument could be a pressure indicator on a nearby vessel or line if the instrumentation is configured to detect the PRD release and report an alarm to the control board.

3. Each PRD must have at least three redundant prevention measures. Examples of prevention measures include deluge systems, relevant instrumentation, inspection/maintenance programs and staged relief systems with initial relief routed to flare. The rule does not include technical specifications for a qualified prevention measure, but refineries are required to document three or more prevention measures for each PRD.

4. For each atmospheric PRD release that results from a pressure release, the refinery must conduct a root cause analysis and corrective action to avoid a recurrence. Recurrences can be classified as violations under certain conditions.

5. PRDs routed to flare or other qualifying emission control systems are generally exempt from these requirements but will now be regulated under MACT CC as miscellaneous process vents.

6. Compliance with the LDAR-related requirements is required immediately (i.e., by the deadline for the following LDAR monitoring period). Compliance with the other PRD requirements is required by Jan. 30, 2019.

3.3 CLEARING EQUIPMENT FOR MAINTENANCE

The post-RTR version of MACT CC regulates vapors from clearing equipment prior to maintenance work. The pre-RTR version of MACT CC simply excluded maintenance clearing vapors from the definition of regulated process vents. Now these equipment clearing vapors are defined and regulated as process vents.[11] The new maintenance process vent requirements only apply if the cleared vapors meet the miscellaneous process vent definition (e.g., at least 20 parts per million organic HAP by volume, but other factors are also considered).[12] The new MACT CC requirements for regulated maintenance clearing are summarized as follows:

1. The cleared vapors can be subject to detailed MACT CC miscellaneous process vent requirements unless the refinery specifically designates each vapor clearing event as a maintenance vent. Refineries will generally want to avoid the administrative and procedural difficulties of detailed miscellaneous process vent requirements for these maintenance clearing activities.

2. Prevent atmospheric release of the vapors until process fluids are removed from the isolated equipment as much as practical, and remaining vapors meet one of several technical qualification options to be opened to atmosphere. These technical qualification options include measuring the lower explosive limit (LEL) to be less than 10 percent, achieving total pressure of 5 pounds per square inch gage (psig) or less, or making sure that the isolated equipment contains less than 72 pounds of VOC.

3. Any clearing operations (e.g., steam or inert gas purging) prior to meeting the above-described technical qualifications must direct vapors to flare, fuel gas or other enclosed system or emission control device.

4. New record-keeping procedures will need to distinguish between different regulated (and unregulated) MACT CC vent types and maintain required details for each regulated maintenance vent occurrence.

5. Compliance with these new maintenance vent requirements is required by Aug. 1, 2017. Until then, maintenance venting must meet the MACT CC general duty requirements in §63.642(n) with the proposed clarification that specified records must be kept for each maintenance vent occurrence.[13]

3.4 ANALYZER VENTS

The post-RTR version of MACT CC also regulates in-situ sampling system vents and on-stream analyzer vents as miscellaneous process vents.[14] The pre-RTR version of MACT CC exempted analyzer vents from all such process vent requirements. Each refinery will need to evaluate each analyzer vent to determine if it meets the updated definition of a miscellaneous process vent (e.g., at least 20 parts per million organic HAP by volume, but other factors are also considered). Each analyzer vent that does meet the updated definition of a miscellaneous process vent must then be evaluated to determine if emission control requirements apply.

Some atmospheric analyzer vents may need to be rerouted to a qualified HAP emissions control system such as a flare or fuel gas system. Analyzer vents that do not require such controls must be added to the MACT CC compliance documents and agency reports. Most atmospheric analyzer vents have low HAP concentrations and flow rates that may qualify as unregulated vents or are otherwise exempt from control requirements. Therefore, only a minority of existing atmospheric analyzer vents should need to be rerouted to HAP emissions control systems. Any projects, compliance program updates and documentation needed to comply must be completed by Jan. 30, 2019.

3.5 SOLUTION OPTIONS

A structured, plantwide evaluation is recommended to identify and characterize potential impacts from the distributed RTR requirement changes for each refinery. Following are several recommended tactics for completing the recommended distributed impacts evaluation:

1. **Mine Existing Data** — Large refinery data sources will need to be mined as part of evaluating potential distributed impacts. Starting a data collection process from scratch should be avoidable. Fugitive piping LDAR programs are generally supported by marked-up process flow diagrams or piping and instrumentation diagrams showing which process streams are in organic HAP gas or vapor service (e.g., at least 5 percent organic HAP by weight, but other factors are also considered). If the refinery obtained air permit authorizations for maintenance, startup and shutdown activities, then the associated permit application should contain helpful information. Responses to EPA's

Information Collection Requests may also contain helpful information. Maintenance work order database systems can be mined for useful information, although it is often difficult to distinguish which work orders have potential emissions (e.g., electrical work and other orders without emissions are irrelevant and distracting).

2. **Document Decisions** — These complex evaluations of distributed impacts will depend on many factors and many decisions by the evaluation team. Decisions need to be made with a consistent approach and documented justifications. Documented decisions will better withstand personal memory limits, personnel turnover and compliance auditing challenges. A basic documentation approach can include a description of the general methods applied to each type of evaluation, the objectives for each evaluation and a tabulation of factors considered for each evaluated item.

3. **Limit Scope** — Using existing data as discussed above may support the exclusion of entire process units or systems from some rigorous evaluations based on general information. For example, a lube oil unit may have no potential for MACT-regulated streams or vapors and can therefore be excluded from rigorous impacts evaluations. Up-front, well-documented strategic decisions to limit evaluation scope will focus detailed efforts on appropriate processes and areas.

4. **Atmospheric PRDs** — Many refineries maintain a pressure relief inventory that will support efficient determination of atmospheric PRDs. As discussed above, limiting scope to PRDs that have the potential to contain 5 percent organic HAP by weight will narrow the PRD list for detailed review. Additional PRDs can be taken off the list based on several technical exemptions found in MACT CC, such as the exemption for thermal expansion relief valves.[15] The final regulated atmospheric PRD list will then need to be supplemented with all the required technical data for each PRD.

5. **Maintenance Vents** — The large number of potential lineups for venting maintenance-related vapors is a major challenge for this evaluation. A clearly documented approach and objectives with evaluation scope limitations will help manage this evaluation. Rather than attempting to identify every potential maintenance venting lineup, it may be more efficient to perform a top-down approach, e.g., by considering the largest and most routine maintenance venting activities first. Larger/numerous events may help establish general tactics to apply to the multitude of smaller and less frequent maintenance venting activities. General clearing practices and VOC vapor weight calculations may be documented to demonstrate the less than 72 pounds of VOC exemption for certain frequent maintenance venting activities (e.g., pumps). Most refineries will probably want to avoid detailed maintenance venting record-keeping requirements for high-frequency events. Consider what information the regulatory agencies could practically obtain to identify noncompliant maintenance venting events, and design the compliance approach accordingly.

6. **Analyzer Vents** — Refinery instrumentation departments often maintain an inventory of analyzers that can serve as the starting point for this evaluation. Analyzers that only vent back into the process, only sample materials with less than 20 parts per million organic HAP by weight, or meet other general exemptions can be excluded from more rigorous evaluations. Analyzers that are already routed to a MACT CC emission control system (e.g., flare header) can be designated as requiring controls without additional evaluation details. The remaining analyzers will need individual evaluations and records to determine whether HAP emission control requirements apply.

4.0 EARLY IMPACTS — STORAGE TANKS AND MARINE LOADING

The earliest substantial compliance deadlines for new RTR requirements apply to hydrocarbon storage tanks and marine vessel loading. These early impacts are more straightforward to address than more complex RTR impacts discussed in the following sections. These RTR changes are to reduce organic HAP emissions as regulated under MACT CC for storage tanks and MACT Y for marine vessel loading.

4.1 MARINE VESSEL LOADING CHANGES

The RTR rulemaking canceled one former exemption from MACT Y requirements for marine vessel loading. The pre-RTR exemption applied to certain existing marine vessel loading facilities located at an area source of HAP (i.e., at a site where potential HAP emissions are less than 10 tpy for each individual HAP and less than 25 tpy for all HAP combined).

The exemption allowed splash filling of regulated HAP-containing liquids into marine vessels at certain refineries. All marine vessel loading of regulated liquids at refineries must be submerged-filled.[16] Although this exemption cancellation may only affect a small number of refinery marine loading facilities, the new submerged filling requirement applied immediately as of Jan. 30, 2016.

All refinery marine vessel loading that relies on a flare for MACT Y compliance must also meet the new post-RTR MACT CC flare requirements as discussed in Section 5.[17] The new MACT CC flare requirements for marine vessel loading must be met by Jan. 30, 2019.

4.2 STORAGE TANK CHANGES

The RTR rulemaking included storage tank requirement changes that apply to both new and existing MACT CC storage tanks. These MACT CC storage tank requirements apply to tanks storing organic liquids that are associated with a refinery process and potentially contain organic HAP (i.e., all petroleum liquids are presumed to contain HAP). Wastewater tanks are regulated under a different set of MACT CC requirements and are not affected by these RTR storage tank requirement changes. Many tanks that serve chemical process units within refineries (e.g., tanks that serve a benzene purification unit) are subject to rules other than MACT CC and are also not affected by RTR changes. The RTR rulemaking included two types of changes to the MACT CC storage tank requirements.

4.2.1 EMISSION CONTROL DETERMINATION CRITERIA

The RTR rulemaking changed the criteria[18] used to determine which tanks are subject to organic HAP emissions control standards. The impact of the determination criteria change is that some previously exempt tanks will now be subject to MACT CC emission control standards. Two factors determine whether formerly exempt tanks will require emissions controls: the maximum true vapor pressure (at storage conditions) of the stored liquid and the design storage capacity of the tank. The total HAP concentration of the stored liquid also affects whether emission controls are required. Therefore, refineries need to evaluate each formerly exempt refinery storage tank to determine if it meets the new post-RTR criteria for MACT CC emission control requirements.

These criteria changes became effective on Jan. 30, 2016. However, an affected refinery has until Jan. 30, 2026, or the next tank emptying/degassing event (whichever occurs first for each affected tank) to upgrade any tank that did not require emission controls under the pre-RTR criteria. The 2026 deadline only applies to storage tanks that were not already equipped with a floating roof before the proposed RTR rulemaking on June 30, 2014.[19]

4.2.2 FLOATING ROOF CONTROL SPECIFICATIONS

The RTR rulemaking changed the technical emission control standards for refinery storage tanks that have floating roofs to comply with MACT CC emission control standards.[20] Most of the detailed standards were found in MACT G for the pre-RTR version of MACT CC, and most detailed post-RTR floating roof standards are now found in MACT WW. Many floating roof requirement changes are technical differences in specifications for fittings that penetrate the floating roof (i.e., guide poles, access hatches and other fittings are potential liquid/vapor conduits through the floating roof). For example, floating roof openings for ladders are exempt from emission control measures under the pre-RTR requirements, but the post-RTR version requires sleeves, pole wipers, flexible enclosures or similar mechanical emission control measures.

The differences between such pre-RTR and post-RTR fittings requirements are limited, and some differences appear to be primarily semantic, but the differences should be evaluated for each floating roof tank. Existing tanks that were equipped with floating roofs prior to the proposed RTR rulemaking on June 30, 2014, must comply with the new post-RTR standards by April 29, 2016.[21]

4.2.3 VAPOR EMISSION CONTROL SYSTEM SPECIFICATIONS

MACT CC emission control standards also changed for storage tanks that route vapors to fuel gas or emission control devices. Such tanks are subject to the detailed emissions control specifications found in MACT SS, whereas the equivalent pre-RTR standards were found in MACT G. Any flares that receive storage tank vapors for MACT CC compliance will be subject to the post-RTR flare requirements discussed in Section 5. Tanks that route vapors to flares and other types of emissions control devices must comply with the new post-RTR standards by April 29, 2016, but the flare or other control device may have later compliance deadlines (e.g., flare deadlines are discussed in Section 5).

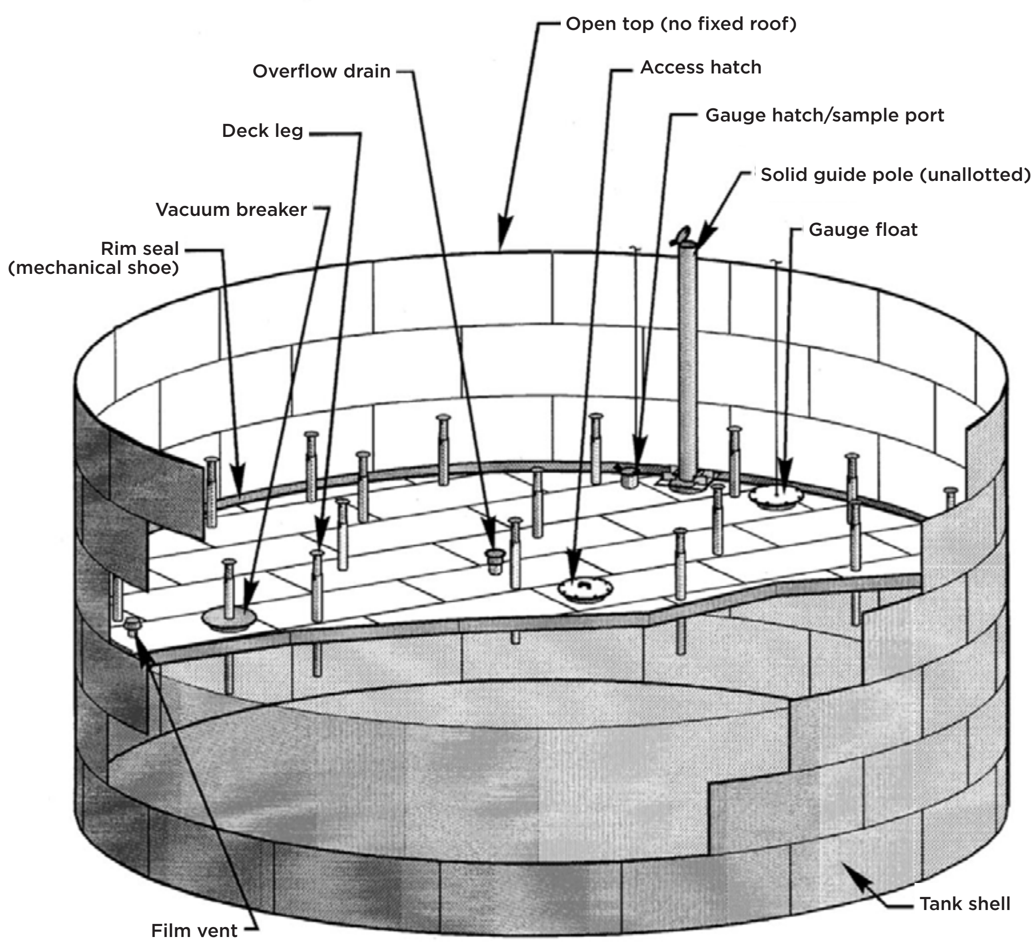

FIGURE 2: *External floating roof tank (double deck). Source: U.S. EPA, AP 42, November 2006.*

4.3 SOLUTION OPTIONS

Each floating roof storage tank that is subject to RTR requirements should be evaluated to identify any gaps with post-RTR requirements. These floating roof tank evaluations should consider each type of floating roof fitting as illustrated for an external floating roof in Figure 2. These evaluations should already reflect the April 29, 2016, deadline for existing floating roof tanks, meeting new roof fitting requirements. Any tanks with RTR compliance gaps can either be upgraded to comply with MACT CC emission control standards (e.g., by installing a floating roof or upgrading roof fittings), or the pre-RTR exemption can be continued by placing the tank in a new service that avoids emission control requirements (e.g., by storing only lower vapor pressure liquids).

5.0 FLARE IMPACTS

The RTR rulemaking includes an overhaul of established flare system requirements that will be a top RTR compliance concern for many refineries. These requirement changes are to reduce organic HAP emissions from the affected flares as regulated under MACT CC (and referenced by MACT UUU). Emissions of VOC and flare combustion pollutants might also be reduced.

5.1 SCOPE

The RTR rulemaking affects all flares that are for compliance with MACT CC or MACT UUU. A minority of refinery flares may be subject to NSPS J or NSPS Ja without any MACT CC or MACT UUU requirements. The older NSPS A §60.18 requirements will continue to apply to such NSPS-only flares along with pre-RTR NSPS Ja flare management requirements, if applicable. In practice, most refinery flares receive some gases that are regulated under MACT CC or MACT UUU. Therefore, most refinery flares must comply with the overhauled RTR flare requirements now found in MACT CC.[22] Existing, reconstructed and new flares are all subject to the same new MACT CC requirements.

5.2 NEW REGULATORY FRAMEWORK

New RTR flare requirements in MACT CC are a sea change compared to the old flare requirements in NSPS A and MACT A, which remained largely unchanged for more than three decades before the RTR. New RTR flare requirements include a new combustion zone compliance focus, an expanded scope of regulated flare operations and new compliance formulas. New prescriptive requirements for advanced instrumentation and other data collection are also required to track conditions within the flare combustion zone. Steam flow ratio controls are not explicitly required, but many refinery flares will need more advanced control systems to avoid a pattern of noncompliance events with the new regulatory framework. The extent of the RTR flare requirement changes is illustrated by these key points:

1. Continuously measure volume flow of all combustion zone contributing flows: waste vent gas, sweep gas, supplemental gas, purge gas downstream of a water seal, total steam, premix assist air and perimeter assist air. Pilot gas is the only stream to feed the combustion zone that is clearly exempt from flow measurement requirements. Indirect volumetric flow measurements are allowed for certain gas stream types. For example, assist air flow can be calculated based on continuous fan speed or power measurements. New flow meter accuracy standards require ±20 percent accuracy up to 1 foot per second (ft/s) velocity and ±5 percent above 1 ft/s, which is an important consideration for metering large-diameter lines. All flow measurements must be converted to standard volume units based on specified temperature and pressure compensation methods.

2. Analyze the quality of all waste gases and fuel gas by instruments (at least one analysis every 15 minutes) or sampling (at least one sample every eight hours) prior to the combustion zone. Most refineries already analyze fuel gas quality at the fuel drum. Many refineries already analyze waste gas quality on the combined header inlet to the flare. Gas quality can be analyzed online by gas chromatography or calorimetry instruments. Any existing instruments or sampling procedures should be evaluated to confirm compliance with the new prescriptive requirements.

3. Calculate the net heating value for the combined combustion zone and flare tip velocity using the measured gas flow data, measured calorimetry/

composition data and prescribed RTR calculation formulas. A calculation is required for each 15-minute period. Each 15-minute calculation must demonstrate compliance with minimum combustion zone net heating value and maximum tip velocity limits specified for each flare.

4. Evaluate RTR flare requirement details specific to each flare design, operating mode and gas stream. For example, the refinery may apply to EPA to exempt certain flare gas streams from quality analysis if the stream quality characteristics are demonstrated to be consistent over time. Also, any perimeter assist air flow is subject to specific calculation requirements. There are too many variants and variant combination possibilities to summarize here.

The combination of new measurement requirements, new 15-minute compliance calculations and new calculation methods creates a fundamentally new regulatory framework for MACT CC and MACT UUU flares. Evaluating each flare for alignment with these new requirements will involve a data-intensive evaluation even for relatively low-flow, normal flare operations. Compliance with all new flare requirements is required by Jan. 30, 2019.

5.3 HIGH-FLOW AND SSM OPERATIONS

As discussed in Section 3, the RTR rulemaking immediately eliminated the general startup, shutdown and malfunction (SSM) exemptions in the pre-RTR versions of MACT CC and MACT UUU. The post-RTR version of MACT CC implies limited compliance flexibility for certain high-flow flaring events (contingent on favorable agency interpretations). More important, flares must now comply with the new MACT CC flare requirements under all operating conditions including force majeure events (e.g., external utility power interruptions, natural disasters and fires). For example, high-rate flaring from process upsets, startup, shutdown, excess fuel gas and steam-out events are now subject to the same MACT CC requirements as for normal flare operation with some caveats. The many different types of previously exempted flaring events will add more difficulty to compliance evaluations and implementation for the new RTR flare regulatory framework discussed above.

5.4 NEW REQUIRED EVALUATIONS AND DOCUMENTS

The RTR rulemaking added MACT CC requirements for new flare system compliance program elements, including specified technical evaluations with associated documents. These new requirements are detailed but allow interpretation in some respects. Following are key examples:

- **Flare Management Plan** — This MACT CC-required plan is similar to the Flare Management Plan required for NSPS Ja-regulated flares;[23] however, some MACT CC plan requirements[24] are more rigorous. Therefore, an existing NSPS flare plan may serve as a good starting point for a MACT CC flare plan, but plan revisions and additions may be needed. One MACT CC requirement not found in NSPS Ja is to specify a single flow rate corresponding to the design smokeless capacity of each flare. The MACT CC plan must include detailed cost and feasibility analysis of flare gas recovery and other flare minimization strategies related to SSM, pressure relief and emergency flaring vents. As required for NSPS Ja flare plans, the MACT CC plans must be submitted to the EPA. The original plan must be submitted by Jan. 30, 2019, and then updated periodically. Implementing the plan is required regardless of whether EPA responds to the submitted plan.

- **Root Cause/Correction Action Analyses** — MACT CC requirements[25] are similar to NSPS Ja-required root cause/corrective action analyses.[26] However, the conditions that trigger these analysis requirements are different. MACT CC analysis requirements can be triggered based on visible emissions, flow rates exceeding the smokeless capacity and tip velocity. Many associated MACT CC requirements are too detailed and conditional for this summary. Information related to these events will be reported as part of the next MACT CC periodic compliance report. One key difference from the NSPS Ja requirements is that MACT CC now specifies several conditions under which events triggering these analyses are automatically considered to be noncompliant. For example, any three visible emissions exceedances (not considering force majeure events) from one flare in a consecutive three-calendar-year period are identified as noncompliant.

- **Pressure Relief Device Releases to Flare** — MACT CC includes new requirements for pressure relief devices[27] that overlap with the flare root cause/corrective action analysis requirements discussed above. These overlapping requirements appear to trigger root cause and corrective action analyses for any MACT CC-regulated pressure relief device that opens into the flare header. Even if the downstream flare did not exceed visible emissions, flow or velocity levels that would trigger a root cause/corrective action analysis under the MACT CC flare requirements, similar analyses would still be required for the release under the MACT CC equipment leak standards.

5.5 SOLUTION OPTIONS

Some refineries completed pre-RTR flare projects that will help comply with the new RTR flare requirements. For example, pre-RTR flare gas recovery projects and advanced flare instrumentation and control projects may be helpful for RTR compliance. A typical flare gas recovery system is illustrated in Figure 3. Some helpful flare projects have been implemented to comply with individual air permits, local regulations or EPA Consent Decrees. However, the final RTR requirements for flares are substantially different from the EPA's original draft version of the RTR requirements and are also quite different from most pre-RTR requirements in permits, local regulations and consent decrees. Therefore, most refineries will need to conduct data-intensive assessments of existing refinery MACT-regulated flares for compliance with the final RTR requirements.

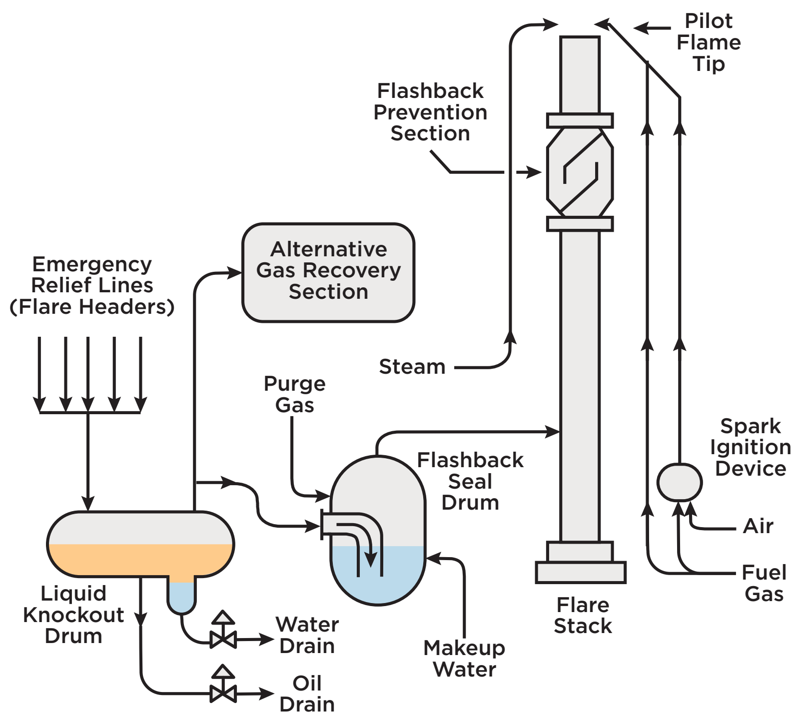

FIGURE 3: *Simplified flare schematic of an overall flare stack system in a petroleum refinery. Source: chemengineering.wikispaces.com.*

6.0 FCCU IMPACTS

RTR impacts on FCCU regenerator flue gas vents are among the most difficult to evaluate. Past FCCU emission standards were already complex, and different FCCU configurations align with different compliance strategies under the old standards. The RTR adds difficulty by updating some standards for normal FCCU operation, changing some compliance demonstration requirements and overhauling SSM-related requirements.

The RTR changed FCCU catalyst regenerator flue gas vent requirements in NSPS J, NSPS Ja and MACT UUU. NSPS J and Ja both regulate criteria pollutant emissions of PM, SO_2 and CO, and NSPS Ja also regulates NO_X. MACT UUU regulates organic and inorganic HAP emissions. Potential RTR impacts on these requirements are discussed below.

6.1 GENERAL OBSERVATIONS

Many different factors should be considered to evaluate an individual FCCU for potential RTR compliance impacts. Following are a few general observations about these factors:

1. All regulated FCCUs are potentially affected by the RTR changes. For any individual FCCU, the RTR impact details will depend on which compliance options are selected under each applicable rule and whether the unit is new, existing or reconstructed.

2. Units already equipped with more robust regenerator flue gas emission control systems are more likely to meet the RTR requirements without significant compliance projects. Examples of more robust systems include a wet gas scrubber (WGS) or electrostatic precipitator (ESP) with third-stage cyclones.

3. FCCU feedstock, regenerator operating mode (e.g., full versus partial burn) and other operating variables interact to influence the emission rates of different regulated pollutants in complex ways that can be difficult to predict. For example, catalyst additive changes, other operating changes or projects to reduce NO_X emissions for one standard could increase hydrogen cyanide emissions regulated under another standard.

4. NSPS J, NSPS Ja and (especially) MACT UUU include multiple compliance options for regulated FCCU pollutants. The RTR reorganized and selectively modified some of these options in ways that should not be generalized. The RTR requirement changes may encourage some refineries to reconsider one or more of the FCCU compliance options. A detailed line-by-line requirements and options analysis is recommended for each FCCU to avoid surprises.

6.2 NORMAL OPERATIONS

Following is a summary of several RTR requirement changes that apply to normal and long-term operation of some FCCUs:

1. Updated metal HAP emissions limit options in MACT UUU[28] now incorporate NSPS Ja limits, which were not reflected in the pre-RTR version of MACT UUU. The updated limits should be rechecked, but many refineries will continue complying with the same or comparable MACT UUU options as before the RTR.

2. Compliance with several MACT UUU emission limits will now be determined for every three-hour period instead of the 24-hour compliance determination period before the RTR.[29] For example, the power/current limits for an ESP and liquid-to-gas ratio/pressure drop limits for a WGS were shifted from 24-hour to three-hour compliance demonstration periods. These shifts from 24-hour to three-hour demonstrations must be completed by Aug. 1, 2017. Shifting from 24-hour to three-hour demonstrations increases the risk that short-term fluctuations will affect compliance with an empirical limit, even if the empirical limit was not updated by the RTR. As discussed below, the RTR added language to accommodate short-term fluctuations for some of these three-hour compliance demonstrations during SU, SD and hot standby events.

3. The post-RTR version of MACT UUU includes a new inorganic HAP compliance option to maintain the atmospheric exhaust opacity to below 20 percent.[30] The pre-RTR version of MACT UUU included opacity-based limit options, but the pre-RTR limits were either set at 30 percent opacity (for older units complying with NSPS J limits for PM) or were set based on

measured opacity during the most recent PM/nickel performance testing. The new 20 percent opacity limit may be advantageous for some FCCUs that cannot opt for the older 30 percent opacity limit, but any relative advantages will depend on unit-specific considerations. All MACT UUU opacity-based limits require installation of a continuous opacity monitoring system on the regenerator exhaust stack.

4. Inorganic HAP performance testing (for PM or nickel) is now required once every five years, unless there is a continuous emission monitoring system for PM. The pre-RTR rule only required a one-time PM/nickel performance test. The first five-year test is required by Aug. 1, 2017. Annual PM/nickel testing is required if test results exceed 0.8 pounds PM per 1,000 pounds of coke burn-off, which is 80 percent of the normal limit. The increased testing frequency could reveal previously undetected PM/nickel compliance issues that would need to be addressed.

5. A new one-time hydrogen cyanide (HCN) emissions test is now required under the post-RTR version of MACT UUU.[31] The HCN test is required by Aug. 1, 2017, unless a qualifying HCN emission test was already conducted. There is no associated emission limit, but this new HCN testing is an indicator that the EPA may consider future FCCU requirements and limits to reduce HCN emissions. At the time of the final RTR publication, the EPA determined that appropriate HCN emission control is ensured by the current 500 ppm volume limit on CO.[32]

6.3 SU/SD/STANDBY OPERATIONS

Refiners should review specific FCCU equipment configurations and operating procedures to determine the best way to comply with post-RTR requirements during SU, SD and hot standby events. During these transitional periods, the regenerator may go through periods of higher NO_X, CO and PM emissions. Operating procedures should define the operating envelope to minimize emissions and manage safe conditions during these periods.

SU-related safety concerns are especially complicating for FCCUs. For example, ESP units have intrinsic safety implications given the potential for explosive gas mixtures in the ESP, as illustrated by recent ESP explosions during FCCU startups. Starting up an FCCU includes initiating catalyst circulation and burning torch oil to increase reactor/regenerator catalyst temperatures prior to bringing in fresh feed. Following are summaries of several RTR requirement changes for FCCUs that only apply during SU, SD and hot standby periods:

1. If not meeting normal metal HAP emissions limits (e.g., the normal opacity limit), then maintain the inlet velocity to the primary internal cyclones of the catalytic cracking unit catalyst regenerator at or above 20 ft/s.[33] For example, this may support compliance and safety when starting up a unit that is normally controlled by ESP because 20 ft/s cyclone velocity can be achieved before energizing the ESP grid.

2. If not meeting normal organic HAP emissions limits (e.g., the normal 500 ppm volume CO limit), then maintain at least one volume percent (dry basis) oxygen in the exhaust based on one-hour averages.[34] The exhaust oxygen concentration can be controlled directly with air rates during the transitional process from cold SU until normal CO emissions can be established.

3. Some MACT UUU compliance limits do not apply during SU, SD and standby periods. For example, the normal three-hour average limits for ESP power and current do not apply during these periods. Also, the normal three-hour average pressure drop limit for a WGS does not apply (but the normal liquid-to-gas ratio limit does apply) during these periods.

4. The pre-RTR general SSM exemptions in MACT A were eliminated as of Jan. 30, 2016. Each MACT UUU-regulated FCCU must comply with the new SU, SD and standby limits discussed above by Aug. 1, 2017[35] (or comply with normal limits during SU, SD and standby). During the period from Jan. 30, 2016, until Aug. 1, 2017, all SU, SD and standby operations can elect to comply with the general duty requirements to minimize emissions and keep records during SSM events.[36]

6.4 SOLUTION OPTIONS

The RTR rulemaking changed some detailed requirements that could complicate compliance for some FCCUs during normal operations. However, such normal operating compliance issues will only affect a minority of FCCUs. The RTR changes related to SU, SD and hot standby operations are more likely to cause compliance issues. Refiners need to review their specific equipment configurations and operating procedures to determine the best way to comply during SU, SD and standby events (Figure 4). Several related observations are discussed as follows:

- Units with a WGS have a great benefit in treating PM, SO_X and NO_X because the scrubber can be placed in operation prior to the SU of the FCCU.

- Units with a CO boiler and no WGS have the benefit of starting up the boiler prior to the FCCU startup for CO control and can control PM with operating procedures, third stage separators (TSS) and/or an ESP. In the case that neither a TSS or ESP exist, it is suggested to review current operating history and determine whether adding one (or both) of these systems will deliver PM emissions compliance during SSM events. For a very robust system, a WGS can be evaluated for compliance with PM, SO_X and NO_X during all operating scenarios.

- Units with an ESP only should consider how opacity limits, cyclone velocity limits and other limits for ESP bypasses will be reflected in compliance programs and safe startup operating procedures. Adding a TSS along with well-thought-out-startup procedures may be sufficient to meet the PM standards. As above, a WGS can be evaluated for compliance with PM, SO_X and NO_X during all operating scenarios.

- Units without a WGS or Selective Catalytic Reduction (SCR) may consider adding a WGS. This will assist with NO_X compliance as well as deliver many other benefits as indicated above. While an SCR is a NO_X control option, the ammonia slip from these units reacting to form fine particulates in the atmosphere is an EPA concern.

Third stage separators (TSS)	CO boiler (Partial burn)	Electrostatic precipitator (ESP)	Selective catalytic reduction (SCR)	Wet gas scrubber (WGS)	Comments
				X	WGS assists with meeting PM, NO_x and SO_x requirements. CO met by complete combustion operation. Robust system.
	X				CO boiler assists with meeting CO. Evaluate incremental investment for TSS or ESP for meeting PM requirements on startup. SCR can assist with meeting NO_x.
		X			ESP assists in meeting PM but typically bypassed on startup. CO, NO_x and SO_x controlled by operating conditions in FCCU.
	X			X	CO boiler assists with meeting CO. WGS assists with meeting PM, NO_x and SO_x. Robust system.

Equipment exists   Equipment to consider as a minimum incremental investment

FIGURE 4: *Incremental equipment considerations for SU, SD and standby compliance.*

7.0 DELAYED COKER IMPACTS

RTR rulemaking impacts on delayed coking units are focused on the pressures that are allowed when venting to atmosphere during drum decoking. The new and revised RTR requirements were issued under MACT CC[37] to reduce organic HAP emissions from drum decoking. Associated VOC emission reductions are possible.

7.1 SCOPE

Determining how the RTR requirements apply to decoking emissions can be confused by differences between RTR and industry terminology. With respect to RTR compliance, it is important to apply the RTR definition[38] of decoking:

> *Decoking operations means the sequence of steps conducted at the end of the delayed coking unit's cooling cycle to open the coke drum to the atmosphere in order to remove coke from the coke drum. Decoking operations begin at the end of the cooling cycle when steam released from the coke drum is no longer discharged via the unit's blowdown system but instead is vented directly to the atmosphere. Decoking operations include atmospheric depressuring (venting), deheading, draining, and decoking (coke cutting).*

As discussed below, new delayed cokers must meet more stringent RTR requirements than existing delayed cokers, but all delayed cokers located at MACT CC-regulated refineries are affected by these RTR requirements.

7.2 REQUIREMENTS

The regulatory framework for delayed cokers is similar in the pre-RTR and post-RTR versions of MACT CC. As each decoking sequence begins, the drum must be depressured to a closed blowdown system until the measured pressure or temperature conditions within the drum meet the specified criteria for atmospheric venting. Until those specified criteria are confirmed, all the depressuring vapors received by the blowdown system must either be captured for processing (e.g., routed to fuel gas recovery) or sent to a MACT CC-regulated organic HAP emission control device (e.g., a flare). Considering that affected refineries should already comply with the pre-RTR requirements, following is a summary of how the post-RTR requirements vary from the pre-RTR requirements:

1. Pre-RTR MACT CC allowed atmospheric venting after outlet pressure dropped below 5 psig. Post-RTR MACT CC tightens the standard from 5 to 2 psig for existing units. For new units, the new standard is 2.0 psig. The EPA's final RTR publication[39] clarifies that the difference in significant figures indicates how to round measured actual values for compliance determination purposes. For example, an actual value of 2.4 psig would comply with the 2 psig standard but not with the 2.0 psig standard.

2. Post-RTR MACT CC also allows atmospheric venting after the drum temperature is measured to be 220˚F or less for an existing unit, or 218˚F or less for a new unit. The temperature criteria are an option that is instead of (not in addition to) the pressure criteria discussed above.

3. For existing units, compliance with the pressure or temperature criteria is determined based on a 60-event (i.e., 60 cycle) basis, which accommodates cycle-specific variances. For new units, each individual decoking event must meet the criteria without averaging.

4. The basic requirements discussed above also include many other technical requirements not addressed in this summary, e.g., regarding measurement accuracy, frequency and quality control. Post-RTR MACT CC also includes specific requirements for water overflow operations and double quenching, when needed.

7.3 SOLUTION OPTIONS

In recent years, many refiners installed new delayed coker units (DCUs) or modified existing DCUs to allow processing heavier crude slates. The new and recently modified units are more likely to already comply with the 2 psig requirements. The need to modify a DCU to comply is more likely to apply to an older unit.

DCUs are designed to operate coke drums in pairs and use two, four or six coke drums depending on the plant capacity and crude slate. The drum pairs operate in a batch mode with one of the drums in operation while the other is undergoing coke removal.

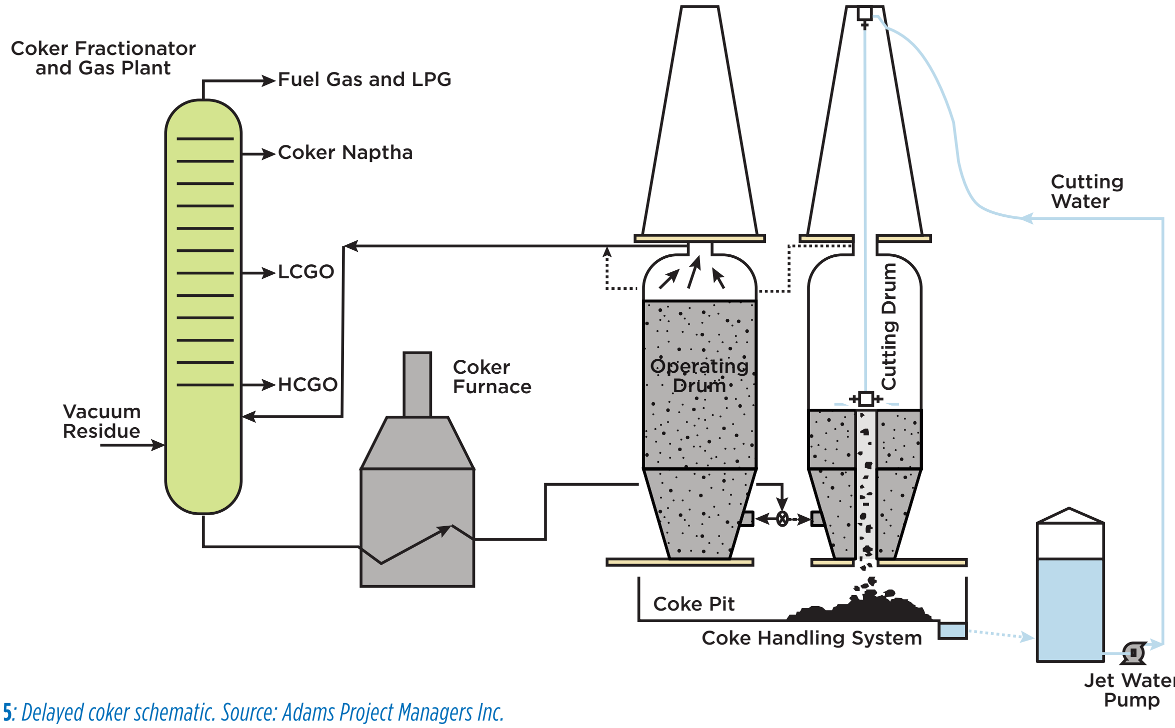

FIGURE 5: *Delayed coker schematic. Source: Adams Project Managers Inc.*

Figure 5 depicts a two-drum DCU operation. In this schematic, DCU feed is vacuum residue that is fed to the coker fractionator. The bottoms from the fractionator is pumped through a coker furnace to achieve a sufficiently high temperature for thermal cracking. The furnace outlet flows upward through the drum that is in operation. Coke is laid down in the drum as the thermally cracked products exit the top of the drum and flow to the fractionator for initial separation. The separated materials are further processed and sent to other refinery units.

During the time that one drum is in operation, the second coke drum is being decoked. This decoking process includes steaming out to remove hydrocarbons followed by quenching and cooling the coke bed. During these steps the coke drum outlet is transitioned from flowing to the fractionator column to flowing to a downstream blowdown system. Finally, the drum is isolated, the water is drained and the top and bottom heads are removed (i.e., deheading). It is during this period that the less than 2 psig requirement applies. When the drum heads are removed, the drum is open to the atmosphere. After deheading, a hole is drilled through the bed of coke and high pressure water is used to cut the coke, which falls out the bottom of the drum by gravity.

The drum pairs go through a full cycle of operation followed by decoking, which is typically in the range of 28-48 hours. Figure 6 provides an overview of a typical 36-hour drum cycle.

OPERATION	HOURS
Coking	18.0
Switch drums	0.5
Steam out to coker fractionator	0.5
Steam out to closed blowdown system	1.0
Slow water quenching/cooling	1.0
Fast water quenching/cooling	3.0
Drain coke drum	2.0
Remove top and bottom heads	0.5
Hydraulic coke boring/cutting	4.0
Reheading/pressure testing	1.0
Drum warm up	4.5

FIGURE 6: *Delayed coker — typical 36-hour drum cycle. Source: Lummus Technology.*

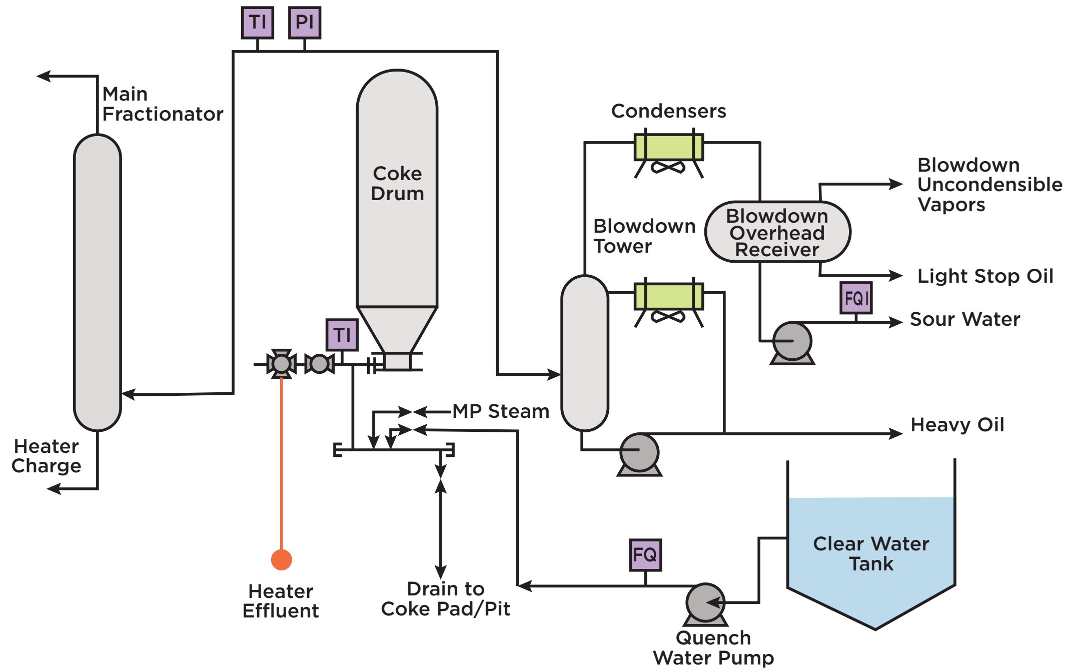

FIGURE 7: *Delayed coker blowdown system schematic. Source: Lummus Technology.*

7.3.1 ACHIEVING LESS THAN 2 PSIG LIMIT

As necessary, refiners need to review their specific equipment configurations and operating procedures to determine the best way to comply with achieving the 2 psig limit.

As described above, during the decoking cycle the coke drum overhead flow is eventually directed from the fractionator to a closed blowdown system. The blowdown system is composed of a blowdown tower, condensers and a blowdown overhead receiver as indicated in Figure 7. The coke drum is venting and the drum pressure is being reduced through this system up until the time that the top and bottom heads are removed.

In the case that a coke drum cannot already achieve 2 psig prior to opening to the atmosphere, various solutions are possible:

- Use a steam ejector system on the blowdown overhead receiver drum to lower pressure further
- Use a compressor system on the blowdown overhead receiver drum to lower pressure further
- Reduce hydraulic limitations through blowdown system (equipment, piping and/or adding condensing capacity)
- Use a Flare Gas Recovery (FGR) system
- Fill coke drums completely with water

It is also feasible to pull directly on the coke drum overhead with a steam ejector or compressor system.

7.3.2 DESIGN CONSIDERATIONS

A selected solution should consider any effects on coke drum cycle time. In the situation where the DCU is operating at maximum throughput, adding cycle time to reduce coke drum pressure to 2 psig may reduce the capacity. This consideration could lead to increasing the capacity of new steam ejectors, a new compressor or an FGR to enable drawing pressure down more rapidly.

Any significant hydraulic limitations through the blowdown system should be determined to identify a bottleneck. Increasing condensing capacity may allow condensing more steam to alleviate congestion.

The decision to use an ejector versus a compressor system may depend on the availability of steam or electricity. In lieu of using steam, a process stream at suitable pressure may be available to use as the motive fluid for an ejector system.

The outlet from an ejector or compressor system may be taken to the main fractionator overhead system. The overhead cooling, compressor and sour water handling capacity of the fractionator overhead system should be evaluated as part of the engineering study.

FGR systems may already exist or can be added in a DCU to recover hydrocarbons in vent streams. An FGR may also reduce emissions and losses to a flare system during the startup, shutdown or malfunction of the DCU.

8.0 CATALYTIC REFORMER IMPACTS

RTR requirement changes for catalytic reforming units are relatively straightforward. The RTR changes affect MACT UUU-regulated organic HAP emissions from reformer regeneration vents prior to coke burn-off.[40] The pre-RTR version of MACT UUU includes reformer requirements for reducing inorganic HAP emissions during and after burn-off,[41] but the RTR did not include any changes to these pre-RTR inorganic HAP requirements.

New and existing reforming units at MACT UUU-regulated refineries are affected by these RTR changes. All reformer types (continuous regeneration, semi-regenerative and cyclic) are affected.

8.1 REQUIREMENTS

Before the RTR rulemaking, both active purging and passive depressuring vents from catalytic reforming units (prior to coke burn-off) were exempt from MACT UUU organic HAP emission standards if the reactor vent pressure was 5 psig or less. The RTR removes this 5 psig exemption for active purging vents. Therefore, post-RTR MACT UUU continues to exempt passive depressuring vents of 5 psig or less reactor vent pressure, but organic HAP emission standards are now specified for active purging vents at any reactor vent pressure. The reformer vents (prior to coke burn-off) that are subject to organic HAP emission standards must either be routed to flare or to some other emission control system meeting the

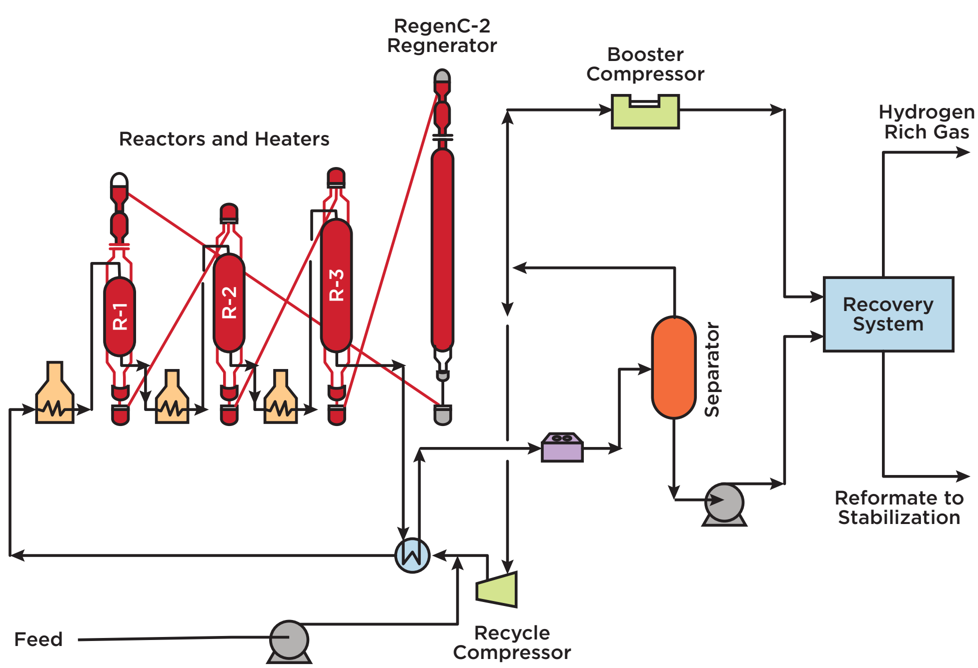

FIGURE 8: *Continuous catalytic regeneration (CCR) system schematic. Source: Axens IFP Group Technologies.*

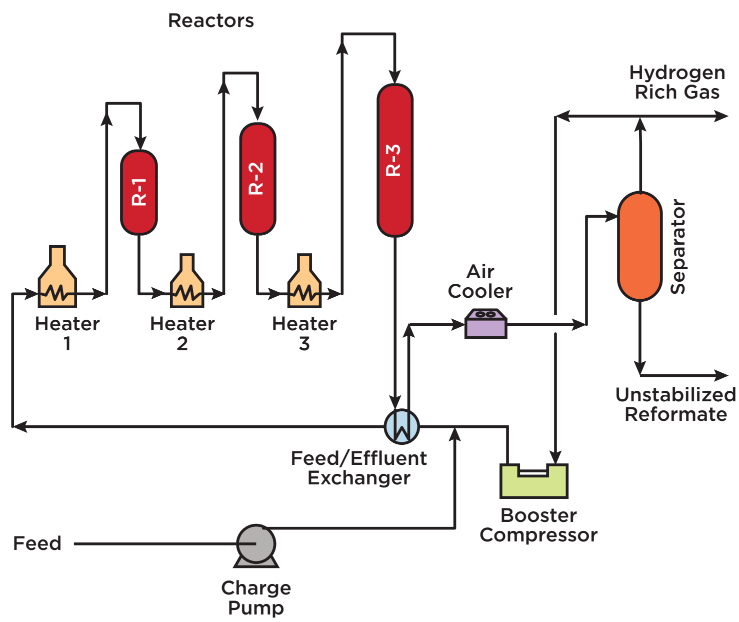

FIGURE 9: *Semi-regenerative system schematic. Source: Axens IFP Group Technologies.*

specified organic HAP emission reduction standards. If routed to a flare, then the flare must comply with the new MACT CC RTR requirements discussed in Section 5.

8.2 SOLUTION OPTIONS

Catalytic regeneration units are either continuous catalytic regeneration units (CCR), cyclic units or semi-regenerative units.

The catalyst is continuously regenerated in a CCR unit (Figure 8). Catalyst regeneration consists of using air to burn carbon off of catalyst to maintain the catalyst performance. Combustion gases from regenerating the catalyst are continuously purged to the atmosphere, typically via a scrubber or an absorbent trap.

The catalyst in the cyclic units is regenerated continuously or weekly using a dedicated regeneration circuit. The combustion gas from regenerating catalyst is typically continuous. The purge gas is typically sent to be combusted in a fired heater.

For a semi-regenerative unit, the entire unit is shut down approximately once per year to regenerate the catalyst depending on catalyst performance (Figure 9). The catalyst beds need to be cleared of hydrocarbons in order to perform the regeneration. The beds are cleared initially to a flare system. Since the unit is shut down, the fired heaters are not operating. The beds are vented to the atmosphere once the pressure is sufficiently low.

9.0 SULFUR RECOVERY UNIT IMPACTS

The RTR rulemaking included changes to requirements that specifically apply to Sulfur Recovery Units (SRU) that are regulated under NSPS Ja or MACT UUU.

9.1 NSPS Ja REQUIREMENTS

NSPS Ja requirements usually only apply to SRUs that were constructed, reconstructed or modified after May 14, 2007, but SRUs can be made subject to NSPS Ja for other reasons. The RTR did not change any SRU-specific requirements in NSPS J. RTR requirement changes under NSPS Ja relate to emissions of sulfur compounds (SO_2 or H_2S, depending on unit configuration).

The RTR rulemaking included a reorganization and rewording of SRU requirements under NSPS Ja.[42] For example, the post-RTR rule includes more detail regarding the required determination of oxygen concentrations for Claus units using oxygen-enriched air with continuous oxygen concentration measurement. The practical impacts will depend on the unit-specific factors (e.g., whether there is a tail gas incinerator). Therefore, each NSPS Ja-regulated SRU should be compared to the post-RTR version of NSPS Ja.

It is unfortunate for purposes of detailed compliance evaluations, but these NSPS Ja requirement changes (as with most NSPS rule revisions) do not specify a schedule to achieve compliance with the post-RTR requirements. The EPA characterized the NSPS Ja rule changes as clarifications, but some of these rule changes could impact how or which requirements are determined to apply to individual SRUs. Technically, the post-RTR requirements under NSPS Ja were effective as of Jan. 30, 2016. In practice, refineries that need time to comply with new or revised NSPS Ja requirements may consider discussing a compliance schedule with the appropriate regulatory authorities.

9.2 MACT UUU REQUIREMENTS

The RTR rulemaking added new SRU startup and shutdown requirements to MACT UUU.[43] These requirement changes apply to new and existing SRUs and relate to HAP emissions. Considering that the RTR eliminated the general SSM exemptions, MACT UUU now includes the following post-RTR startup and shutdown options:

1. Tail gas emissions can be managed to meet the normal MACT UUU limits at all times and without any uncontrolled purge gas venting.

2. Purge gases can be sent to a flare that meets post-RTR requirements discussed in Section 5 by the specified flare compliance date. This option may involve additional complexity because the purge gas could be subject to NSPS Ja flare minimization requirements (i.e., root cause and corrective action analyses could be triggered).

3. Purge gases can be sent to an incinerator. The incinerator must maintain an hourly average combustion zone temperature of at least 1,200° Fahrenheit and an hourly average oxygen concentration of at least 2 percent by volume in the incinerator exhaust.

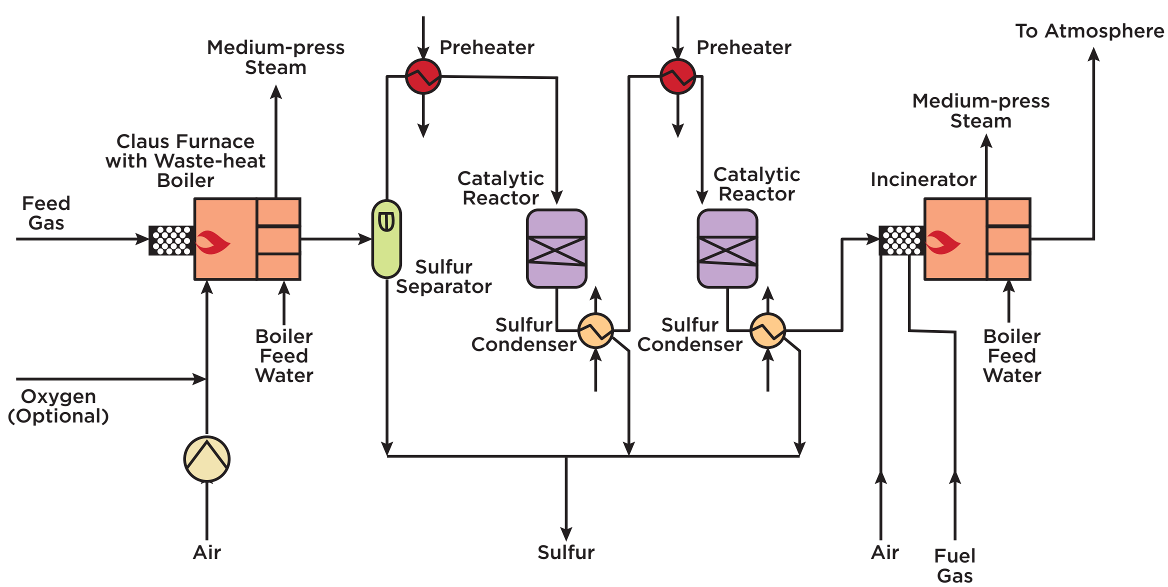

FIGURE 10: *Sulfur recovery unit (SRU) Claus technology schematic. Source: M. Heisel, B. Schreiner and W. Bayerl.*

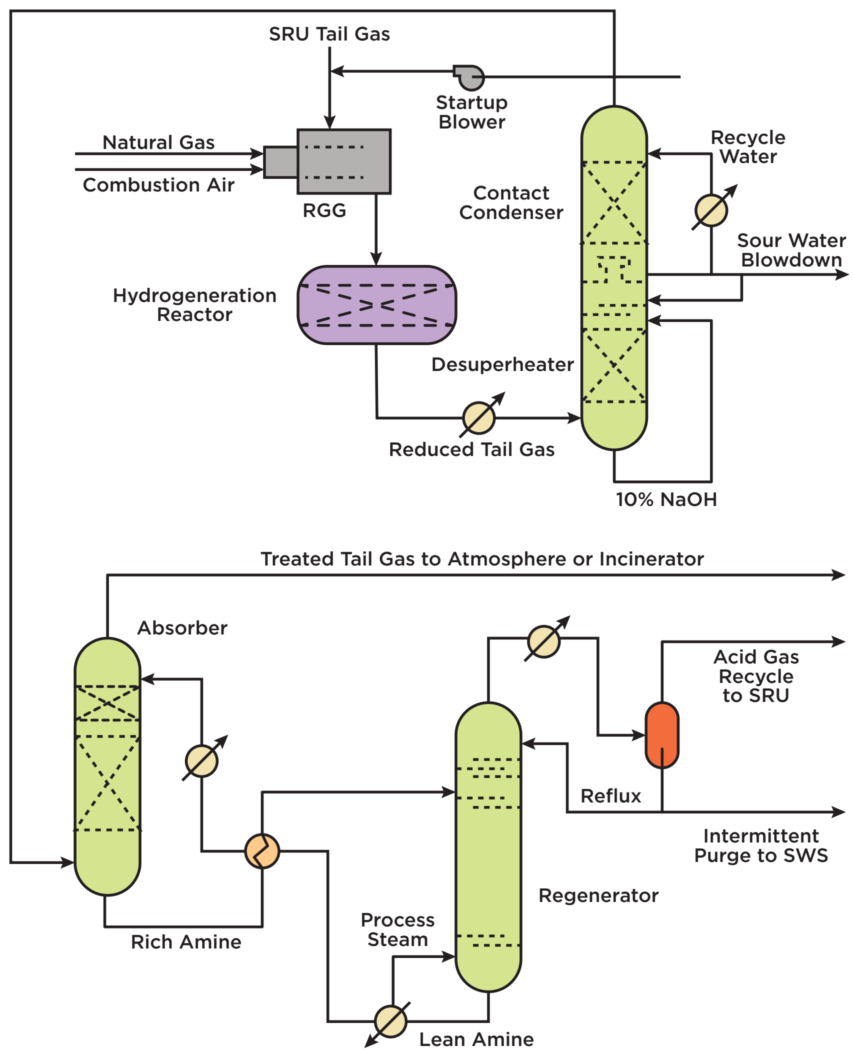

FIGURE 11: *Tail gas treater unit schematic. Source: WorleyParsons.*

Compliance with these new MACT UUU SRU startup and shutdown requirements must be achieved by Jan. 30, 2019.

9.3 SOLUTION OPTIONS

Refinery SRUs utilize Claus technology (Figure 10). Acid gas is sent to a reactor where feed is combusted. The effluent is sent to a separator drum where sulfur is condensed. The vapor is sent to further stages of preheat followed by catalytic reactors and condensers where sulfur is condensed out. The sulfur from each condensing step is combined and flows out as a product. The vapor from the last condenser is sent to an incinerator with the flue gas exiting a stack to atmosphere.

SRU tail gas is sent to a Tail Gas Treater (TGT) unit (Figure 11). The tail gas is combusted, reacted and scrubbed. The scrubbed gas continues on to an amine absorber system and the absorber overhead is either sent to the atmosphere or to an incinerator.

With the latest RTR regulation, the treated gas from the TGT unit should flow to the incinerator. During the startup and shutdown the incinerator should remain in service, and RTR stipulates that the incinerator should be maintained at 1,200° Fahrenheit and O_2 concentration should be a maintained at a minimum of 2 percent for compliance.

10.0 BENZENE FENCE LINE MONITORING

The RTR rulemaking includes new MACT CC requirements for a benzene fence line monitoring program.[44] This program has no precedent in the EPA Clean Air Act regulations. The EPA's RTR rulemaking Fact Sheet[45] states the following:

> *... for the first time in a national regulation require refineries to monitor emissions at key emission sources within their facilities and around their fence lines.*

10.1 REQUIREMENTS

The new fence line monitoring requires every MACT CC-regulated refinery to install an ambient air monitoring sampling network around the refinery perimeter. The sampling network is based on passive absorbent sample collection and analytical laboratory methods that can detect benzene concentrations down to low parts per trillion levels. The measured benzene concentration data must be disclosed to the public. Following is an overview of selected requirements to illustrate the nature of the required monitoring program (many details are omitted):

1. Install 12 to 24 passive monitoring stations along the entire refinery fence line. The number of required stations is prescribed based on the area occupied by the refinery property. Additional sample station locations are required under some specified circumstances. The requirements and options for selecting the station locations are detailed, but these requirements include consideration for potential off-site benzene sources and other potential interferences.

2. Install a meteorological monitoring station to measure wind direction and speed, temperature, and humidity. An existing off-site United States Weather Service (USWS) meteorological station can be relied upon if located within 25 miles of the refinery. Under some circumstances, an on-site meteorological station is required.

3. Deploy passive adsorbent sample tubes at each sampling station. Collect and replace the tubes once every two weeks. Conduct the prescribed laboratory benzene analysis on the collected tubes. Sample collection frequency can be progressively decreased (e.g., to once every four weeks and so on) over a period of years if measured concentrations are below specified levels.

4. Adjust the analytical benzene concentration results to reflect the refinery's contribution (i.e., the μc value) based on measured background (e.g., upwind) concentrations and other prescribed adjustments.

5. Disclose the measured and adjusted benzene concentration data via the EPA's dedicated website.

6. Conduct root cause analysis and (in some cases) correction action analysis for measured and adjusted benzene concentrations that exceed the specified 9 microgram per cubic meter (μg/m^3) action level.

10.2 PUBLIC DISCLOSURE

Disclosing measured ambient benzene concentration data to the public raises several uncertainties for the refineries. There are limited relevant precedents to help set reasonable expectations for the nearby communities, regulatory agencies, environmental interest groups and other interested parties. Some parties may misinterpret or misrepresent the 9 μg/m^3 action level as a limit or a protective health-based value. Also, it is unclear how the EPA will respond to individual refinery monitoring plan proposals for addressing potential measurement interferences (e.g., high humidity, off-site sources and near-field sources). These uncertainties could lead to unjustified concerns or public relations impacts. Such uncertainties and potential concerns should be evaluated as early as possible because the benefits of public outreach and other potential management options can be schedule-sensitive.

10.3 DATA MANAGEMENT OPTIONS

The RTR requirements include technical details for processing fence line monitoring data, but each refinery will have considerable discretion to select a data management system. Any successful data management approach will support efficient, error-free reporting via the EPA's mandated online reporting system. A relatively simple spreadsheet data management tool may be an adequate low-cost solution for some refineries. Other refineries may select advanced custom-built data management systems for added functionality. Following are several factors that should be considered when deciding how to manage fence line monitoring program data:

1. Meteorological data source is a key factor in how much data management is required. Reliance on data from a qualifying off-site USWS meteorological station will reduce the overall quantity of data to evaluate, manage and summarize for each sample cycle. Off-site USWS station data still needs to be evaluated and summarized for each sample cycle. Managing data from a refinery-operated on-site station will require much more attention than for an off-site station (e.g., the refinery will need to perform calibrations and maintenance and keep associated records).

2. Other data systems may be useful for fence line monitoring data management. For example, an existing Laboratory Information Management System (LIMS) or groundwater concentration database may provide some functions needed for managing fence line monitoring data. As an alternative, a dedicated fence line monitoring database may need to automatically retrieve information from LIMS, an external USWS meteorological database or other database systems.

3. Available resources affect what data management options are a best fit. Reviewing and managing the data will take attention that needs to be considered in terms of individual roles and responsibilities and for plant department budgeting. Some refiners may choose to outsource as much of the work as possible, which may include (for example) expanding the scope of existing on-site environmental compliance services to cover sampling field work and data management. Commercial laboratories may also offer varying levels of data management support.

4. Number of sites and users are key data management design considerations. A simpler system design may be difficult to manage for multiple sites, especially if system users in different locations need simultaneous access to read, write and approve information. More complex systems may offer more features to manage customized read/write/approval permissions, which may be a priority if some data management tasks will be performed by a laboratory or other service provider.

5. Data presentation features also affect system design. More complex data management systems can be designed with additional display features, including concentration trends, concentrations and contributing event correlations, integrated weather/concentration graphics, and other display options to support efficient analysis and decision-making.

10.4 PILOT STUDY OPTION

Many refineries are conducting pre-compliance pilot studies to support better informed decisions for long-term compliance program design. For example, pilot study data can indicate the relative likelihood of exceeding the defined 9 $\mu g/m^3$ action level and this information can inform whether a more advanced data management system is worth the additional cost. Pilot study results may also help to identify benzene sources that need more focused pre-compliance evaluations. Pre-compliance source evaluations can identify on-site emission reduction opportunities. Pre-compliance source evaluations can also help justify the refinery's off-site source and near-field interference adjustments, which must be included in the site-specific fence line monitoring plan for the EPA's review. A pre-compliance pilot study may be relatively more advantageous for refineries with nearby off-site benzene sources or local environmental activism, but many other factors should be considered.

11.0 CONCLUSIONS

The RTR adds to today's perfect storm of changes for the industry to manage: energy price trends, lifting the crude export ban, feedstock changes and market uncertainty. Minimizing the costs and other impacts of RTR compliance will challenge each affected refinery to align stakeholders, secure resources, execute complex projects and maintain focus during a time of unprecedented change for the industry. The sections above include conclusions, recommendations and solution options along with the RTR requirements that apply to each regulated unit and equipment category. Following are several common themes that merit additional emphasis:

- **Priority** — RTR compliance implementation can cost a refinery on the order of several million dollars over the next three years, and actual costs will depend on many site-specific factors. Detailed site-specific analysis is needed to develop reasonable estimates for short-term implementation costs and long-term compliance costs. Although some requirement details may be revised in the future, there is no relevant precedent for reversing a rulemaking of this scale.

- **Complexity** — Compliance implementation planning will require multiple parallel efforts including compliance gap evaluations, potential engineering projects, operating changes, compliance program updates, environmental permitting and new services to outsource. Multiple refinery units, processes and departments may be affected.

- **Urgency** — The rules include multiple compliance deadlines, and some required projects need to be aligned with other projects or refinery turnaround plans. Therefore, some deadlines may be difficult to meet. Discussing potential compliance delays with the relevant regulatory agency as early as possible can minimize agency relationship impacts.

- **Strategy** — Up-front management decisions are recommended to assemble an RTR compliance team, establish a comprehensive compliance plan and emphasize compliance commitment. An empowered team, committed to compliance success and aligned by a well-designed road map is the best strategy to meet this demanding matrix of RTR compliance challenges.

12.0 OBJECTIVES AND LIMITATIONS

The new RTR air quality rulemaking by the U.S. EPA involves voluminous documents[46] and complex technical implications. The objective of this paper is to provide management-oriented information to help understand the nature of associated compliance challenges. This paper includes an overview of selected RTR requirements, and many important details are omitted. Several key limitations of this paper are summarized as follows:

1. This paper focuses on aspects of the RTR rulemaking that may involve complex compliance implementation efforts, including engineering and construction projects or process operating changes.

2. Many environmental compliance program implications of the RTR rulemaking are omitted. Environmental compliance program implications can generally be addressed by refinery environmental professionals with external consulting and compliance resources as needed. Most environmental compliance program implications do not involve complex engineering or construction projects. For example, this paper does not address RTR-related changes to compliance record-keeping, reporting and notification requirements.

3. This paper focuses on conventional source-specific requirements of the RTR rulemaking. Some of these source-specific RTR requirements do not apply to refineries that elect to comply with emissions averaging requirements. Emissions averaging compliance options are not addressed in this paper.

4. No guarantees, warranties or assertions as to the accuracy or completeness of the information in this paper are given or implied. This paper is provided for information purposes only and should not be relied upon to support compliance decisions, commitments, budgeting or expenditures of any kind. This is a technical paper representing the personal opinions of the authors and does not include any legal advice.

REFERENCES

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2. Clean Air Act Section 112(b)(1) as modified in Federal Register, June 18, 1996 (61 FR 30816).
3. "Historical Air Emissions from United States Petroleum Refineries" by Thomas A. Nelson and Brian Nguyen of Sage Environmental Consulting, LP, published April 2015: https://www.afpm.org/uploadedFiles/Content/documents/Sage-Report.pdf
4. For example, as per MACT CC, §63.640(m).
5. Ibid.
6. 40 CFR 63 Subpart CC, §63.642(n)
7. As per NSPS A, §60.8(c) and §60.11
8. Most of these PRD requirements are found in MACT CC, §63.648(j) under section §63.648 for "Equipment leak standards."
9. As per MACT CC, §63.641 definition of "Miscellaneous process vent".
10. As per MACT CC, §63.648(j)(5).
11. Most of the new maintenance vent requirements are found in paragraph §63.643(c) under section §63.643 "Miscellaneous process vent provisions."
12. Ibid.
13. As per §63.643(d) of the RTR clarifications and corrections proposed on Jan. 29, 2016.
14. The RTR updated the §63.641 definition of "miscellaneous process vent" to include analyzer vents after Jan. 30, 2019, and most associated requirements are found in section §63.643 "Miscellaneous process vent provisions."
15. As per MACT CC, §63.648(j)(5).
16. As per the post-RTR version of MACT Y, §63.560(a)(4), marine vessel loading must use submerged filling based on the cargo filling line requirements in 46 CFR 153.282.
17. As per MACT CC, §63.651(e).
18. The criteria change was implemented in MACT CC by updating the definition of "Group 1 storage vessel" (which is a vessel that is required to meet emission control standards) as per §63.641 "Definitions."
19. As per MACT CC, §63.660(d).
20. Most MACT CC emission control standards are found in §63.646 "Storage vessel provisions" (the pre-RTR requirements, which reference MACT G) and in §63.660 "Storage vessel provisions" (the post-RTR requirements, which reference MACT WW for floating roofs and MACT SS for tanks vented to emission control systems).
21. As per MACT CC, Table 11 "Compliance Dates and Requirements."
22. As per Section §63.670 "Requirements for flare control devices" and Section §63.671 "Requirements for flare monitoring systems."
23. As per NSPS Ja, §60.103a(a) and (b).
24. As per MACT CC, §63.670(o)(1) and (o)(2).
25. As per MACT CC, §63.670(o)(3).
26. As per NSPS Ja, §60.103a(c).
27. As per MACT CC, §63.648(j)(4), (j)(6) and (j)(7) under the §63.648 "Equipment leak standards."
28. As per MACT UUU, §63.1564(a).
29. As per Table 2 to Subpart UUU of Part 63 "Operating Limits for Metal HAP Emissions from Catalytic Cracking Units."
30. As per Table 2 to Subpart UUU of Part 63.
31. As per MACT UUU, §63.1571(a)(6).
32. As per Federal Register/Vol. 80, No. 230/Dec. 1, 2015/Rules and Regulations, page 75204.
33. As per MACT UUU, §63.1564(a)(5).
34. As per MACT UUU, §63.1565(a)(5).
35. Aug. 1, 2017, compliance date is found in EPA's proposed corrections published in Federal Register/Vol. 81, No. 26/Feb. 9, 2016 "Proposed Rules" page 6822.

36. General duty standard is found in MACT UUU, §63.1570(c).
37. Most delayed coker requirements are found in MACT CC, "§63.657" Delayed coking unit decoking operation standards.
38. As per §63.641 "Definitions."
39. As per Federal Register/Vol. 80, No. 230/Dec. 1, 2015/ Rules and Regulations, page 75209.
40. Most RTR changes for organic HAPs from reformers are found in MACT UUU, §63.1566 "What are my requirements for organic HAP emissions from catalytic reforming units?"
41. As per §63.1567 "What are my requirements for inorganic HAP emissions from catalytic reforming units?"
42. Most NSPS Ja requirement changes for SRUs are found in §60.102a(f), §60.104a(h), §60.106a(a) and §60.106a(b).
43. Most new MACT UUU requirements for SRU startup and shutdown are found in §63.1568(a).
44. Most MACT CC fence line monitoring program requirements are found in §63.658 "Fence line monitoring provisions."
45. Ibid.
46. Many of these documents are found on EPA's "Consolidated Petroleum Refinery Rulemaking Repository" website: http://www3.epa.gov/airtoxics/petref.html

BIOGRAPHIES

BLAKE SOYARS, PE, practices environmental consulting with a focus on siting, licensing and permitting for industrial projects and compliance for existing facilities. Blake applies his primary technical knowledge in air quality to serve the petroleum refining, chemical manufacturing and other energy industry sectors. Over his 25 years of professional consulting experience, Blake has managed projects in all environmental media, managed business relations with many industrial clients, permitted dozens of industrial capital projects, and provided technical air compliance advice for many industrial facility audits and pre-acquisition evaluations.

MARK LOCKHART, PE, has over 30 years of experience in the process engineering industry, managing all phases of process engineering and project execution with a strong process technology background. He is known for his experience in petrochemical/chemical technologies, including all facets of process design, first-of-a-kind commercialization and plant operations, and has held varying roles including managing process engineering in a licensing technology company, director of technology, head of process engineering in a startup engineering company, and as a leader in numerous front-end phase initiatives.

JIM CORBIT is an environmental consultant with over 22 years of experience conducting and managing air quality services and environmental regulatory support projects for the oil and gas, refining, terminals, chemical, transportation, power and manufacturing industries. He has detailed knowledge of facility operations and related state and federal air quality regulation, and has conducted a full range of air quality compliance projects. Jim also has experience with implementing and maintaining compliance software solutions for several clients in the oil and gas, chemical, and petrochemical industries.

GREG NEVE is a project manager with more than 34 years of industry experience in a variety of roles ranging from management of process plants to engineering management and project management in FEED and detailed engineering projects.

12200-RTR-1016