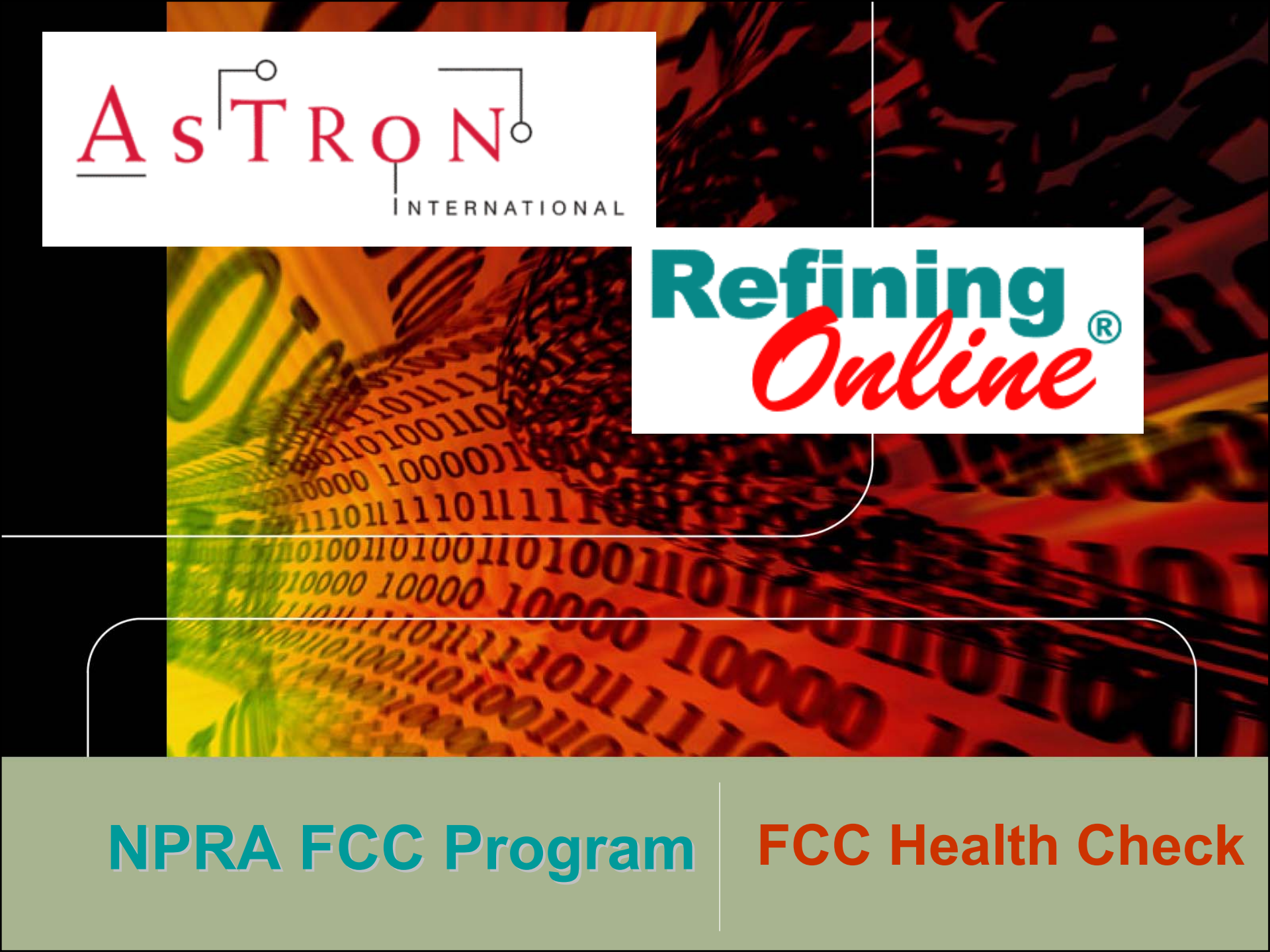


NPRA FCC Program

FCC Health Check

FCC Health Check

- Workshop format
  - Want input from everyone in attendance
- Agenda
  - Survey
    - short one on next 2 slides – will compile in real time and show before end of workshop
    - Results of ROL conducted survey from Q1 2008 shown
  - FCC Health Check Practices
    - Frequency?
    - Catalyst retention
    - Rotating Equipment
    - Yields

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

Survey Questions

1 – What is your FCC feed rate (BPD)?

2 – Target run length between turnarounds this run and last run?

3 – How many shutdown days this run?

4 – How many days down in 2008 excluding scheduled turnaround?

Example Text Message:

1 – 40000, 2 – 4,3, 3 – 12, 4 - 5

Survey – Last 2 Questions

5 – During the last 2 runs, which of the following has brought the unit down?

A – cat loss/cyclone failure
B – loss of circulation
C – air blower
D – wet gas compressor
E – Expander
F – Utility
G – Slide valve
H – Human error
I – corrosion/fouling
J - Other

6 – How often do you conduct a performance test run looking at yields, heat balance, and equipment performance?

A – daily
B – 2x per week
C – 1x per week
D – 2x per month
E – 1x per month
F – 1x per quarter
G – 2x per year
H – 1x per year
I – less than 1x per year

Example Text Message:5 – a,d,f,j, 6 – b

Compiling answers in real time & will provide table at close of workshop (assumes network connection)

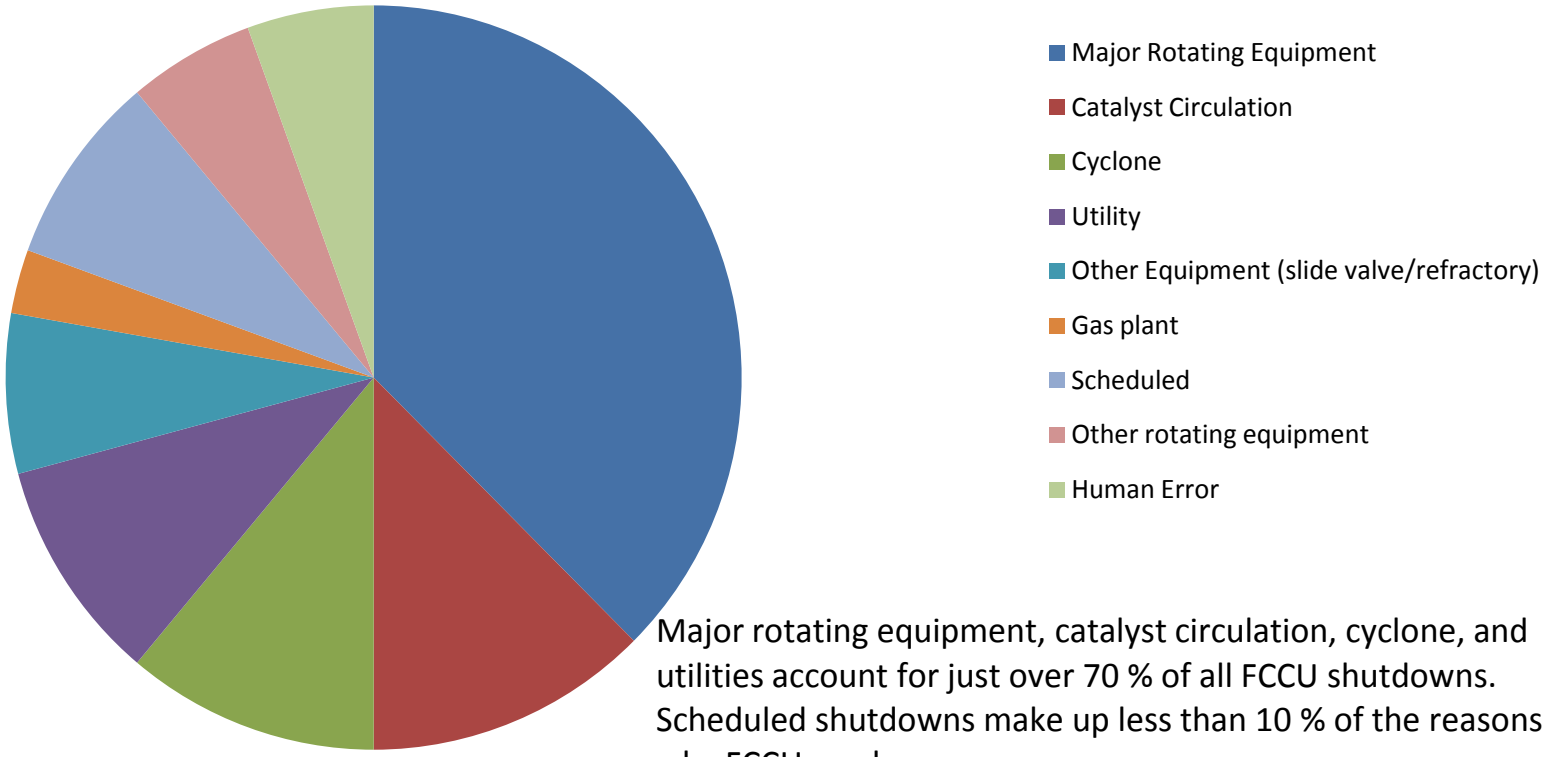
Previous Survey run in 2008

- Ran the following survey earlier this year on Refining Online
- Responses generally outside North America
- Approximately 30 units responded rapidly, still have a few trickling in now

FCC Shutdown Survey Results

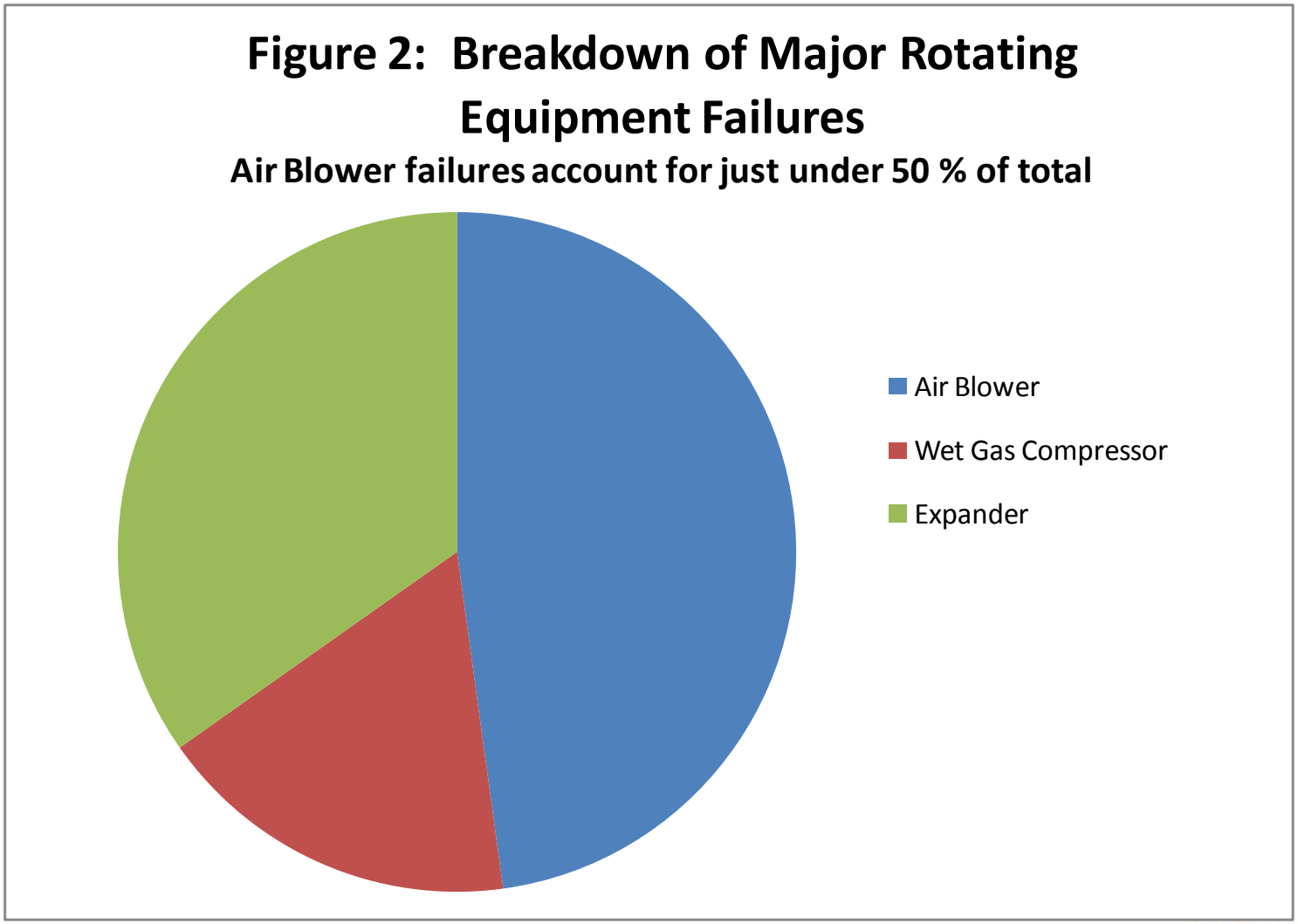
Figure 1: Survey Results

Causes of FCCU Shutdowns



Major rotating equipment, catalyst circulation, cyclone, and utilities account for just over 70 % of all FCCU shutdowns. Scheduled shutdowns make up less than 10 % of the reasons why FCCUs end runs.

FCC Shutdown Survey Results



FCC Health Check

- What is a health check?
  - Test run that looks at:
    - Yields
    - Equipment performance
- 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

Health Check Topics

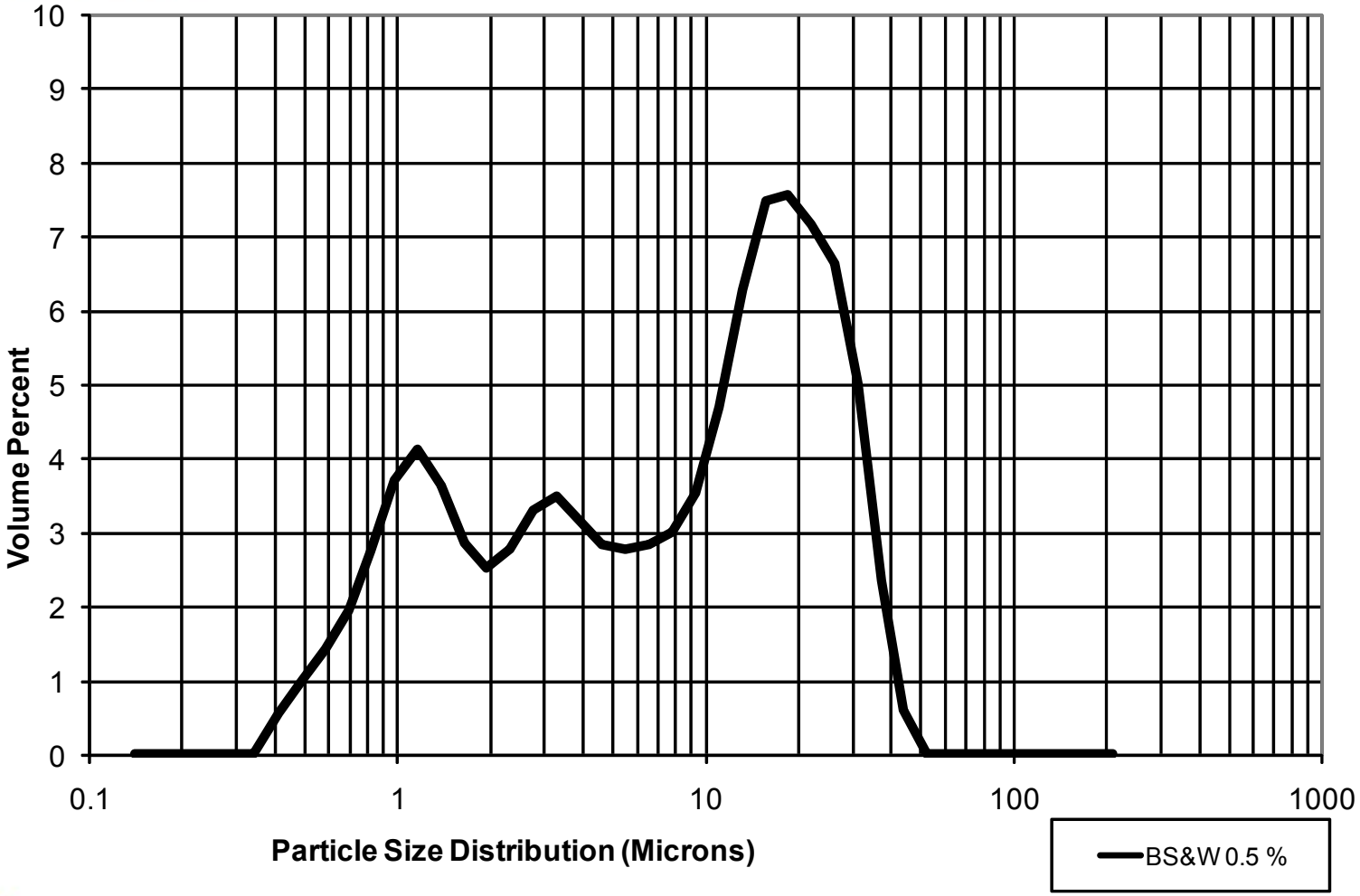
- Shutdown causes give a good idea of what should be checked
  - Cyclones & Catalyst material balance
  - Major distributor performance
    - Feed nozzles, air grid, stripping steam at a minimum
  - Major rotating equipment performance
- Also look at yields & how they compare to expected and historical

Cyclones & Catalyst Material Balance

- Know your cyclone health
- 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

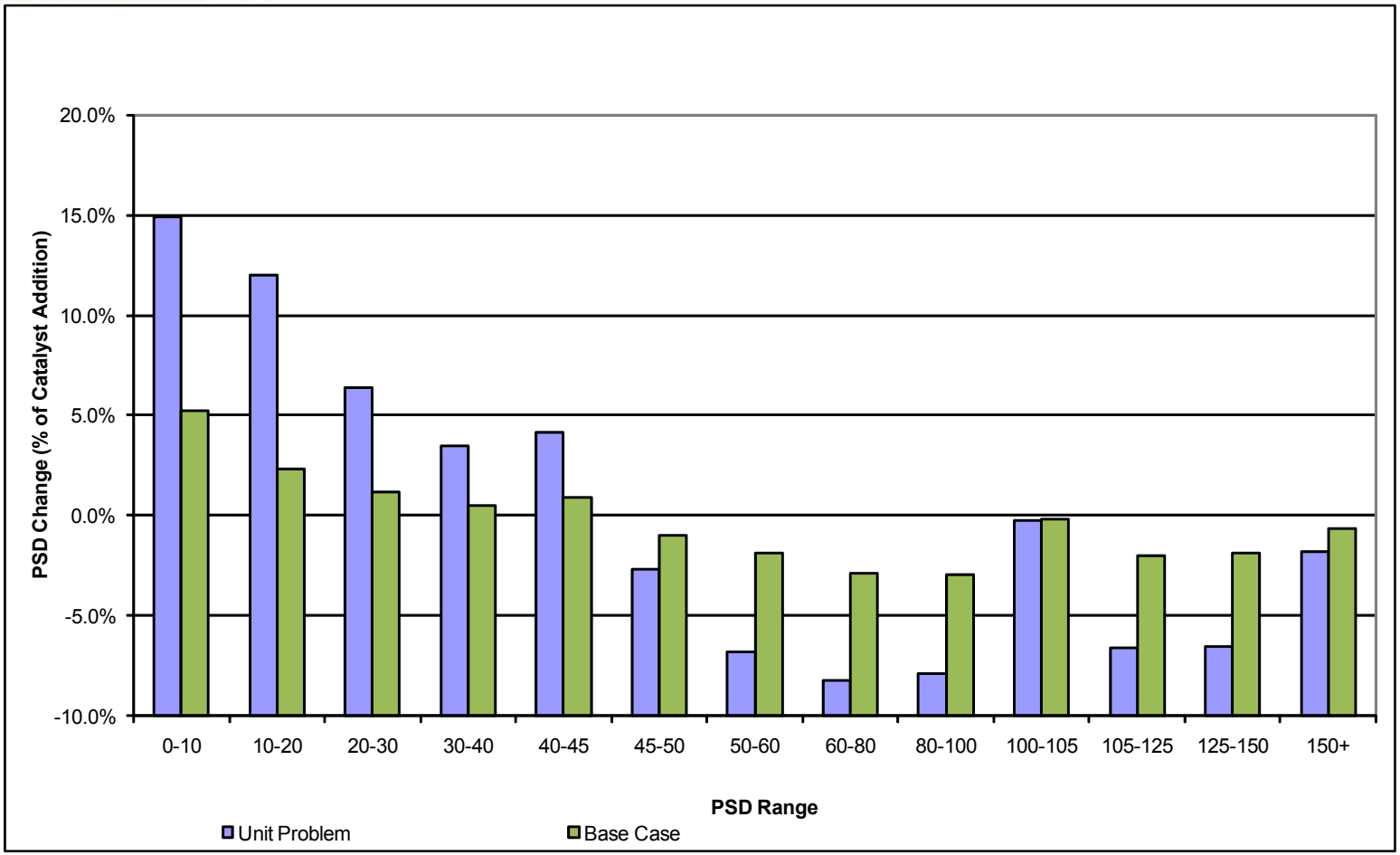
Erosion at Top of Dipleg
Most Common Cyclone Failure

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

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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?

Power Recovery

- Deposits
  - Small Fines (< 3 microns) Fuse and Accumulate on Shroud and Stators
  - Deposit Thickness Contacts and Rapidly Erodes Rotor
  - Smallest Fines, Flue Gas Water, 'Sticky' Contaminants and Velocity Have Negative Impact
  - No Specific Catalyst has Correlated to Deposit Formation
    - Lots of opinions in industry regarding attrition characteristics
  - Larger Particles (> 10 microns) Directly Erode Stator and Rotor Blades
  - Must monitor vibration and power generation and take action as needed

Power Recovery Deposition

- Deposit Control and Removal
  - Eliminate chemical binding materials
  - Reduce fines generation
  - Spall Deposits with Erosive Material, i.e. Walnut Shells, Rice Husks, Ecat
    - Also Erodes Blades
- Thermally Cycle to Spall Deposits
  - Close Expander Inlet Butterfly Valve
  - Add Steam, Air or Water to Cool Inlet 200-500°F
  - May Need to Cut Feed and Air Rate to Reach Temperature
  - May Not Result in Uniform Deposit Removal and May Need Repeating
  - More Mechanical Stress on Expander

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 FCC design is distributor work

Distributor Checks

- **Field Checks**
  - **Inlet Pressure Agrees with Calculated based on Estimated Internal Pressure plus Calculated Distributor Pressure Drop**
  - **Flow Control Valve Position Reasonable for Flow Quantity**
  - **Outlet velocity**
  - **Orifice velocity**

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
  - Popularity of HPLC has led to multiple theoretical potential conversion calcs
  - 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

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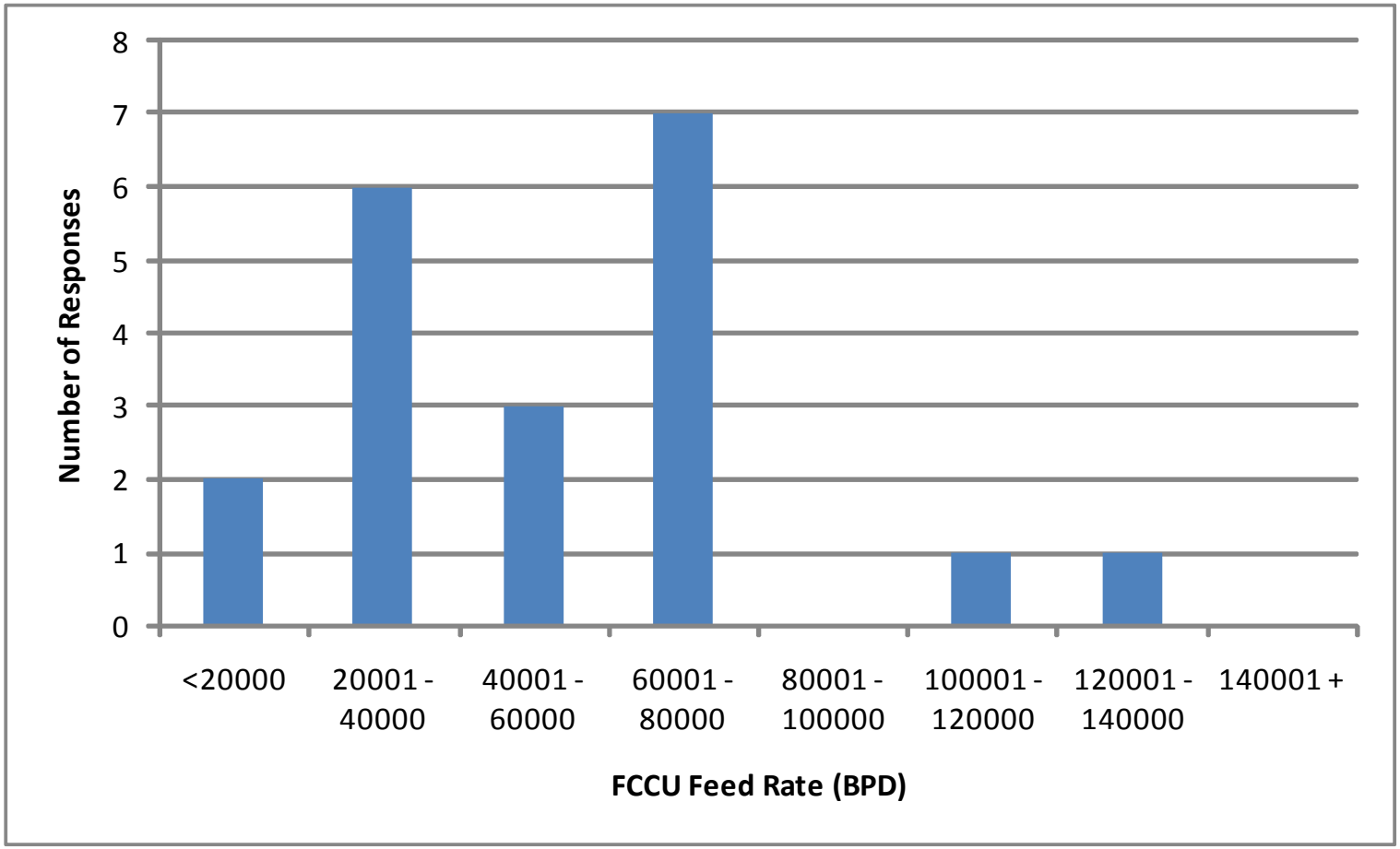
Key Items?

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

Survey Results

- Compiled in real time at Houston office
- Results will be made available to NPRA via their website
  - Can email direct if you provide email address & participate
  - Will also post on refining online (www.refiningonline.com)
- As always, your mileage may vary…statistics are not infallible

Survey Question 1: FCCU Feed Rate (BPD)



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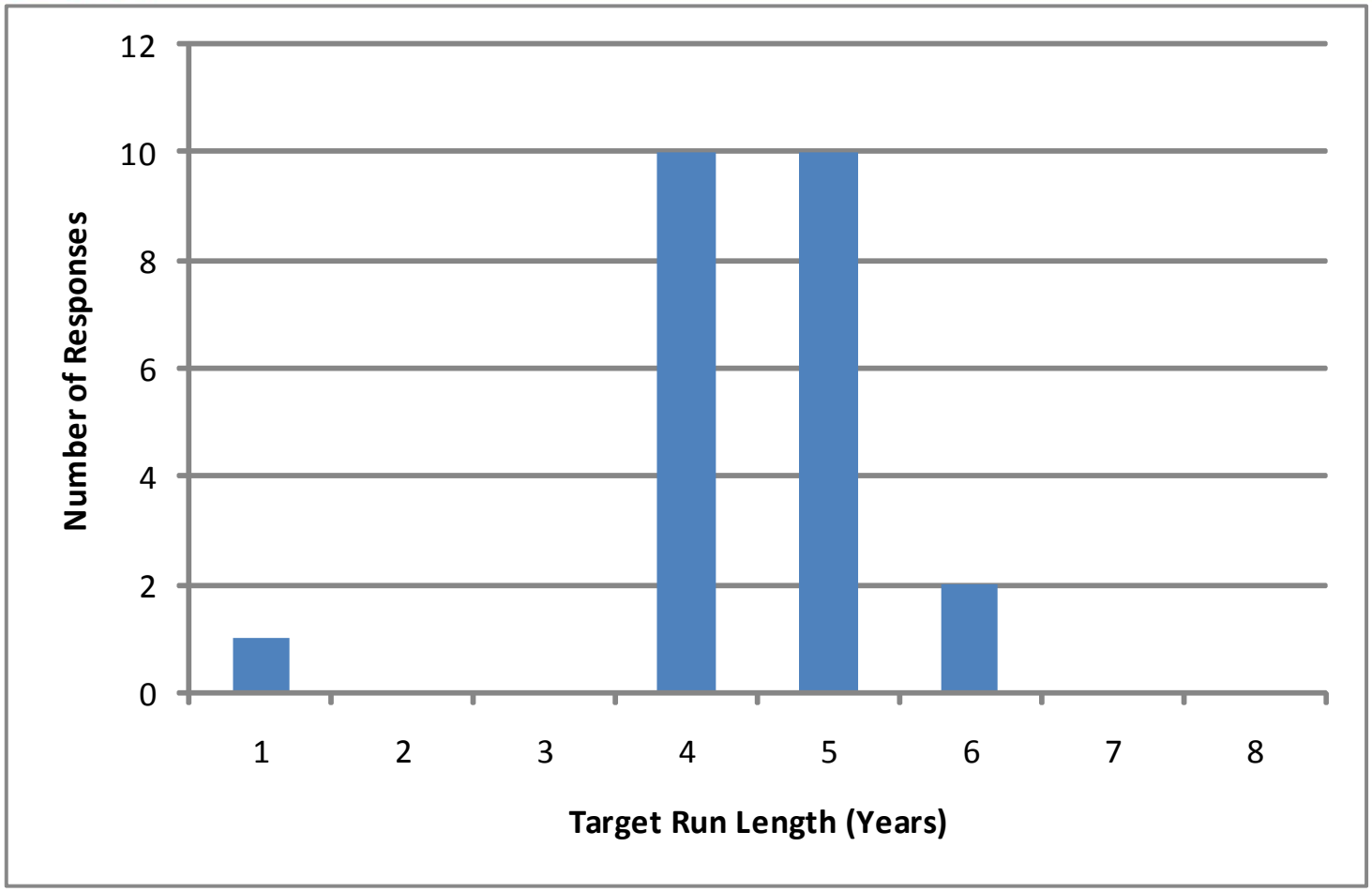
Survey Question 2: Target Run Length (Years)



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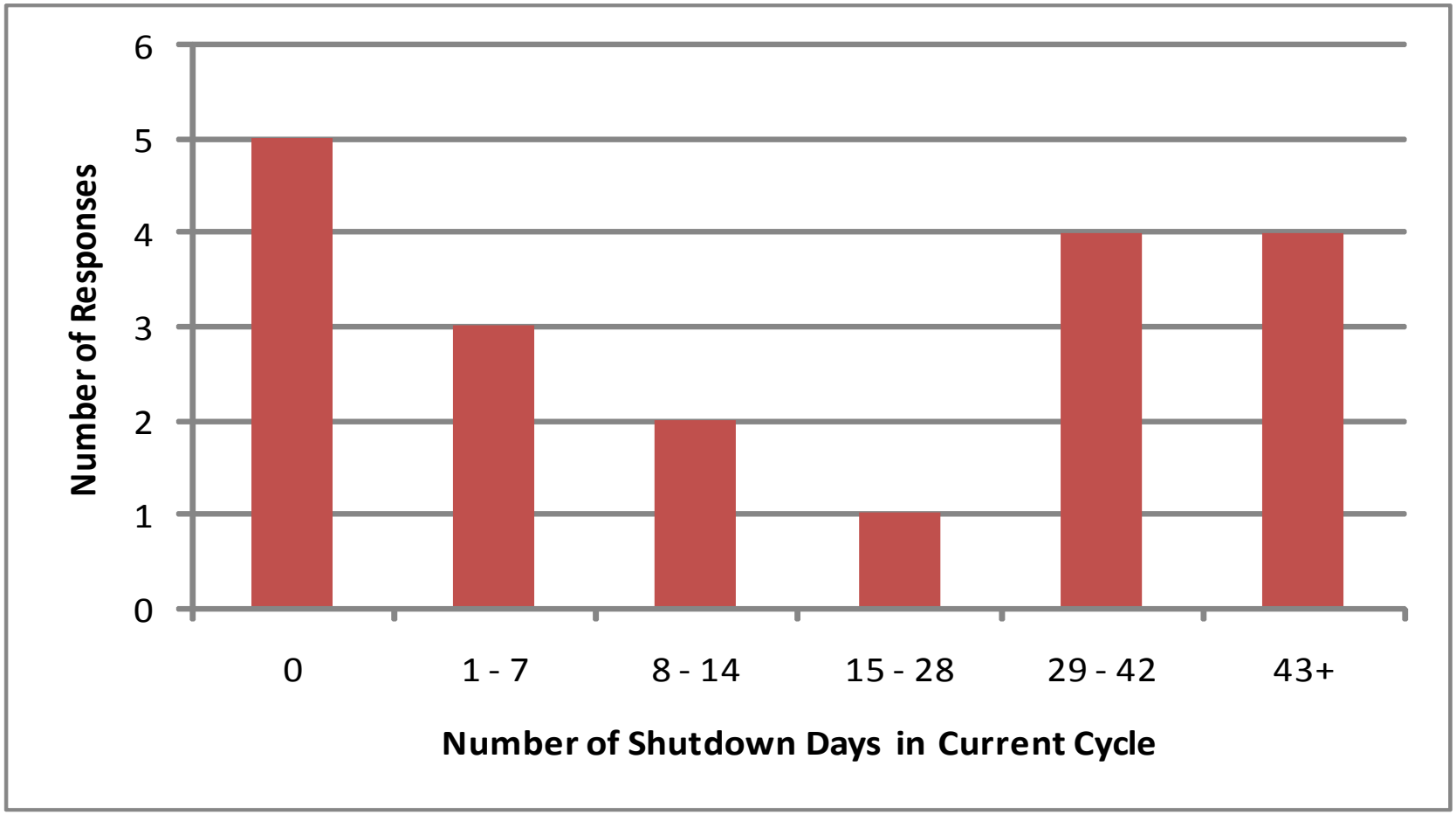
Survey Question 3: Shutdown Days During Current Run



5 units with no shutdowns, 8 units with 1+ months

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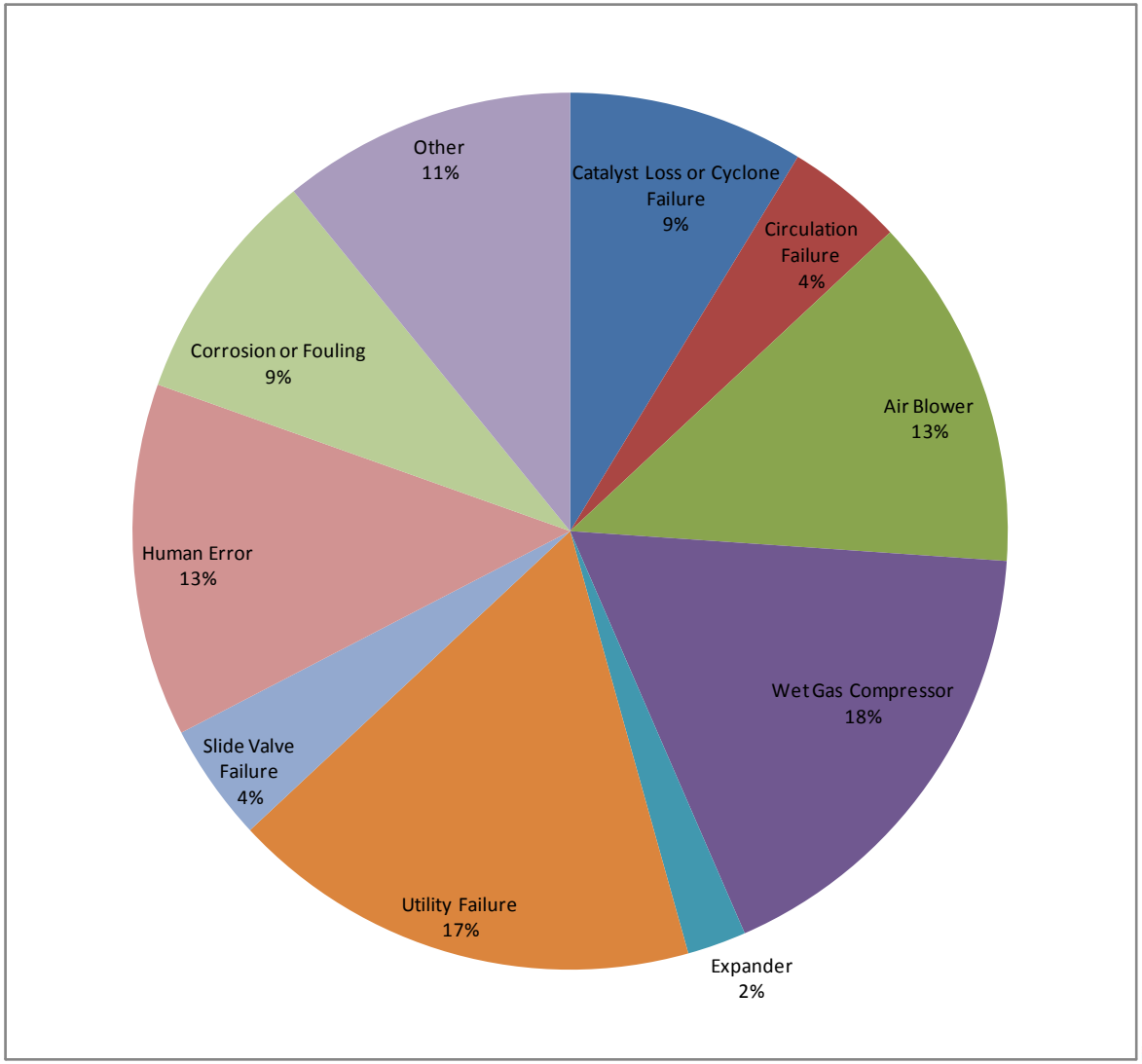
Survey Question 5: Causes of FCCU Outages

Air Blower, Wet Gas Compressor, and Expander make up 33 % of total outages



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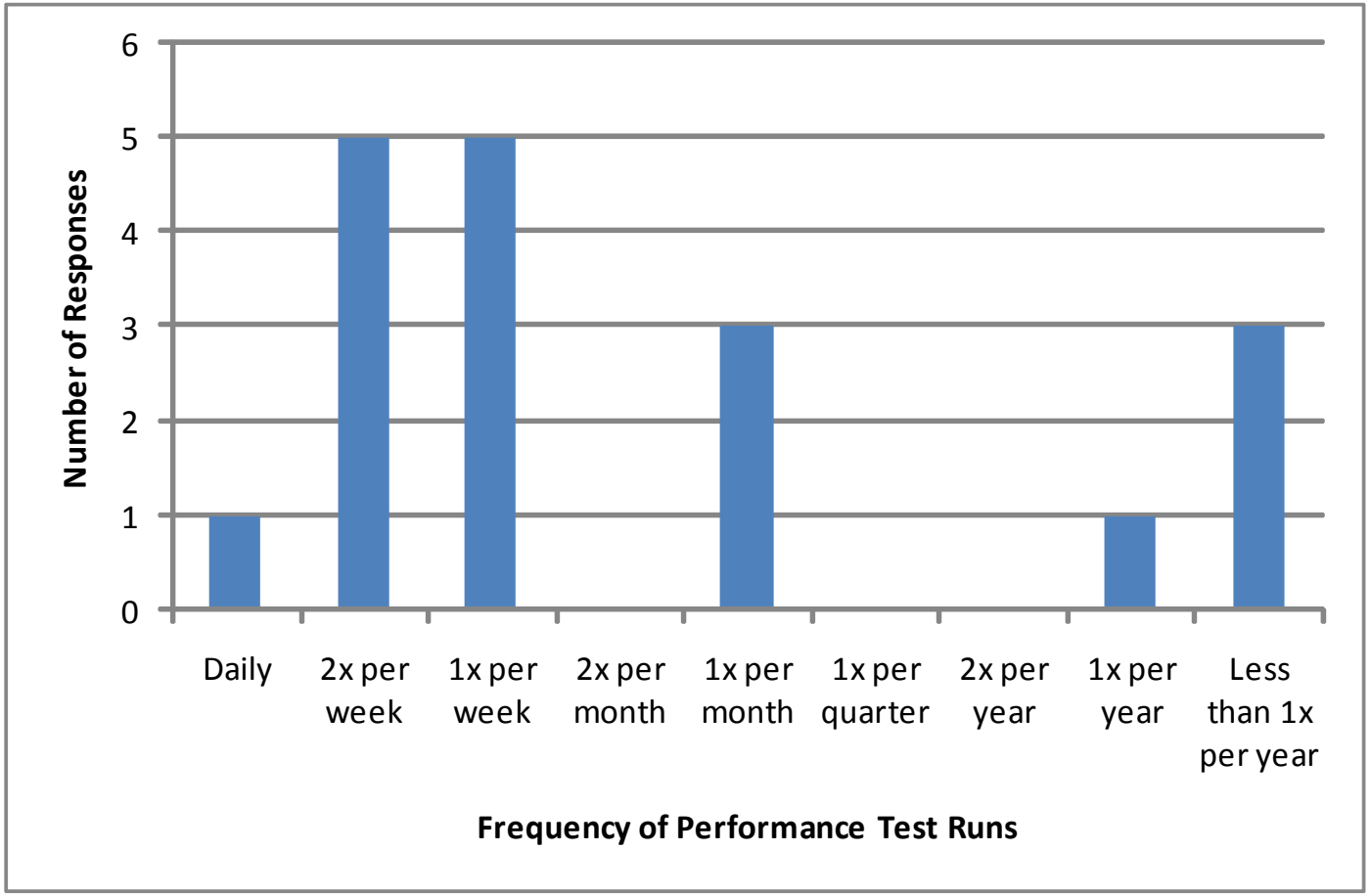
Survey Question 6: Frequency of Performance Test Runs



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