The energy problem of Crude Distillation Unit of a refinery

FORTUNE 500 CORPORATION | OIL AND GAS |

This is a case story from Petrocham Oil Refineries Ltd (PORL) (name changed). This story communicates the key message that data collection should be correct otherwise results may defer. It is good to check the measurement system before collecting data.

BACKGROUND OF THE PROJECT

PORL presently has a crude oil processing capacity of 9.5 MMTPA (Million Tons per Annum) in its two Crude Distillation units (CDU). Crude oil is first processed in the CDU where it is heated in heaters depending on the type of crude oil after removing impurities such as sodium and magnesium salts, water and other sediments. Crude oil is then fractionated in a distillation column where lighter fractions such as LPG, Naphtha, Kerosene and Diesel are separated.

In one of the CDU of PORL, Crude is heated in two heaters named as CH1 and CH2 and then crude is fed to the main fractionating column. To heat the crude, air is supplied to heaters by two Forced draft (FD) fans. These fans are driven by High tension motors with Fluid Coupling (scoop loading mechanism) for transferring energy from motor to fan. By varying the scoop loading, air supply is maintained.

As design data of FD fans, each fan share 50% load, and in case of failure of one FD fan, the other goes to full load. As both FD fans were running in parallel, there was high energy consumption in the CDU.

So, as a Lean Six Sigma Green Belt project, the problem was given to a team of 2 Petrocam employees (Mr. Ramesh and Mr. Suresh). Let's see what the team found out.

VOICE OF CUSTOMER (VOC)

Team did a Gemba walk to CDU and interviewed few persons. Below is the summary of what they said.

CDU In-charge: "*We need to ensure a 120t/hr air to heaters for proper combustion".*

Panel In-charge: "*Scoop loading of each FD fan is less than 50% which is leading to energy wastage*" (

Panel Operator: "*Maximum load of fan should not exceed 39.5Amps"*

Maintenance department: "*There are many air leaks which leads to high energy consumption. And the discharge damper is not fully close also."*

After getting inputs from all concerned persons, the team met their Six Sigma project coach and explained the issues.

The coach asked, "*Why are we running both FD Fans on 50% load when we can get the same air requirement from one FD fan running on 100% load?*"

Ramesh replied, "*Yeah, it can be done but there will be reliability issues if we run only one FD fan. Now if one FD fan trips, other take the full load*"

The coach replied, "*Okay!! But why Scoop loading for each fan is around 50%? We are wasting rest 50% energy here."*

Ramesh replied, "*We cannot supply air more than the requirement. We need to maintain the ratio of air flow to crude throughput of heater at 0.18. If this ratio increases, heater will be smoky.*"

Coach replied, "*Correct. What about the maximum load of fan? Is it exceeding 39.5 Amp?"*

Ramesh replied, "*We need to check this. We will collect data and come back to you on this."*

Team further analyzed the issues with the Coach and decided the CTQ as "Energy consumed/hour by both FD Fan motors in CDU heater".

Team collected the data and met the coach again. From the data, it was found out that maximum load of fan was mostly exceeding 39.5Amp.

Coach asked, "Are you sure that data is recorded correctly? Did you check the Ammeter calibration?"

Suresh replied, "These readings are recorded by field operator and it may not be accurate as the ammeter is not digital".

Coach asked them to check the ammeter again. Team again visited the CDU and compared the ammeter with the source ammeter (from where the power is supplied to CDU). It was found out that ammeter readings of CDU was not correct. In fact the field ammeter had a multiplication factor which the operators were unaware of. Field operators should multiply the reading on the guage with a correction factor of 0.83. The team, based on this information, corrected the data. After correcting the data, team found out that load of fan was not exceeding 39.5 Amp.

Team further calculated the power consumption of both FD fans. A graphical summary is given below.

GRAPHICAL SUMMARY OF "ENERGY CONSUMED BY FD FANS IN CDU HEATER"

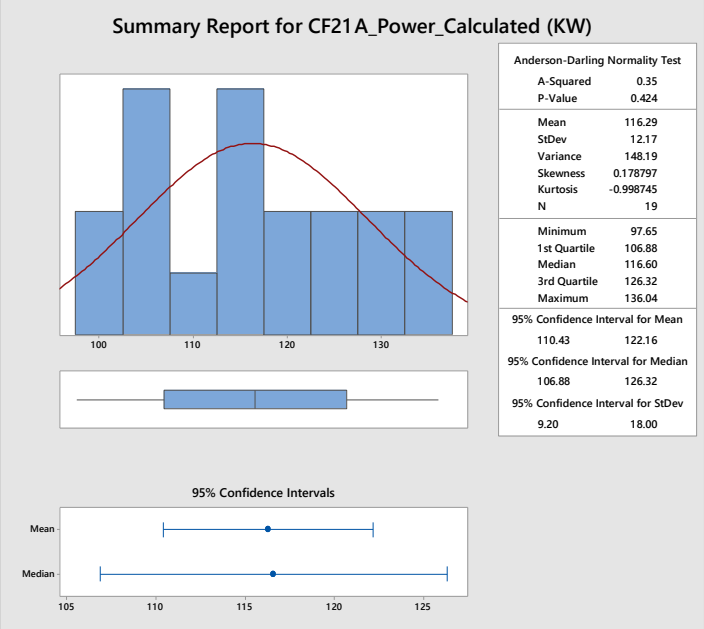


Figure 1: A graphical representation of "Energy consumed by CF21A FD fan" P value: 0.424 => Data is normal => Mean is right metric to summarize the data

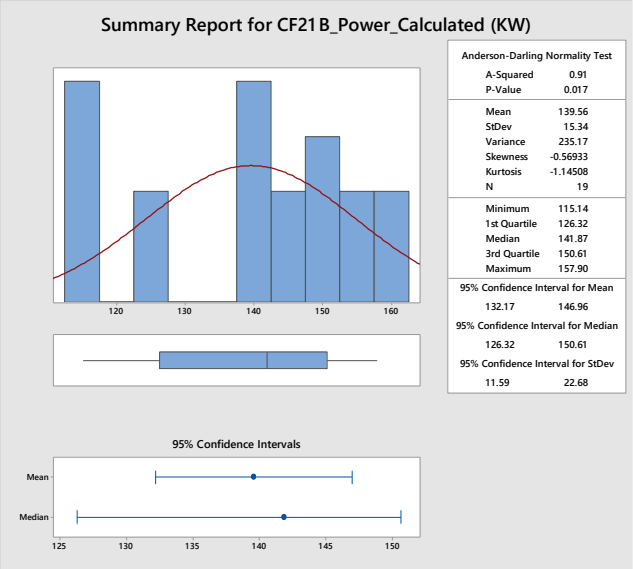


Figure 2: A graphical representation of "Energy consumed by CF21B FD fan" P value: 0.0017 => Data is not normal => Median is right metric to summarize the data

- For CF21A, average power consumption = 116.29 KW
- For CF21B, average power consumption =141.87 KW

You can note that CF21B had higher power consumption. The team had to find out why?

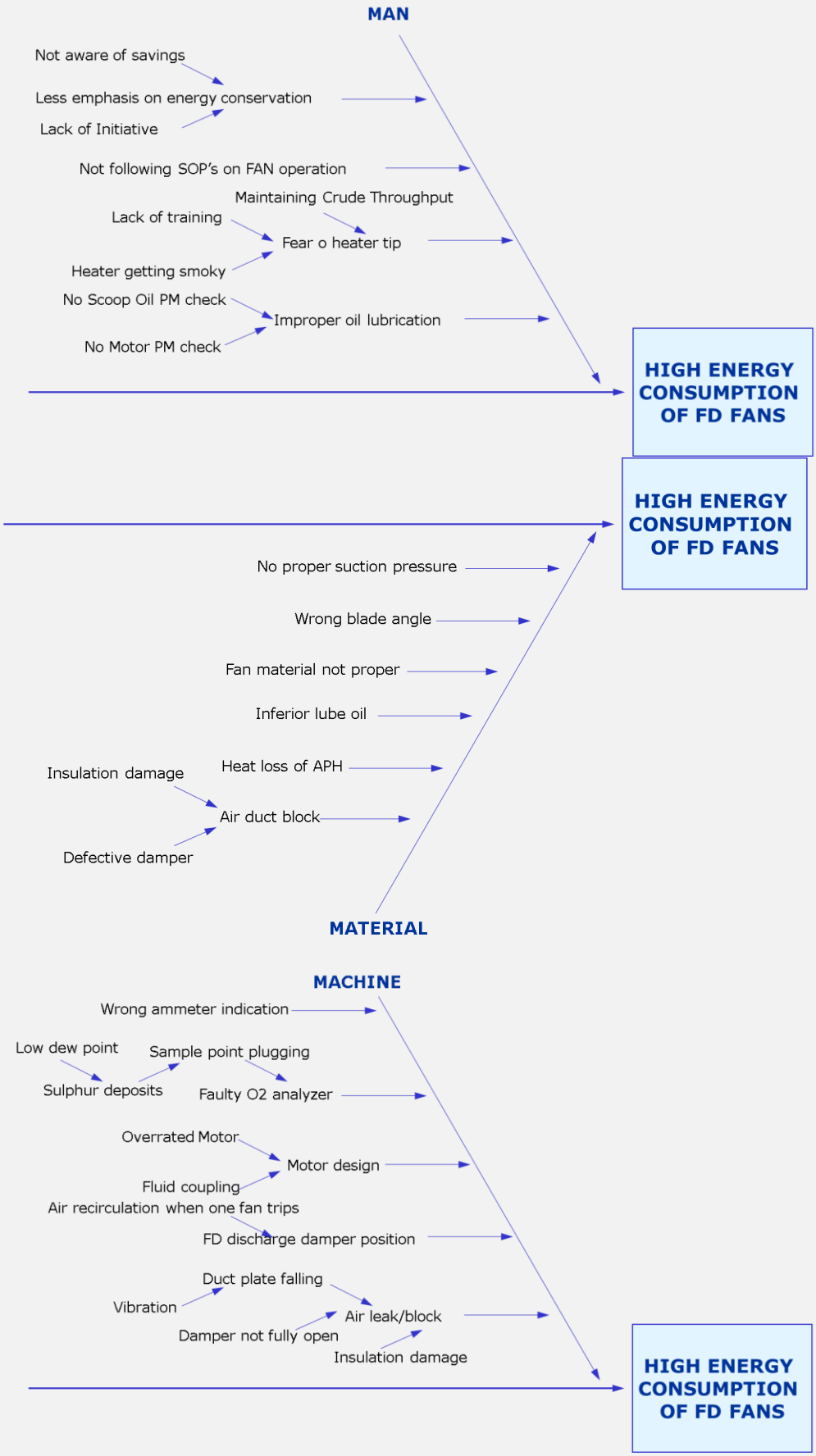
PROBABLE CAUSES

Team discussed the issue with stakeholders and populated a Fishbone diagram with all the probable causes.

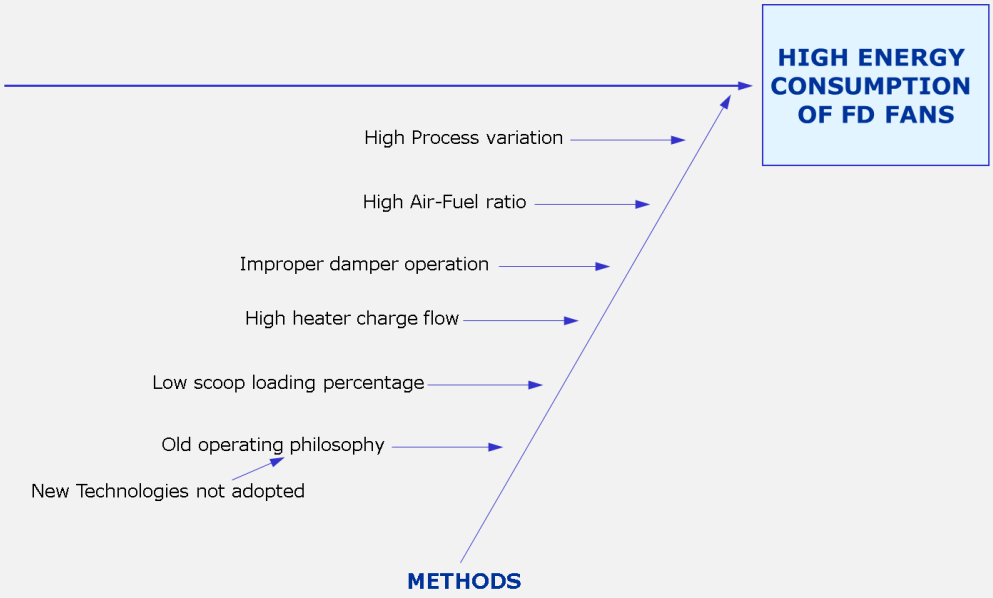
After detailed analysis of all probable causes, following causes were found out.

- Wrong ammeter indication
- Air leakages or blocks in passages
- Improper damper operation
- Improper insulation of air ducts
- Air duct blockages at various locations

The Team also created an elaborate fish bone diagram. For easy reading, we have broken it into parts.


MAN
Not aware of savings
Less emphasis on energy conservation
Lack of Initiative
Not following SOP's on FAN operation
Maintaining Crude Throughput
Lack of training
Fear o heater tip
Heater getting smoky
No Scoop Oil PM check
Improper oil lubrication
No Motor PM check
HIGH ENERGY CONSUMPTION OF FD FANS
HIGH ENERGY CONSUMPTION OF FD FANS
No proper suction pressure
Wrong blade angle
Fan material not proper
Inferior lube oil
Heat loss of APH
Insulation damage
Air duct block
Defective damper
MATERIAL
MACHINE
Wrong ammeter indication
Low dew point
Sample point plugging
Sulphur deposits
Faulty O2 analyzer
Overrated Motor
Motor design
Fluid coupling
Air recirculation when one fan trips
FD discharge damper position
Duct plate falling
Vibration
Air leak/block
Damper not fully open
Insulation damage
HIGH ENERGY CONSUMPTION OF FD FANS

KINDUZ



Team further collected data to validate causes. The data analysis is as follows:

- Performance of FD fan was checked when other FD was stopped for maintenance. It was found out that average air consumption in CH21 was 80t/hr. One FD fan can cater to the air requirement, but the safe & reliable operation of the other fan, on tripping of running FD fan was a constraint. Also, discharge damper of FD fan did not close fully and has caused frequent problem when the other FD fan stops. Hence, it was recommended to go for Variable Frequency Drive. VFD is a type of adjustable-speed drive to control motor speed and torque by varying motor input frequency and voltage. A detailed energy saving calculation is given below.

Energy Saving Calculation for VFD	
Rated Power output of CF21 A/B in KW	180
Rated Flow per Fan, m^3/Hr	83298 (Normal , Wet Basis)
Rated Flow per Fan, T/Hr	(83298 /1.032) X 1.14 = 92
Actual Combined flow, T/Hr (Median Value)	118.76
CF21A Load KWH	117.66
CF21B Load KWH	143.5
Actual Combine Power, KWH	= 117.66 +143.5 = 261.16
Power Consumption After VFD, KWH	((180 X 2) X ((119/(92X2))^3)/0.9 =107 KWH
Power Saved, KWH	=261.16 – 107 = 154.16
Annual Power Saving, KWH	1229534
Rs / KWH	10
Annual savings (INR)	**1,22,95,340 /-**

- Relationship between hot air damper opening and air flow was checked and it was found out from figure 3 & figure 4 that CH21 & CH22 Hot Air damper opening could be increased further to reduce pressure drop across damper, thereby reducing power consumption.

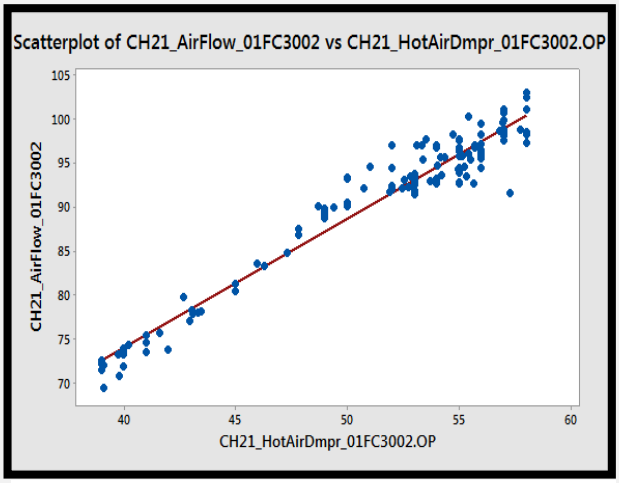


Figure 3: Relationship between hot air damper opening (X-axis) and air flow (Y-axis) for CH21

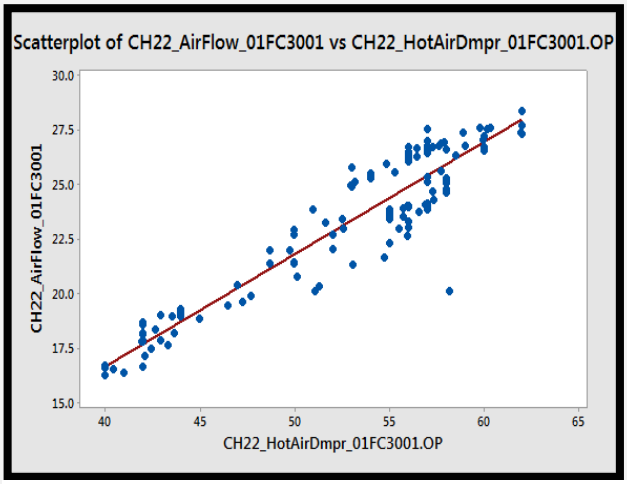


Figure 4: Relationship between hot air damper opening (X-axis) and air flow (Y-axis) for CH22

- Air leakages across CH21/Ch22 APH was calculated by performing energy balance

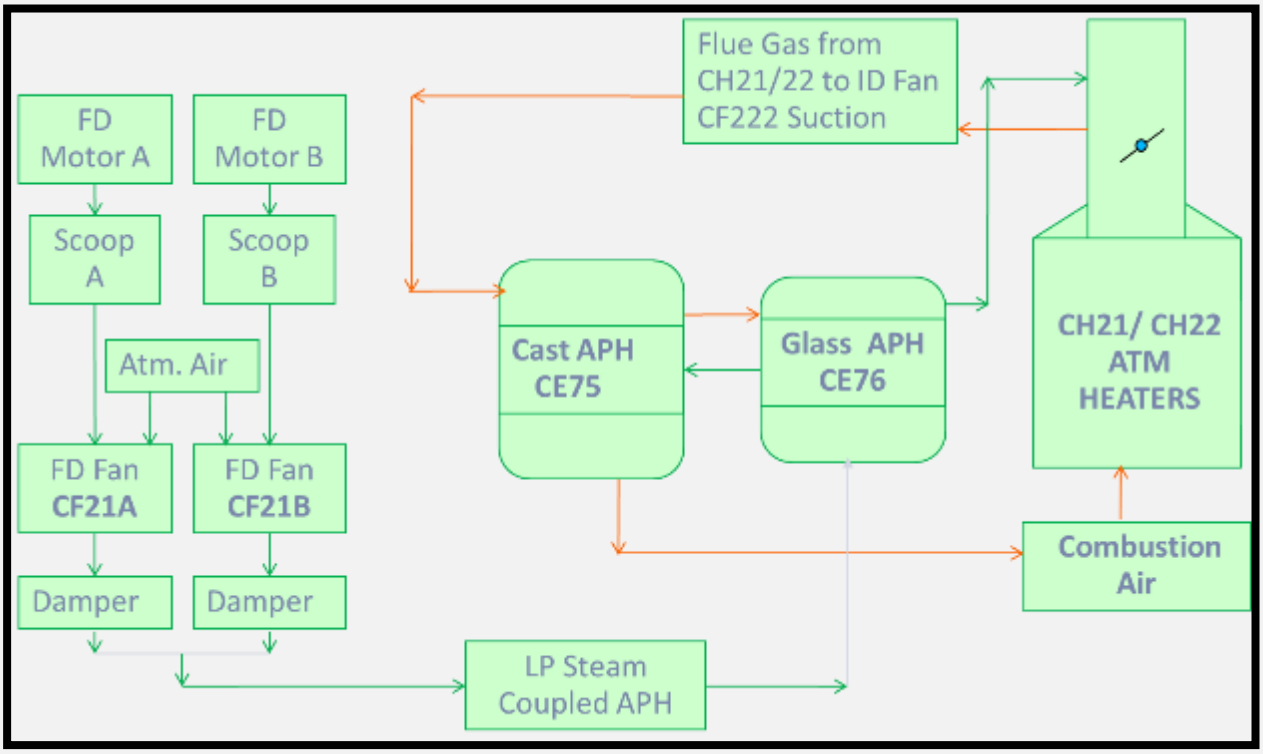


Figure 5: A line diagram of air flow in Crude Distillation unit from FD fans to Crude Heaters

Equation for energy balance across steam coupled APH is as follows:
Mass of steam X Latent Heat of steam = Mass of air X Cp of air X (Outlet temp – Inlet temp)

Steam Flow to SCAPH	= 1.428 t/hr. (Mean Value)
Latent heat of Steam	= 2107.42 KJ/KG
Specific heat Cp of Air	= 1.0 KJ / kg K
Inlet Temperature to SCAPH	= 36.37 deg C
Outlet Temperature of SCAPH	= 60.0 deg C

Mass of air = (Mass of steam X Latent Heat of steam)/ (Cp of air X (Outlet temp – Inlet temp))

Mass of Air (Ma)	= (1.44*2107.4)/ (1.0 *(59.61+273)-(36.27+273)) = 127.35T/hr
Actual Air flow to Heaters	= 118.76 t/hr. (Mean)

Air leakage in duct = Mass of air in t/hr - Actual air flow to heaters in t/hr

Air leakage in Duct	= 126.409 – 118.76 = 8.59 T/hr
Total Power Consumed for 118.76t/hr.	= 261 KW
Total Power if leaks arrested	= 261*((118.76-8.59)/118.76) ^3/0.9 = 231.51 KW
Power Savings	= 261 -231.51 = 29.48 KW

Annual Savings = Power savings X total Hrs in a year X Rs. per KW/Hr

Annual Savings	=29.48 X 8000 X 10 = INR 2,358,612.55

Air flow transmitters with indications in DCS for Detection of Major Air leakages was recommended.

- Reduction of excess oxygen in CH21 was recommended by 0.5 %. Benefits from the reductions is as shown below.

Average Fuel Consumed = 5.46 MT/hr

If 0.5 % reduction in oxygen, fuel saved = (5.46 X 0.5)/100 =0.0273 MT / hr

Total fuel saving per year = 0.0273 X 8000 = 218.792 MT

Average RTP of fuel for 2013-14 = Rs. 40,000 per ton

Total annual saving = 218.792 X 40,000 = INR 8,751,711

RESULTS

Total annual savings = INR 23.4 million