ASTRON INTERNATIONAL

Refining Online®

Managing FCC Reliability and Run Lengths

CatCracking.com

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Who is Astron?

- Delivering solutions to the refining industry since 1995
- Founded by Atulya Saraf & Rajul Rastogi
  - Chemical engineers, previous FCC design experience at Stone & Webster
  - Specializes in web applications for technical service needs
- Formed Refining Consulting Division in January 2008
  - CJ Farley brought in to lead consulting effort
    - More than 20 years FCC experience in operations, design/technical services, and catalyst manufacturing

The Reliability Challenge and Meeting Your Run Length

- Demands for process personnel's times have gone up dramatically in last 20 years
  - Management of change
  - Process Hazards Analysis
  - Environmental reporting
  - Lack of process engineers in refining
  - Process engineers are also younger on average
- Success for refiners is not usually measured by 'only' making 1 % more gasoline
- Instead, its…
  - Maintaining or reducing emissions,
  - Improving unit uptime or availability,
  - Operating within the plan,
  - AND making 1 % more gasoline

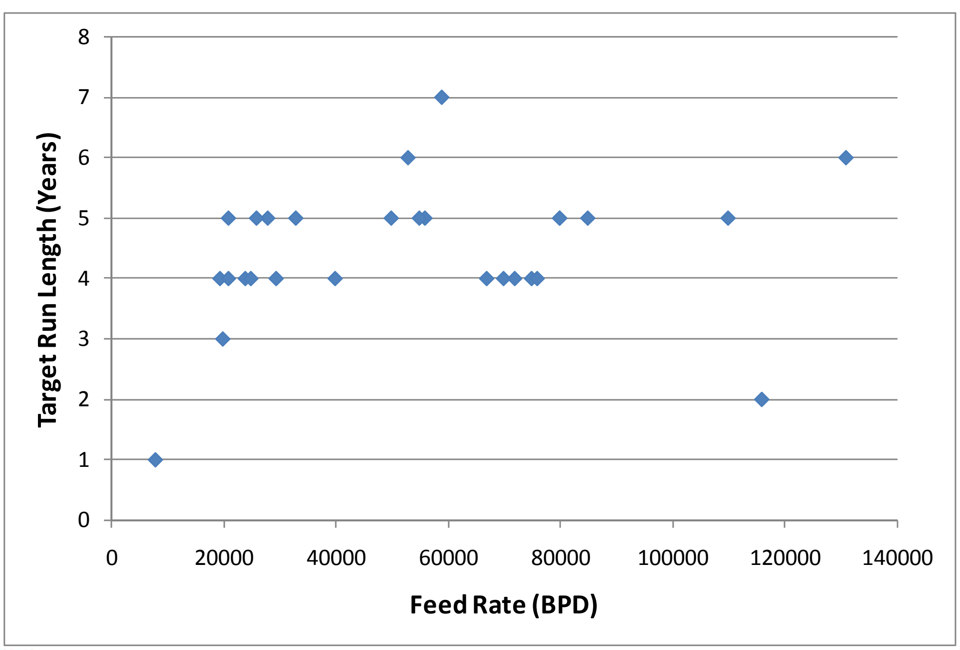
How Refiners Have Managed Reliability

- Reliable operation meets production targets, run lengths, and allows proactive management and planning of unit turnarounds
- How do you accomplish reliability with an already overstressed workforce?
  - When proactive management has been practiced, most organizations have been outsourcing, by…
    - Hiring contract employees (could be a centrally located cost center employee, not a locally based refinery based operation)
    - Leveraging catalyst suppliers or E&C providers

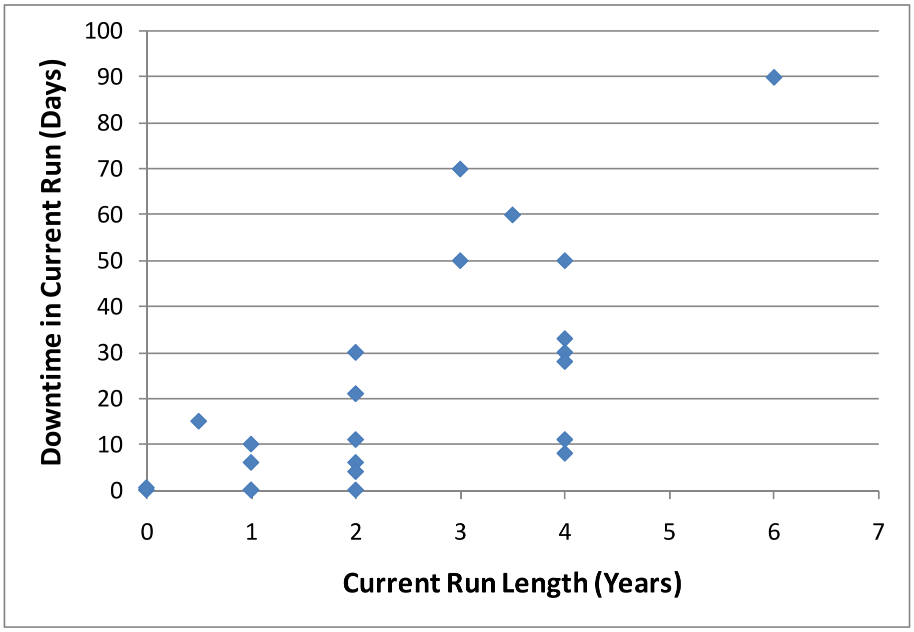
What Helps Create "Good" Reliability Metrics

- Two key behaviors identified to date:
  - avoiding short term outages that have a chance to develop into something more serious
  - Monitoring unit condition routinely to head off problems before or as they develop (ie, health checks)
    - Not taking the unit outside a reasonable operating envelope and understanding what those limits are

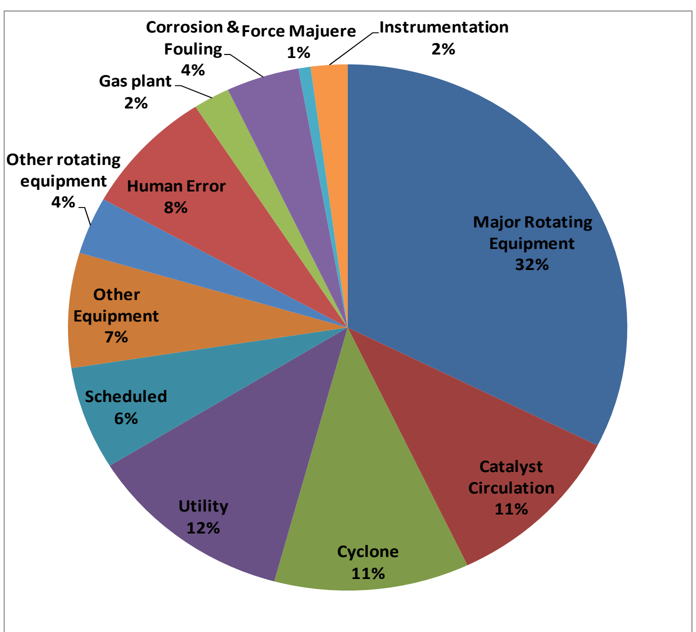
Feed Rates and Run Lengths (to show breadth of survey only)



Downtime vs. Current Run Length



What brings the FCC down? Not always what starts a turnaround



Major rotating equipment includes wet gas compressor, air blower, and expander (if present)

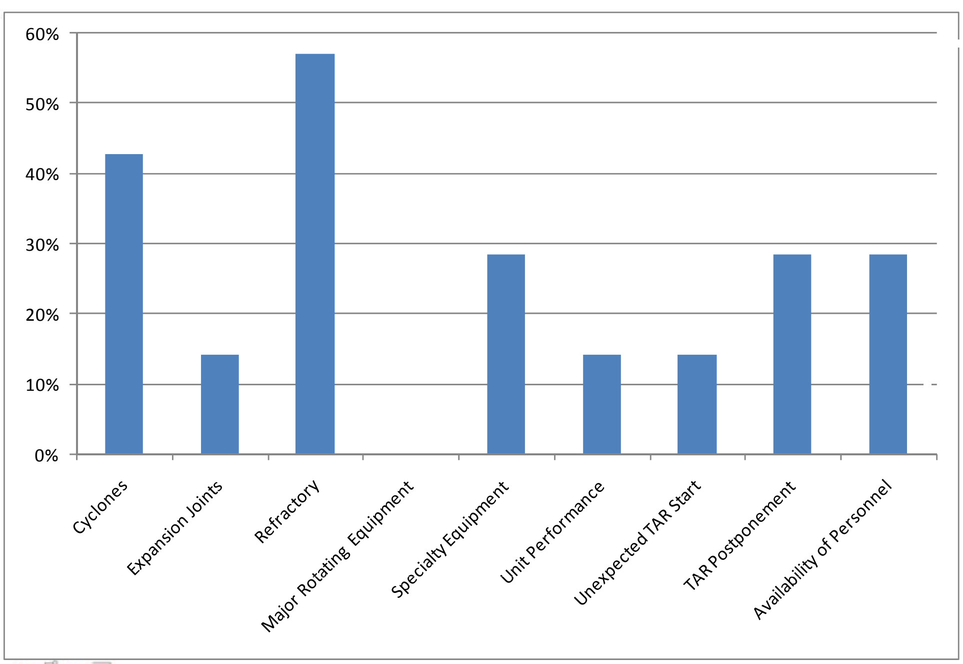
Major rotating equipment is ~ 50% air blower related, 33 % expander, ~ 17 % wet gas compressor

Data from ~ 15 % of the refining industry presented (~ 65 units)

Major Rotating Equipment

- Includes air blower, wet gas compressor, and expander
  - Air blower results surprising
- Industry loss data still dominated economically by rotating equipment failures
  - Not a high incident rate, but LONG downtimes when they do take place (check valve failures still on list from ~ 20 years ago)

Concerns Reported by Units Heading into Turnarounds



Over half concerned about refractory

No concerns from units on major rotating equipment

Adds to more than 100 % as several refiners made multiple selections

The Long Term Problem with "Short" Outages

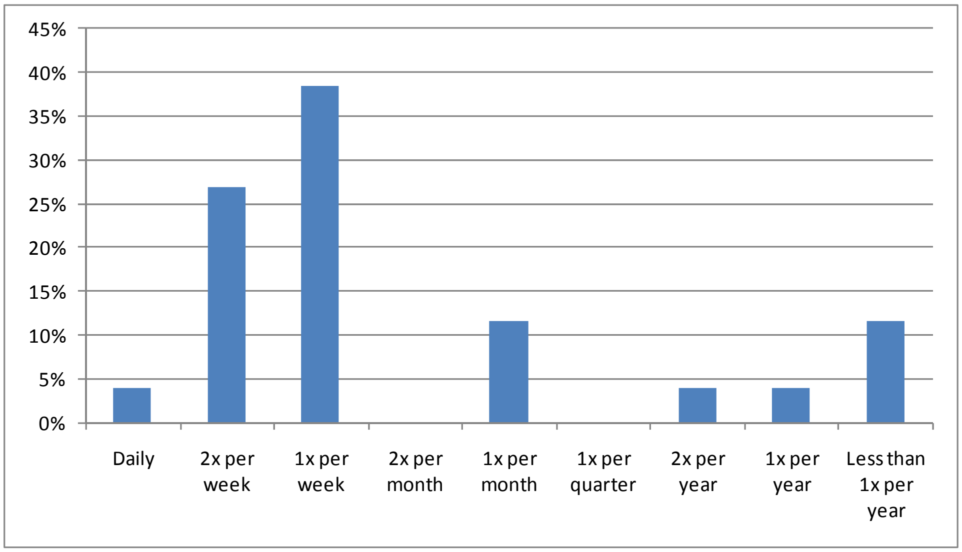
- "Simple" FCC outages develop lingering problems 10-15 % of the time.
  - Plugging distributors, rotating equipment damage, refractory or coke spalling are common examples

- Each time you cycle the unit, there are many chances to create this lingering problem
- The BEST operations and maintenance teams will eventually suffer a failure given enough chances.

FCC Health Checks and Unit Monitoring

- What is a health check?
  - Test run that looks at:
    - Yields
    - Equipment performance
    - Looks for unit trouble that has occurred or might be developing
- How often should you do?
  - More frequently is better
  - Must have historical view – what has changed?
- Why should you do it?
  - Lot of work, you will break a sweat
  - Important to predict future unit performance & can mean the difference in meeting your operating plan & budget

Performance Test Run Frequency



~ 70 % once a week or more frequently

~ 20 % every 6 months or less frequently

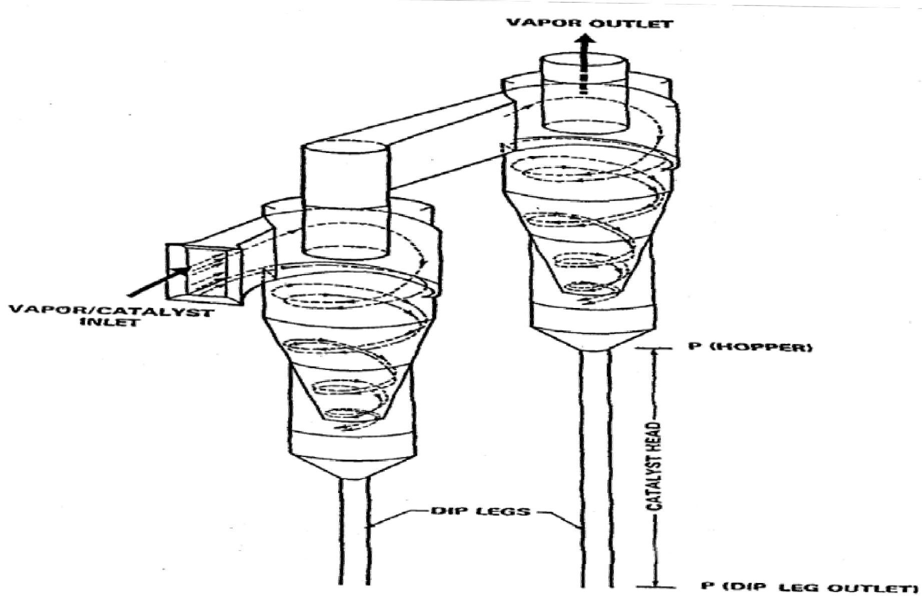
Health Check Topics

- **Shutdown causes give a good idea of what should be checked**
  - **Cyclones & Catalyst material balance**
  - **Major distributor performance**
    - **Feed nozzles, air grid, stripping steam at a minimum**
  - **Major rotating equipment performance**
- **Also look at yields & how they compare to expected and historical**

Cyclones & Catalyst Material Balance

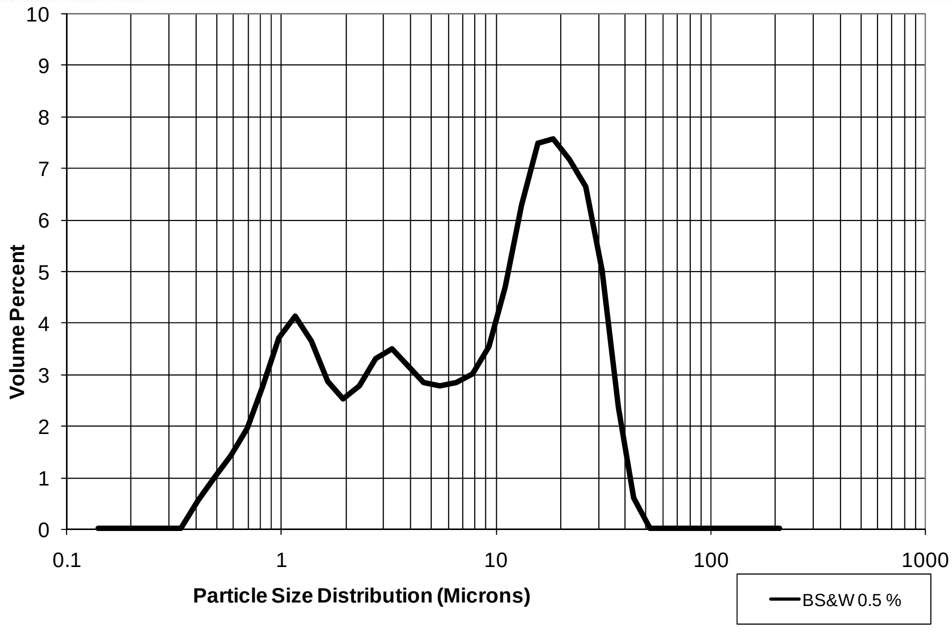
- Catalyst material balance important
  - Know additions, withdrawals, and losses
  - Go one step further, calculate differential particle balance
- Monitor:
  - Pressure drops
  - Dipleg levels
  - Inlet & outlet velocities
  - Calculated efficiencies
    - Total losses per side vs loadings
    - 99.997 % or higher is target

Typical FCC Cyclone Pair



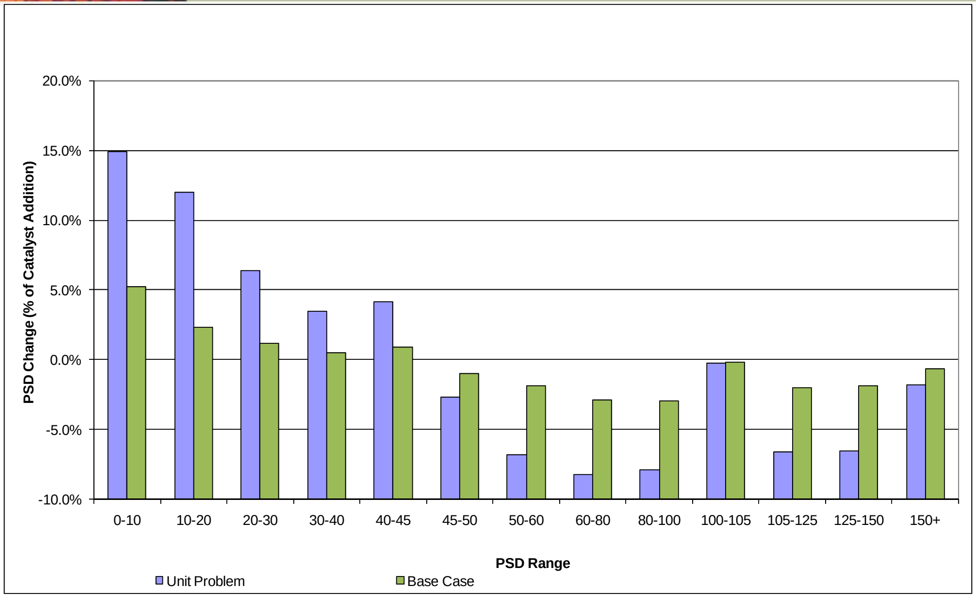
Erosion at Top of Dipleg Most Common Cyclone Failure

Typical Slurry or Scrubber Solids



Monitor over time – do peaks shift left or right, or get larger?

Calculate Differential Catalyst Particle Size Generation Rates



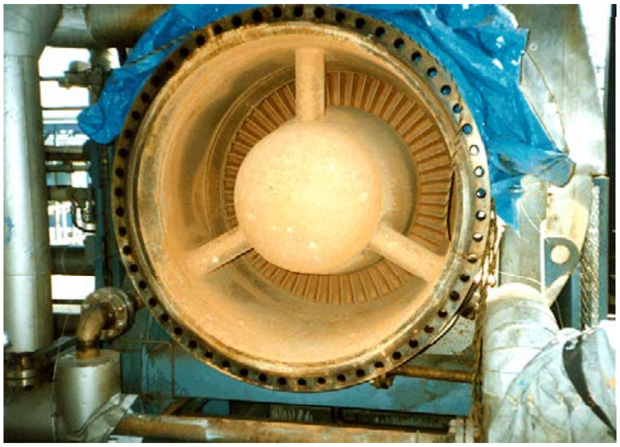
Base case important when looking at potential unit problems

Major Rotating Equipment

- Air blower, wet gas compressor, and expander
  - Air blower results surprising in terms of outages outside the US
- At a minimum, look for trends in vibration
- Health checks should look at:
  - Flow vs discharge pressure, horsepower
    - Plot on design curve, look for changes over time
  - Look for changes in efficiency, might indicate fouling or erosion

Rotating Equipment Maintenance

- Major rotating equipment repairs can be costly & time consuming
- What is the preventative maintenance strategy?
- How do you control fouling & erosion?



Expander Erosion

- Erosion caused by large particles (> 10 microns)
- All expanders suffer from erosion
- Statistical run lengths are ‘short’ relative to rest of unit, but technology has improved dramatically over 20 years

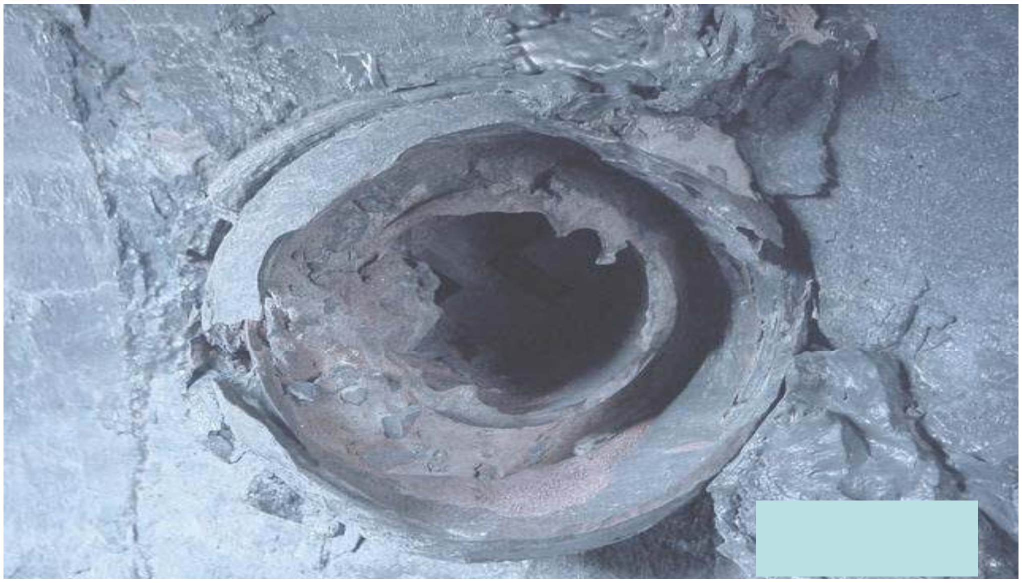
Distributors

- Three main distributors of interest (feed, air, stripping steam)
- Feed Distributors
  - High Vapor Outlet Velocities (100-250+ fps)
  - Generally low attrition source
- Stripping Steam and Air Distributors
  - High Vapor Outlet Velocities if partially plugged, poorly designed or operated at very high flow
- Many other distributors in the unit
  - Half of the FCC design is distributor work

Distributor Performance Checks Required

- Inlet Pressure
  - Should agree with Calculated based on expected pressure drop accounting for inlet pressure
- Inlet control valve position consistent with distributor flow? No changes over time that are unexplained?
- Outlet velocity
  - If flow rates are being pushed over time, outlet velocity can be high enough to be a concern
- Orifice velocity

Eroded Feed Nozzle Cap



Eroded Air Distributor Nozzle

Yields

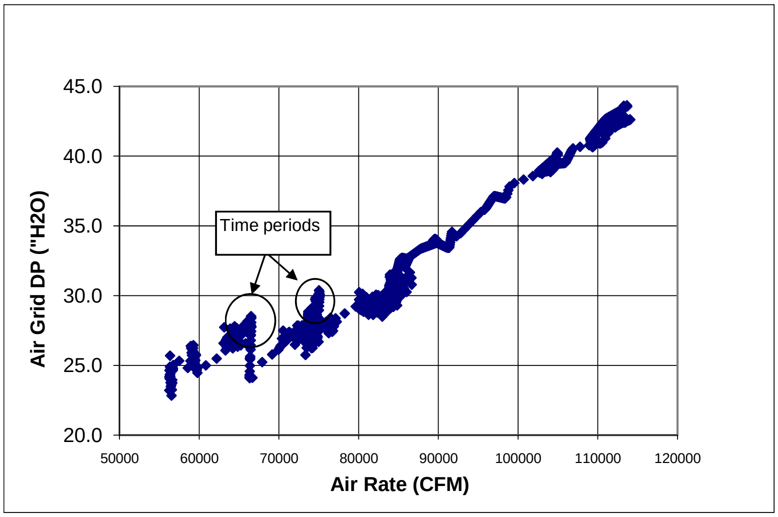
- Yield shifts over time can indicate trouble
  - Conversion & coke selectivity shifts?
  - Distillation gaps?
  - Carbon levels on catalyst & distribution?
  - Volume gain?
- Feed monitoring can help
  - 10 years ago, popularity of HPLC has led to multiple theoretical potential conversion calcs, but that instrument is essentially non-existent today
  - Be careful not to over interpret value of theoretical conversion

Know how coke is being made in your unit - overall coke yield set by enthalpy balance (KBC Profimatics FCC-SIM output)

Profiles		Unit 1 Gas Oil with high preheat	Unit 2 Resid with catalyst cooler
Coke	---		
-Total	**Wt %**	4.06	6.52
-Catalytic	**Wt %**	59.45	20.78
-Feed Concarbon	**Wt %**	4.24	13.30
-Metals	**Wt %**	6.31	50.92
-Stripper	**Wt %**	30.00	15.00
-Non-Vaporized Feed	**Wt %**	0.00	0.00
Conversion	**Vol %**	82.54	68.51

Lower catalytic coke yield is an indicator of being further away from maximum conversion, as determined by feed properties

Example of FCC Reliability Analysis – High Catalyst Loss from Regen upon Restart

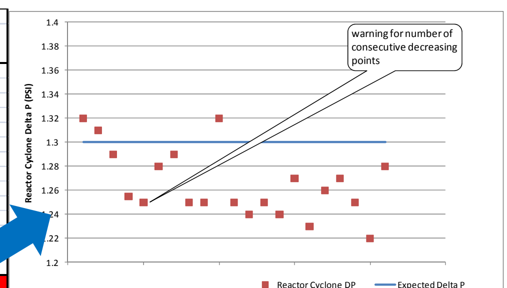


Intermittent air grid plugging taking place

Results in restricted dipleg operation as well as high localized velocities

Example of Reliability Analysis – Catalyst Losses Elevated Mid-run

Reactor Cyclone Operation	Max during report	Min during report	Avg during report	Industry Max	Industry Min
1st Stage Inlet (fps)	67	43	55	65	45
2nd Stage Inlet (fps)	79	45	65	75	55
1st Stage Outlet (fps)	67	43	55	65	45
2nd Stage Outlet (fps)	135	100	127	150	-
1st Stage Dipleg Flux (lbs/ft2-sec)	180	90	110	125	30
Clear 1st Stage Dipleg Remaining (ft)	13	6	9	-	3
Clear 2nd Stage Dipleg Remaining (ft)	11	1	8	-	3
	Max during report	**Min during report**	**Avg during report**	**Normalized to base conditions**	**Alerts**
Combined Cyclone Pressure Drop (psi)	1.9	0.7	1.4	1.3	-6% rate of change
Overall Collection Efficiency (%)	99.9995	99.97	99.9975	-	-2% decrease



Reactor cyclone operation shown here for 3 weeks of operation

Critical flags were operating within minimum remaining dipleg on 2nd stage and decreasing pressure drop

Losses jumped by ~ 0.5 TPD

Analysis indicates partial bypassing of 1 second stage

Analysis of slurry solids confirmed, came AFTER the process work

Manage the Small Things

- Most major (the ones that make the news) incidents require 4 – 7 small issues to take place at the same time
- Managing small issues as they manifest remove them from the equation in terms of creating large problems
- Many times, the post-audit reveals improper preventative maintenance or monitoring took place
- Be extremely careful on restarts – empirical observation (of hundreds of unit start ups) is that between 10 and 15 % of the time, a problem takes place during start-up that ultimately requires a unit outage to resolve

The Astron Advantage Industry Expertise • Web Solutions • Tech Service Applications

FCC Reliable Run Length Management Conclusions

- 75 % of shutdowns driven by:
  - Rotating equipment failure
  - Distributor failure
  - Excessive catalyst loss
  - Catalyst circulation failure
- Approximately 1/5th of units do test runs every 6 months or less frequently
- Minimize unexpected outages – there is no free start-up
  - Unit troubles can linger 10 – 15 % of the time after each start-up
- Monitor unit health routinely and manage the ‘small’ issues to eliminate or mitigate large issues

Key Items?

Reactor termination/cyclone pressure drop, velocity, dipleg operation
Reactor vapor line pressure drop
Reactor/stripper bed height & density
Stripper flux, residence time, net upward steam velocity
Stripping steam distributor(s) outlet velocity, orifice velocity, pressure drop
Spent standpipe flux, pressure build up, density
Spent slide valve position and delta P
Regen bed level/height and density
Regen cyclone pressure drop, velocities, dipleg operation
Air distributor outlet velocity, orifice velocity, pressure drop
Regen residence time & afterburning monitoring
Regen standpipe flux, pressure build, density
Regen slide valve position & delta P
Riser pressure drop
Riser velocities (bottom, pickup, outlet)
Feed injection monitoring (distribution/flows, delta P)
Air blower performance monitoring (discharge pressure, flow, horsepower)
Wet Gas Compressor performance monitoring (discharge pressure, flow, horsepower)
Expander (if present) monitoring
Main column loadings & fractionation efficiencies
Heat transfer monitoring for main column PA, feed exchangers, flue gas circuit
Delta coke monitoring
Hydrogen & dry gas monitoring
Conversion and selectivity monitoring
Trends of operation to pinpoint economic performance issues early