Processing Focused Troubleshooting

First-of-a-Kind (FOAK) plants often surface a multitude of process design issues that arise during or shortly after start-up and commissioning. An overwhelming amount of pressure mounts to quickly solve these issues, which can slow down or halt valuable production. Engineering service providers, therefore, need process-focused troubleshooting capabilities, quick response, the ability to mitigate the negative impacts of uncertainty, and to engage proper technology equipment providers when necessary.

In this case study, response to FOAK issues are exemplified by services provided by Valdes to one of our clients who made a considerable investment in a unique facility to produce Recycled Carbon Black (RCB) from waste tires. The technology generates RCB by process of pyrolysis that drives off a hydrocarbon-rich vapor stream, leaving behind RCB and the steel belts. Once the steel is magnetically removed, the RCB competes favorably with Virgin Carbon Black (VCB) for use in providing the black color and strengthening properties in plastics and rubber.

The evolved vapor from the pyrolysis process is quenched, thereby producing liquid oil and light ends products. Quenching is accomplished by recycling cooled pyrolysis oil (quench oil). A few months after start-up, the client experienced rapidly declining quench oil flow rates due to high pressure drop through the oil-side of the water-cooled heat exchangers. To help alleviate this issue, Valdes was contacted to troubleshoot, evaluate options to solve the problem, bring in equipment technology expertise, and develop a design that could be installed immediately so the plant could begin full capacity operation.

A simplified diagram of the pyrolysis oil recirculation loop is shown in Figure 1.

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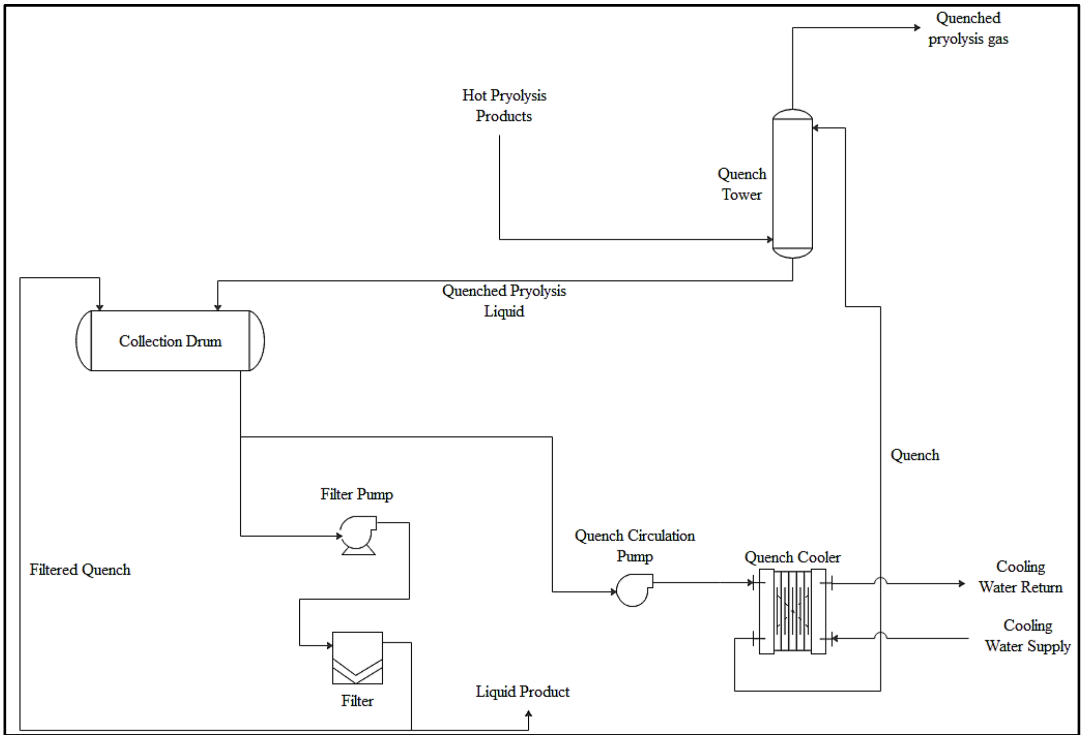
Figure 1- Quench liquid recirculation loop



As illustrated in Figure 1, the pyrolysis vapor is cooled in a quench tower via recirculating quench oil. Oil is condensed in multiple quench towers while the remaining "dry" gas is sent for further processing. The oil is collected with a portion cooled and sent back to the to the quench towers. Without adequate flow of cooled oil to the towers, the pyrolysis system became inoperable.

The quench circulation loop was designed to withdraw oil from the collection tank using a set of circulation pumps to forward the oil to plate-and-frame heat exchangers for cooling. The original heat-and-material balance was based on the assumption that up to 2 wt% of the liquid could contain pyrolysis reactions such as sludge and solids. The plant was built with a small filter primarily to remove sludge and solids entrained in the oil being transferred to export storage with intended flexibility to operate in a slip-stream mode recycled back to the collection tank, thereby helping to maintain restriction free circulation. Unfortunately, the characteristics of the sludge and solids were not well understood at the design phase such that the filter proved to be largely ineffective and the plate-and-frame heat exchangers had clearances that were too tight.

The sludge and solids in the quench liquid quickly built-up, plugging the heat exchangers and severely restricting oil flow to the quench towers. Cleaning the heat exchangers proved costly and ineffective at maintaining flow rates. At the time Valdes was called to evaluate the issue, the flow was so highly restricted that overall plant pyrolysis capability was reduced 95%.

Valdes offered process focused troubleshooting and engineering services to assess the situation, evaluate options and recommend the quickest, most cost-effective technology for design, procurement, and installation.

Assessing the Situation

Based on maintenance performed on the oil circulation pumps, local pressure indication, and attempts to clean and keep clean the plate-and-frame exchangers, it appeared that the accumulation of sludge and solids in the exchangers was the most likely cause of the restricted flow.

Potential reasons for the accumulation of sludges and solids in the exchangers were as follows:

- Ineffective and/or inadequate filtering technology
- Improper heat exchanger technology; plate-and-frame exchangers are prone to fouling
- Higher than expected production of sludges and solids
- Insufficient purging of sludge and solids in the circulating system
- Insufficient slip stream filter capacity
- Plating out of solids as the liquid was cooled in the heat exchangers

Although, information on the type, size, density and composition of the sludge and solids was unknown, samples showed that the sludge and solids were denser than the bulk liquid and would, therefore, separate by gravity.

Options Identified and Screened

The following options were identified and screened to alleviate the pressure drop issue in the quench liquid circulation:

1. Rate of solids removal
    a. Full quench stream solids removal
    b. Slip stream solids removal
2. Placement of solids removal
    a. Upstream of heat exchangers
    b. Downstream of heat exchangers
3. Solids removal technology
    a. Centrifuge
    b. Continuous roller press
4. Heat exchanger technology
    a. Spiral or Shell and Tube Exchanger

The screening analysis is summarized in Table 1.

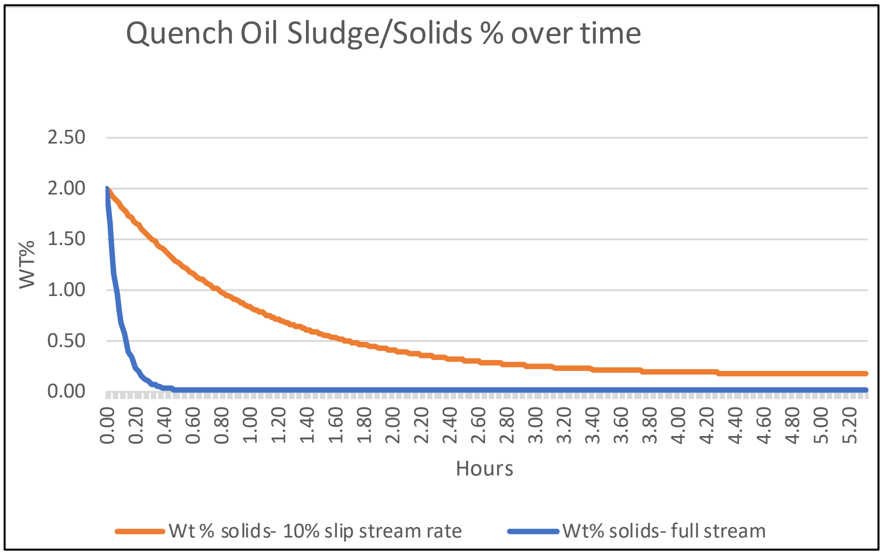
Table 1- Screening Analysis Table

Quench Oil Solids Decision Matrix							
	Full Stream	**10% Slip Stream**	**Upstream Coolers- Slip Stream**	**Downstream Coolers- Slip Stream**	**Slip steam Centrifuge**	**Slip Stream Continuous Roller Press**	**Heat Exchanger Design Change**
Advantages	• With appropriate filtering technology removes sludges and solids to an equilibrium concentration of ~0% in less than 1 hour of operation	• With effective filtering technology, removes sludges and solids to equilibrium of roughly 8% of produced concentration in ~4 hours of operation	• Piping is simplified. With full rate system, essentially eliminates any sludges and solids from entering cooler	• Piping is difficult	• Pending lab testing likely to remove solids • Skid mounted system with just power required • Possible rental skids available for testing • Parallel centrifuges can be added to increase flow rate for filtering	• Less complex than centrifuge • Skid mounted with just power required • Possible rental skids available for testing • Parallel centrifuges can be added to increase flow rate for filtering	• Least complex • Can handle relatively large amounts of sludge and solids • Does not change flow-scheme nor adds equipment
Disadvantages	• Capital Cost is high	• Capital Cost is lower	• Does not protect coolers from solids coming out of solution due to colder temperatures	• Potentially removes solids coming out of solution due to colder temperatures	• Relatively expensive compared to filter • Requires maintenance • Rotating equipment	• May not work given unknown characteristics of sludge and solids • Requires maintenance • Rotating equipment	• Most expensive • Physically difficult from a constructability and maintainability standpoint
Rough Order of Magnitude Equipment Cost	• Depending on slip stream size could be 5 to 7 times the cost of slip stream	• Depends on Technology	• Adds approximately 20% to cost over downstream filtering options	$500 K for centrifuge	$500 K	$500 K	$800 K

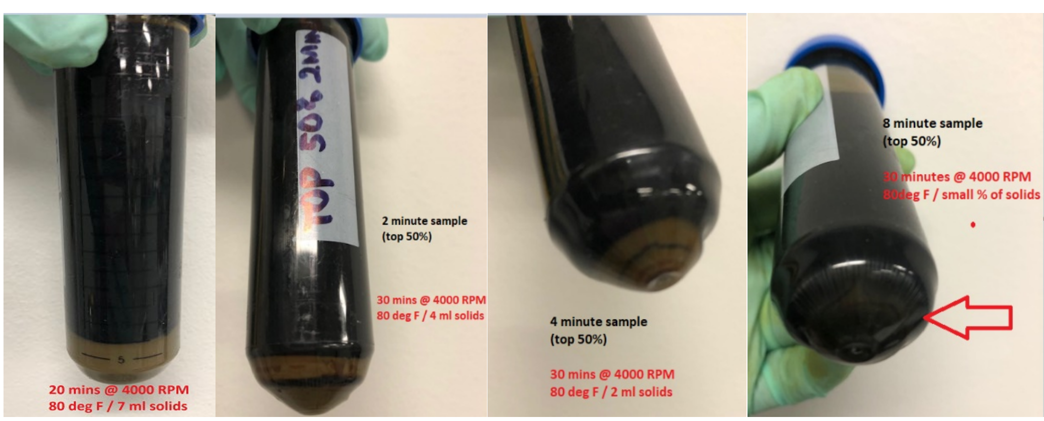
Further to Table 1, the screening analysis proceeded as follows:

- **Full Stream vs. Slip Stream -** Based on the concentration curves in Figure 2, a slip stream of roughly 10% of the flow produced a reasonably low concentration of sludges and solids relatively quickly, and, given the cost difference compared to the full stream option, became the logical choice.

Figure 2- Sludge and Solids Concentration as a function of Time



- **Heat Exchanger Replacement –** Due to cost and space constraints for construction and on-going maintenance, replacing the heat exchangers with a different type of exchanger was determined to be a last resort should a sludge and solids removal system not work.
- **Sludge and Solids Removal Technology –** An equipment technology firm was contacted to take a sample, and, based on results of lab testing, recommend a technology. The results were summarized as follows:
  - Temperature had little to no impact on the total suspended sludges and solids.
  - Based on spin test results, the technology firm indicated a centrifuge separation system would adequately separate the sludge and solids as shown below:



    - The tests showed that 50% of the solids were less than 40 microns. The plant had performed testing with sock filters and determined that filters of less than 200 microns plugged too quickly to be of practical use.
- **Location, Upstream or Downstream of Exchangers –** Based on the testing performed, temperature had little to no impact on total suspended solids, therefore, slip stream solids removal upstream of the exchangers was recommended.
- **Recommendation –** A disk stack centrifuge was recommended, which was estimated to remove about the same total solids as indicated in the four samples, combined.

Decision Support and Fast-Track Installation Details

A skid-mounted centrifuge was located, and arrangements were made to have it on-site within 10 days. This unit was procured on a rental basis with an option to purchase. Decision support provided to the client provided rational to rent the centrifuge and temporarily install it to prove out the concept. Support included the following:

- From a prior project in the same area, Valdes' laser scan data was available for locating equipment and piping.
- Based on the laser scan and complemental walkdowns, it was determined that existing filter piping and flange locations could be used to temporarily connect the centrifuge with hoses at the necessary flowrates.
- Because the plant was currently shutdown waiting for the centrifuge to arrive at site, a unique tie-in location and pipe detail plan was developed so that additional centrifuges, if needed, could be installed in the future while the plant was operating.
- Installation drawings for connections that included the flexibility described above were quickly developed and implemented by an on-site piping contractor.
- Depending on operational success, the client could proceed with purchase of the rental equipment, add additional centrifuges, or switch to a different technology.

Summary

With an eye to detail and applying troubleshooting skills, Valdes was able to determine the root-cause contributing to the reduced quench oil flow and identified a solution to improve the FOAK process design. This project resulted in a good solution and a very quick implementation to resolve the issue at hand with options should our client decide to add or revise the design after additional operational data becomes available. It takes an understanding of the process, appreciation of the uncertainties, and appropriate mitigation and testing to solve these special problems encountered by FOAK plants. Success was achieved through partnership with Valdes.

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