AIChE PAPER NUMBER 146B

CRACKING FURNACE FUEL SUPPLY DESIGN, OPERATION AND MAINTENANCE

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Prepared for Presentation at the 2015 Spring National Meeting

Austin, Texas, April 26 – 30, 2015

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Abstract: This paper outlines the challenges faced in the design, operation and maintenance of ethylene plant fuel supply systems. There are a number of design practices that can influence the long-term cleanliness of the fuel supply which can have a detrimental impact on the firing uniformity and emissions performance of the burners. If uncorrected, a degradation of fuel firing uniformity has the potential to impact cracking furnace performance resulting in shortened run length and reduction in radiant coil service life, while degraded emissions performance has the potential to impact compliance with the site environmental permits.

Potential improvements in design, operation & maintenance practices are presented with focus on fuel supply system design upgrades and implementation of a fuel flow uniformity checking procedure. The implementation of a fuel flow uniformity checking procedure is a quantitative method to identify burners that require maintenance.

Challenges & opportunities exist in the design of cracking furnace fuel supply systems and in the related operating and maintenance practices applied.

Fuel Supply System Design Configuration

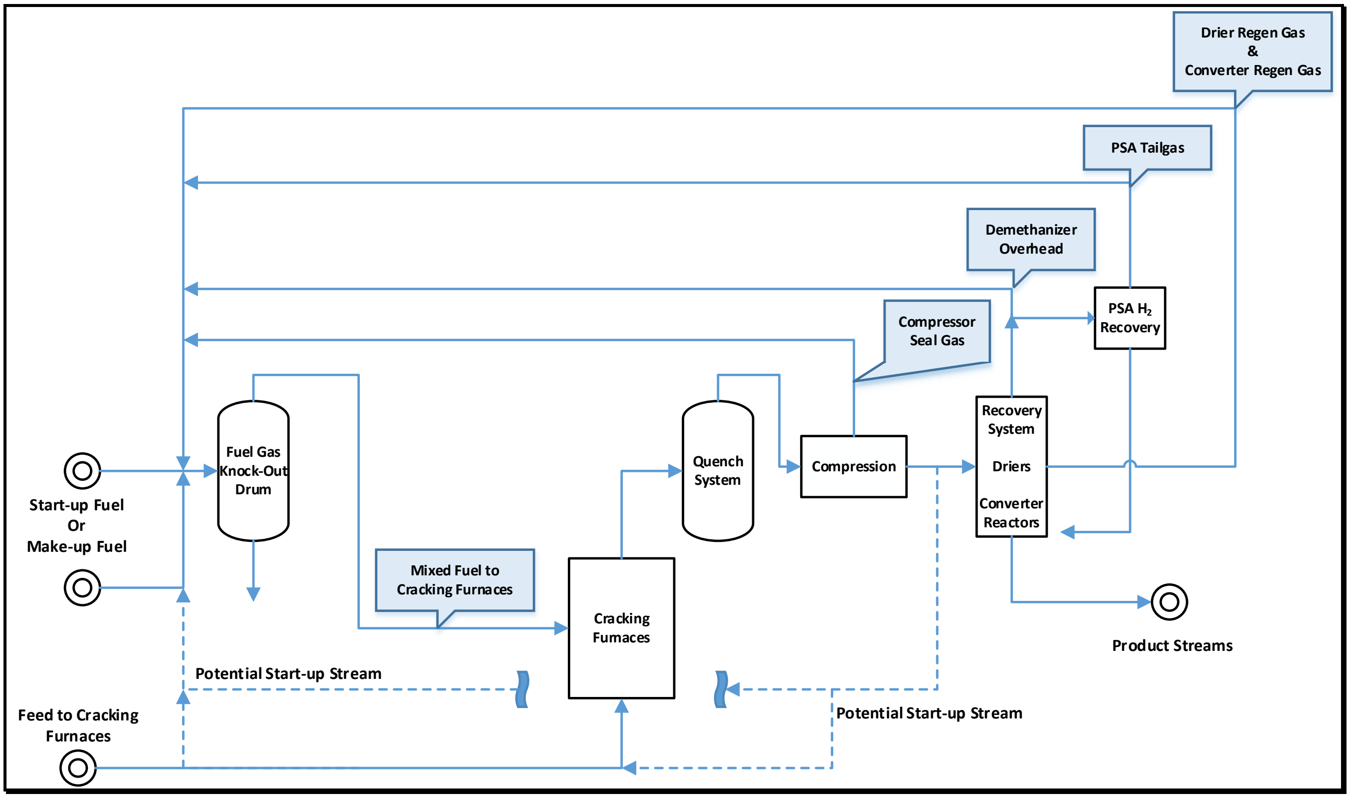
The design of cracking unit fuel supply systems is heavily influenced by the need to conserve both feed and fuel in the operation of the plant while remaining compliant with the environmental permits established for the unit. These needs dictate the routing of various hydrocarbon streams throughout the plant during all phases of start-up, normal operation, and during the handling of abnormal or emergency conditions. With reference to Figure 1, a representative ethylene plant fuel supply system indicating both typical and potential streams that may be routed to the fuel supply is described briefly below.

A major portion of the fuel for ethylene unit cracking furnaces originates within the plant, typically from the overhead of the demethanizer and from PSA unit tail gas. Since these streams are not available during start-up of the unit many plants utilize pipeline natural gas or may also use plant feed gas or vaporized LPG as cracking furnace start-up fuel if pipeline natural gas is not available to the plant.

During plant start-up as hydrocarbon feed is introduced to the unit, cracked gas is sometimes recycled back to the furnace feed with a portion of that cracked gas utilized as start-up fuel for the cracking furnaces. Other plants may initially introduce natural gas as the hydrocarbon feed to the unit during this phase as a means to bootstrap the front end operations, get the steam generation started from the cracking furnaces and quench system, and to produce sufficient steam for operation of the major compressor steam turbine drives.

During normal plant operations there are additional hydrocarbon streams often routed to the cracking unit fuel system with the intent of gaining the energy efficiency benefits of burning these streams in the cracking furnaces while reducing energy losses to the flare system. Streams such as vent gas from compressor seals, molecular sieve regeneration gas, and convertor catalyst bed regeneration gas would fall into this category. Compressor seal gas flows would be relatively small, but might contain small amounts of entrained oil. Flows of regeneration gases would be intermittent, but might contain small amounts of green oil from regeneration of convertor catalyst, or dust and/or moisture from molecular sieve bed regeneration.

The fuel supply system will generally include a fuel mixing drum or a knock-out drum prior to routing to the fuel gas distribution header. This drum may be intended to handle gross separation of liquids from the fuel gas stream but is not intended or adequate to function as an effective coalescer.

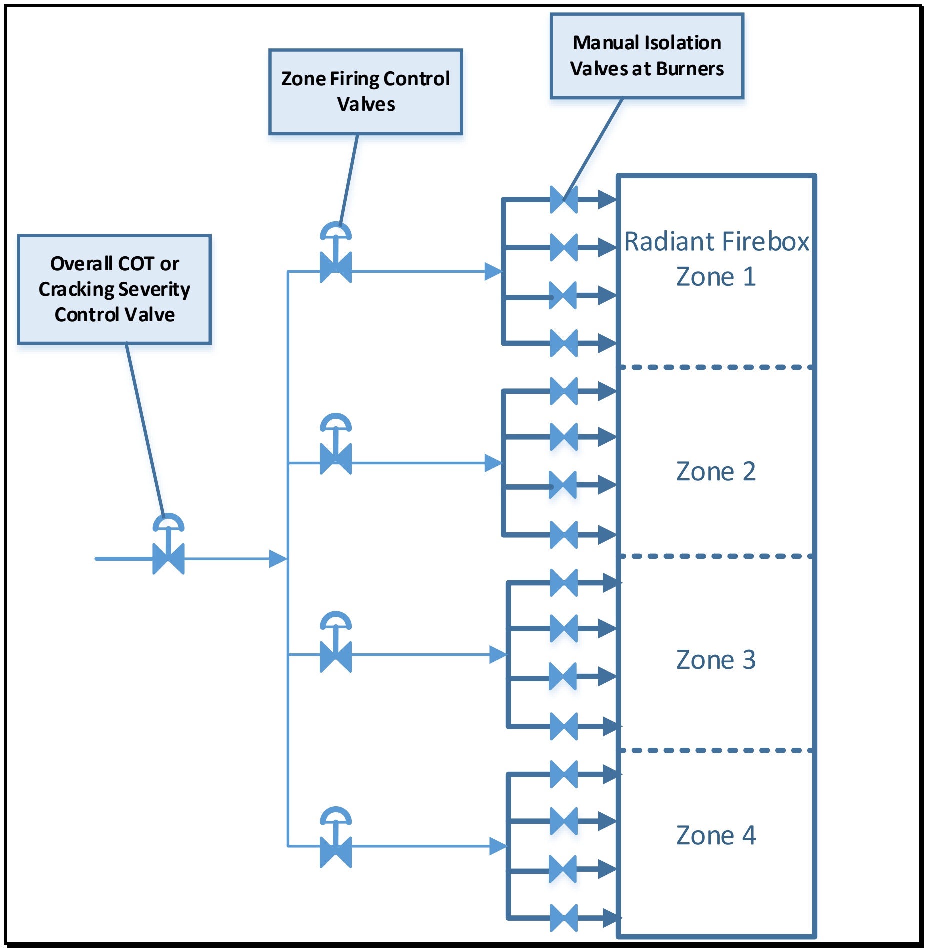


Typical and Potential Cracking Furnace Fuel Gas Sources
Figure 1

Normal Operating and Maintenance Practices

Control of cracking furnace fuel supply is set to achieve a desired feed conversion or cracking severity but may also have provisions for manipulation of firing distribution within various zones of a firebox to optimize heat input to the cracking coil [Figure 2]. Most designs rely upon the burner itself as the final component of a fuel gas distribution system to achieve uniformity of fuel firing among a group of burners supplied from a common fuel supply system.

In effect, the burner tip functions as a flow distribution orifice, however, uniformity of fuel flow distribution to each burner depends upon the control of burner tip drilling tolerances and on burner tip cleanliness. Any accumulation of pipe scale or other debris in an individual burner tip can result in a restriction of fuel flow to that tip. Restricted flow can then result in exposure of the burner tip to higher temperature due to loss of cooling. Higher temperature of the burner tip can in turn cause thermal cracking of heavier components or entrained hydrocarbon liquids that might be present in the fuel gas which can lead to coke accumulation and complete plugging of the burner tips.



Representative Fuel Firing Distribution and Control
Figure 2

Issues with restriction or plugging of burner tip orifices are often more serious for cracking furnaces equipped with burners designed for reduced NO_x emissions. Most burners designed for reduced NO_x emissions use a greater number of burner tips with smaller burner tip orifices that tend to become restricted and/or plugged more readily. The NO_x emission performance of these burners will also tend to suffer if burner tips become restricted or plugged, thus placing environmental compliance at risk.

During operation, plant operators make adjustments to individual burners based on a number of visual observations of the burner and/or based on tube or firebox temperature measurements. Depending on the type of burner, the flame appearance, the coloration or brightness of the surrounding burner wall, or the relative uniformity of tube temperatures may justify taking actions to adjust combustion air flow to the burners or to manipulate fuel firing to achieve improved uniformity. Generally speaking, run-length and overall performance improves with more uniform heat input.

Restriction of fuel flow due to pipe scale accumulation or coke accumulation in burner tips is an added complication that can have a significant impact on fuel firing uniformity. Lack of firing uniformity caused by burner tip plugging is generally impossible to correct with adjustment of combustion air flow or manipulation of zone firing. Burner tips must be continually monitored for signs of coke accumulation and must be cleaned as necessary in order to maintain fuel firing uniformity.

Typical signs of burner tip coke accumulation include:

- Observation of hot burner tips – glowing or bright red burner tips
- Observation of abnormal flame – distorted flame or non-uniform tile coloration
- Observation of relatively low temperature areas – non-uniform refractory or tube color

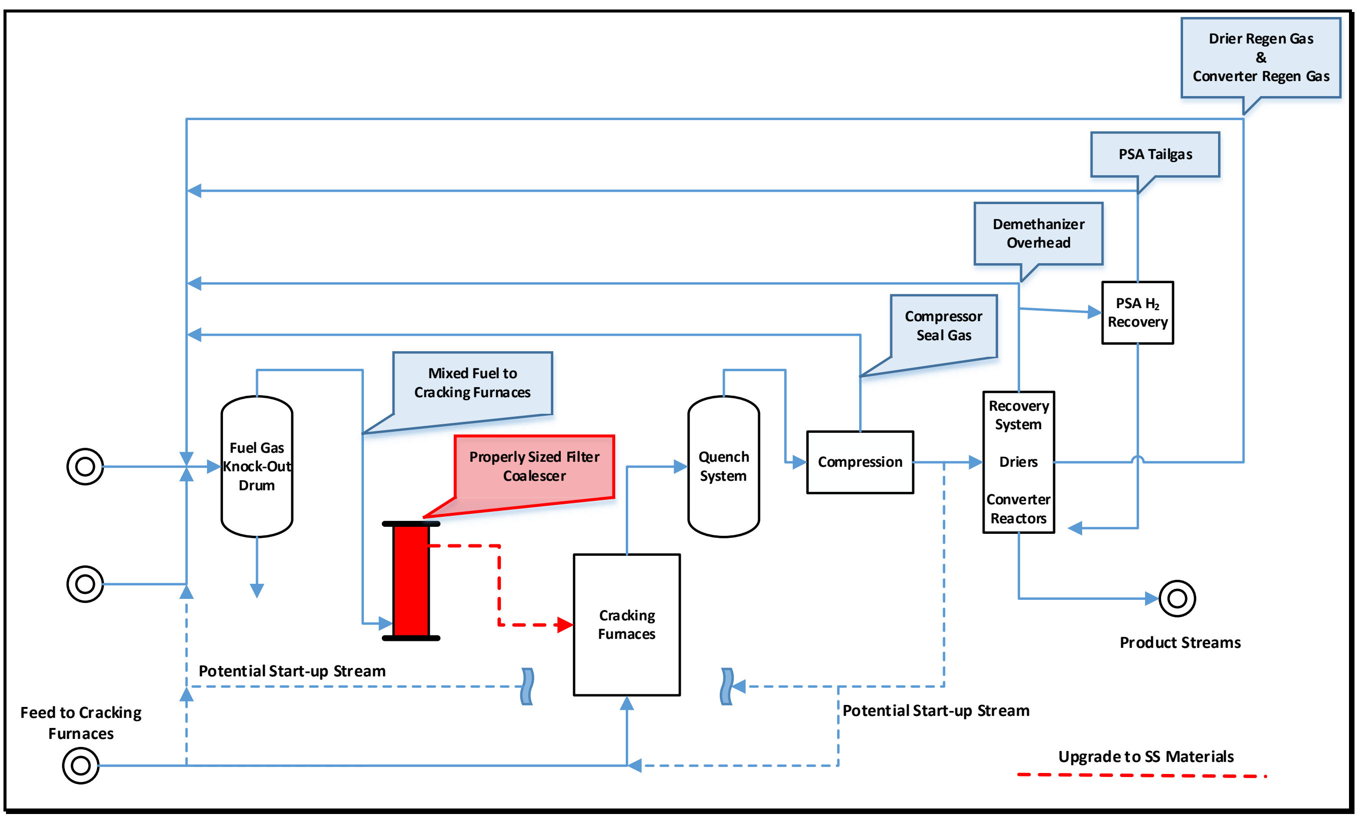
Regular observation of firebox conditions, periodic close visual examination of each burner, measurements of cracking coil tube metal temperatures, and thermal imaging of the firebox can collectively identify burners that are experiencing fuel flow restriction due to burner tip issues. When identified, individual burners can be taken out of service to allow burner tip removal for cleaning or replacement as necessary. Once the restricted burner tips are cleaned/replaced and re-installed, firing can be restored and heat input uniformity to the cracking coil is improved. In some plants, needed maintenance to clean burner tips is a continual activity and a major challenge to operations and maintenance personnel. Many plants struggle to maintain clean burner conditions while incurring significant cost for replacement burner tips, time required for both operation and maintenance personnel, as well as the costs related to non-ideal heat input conditions to the cracking coil which can result in shortened run length, incremental loss of production and product yield, and the added wear and tear on the radiant coil due to more frequent decoking intervals. When the full costs are considered, there is strong justification for seeking out improvements to the conventional system design and maintenance practices.

Potential Fuel Supply System Upgrades

Long-term operations can result in accumulation of trace fouling materials throughout the fuel gas piping supply system. To prevent this accumulated fouling from reaching the burner headers and burner tips, the appropriate location and installation of a properly designed and sized fuel gas filter coalescer is the best practice. There have been several excellent papers presented on the benefits of installing a fuel gas filter-coalescer [ref [1]]. It is imperative however, that a filter-coalescer added to an existing unit be sized based on solid input of particulate and liquid loading in order to handle the separation needs with reasonable attention from plant maintenance personnel. If undersized, the equipment may require an excessive effort to keep the equipment in service and there is risk that this might drive a decision in the plant to bypass the equipment.

The accumulation of fouling materials can result in corrosion and scaling of fuel gas supply lines. Migration of pipe scale through the fuel supply lines can then occur. The use of stainless steel piping downstream of a fuel gas filter coalescer to avoid scaling is another upgrade that can help to avoid recurrent restriction and plugging of burner tips.

Reliance upon the burner tips as the final system component to achieve uniformity of fuel flow can be improved upon through use of a distribution orifice in the branch line between the fuel gas supply header and the burner. The use of a distribution orifice to add system pressure drop independent of the burner tip provides distribution resistance while also allowing the burner tip orifices to be incrementally enlarged thus reducing the possibility of burner tip plugging.



Potential Fuel Supply System Upgrades
Figure 3

Potential Maintenance Practice Improvements

Normal operation and maintenance practice to identify and correct plugged or restricted burner tips is highly dependent upon the skill and experience of personnel involved in these activities. Proper attention to these activities can also require substantial investment of time from these skilled and valuable resources. The implementation of a systematic flow uniformity checking procedure provides a means to quantify the degree of uniformity and to positively identify burners that require maintenance attention.

One such fuel flow uniformity checking procedure that has been applied successfully can be carried out when the individual furnace is out of service. With the furnaces offline for maintenance and all manual burner valves closed, the fuel distribution piping is supplied with nitrogen through a line that includes a flow orifice and pressure transmitters upstream and downstream of the flow orifice. The opening of one individual manual burner valve and recording of the pressure upstream and downstream of the nitrogen supply flow orifice is a quantitative means to measure the flow resistance to that individual burner. Repeat of this measurement for each individual burner will allow identification of burners that are outside of an acceptable flow resistance tolerance. With record of the flow resistance of all burners of a furnace, individual burners that exhibit a flow orifice differential pressure that is less than 95% of the average indicate evidence of burner tip flow restriction and a need for cleaning or replacement of the burner tips. Individual burners that exhibit a flow orifice differential pressure that is greater than 105% of the average indicate evidence of burner tip orifice enlargement [possibly due to oxidation and erosion] and a need to replace those burner tips.

An alternative set-up of the nitrogen supply as described above is to use a flow transmitter rather than measurement of flow orifice differential pressure. The benefits are the same except that recommended flow tolerance uniformity would be +/- 2.5%.

A valuable benefit of the flow uniformity checking method is that only the burner tips requiring maintenance attention are pulled for cleaning or replacement. This can significantly reduce the number of burners that are disassembled for maintenance during a furnace shutdown.

One variation of this flow uniformity checking method is to carry out this check during normal operation or during online decoking operation of the furnace. In this case, the fuel supply to an individual burner must be positively isolated and the fuel supply line to that individual burner must be disassembled. By connecting a portable nitrogen supply rig to that individual burner a similar test can be carried out on the burners. The nitrogen supply rig would have a nitrogen hose connected to a length of pipe with a ball valve, a flow orifice and/or a flow transmitter.

Another variation of this flow uniformity checking method is similar to the online checking method above, but using plant air instead of nitrogen supply to the portable flow testing rig. By using air, it is often possible to burn out and clear accumulated coke deposits from an individual burner tip. This can effectively clean some number of burner tips without requiring removal for cleaning.

Flow Uniformity Checking Procedure

Prerequisites:

- Furnace is offline / shut-down
- Main fuel is isolated
- Zone firing control valves open
- All individual burner manual isolation valves closed

Step by step procedure:

1. Open N2 checking gas supply to header
2. Open one individual burner manual isolation valve
3. Record the indicated differential pressure across the flow orifice
4. Close that individual burner manual isolation valve
5. Open next individual burner manual isolation valve and record indicated flow orifice differential pressure
6. Repeat steps 4 and 5 until all burners have been checked
7. With differential pressures measured for all burners, calculate overall average

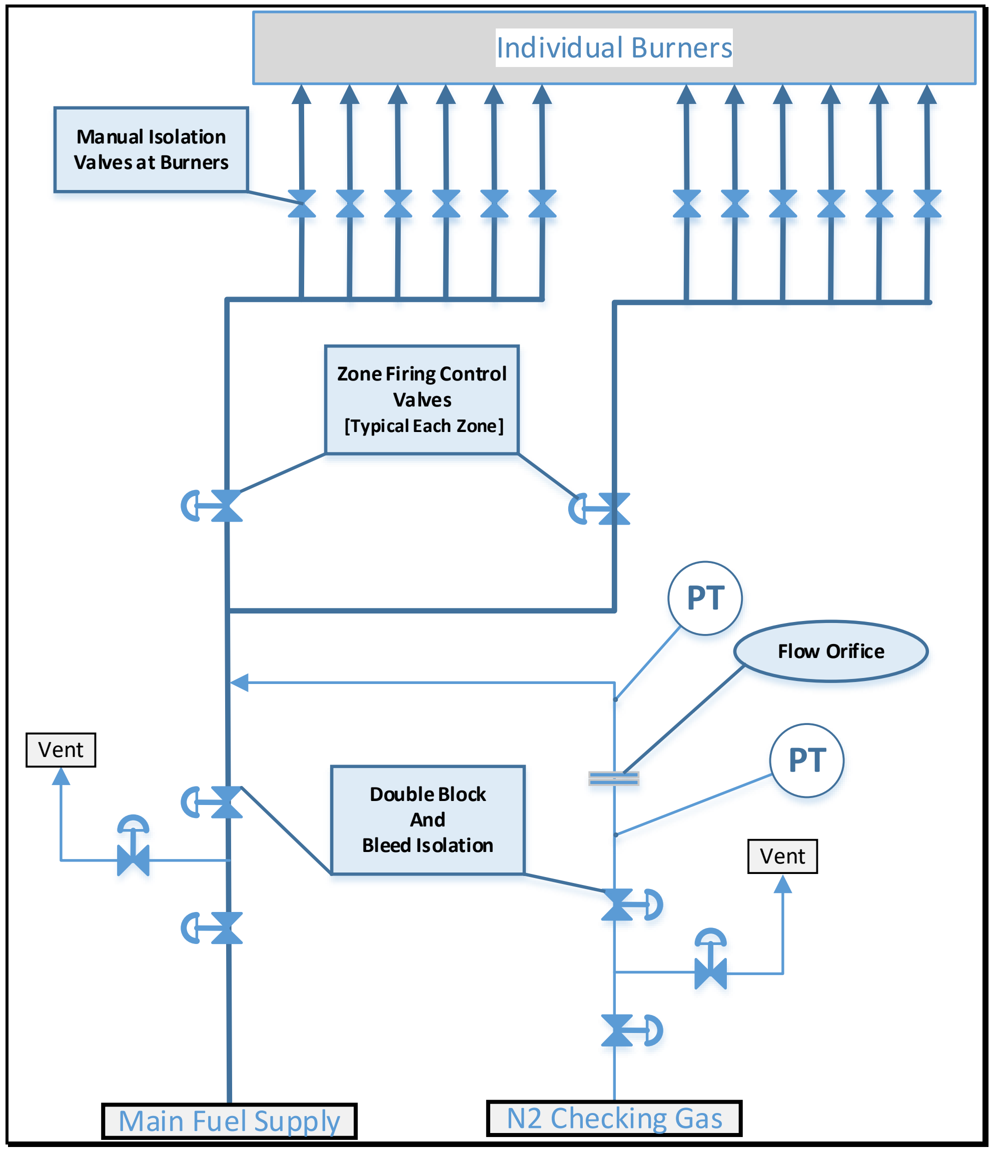
Criteria for actions:

Burner tip cleaning or replacement required if:

- Flow orifice differential pressure less than 95% of the average
- indicates restricted and/or plugged burner tip orifices

Burner tip replacement is required if:

- Flow orifice differential pressure is greater than 105% of the average
- Indicates enlarged/eroded burner tip orifices



Flow Uniformity Checking Schematic

Figure 4

Conclusions and Recommendations

There are over-riding economic and environmental compliance needs that dictate configuration of a fuel supply system in a manner that conserves all hydrocarbon streams within the plant. However, the system must also be designed for most economic and efficient long-term operation and maintenance. This means that recognition of all costs related to the fuel supply system is essential. These costs include:

- Personnel assigned to fuel system and burner maintenance
- Replacement burner tips / components
- Cost related to non-optimum fuel firing uniformity
    - Shortened furnace run-length & reduced on-stream factor
    - Incrementally reduced yield of product
    - Reduced service life of cracking coils

With recognition of the full cost of proper handling of fuel supply issues, upgrade of the system and implementation of methods to improve confirmation of fuel firing uniformity can be easily justified.

System upgrades that should be considered include:

- Installation of a fuel supply filter-coalescer
- Use of stainless steel piping downstream of the filter-coalescer

Improved Maintenance and Operation methods would include:

- Implementation of a fuel flow uniformity checking procedure
- Consideration of periodic online fuel flow uniformity checking using air
- Check and control fuel flow uniformity tolerance within +/- 2.5% or better
    - achieve improved run length
    - higher on-stream factor for the cracking furnaces
    - extended service life for cracking furnace coils

References:

[1] Wines, T. H., "Improve Contaminant Control in Ethylene Production," *Hydrocarbon Processing,* April 2005