PRACTICE SHARING

FCC Safe Torch Oil Operations

Purpose and Use:

The purpose of this document is to share practices generally used to minimize the risks associated with using torch oil in the Fluidized Catalytic Cracking (FCC) unit regenerator. Improper use of torch oil has resulted in either an explosion or the release of a hydrocarbon plume that could have ignited under different circumstances. Special attention is given to providing guidance in the appropriate use of torch oil to frontline staff. Consider with caution the use of torch oil during abnormal unplanned situations using well thought out procedures in advance. Highlighting the key items for safe torch oil use in the FCC procedures (start up, shut down, and emergency) as well as in the operator training can help reduce the associated risks.

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Scope:

This Practice Share document applies to most, if not all, FCC units because torch oil is a common feature of these units. Users of this practice may decide to modify their operating procedures, operator training modules, and operator qualification requirements to assure the key aspects of torch oil use are well understood and documented.

Description and Implementation:

Introduction and use of torch oil is most common in standby modes 2 and 3, as defined in the FCC Standby Operations Practice Sharing document. Torch oil is also occasionally used during normal (on-oil) operations, in order to supply additional heat if heat balance challenged (i. e., very light feed and low coke operation). The primary risk associated with the use of torch oil in the regenerator is a lack of proper combustion leading to the formation of a fuel rich atmosphere in the unit which could encounter sufficient oxygen and an ignition source in an uncontrolled manner, leading to fire or an explosion.

The risk scenarios can be separated into five categories. While the most hazardous step associated with the use of torch oil is the initial introduction, as highlighted in categories 1 and 2, ongoing use of torch oil still has several hazards associated with it.

1. Lack of sufficient air flow to the regenerator.

The typical response to low regenerator temperature might be to introduce torch oil. This is especially true when the unit loses feed quickly and there is a desire to keep the unit in hot standby to bring it back online quickly. This response may lead to undesirable events if safeguards are not in place. If the unit has tripped due to a loss of air supply, or if the balance of fuel and air in the regenerator has been upset for some other reason that results in a loss of temperature, avoid the use of torch oil. Steps are taken to ensure proper conditions for complete combustion are confirmed before introducing torch oil to the regenerator.

Once torch oil has been introduced, continuous monitoring of the available air is maintained. For example, as the catalyst circulation rate increases during start up to heat the reactor, the torch oil flow is increased periodically to maintain the regenerator temperature. As the torch oil flow is increased, increases in the air flow may be required to achieve complete combustion. Combustion air flow rate / excess oxygen are monitored closely along with the other monitoring variables to confirm stable, full-burn combustion of the torch oil.

To ensure safe torch oil combustion, operations monitors regenerator temperatures, combustion air flow, torch oil flow, flue gas carbon monoxide content and flue gas oxygen content to maintain full-burn combustion.

Implementation:

- Operator training and emergency procedures highlight that regenerator excess oxygen is always checked and verified as being sufficient to sustain additional combustion prior to introducing torch oil to the regenerator.
- Torch oil flow, regen bed temperature and regenerator flue gas excess oxygen are included on the DCS Standby Startup Screen. Refer to the Practice Share document FCC Simplified DCS Screen for Standby Operations. A safety interlock may be added to the control system to reduce the chance of torch oil use at low air flow. Training on considerations for bypassing safety interlock functions during emergencies can help to prevent repetition of past incidents (torch oil introduction with insufficient air for complete combustion).

2. Lack of sufficient temperature to ignite the torch oil when it is introduced.

The heavy oils typically used for torch oil require sufficient temperature to vaporize and auto-ignite. If torch oil is introduced to the regenerator and does not ignite immediately, a large amount of combustible material can accumulate in the regenerator, migrate to the flue gas system and out the stack.

It is critical that torch oil combustion initiates at the point of introduction to the regenerator. If not, an uncontrolled ignition can occur due to several ignition sources depending on the scenario and unit configuration. For example, if the regenerator temperature is increased with the use of an air heater, such as would be the case during a startup, an explosion could occur when the oil eventually ignites via autoignition. If the temperature does not increase, the unit can be left in a situation with oil-soaked catalyst inside the regenerator.

Implementation considerations:

- All relevant procedures clearly state a minimum temperature for introducing torch oil to the regenerator. A typical target might be between 750°F and 800°F (400°C and 425°C).
- All relevant procedures clearly refer to temperature indicators (at the level of the torch oil nozzles) to monitor for signs of torch oil ignition within a given timeframe. For example, 'Monitor TI-000X - TI-000Y for a sharp increase in temperature when torch oil is introduced. If no temperature increase is observed within 3 min, stop torch oil flow
- All relevant procedures clearly refer to a required time delay, temperature increase and purge volume/time of the regenerator after any failed torch oil ignition attempt. For example, following any attempt to light torch oil, the regenerator temperature should be increased 20°F (10°C). The regenerator should be purged with at least 3 volumes of air or a minimum time period (e.g., 30 min) before re-introduction of torch oil allows residual hydrocarbon in the bed to dissipate.
- In addition to temperature monitoring, units that are equipped with CO_2 Continuous Emissions Monitoring at the regenerator flue gas outlet can use increases in CO_2 (as well as CO) as an indication of combustion, as it may indicate ignition before temperature increases are observed.

Operator training highlights the importance of having sufficient temperature to ignite the torch oil in the regenerator as well as the risks of allowing uncombusted oil to accumulate in the vessel if it does not ignite quickly.

3. Improper catalyst level or density at the point of torch oil injection

Catalyst present at the level of the torch oil nozzles can provide both an ignition source for the oil as well as a heat sink to protect the equipment from damage. Firing torch oil with insufficient catalyst level present could lead to combustible materials reaching the flue gas system.

Implementation:

- All relevant procedures state a minimum regenerator level or density for torch oil firing.
- Include a temporary alarm or other method to alert of operation below minimum bed level during and in advance of torch oil use.
- All relevant procedures provide actions to take in case the level drops too low, including a necessary timeframe for action. This could include the transfer of catalyst from the reactor back to the regenerator or discontinued use of torch oil. Typically, loading additional catalyst is not a sufficiently rapid response.
- Operator training includes the risks and procedural responses surrounding level/density control while firing torch oil.

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4. Torch Oil Quality

The most common sources of FCC torch oil are FCC feed, heavy cycle oil or main column bottoms. However, in some situations these typical sources may not be available. The use of low boiling-range material as torch oil can result in excessive vaporization prior to combustion, leading to burning or ignition in the upper regenerator/flue gas system. It is therefore important to ensure the right boiling-range material will be used as torch oil.

Implementation considerations:

- All relevant procedures state the distillation requirements for any material considered for torch oil use, along with the steps to verify the material meets the requirements if there is any uncertainty. An example of this would be:
- 5% pt > 390°F (200°C)
- 50% pt > 600°F (315°C)
- All relevant procedures and operator training should consider any recycle streams that may be placed in service between the feed system and gas plant during startup which may impact torch oil distillation properties.
- Operator training highlights the risk of using light oils as torch oil, which could potentially occur in an emergency situation under certain circumstances.
- Use a stable source of torch oil to avoid potential issues as conditions change throughout the start up. If this is not possible, all relevant start up procedures should highlight the risks and potential sources for quality changes during torch oil use so these can be understood in advance and considered while torch oil is in use.

5. Torch Nozzles Operation

The torch oil nozzles are designed to atomize the oil into a fine spray in order to aid combustion. Partial plugging of the distributors could lead to poor burning in the regenerator bed resulting in combustible material reaching the flue gas system. Furthermore, the number of torch oil nozzles in a regenerator will depend on the unit design, usually related to the regenerator diameter. In larger regenerators, if a significant portion of the torch oil nozzles are out of service due to inoperability/plugging, it is possible to locally consume all of the oxygen in the area of injection. In this situation, oxygen from other parts of the regenerator could mix with uncombusted hydrocarbons in the flue gas system, possibly resulting in an explosive mixture.

Implementation considerations:

- Damaged torch oil nozzles are replaced or repaired during turnarounds.
- All relevant procedures clearly state when purge steam to the torch oil nozzles is placed in service and when it is removed from service to avoid catalyst ingress and plugging
- In cold climates, torch oil piping is well insulated, and heat traced or blown clear and placed under inert purge when not in use to ensure the lines do not plug and are ready for service when needed.

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- All steam sources to the torch oil nozzles are dried to avoid nozzle damage or plugging in the nozzles from wet steam.
- Care should be taken to ensure torch oil spray does not impact regenerator wall or internals such as standpipes that could cause loss of containment. In addition, incorrect nozzle design, external piping or purge operations could result in regenerator hot spots and/or loss of containment.
- All relevant procedures clearly identify temperature indicators (cyclone inlets, outlets, and flue gas line) to monitor for signs of excessive combustion outside the catalyst bed. For example, Monitor TI-000X – TI-000Y to ensure the regenerator temperature profile does not show more than 50°F (25°C) post combustion. If excessive post combustion is identified while only torch oil is in use, adjust steam, air, and torch oil flow to determine if the issue can be resolved. In extreme cases, >200°F (100°C), alternative actions may be needed.
- Operator training includes the hazards of poor torch oil distribution, the methods for identifying it, and the proper response.
- If atomizing steam is used, all relevant procedures state the required steam pressure and the steam/oil differential pressure to prevent incomplete combustion as well as oil backflow to the steam system.

Other Considerations

I. <u>During Torch Oil Use</u>

- Upon initial introduction of torch oil, place one torch oil nozzle in service at a time, ensuring that ignition is achieved at each prior to proceeding to the next. However, when using torch oil, all nozzles that can be used should be placed in service, i.e., avoid leaving nozzles out of service because of low usage as much as possible.
- Once all the nozzles are in service, it is desirable to maintain smooth and continuous control of the torch oil flow while it is in use. Large temperature variations or “batch” operation of the torch oil is avoided along with manual flow control using gate valves.
- The torch oil valve position is monitored along with its flow rate (if a meter is available). Flow meters in this service are not used frequently and the supply pressure can fluctuate, especially during start up. Therefore, the measured flow rates are often unreliable.

II. <u>Post Torch Oil use</u>

- After torch oil is taken out of service, the supply lines are isolated with block valves in addition to the control valves (blinding if necessary). Proper isolation is verified to assure there is no leakage into the process.
- As part of torch oil isolation from the process, the torch oil piping system is flushed with a low pour point material to prevent solidification and blockage.
- Consider modifying torch oil nozzle purge gas line-ups after use to assure adequate, yet not excessive, purging of the nozzle tips and sleeves to prevent plugging. The purge gas rate is regulated with a properly sized restriction orifice.

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III. Safety Instrumented Functions

Consider providing the following Torch Oil trips and startup permissive on:

- High Regenerator Temperature
- Low Regenerator Temperature
- Low Dense Bed Level
- Low Total Air Flow

IV. Elimination of potential downstream ignition sources

CO boilers and ESPs (Electrostatic Precipitators) represent potential ignition sources for explosive hydrocarbon/air mixtures. Consider steps to monitor and, if necessary, remove ignition sources from the flue gas pathway. These can include bypassing these facilities during torch oil use, or the use of high CO trips to deenergize ESP's.

V. Elimination of other uncontrolled hydrocarbon sources

Routine flue gas (Lower Explosive Limit) LEL measurements (if available). Maintaining the Reactor pressure above the Regenerator to prevent reverse flow of hydrocarbon from the Main Fractionator or Gas Recovery Unit. The air-line heater is equipped with a Burner Management System (BMS) to shut down the fuel to the air-line heater if the flame goes out.

Implementation Checklist

Use the following checklist to benchmark FCC training, operating procedures, and equipment design to ensure implementation of the items outlined in this practice share.

Procedures

Torch oil light-off and use

- ☐ Warning statements are provided regarding the hazard of accumulating unignited torch oil (TO) on the regenerator bed
- ☐ Specify changes to purge/atomization gas line-ups required for torch oil (TO) introduction
- ☐ Downstream ignition sources removed during TO use (ESP, CO boiler, etc.)
- ☐ Place 1 nozzle in service at a time, equalizing flow to all in-service nozzles
- ☐ Specify required material and boiling range to be used for torch oil
- ☐ Specify required conditions of air rate, bed temperature(s), bed level, bed density, superficial velocity, etc. before TO introduction.
- ☐ Specify monitoring points for indication of ignition (TI's, CO_2, O_2). Specify which Tis are associated with each TO nozzle.
- ☐ Specify allowed time to attempt TO ignition (e.g., 3 – 5 min), and if ignition not observed, required purge time and temperature increase before retrying

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- Procedures state required steam/oil differential pressure to prevent oil ingress to the steam system

Torch oil removal and isolation

- Torch oil removal and isolation: procedure for blocking torch oil from nozzle tips, potentially including blinding
- Torch oil removal and isolation: specify line-ups for proper torch oil nozzle purging. N_2 purging is preferred in cold climates.
- Torch oil removal and isolation: flush torch oil piping system with low pour point material to prevent solidification.

<u>Training</u>

- Combustion basics: fire triangle, limiting component(s) to prevent ignition.
- Hazard awareness for torch oil introduction and use, including a summary of prior incidents
- Procedure training for proper introduction, use, removal, and isolation of torch oil

<u>Equipment, Piping and Design</u>

- Design to minimize regenerator wall erosion (e. g. protective collar around nozzles)
- Proper tip design for spray pattern and atomization
- Sufficient number of nozzles distributed around circumference for proper coverage across the bed
- Torch oil nozzles at proper elevation to assure sufficient bed level above and distance from air grid below
- Facilities for isolation and flushing of piping system with low pour point material post torch oil use
- Facilities for adequate nozzle purging when not in use (tip and annular sleeve purge if applicable).
- Restriction Orifices (RO's) sized for proper and not excessive purge rate.

<u>Control System</u>

- Permissive and/or shutdown system for torch oil. Torch oil trip initiators may include low air rate, low bed level, low temperature, etc.
- FCC SIS system isolates torch oil for all trip initiators that divert feed and stop circulation
- ESP SIS system provides proper protection during TO use. Consider trip functions for TO use (e.g., valve position), inlet CO, and/or other volatile components at inlet (e. g. methane).

References:

AFPM Event Sharing Database items #523 and #575 on the AFPM Safety Portal.

Practice Share document, *FCC Non-Routine Operations Standby Checklist* available on the AFPM Safety Portal at https://safetyportal.afpm.org/File/1714/1

Practice Share document, *Simplified DCS Screen for FCC Non-routine Operations* available on the AFPM Safety Portal at https://safetyportal.afpm.org/File/1676/1

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Revision	Date	Summary of Changes
Initial Draft	August 2024	Initial Version
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