TRACERCO Diagnostics™
FCCU Study

Introduction
The Fluidized Catalytic Cracking Unit (FCCU) is the economic heart of a modern refinery. Even small increases in its yield can bring about significant overall gains in productivity and revenue.

Tracerco is a world leading industrial technology company providing unique and specialized detection, diagnostic and measurement solutions.

A TRACERCO Diagnostics™ FCCU Study will provide you with the information you need to optimize or troubleshoot your specific process:

- All testing is performed while the FCCU is online.
- There is no interference with normal unit operations or production scheduling.
- Data collected can be used to identify operating parameter changes to improve unit productivity or gauge the accuracy of process modeling and simulation.
- Tracerco’s experience involves numerous studies performed on units worldwide.

A typical study may employ upwards of 75 detectors, measuring almost the entire system from a common injection point. The tagged process stream can be followed completely through either the Reactor or the Regenerator.

For example, tracer material injected into the riser can provide:

- Catalyst and vapor traffic velocities and slip ratio through the riser

- Determination of efficiency of the riser termination device
- Flow distribution through the reactor and stripper
- Cyclone distribution/operating characteristics
- Reactor/stripper residence times

Vapor traffic is tagged using an inert gas. The catalyst traffic may be tagged using system native catalyst – E-Cat, Fines, or any specific particle size distribution – which has been activated by Tracerco.

TRACERCO Diagnostics™ FCCU Studies utilize both sealed source and tracer technologies. A typical study will use these technologies to measure the density of the catalyst/vapor mixture, and the velocity, distribution, and residence time of the catalyst and vapor through each part of the FCC including:

- Reactor Riser
- Reactor
- Reactor Stripping Section
- Regenerator
- Spent Catalyst & Regenerated Catalyst Standpipes

The operation of the associated downstream Main Fractionator column can also be investigated using Tracerco’s TRU-SCAN® technology.

In order to offer our customers a rapid response we operate from a number of regional bases strategically close to major industrial centers.
TRACERCO Diagnostics™
FCCU Study

**Reactor**
- Cyclone Operation and Distribution Study
- Catalyst Bed Level Measurement
- Efficiency of Riser Termination Device
- Residence Time

**Regenerator**
- Cyclone Operation
- Cyclone Distribution Study
- Catalyst Bed Level Measurement and Extent of Bed Dilute - Phase
- Catalyst and Air Distribution Study
- Residence Time

**Spent Catalyst & Regenerated Catalyst Standpipes**
- Catalyst Slugging Study
- Catalyst Density Profile

**Stripping Section**
- Density Profile
- Catalyst and Vapor Flow Distribution & Residence Time

**Reactor Riser**
- Riser Density Profile
- Catalyst and Vapor Distribution
- Catalyst and Vapor Velocities (Slip Ratio)
Reactor Riser: Scanning Density Profile and Flow Distribution

Riser Density Profile: TRU-SCAN®
Poor fluidization or poor mixing of catalyst and oil causes localized variances in the oil-to-catalyst ratio and cracking reactions. The over-cracked portion of the feed generates low-value light components, while at the same time the under-cracked portion produces more residue.

A TRU-SCAN® of the riser provides the catalyst density profile up the length of the riser. Results illustrated in Figure 1 show the density profiles at high and low steam rates. In this example, the aerated catalyst density in the riser feed zone at scan elevation 13-18 ft. decreases with the higher steam rate. The scan also indicated that the feed expansion zone covered approximately 8 ft. from the feed nozzles.

Catalyst and Vapor Distribution: Tru-CAT™ Scan
This method generates a detailed cross-sectional density profile of the reactor riser at a fixed elevation or riser cross section.

The information is used to determine the uniformity of distribution between the catalyst and feed and to identify flow inefficiencies, such as catalyst mal-distribution. A Tru-CAT™ Scan is often used to evaluate changes in design and operation of feed injection or lift steam nozzles. An example of this is shown in Figure 2, where two Tru-CAT™ Scans were performed, one with all six feed nozzles open and another with one of the nozzles shut (nozzle #3) to simulate a plugged or fouled nozzle.

Figure 1: TRU-SCAN® detector placement and density profile.

Figure 2: Tru-CAT™ Scan simulated plugged nozzle.
One common application applied to an FCCU is measurement of stream velocities. Ideally, catalyst and vapor should be in plug flow condition to eliminate back-mixing, which can produce undesirable secondary reactions. However, because of its greater density, the catalyst always flows up the riser at a lower velocity than the vapor. This phenomenon is known as “catalyst slip”. An ideal plug flow riser should have a slip ratio of 1.0. Discrepancy from 1.0 or design expectation is often used as a measure of the fluidization performance. The slip factor can be determined by measuring the velocities of the vapor and catalyst via a TRACERCO Diagnostics™ Flow study. Figure 4 represents test results that involve two tracer injections, one for the oil vapor phase and the other for the catalyst phase. The velocities of the vapor phase and catalyst phase are measured over the same section of the riser.

![Diagram of reactor riser with tracer injection and detector positions.]

**Figure 3:** Riser traffic velocity tracer test detector positions.

**Figure 4:** Riser traffic velocity.
Cyclone Operation: TRU-SCAN®

The loss of catalyst through the reactor cyclones is a fairly common problem. Identifying the reason for the loss is often difficult. TRU-SCAN® gamma scans can be a powerful tool for gathering essential information about the problem. In Figure 5, four TRU-SCAN® gamma scans were performed to obtain a density profile of each reactor cyclone. The scans identified that there was one plugged cyclone and a dipleg that was full of catalyst.

Catalyst Bed Level Measurement

TRU-SCAN® gamma scans can be performed to obtain information on the reactor or regenerator bed levels. In the example below, operations personnel were suspicious of the calibration of the level gauge. Results from the three scans performed (Figure 6) found that when the instrument reading was 100' pressure (the normal level reading until recently), the bed was too low and the diplegs were uncovered. The TRU-SCAN® results helped recalibrate the level instrument and avoid a shutdown.

Figure 5: Reactor cyclones distribution study.

Figure 6: Tru-Scan® results assist with level instrument calibration.
Cyclone Distribution Study

Since FCCU’s have been modified to achieve the cracking reaction in the riser instead of the reactor, the reactor’s present-day role is to minimize post riser reactions by providing efficient catalyst/hydrocarbon disengagement.

A TRACERCO Diagnostics™ Distribution study is used to determine relative amounts of vapor or catalyst traffic entering the primary reactor cyclones. A group of radiation detectors are placed at the cyclone inlets and outlets (Figure 7). Usually only the primary cyclone inlet and the secondary cyclone outlets can be monitored, because the cyclone pairs are internally coupled. For a normal cyclone system, each of the primary cyclones should receive the same amount of vapor and catalyst traffic, so all of the detectors should receive the same amount of tracer radiation response. Comparing the integration of the areas beneath each of the distribution detector responses allows identification of flow mal-distribution (Figure 8).

Figure 7: Illustrated above is a typical set-up showing the placement of radiation detectors used in a TRACERCO Diagnostics™ Distribution study.

Figure 8: The TRACERCO Diagnostics™ Distribution study illustrated is an example of a typical distribution profile exhibiting mal-distribution at the Reactor cyclone inlets.
Stripping Section: Scanning

Density Profile

The Spent Catalyst Stripper is designed to prevent hydrocarbon from being carried from the reactor to the regenerator with the catalyst. Steam is injected counter current to the flow of catalyst to strip the hydrocarbon adsorbed onto the catalyst.

A Tru-Grid™ Scan of the reactor stripping section can identify differences in the density of the aerated catalyst to show if mal-distribution of the stripping steam is occurring, if excessive catalyst hold-up is occurring on any of the trays and if the trays are in place. In a Tru-Grid™ Scan, four scans are performed through the stripper in an orthogonal grid pattern (Figure 9).

When the results of the four scans are overlaid on a single plot (Figure 10), areas where the scan results do not overlay are areas of the stripper where the aerated catalyst density is different. The absence of low density areas under each tray is an indication of flooded trays.

Figure 9: Tru-Grid™ Scan detector placement.

Figure 10: Response profiles.
In the stripping section, trays or packing, are installed to improve the stripping efficiency. Steam/catalyst distribution can be inferred from the Stripper Tru-Grid™ Scan results previously described. However, if superficial velocities and mean residence times are to be measured, then the relative steam/catalyst distribution can be measured using a tracer injection technique. Uniform distribution of catalyst and steam in the stripper is critical to achieve high stripping efficiency (less carry-down of the hydrocarbon products from reactor to regenerator).

A TRACERCO Diagnostics™ Distribution study of the stripping section of an FCCU requires two groups of radiation detectors (four or more detectors for each group), placed respectively at the top and bottom of the stripper (Figure 11). The steam and catalyst response profiles can be overlaid and interpreted for superficial velocity and distribution (Figures 12 and 13).

Figure 11: Detector placement.

Figure 12: Catalyst flow and distribution.

Figure 12 and 13: Study of the catalyst and steam flow requires two tracers injected separately, one for tracing the catalyst and one for tracing the steam.

Figure 13: Steam distribution.
Regenerator: Scanning

Catalyst Bed Level Measurement

The dense bed level elevation in a Regenerator can be determined with the sealed source TRU-SCAN® and Tru-Grid™ Scan technology (Figure 14). The TRU-SCAN® will produce a density profile at the catalyst bed level area that will indicate dense phase and dilute phase levels. It can be performed over varying operational conditions to assess the changes in level and help calibrate level control.

By using four scan lines in a grid arrangement (Figure 14), a more accurate indication of the Regenerator’s catalyst bed level can be determined. Overlaying the four scan lines will identify the dense and dilute phase catalyst levels and determine if the levels are uneven which may be indicative of air mal-distribution and air grid problems (Figure 15).

Cyclone Density Study

As with Reactor Cyclones, a TRU-SCAN® can be performed on each Regenerator Cyclone to search for high catalyst levels in diplegs or plugged Cyclones that will explain high catalyst loss.

Figure 14: Illustration of a Tru-Grid™ Scan orientation used on a Regenerator.

Figure 15: Tru-Grid™ Scan results to determine the Regenerator catalyst bed level.
Air Flow and Distribution Study

A TRACERCO Diagnostics™ Flow study can measure several flow parameters around the Regenerator with a single injection of radiotracer. For example, both the air rate and flue gas rate can be determined simultaneously with a study of the air distribution from the air grid and/or the vapor distribution to the cyclones.

This is accomplished by placing a group of detectors at a known distance apart on the air supply line to the Regenerator and another set on the flue gas line leaving the Regenerator (Figure 16). The flow rates will be calculated by converting the measured velocities to volumetric flow with respect to line diameter, process pressure and temperature.

Figures 17 and 18 illustrate vapor distribution test results from when eight detectors were positioned near the eight primary cyclone inlets (Figure 17) and twelve detectors were positioned in a ring just above the upper air ring (Figure 18). Test results showed that some detectors had much larger responses than others, indicating mal-distribution.

Figure 16: Detector placement.

Figure 17: Vapor distribution at cyclone inlets.

Figure 18: Vapor distribution above air grids.
Spent & Regenerated Catalyst Standpipes: Scanning

Catalyst Stationary Monitoring Slugging Study

This test uses TRU-SCAN® technology designed to measure density variations over time as the catalyst circulates. A small source and detector are positioned vertically on the standpipe being inspected and the transmitted radiation is continuously monitored (Figure 19). Fluctuations in the transmitted radiation are recorded and provide a relative measurement of the fluid density variations within the pipeline over time (Figure 20).

The case study illustrated in Figure 20 was performed because of catalyst circulation problems. A TRU-SCAN® stationary monitoring test was designed to observe and record density fluctuations. The sources and detectors were positioned and connected to a computer to collect data over time. These results justified a short outage where a hole was found in the overflow well. The hole allowed air to leak into the downward flowing catalyst and be entrained into the standpipe. Operations can also make changes to the re-circulation rate to see the effect of the fluidized flow density profile in the standpipes.

Figure 19: Set-up for slugging study.

Figure 20: TRU-SCAN® stationary monitoring test results justified a short outage where a hole was found in the overflow well.
Spent & Regenerated Catalyst Standpipes: Scanning

Catalyst Density Profile

A TRU-SCAN® of the spent catalyst standpipe can be performed to investigate the cause of circulation problems. Scan results from two scans of a spent cat standpipe showed an increase in density in the standpipe, but the red scan (N-S vertical scan, Figure 21) showed an area of very low density below the area of high density. This was theorized to be a blockage that caused the catalyst to flow to one side of the standpipe, leaving the area under the blockage clear of catalyst. With this information, a shutdown was authorized and a large piece of refractory was found to be causing the blockage.

Figure 21: A TRU-SCAN® of the spent cat standpipe can be performed to investigate the cause of circulation problems.
Tracerco has provided gamma scanning services worldwide to evaluate trayed and packed towers to identify damage, fouling, flooding, mal-distribution and many other problems that can exist inside of the tower. This service is provided online, externally to the column, with no interference to normal plant operations. The ability to accurately determine what is happening inside the column, without having to shut it down for a visual inspection, effectively provides our customers with ‘insight onsite’.

A Main Fractionator was not operating properly at normal capacity and was showing symptoms of flooding from tray 2 (red curve, Figure 22). Tracerco’s TRU-SCAN® application pinpointed the location of flooding that was probably due to fouling (coking).

After the Main Fractionator was cleaned, a baseline scan (blue curve) was performed to use for future diagnosis of coking problems at an earlier stage before the flooding reached such a severe condition.

A scan a few months later (green curve) showed that Tray 2 was again starting to show the same problem with coking and the subsequent liquid hold-up and flooding. Using this data, plant operations and maintenance were able to determine where the limitation in the column was occurring and prepare corrective action.

Figure 22: TRU-SCAN® baseline and troubleshooting results provided operations and maintenance personnel advance warnings of approaching problems so they could prepare for corrective action.
Main Fractionator: TRACERCO™ LevelFinderPlus

Tracerco provides a range of specialist measurement solutions to the process industry, measuring key parameters such as level, density and interface. These instruments are all non-wetted devices, allowing them to be used in the harshest of process conditions such as high temperatures, slurries and corrosive materials.

**TRACERCO™ LevelFinderPlus**

The TRACERCO™ LevelFinderPlus, which provides real-time measurements, has been applied to FCC Main Frac towers to measure the bottom liquid level. The gauge is mounted externally on the tower for easy retrofit or new build installation. There are no moving parts, which eliminates the possibility of mechanical failure or fouling by debris such as coke.

The inaccurate measurement of a tower’s base liquid level is one of the most problematic causes of tower malfunctions. In an industry survey problems with the tower base and reboiler return was the number 2 cause of tower malfunctions. Tracerco, relying on its developed expertise in radiation detection instruments has a range of reliable nuclear instruments including liquid level instruments. If you have a particularly challenging or troublesome base liquid measurement application, contact a Tracerco Technical Advisor in your area.
A worldwide network of agents and service partners enable Tracerco to deliver its products and services to our customers anywhere in the world, while still retaining the important aspect of local service.

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