PROCESS OPTIMIZATION OF AMINE REACTIONS

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Abstract

Ospira is an inhalation anesthesia manufacturing facility. The main products are Deramine and Dexoflurane. To produce these anesthetics, chemical reactions and distillation processes are required. For Deramine it is necessary to do an Amine Reaction.
The importance of this study is to avoid the loss of product during the reaction process. When the product does not recover, it affects the efficiency of the reaction and the company performance. The reaction process must be improved to obtain a better percentage of recovery and avoid product losses. Increasing 2% of the amine recovery percentage will represent a reduction of approximately $20,000 per month. In order to reduce the process variability, to align customer's expectations, and to provide high financial returns; a Six sigma methodology is appropriate.

Project Description

The percent recovery and yield percent are directly related to the chemical reactions and its involved efficiency. All the time, the Amine Reaction process has showed a low percent recovery, obtaining financial losses and affecting the yield percent. Actual recovery percent is 88% and the expected value is 90%. This development goes to effort on the progress of Deramine.

Objectives

- Increase the Deramine yield by 2%
- Increase the recovery of reactions from 88% to 90% to reduce the losses
- Increase the financial performance of the plant

Methodology

DMAIC process is a core component of the Six Sigma Methodology. It is used when making improvements to an existing process. DMAIC is an acronym for the five key powerful phases: Define, Measure, Analyze, Improve and Control. DMAIC is a Six Sigma methodology which helps in achieving process improvements by reducing variation. [1] [2]

Results and Discussion

Define Phase

Every year, the Amine Reaction process has showed a low percent recovery, obtaining financial losses and affecting the yield percent. Actual recovery percent is 88% and the Amine yield is 0.788. Manufacturing Department also will have a positive contribution since improving the process will reach the target of the recovery, complying the customer needs. [1] [2]

Figure 1: Recovery Percent and Yield

Measure Phase

The main objective is to collect data pertinent to the scope of the project. The data collection will be address to the temperatures, pressure, cooling system, product transfer and addition rate. The measure will be address to those reactions with more recovery vs reactions with less recovery. The comparison will show the good reactions (high recovery) vs bad reactions (lowest recovery). A SIPOC diagram was used to identify all relevant elements of a process improvement project before work begins. It helps define a complex project that may not be well scoped.

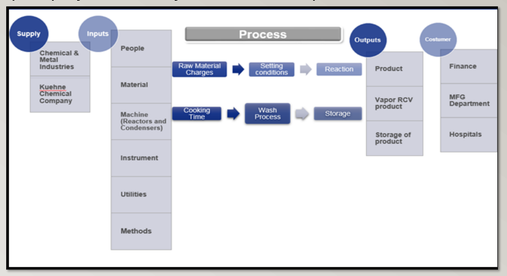

Figure 2: SIPOC Diagram

Process Map involved is the Supply to made the anesthesia, Operators (people), Material (purity of compound), Reactors and condensers (Machine), temperatures, pressure (Instrumentation), Cooling (Utilities) and Gas Chromatography Analysis (Methods). The main steps of the process (setting conditions, reaction time, cooking time). The Amine product is the output, while Finance and Manufacturing are the costumers.

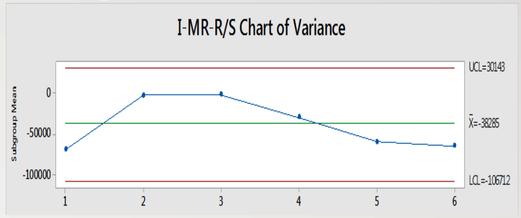

Figure 3: I-MR Chart Diagram

The data collected of total losses of the process was plotted using an I-MR chart. The average in losses are -$38,285 per month. Even though, UCL was $30,143 and the LCL was $106,712.

Analyze Phase

Analyze phase will reveal the root cause of business inefficiencies exposes areas where the implementation of change can provide the most effective results. One way ANOVA was used to observe the difference (visually) of the pressure, temperatures, and cooling flow rate during the reaction period.

One-way ANOVA: DR1411RCY-16-008, DR1412RCY-15-021

```
Source  DF      SS     MS      F      P
Factor   1   324.6  324.6  27.12  0.000
Error   48   574.6   12.0
Total   49   899.2

S = 3.460   R-Sq = 36.10%   R-Sq(adj) = 34.77%

                                        Individual 95% CIs For Mean Based on
                                        Pooled StDev
Level                N    Mean  StDev  ------+---------+---------+---------+--
DR1411RCY-16-008    25  135.05   4.89                          (------*------)
DR1412RCY-15-021    25  129.96   0.15  (------*------)
                                        ------+---------+---------+---------+--
                                           130.0     132.0     134.0     136.0

Pooled StDev = 3.46
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Figure 4: Comparing cooling flow rate (gpm)

Analyze Phase (cont.)

One-way ANOVA: DR1411-16-046, DR1412RCY-15-020

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Source  DF      SS     MS      F      P
Factor   1   142.2  142.2   3.29  0.077
Error   42  1814.6   43.2
Total   43  1956.8

S = 6.573   R-Sq = 7.27%   R-Sq(adj) = 5.06%

Level                N     Mean  StDev
DR1411-16-046       22   -7.505  7.254
DR1412RCY-15-020    22   -3.909  5.812

                        Individual 95% CIs For Mean Based on Pooled StDev
Level                -+---------+---------+---------+---------+---------
DR1411-16-046        (-----------*-----------)
DR1412RCY-15-020              (-----------*-----------)
                     -+---------+---------+---------+---------+---------
                    -10.0      -7.5      -5.0      -2.5

Pooled StDev = 6.573
```

Figure 5: Condensed organic temperature

The analysis was conducted to compare the reactions resulted with high recovery versus batches with lowest recovery. Figures showed that the reactions with high recovery had more cooling flow rate (cold oil in gpm) and the condensed organic temperature was more cold.

The analysis showed the following:

Reactions with high recovery

- ✓ There are no pressure problems
- ✓ Condensed organic temperature is low
- ✓ Cooling Media was consistent (135 gpm)

Reactions with low recovery

- ✓ Pressure variations
- ✓ Condensed organic temperature is almost positive (there was no sufficient condensed organic)
- ✓ Cooling Media less than 135 gpm

During Amine reaction process it is required to maintain good cooling media because the boiling point of Amine is 23.5 C; possibly means that the product is losing during reaction or cooking time, affecting the low recovery. Also, reactions with high recovery showed low temperatures of condensed organic because the material was recovered through condenser.

Improve Phase

The objective in the improvement phase is to bring proposed solutions and implement them to solve each problem.

a. As present condensers behaviors, we need approximate 125% more area in order to cool everything (peak gas solution rate). Condenser with more area and cooling will increase the recovery since the organic vapors will not loss.

b. If instead of -32 C Cold Oil Supply temperature is -37 C, these 5 C of change in cold oil temperature affects positively the condensers performance. The temperatures of condensed organic temperature can reach -3 to -14 C.

c. Reevaluate the cooling set point (135 gpm) of condensers. If we have more flow of cold oil, the organic vapors can be converted to liquid easily. See diagram below.

d. Perform a pressure test through all system to assure the integrity of the lines and equipment.

After modifications in the Amine Reaction Process, the yield has increased from 0.788 (annual average) to 0.806. Using the baseline 0.809 for the yield, the percent increased by 3%.

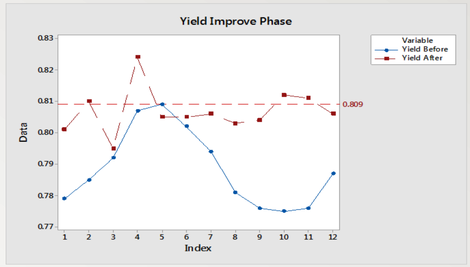

*Figure 6: Amine **Yield Before and After***

Improve Phase (cont.)

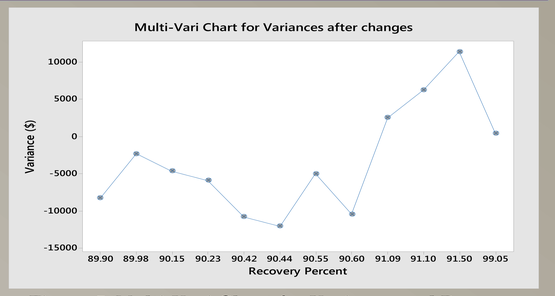

Figure 7: Multi-Vari Chart for Variance and Recovery

As shown in the graph in graph, the Amine Recovery Percent is around 90% and there no significant variances comparing with last performance mentioned in Define phase

Control Phase

One key to achieve continuous improvement is to standardize the process. In order to accomplish this, new process was implemented:

- ✓ Manufacturing Batch Records were revised to include new setpoint of Cold Oil flow by 185 gpm instead of 135 gpm.
- ✓ Utilities Department fixed the Cold Oil temperature by -37 C.
- ✓ Everyone involved in the process received proper training and that effective communication occurred.
- ✓ Process monitoring is important to identify opportunities for continuous improvement, to confirm the new process, and measure achievement.

The I-MR chart below shows that average in variances is $-3,205 and with this result the process has been recovered $35,080 per month.

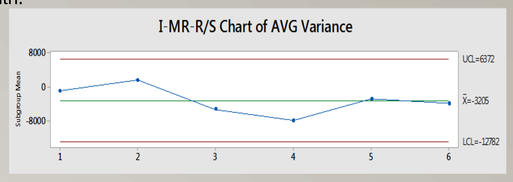

Figure 7: I-MR Chart for the variance average ($)

Conclusion

Six Sigma looks at all work as a series of processes with inherent variations, which can cause inefficiency. According to the data collected, the Amine process was able to increase the recovery percentage by 2% and the Deramine yield by 3%. These factors have a greater impact in financial terms. At the end of the project, all the objectives were achieved, exceeding the loss reduction by $35K per month and the performance by 1%.

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[1] Six Sigma DMAIC Roadmap." ISixSigma, 2000,"
[Online]. Available: www.isixsigma.com/new-to-six-sigma/dmaic/six-sigma-dmaic-roadmap
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