Six Sigma Success

Charles McGrew, William Martin and Gary Marr, UOP LLC, USA, discuss the Six Sigma methodology and present a casestudy on its application to catalyst technology.

Six Sigma is a widely used methodology, shown to improve manufacturing processes. Its principles can also be applied more broadly to business functions dealing with research and finance processes. The Six Sigma methodology was developed by Motorola in the 1980s and later used by Honeywell, GE and other companies. In 1995 UOP began using the Six Sigma process to analyse and improve its manufacturing processes. The manufacturing process for refining and petrochemical catalysts was one of the first applications of Six Sigma methodology within UOP. This article covers a casestudy where UOP utilised Six Sigma methodology to develop two new light naphtha isomerisation catalysts, I-6 Plus™ and I-62™.

What is it?
Six Sigma is a comprehensive, flexible and integrated set of methods and tools used to achieve, maximise and sustain business success. Six Sigma, when used to improve a manufacturing process, can result in lowered manufacturing costs, increased product quality and an overall reduction in the defect rate.

Six Sigma takes its name from σ (sigma), a letter in the Greek alphabet which is the symbol for standard deviation. It is the measure of variance in a process. The goal of Six Sigma is to reduce the process output variance so there are at least six standard deviations (hence Six Sigma) between the mean and the nearest specification limit. When a process is operating at Six Sigma, there can be no more than 3.4 defects per million production units.

Six Sigma is different from other quality improvement initiatives in that it utilises an extensive set of interconnected tools allowing a larger business and customer focus emphasis. The key principle is data driven methodology with decisions based upon facts. All of its projects follow the structured, data driven DMAIC process, which progresses through a series of phases. These phases are:

- Define.
- Measure.
- Analyse.
- Improve.
- Control.

Tools
The many tools available are what set Six Sigma apart from other quality improvement initiatives. The number and type of tools used are dependent upon the complexity of the project. Table 1 summarises the primary tools used in each of the phases.

Another key element of the method is the use of teams comprised of individuals with intimate knowledge of the process being investigated. The combination of the data based methodology and a knowledgeable project team make the process a powerful tool.

Penex™ Light naphtha isomerisation process
Upgrading light naphtha octane via isomerisation has been popular since UOP commercialised the first Penex unit in 1958. Figure 1 is a flow diagram of a typical once through Penex unit. The Penex process is a catalytic process for isomerising a low octane light naphtha feed (containing a mixture of pentane and hexane) to a higher octane, branched pentane and hexane isomers. Typically a light naphtha stream can be upgraded from approximately 70 RONC to as high as 85 RONC in a once through Penex unit. Isomerisation of a light naphtha feedstock allows a refiner to economically produce a relatively high octane, environmentally clean, gasoline blending component, free from benzene, aromatics,
reactor temperatures and to therefore produce a product with a high octane.

### I-8 Catalyst Six Sigma project

The I-8 catalyst has been widely accepted by the refining community, however UOP is committed to providing better value to its customers via continuous process improvement in the work place and quality improvement in manufacturing plants. UOP has a number of tools to improve its work process and to develop new catalysts. Examples of these tools are:

- Combinatorial chemistry: allows for the testing of hundreds of samples in a short period of time. This allows for the development and commercialisation of new catalysts much faster than in the past.
- Catalyst design engine: uses fundamental chemistry and material properties to tailor a catalyst for a specific application.

Some of these tools, for example, combinatorial chemistry and catalyst design engine, are primarily used for the development of new catalysts and new processes. Other tools are used to improve existing processes.

One of the primary tools that UOP uses to improve its manufacturing processes is Six Sigma methodology. To identify improvements in the manufacture of I-8 catalyst, UOP formed a Six Sigma team comprised of operations and development experts with an intimate knowledge of the I-8 catalyst manufacturing process.

The team utilised the DMAIC process and many of the tools identified in Table 1. The team clearly mapped the process steps, quantified baseline metrics, developed a 'should be' map and designed an implementation plan to identify several areas for improvement. The recommendations of the team were actioned according to the implementation plan. Areas of manufacturing improvement ranged from simple changes such as those in SOP (standard operating procedures) to complex changes such as capital investment for new instrumentation and new process equipment.

The manufacturing improvements resulted in a 15% increase in the relative activity of the I-8 catalyst (Figure 2). The process enabled UOP to improve its manufacturing process and create the new I-8 Plus™ catalyst.

### I-8 Plus catalyst

To quantify the benefits of improving UOP’s manufacturing process, I-8 Plus catalyst was loaded into a commercial once-through Penex unit and the performance was compared with the unit’s previous performance with I-8 catalyst.

Figure 3 plots the operating severity versus the paraffin isomerisation number (PIN) data measured during these operations. The PIN is the sum of the non-normal isomers contained in the product. The higher the PIN, the higher the activity of the catalyst and the greater the degree of isomerisation performed in the unit. As Figure 3 demonstrates, I-8 Plus catalyst produces a PIN that is four numbers higher than that produced by the I-8 catalyst.

Using I-8 Plus catalyst provides the following benefits:

- Increased activity, which permits operations at lower temperatures and higher octanes.
- Increased time between catalyst replacements due to lower reactor temperatures.

### I-82 catalyst

The I-8 catalyst has been the workhorse in light naphtha isomerisation for over 20 years. However, in response to the refining industry’s need for a catalyst with even higher activity, UOP commercialised I-80™ catalyst in 1999. I-80 catalyst provides the following benefits relative to I-8 catalyst:
- Increased activity enabling the production of a higher octane product. In a once-through Penex unit, operating with a typical light naphtha feedstock, the more active I-80 catalyst produces a 0.9 higher RONC product.
- Increased time between catalyst replacements, due to lower reactor temperatures.

During the project, the team identified manufacturing improvements which produced the I-8 Plus catalyst that is 15% more active than I-8 catalyst. However, the activity of I-80 catalyst remains higher than that of I-8 Plus catalyst. The next step in the Penex catalyst development process was to take the findings from the project and determine if they could be applied to the I-80 catalyst.

When I-80 was examined, the team concluded that the information from the development of I-8 Plus could best be applied to a new alumina raw material. A new, low density, raw material would require less catalyst to be purchased by the refiner to fill a given reactor volume. This in turn means less platinum is required.

Using a new alumina raw material and the manufacturing improvements identified in the project, UOP developed a new high activity catalyst, I-82™. Figure 4 shows the yield/octane performance for I-82 catalyst and I-80 catalyst. As Figure 4 demonstrates, the performance of the I-82 and I-80 catalysts are essentially identical. Table 2 summarises some of the physical properties of I-80 and I-82 catalysts.

Compared to I-80 catalyst, the I-82 catalyst provides the same activity with the following benefits:
- Less catalyst required for reactor loading. I-82 catalyst is approximately 9% less dense, and therefore less catalyst by weight needs to be purchased for a given reactor volume.
- Less platinum required. I-82 catalyst contains 9% less platinum for a given volume.

Commercial experience
As of August 2003, the I-82 catalyst is partially loaded into one Penex unit; and the I-8 Plus catalyst is partially loaded into 14 Penex units, and fully loaded into one Penex unit.

Conclusion
There are a number of different tools used by UOP to improve work processes and manufacturing efficiencies and to develop new catalysts. Six Sigma is one of these tools. It is a data-driven, fact-based methodology, that has a large number of tools that can be utilised to not only improve manufacturing processes but also much broader business processes.

UOP has used Six Sigma methodology to improve its catalyst manufacturing capability, not only creating a more efficient manufacturing process but by also developing improved catalysts, I-8 Plus and I-82. The I-8 Plus catalyst allows refineries to increase revenues by producing a higher octane product. Operating costs are reduced by extending the time required between catalyst changes.

The I-82 catalyst is perfect for refineries needing high activity. Due to its lower density than I-80, refineries can produce the same product using 9% less platinum and catalyst.

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