History of Catalyst Handling

Back in the early 1960s, refinery and chemical processes were becoming more complex. This changing complexity required catalysts capable of providing greater yields while operating under more severe conditions. The severity of the production runs caused the reactor units to change with greater frequency. These more expensive catalysts were often reusable, but required careful handling. The traditional programme during a shut-down and after regeneration was to dump the catalyst into the bucket on a front-end loader and take it to another site for screening by hand. It was important to treat the catalyst gently because of its friability. Separating the broken chips and fines from the full- or larger-size catalyst particles and the inert balls required special material-handling systems. Some plants did not have this equipment. Others acquired various types of equipment, including screeners, to perform the task. Unfortunately, plant personnel with experience and knowledge about operating this equipment were often needed elsewhere.

One small contractor company based in Alvin, Texas that performed various contract services for one of the local plants recognised a need to improve this system. They built a system with specialised components that would operate efficiently and provide the customer with a clean, perfectly sized catalyst for re-use in the process units. The contractor company, after carefully removing and drumming the catalyst, convinced the customer to allow it to be taken to their facility for proper screening and sizing.

After about a year of operation, it became apparent that a mobile unit would be more efficient. The contractor used the services of Merlin G Hoiseth, PE, a contract engineer, to design and build a self-contained mobile screening machine with dust-collection capabilities. The result was the patented Soft-Flow Catalyst Screener. This unit was demonstrated to several more plants and was soon used throughout the industry. The new screener set a standard by which all screening results were measured.

Along with the need to screen the catalyst, there was also a need to remove it from reactors easily. A self-contained vacuuming system with an air/material separation chamber (cyclone), a dust collector and an engine-driven vacuum pump needed to be designed. This original trailer-mounted unit proved useful but cumbersome and difficult to manoeuvre in and around a plant. A modified design – the Supersucker – followed and became the forerunner of today’s mobile vacuuming system.

Catalyst screening – sieving, sifting or shaking, depending on the relevant industry – became a frequent necessity for most process units. Sulphuric acid converters required the dust and chips to be removed no less than once a year. Gas processing plants had a need to do the same for their dryers. Also, more refinery units needed such service, particularly in their reformer units. By the late 1960s, there were three companies providing such services, located in California, Tennessee and Texas.

Removing and screening the catalyst quickly and efficiently became only a part of the total picture. Improvement was directed towards more efficient loading systems. Flow bins were designed and implemented for loading catalyst or inerts, and temporary storage of a screened catalyst was improved. Cranes or cherry-pickers for lifting the flow bins became standard. Loading catalyst into tubular reactors, such as hydrogen furnaces, ethylene oxide (EO) reactors and small-diameter tubes, required different techniques – such as the plastic sock method for loading hydrogen furnace tubes – and equipment – such as the multitube loader.

Soon, refiners were finding the need to change catalyst more frequently, and downtime became critical. Each day that could be saved meant significant reduction of lost production costs. Ways were sought to minimise downtime, one of which was to purge the units with nitrogen and dump the catalyst un-regenerated. Another way was to dump the catalyst saturated with light oil. The light oil method had remaining residue, which was often more than half the bed and had to be flushed out with water, thus destroying the catalyst. Purging the units with nitrogen allowed the catalyst to be regenerated ex situ if kept in an oxygen-free container.

Personal safety was of primary concern when considering the nitrogen purge dump. Multibed reactors, such as hydro-crackers, posed a greater problem when dumping, and often required workers to enter the vessel to unplug the internal dump tubes. Whether or not the catalyst was wet with oil or water, it might contain fluorides, might be coked and pyrophoric or there might have been a formation of carbonyls. With all these possibilities, Shell Oil requested better equipment and techniques for personnel working in such conditions.

Since resources were limited, the Bendix Corporation, which designed equipment for the space programme, was contracted to design and build the breathing apparatus. The criterion was the use of a hard hat helmet that could be locked on to the worker to
prevent it from being removed. With redundant air supplies controlled through a console and monitored by an operator, the worker could safely perform his or her duties. Once the equipment was built, Shell decided to sell the system to a company called Alien Atmospheres, which became the first company to commercialise the performance of work in a nitrogen-saturated environment, or one immediately dangerous to life and health (IDLH).

Inert entry – the term used when workers performed catalyst handling functions in reactors while being purged with nitrogen – gained acceptance very slowly. Two of the factors influencing its viability were assurance of the workers' personal safety and an increased need for ex situ catalyst regeneration.

Assurance of the workers' safety was achieved by:

- demonstrating that the air supplied to the ‘respirator’ would be provided by three independent sources.
- locking the helmet on to prevent removal in case of panic;
- communicating continuously with all the crew; and
- training the workers in the procedures of performing work under such conditions as well as emergency rescue operations.

In 1976, Reactor Services International, Inc. (RSI) redesigned the ‘life support system’ by modularising the system so that each worker had his or her own primary and secondary console. In addition, the console was totally air operated without dependence on electrical components as alarm indicators. This new system was the Supplied Air Monitoring System (SAMS®), and was ultimately approved by the National Institute of Occupational Safety and Health (NIOSH).

RSI and other operators are also to be credited with developing some innovative catalyst-handling ideas. An example is the Catalyst Oriented Packing (COP®), which is a method of loading catalysts, a multitube loading device for loading tubular reactors and an electronic magnetic separator for removing trash iron from the catalyst as it is dumped.

Professionals in the catalyst-handling industry have a challenging responsibility to keep up with new developments. The technology itself is continually evolving. There are many types of refinery processing units and myriad processes in the chemical industry – as well as in natural and synthetic gas, ammonia and sulphuric-acid manufacturing – each with its own unique requirements. Add to this over 1,000 different designations of manufactured catalysts, and it is evident that the learning curve for new technologies has been steep. Those who succeed in this business accept the above as a given and budget the resources to keep up with new technologies as they appear. Furthermore, almost all of the catalyst-handling techniques in use today have been well established for some time now. The bigger challenge in the present business climate is keeping up with new developments in government regulations while continuing to meet client expectations.

What Is Really New in Catalyst Handling Today?
Safety, safety and more safety. The biggest challenge today is dealing wisely with the issues of protecting workers and the environment. In the push for productivity, the cost of doing business goes up when
History of Catalyst Handling

worker safety and environmental impacts are ignored. Improving the industry’s performance in these areas is clearly a vital goal.

The current guidelines – Occupational Safety and Health Administration (OSHA 1910.119), Process Safety Management – have become the predominant focus of most of the industry’s management personnel. Safety is the catalyst industry’s primary emphasis.

Experienced contractors must be familiar with processes ranging from those found in a refinery to those found in a petrochemical plant. Likewise, contractors must be familiar with reactor designs associated with the particular processes.

Pre-job and Pre-bid Considerations

The bidding contractor has a number of considerations to make when presenting a proposal for changing catalyst. In dealing with the hydro-processing units, the following questions are considered:

- What are the unit operating conditions prior to shut-down?
- What was the length of the run or last change-out?
- What is the type of catalyst in the reactor?
- What are the shut-down procedures and vessel cool-down preparations?
- Is the catalyst un-regenerated or regenerated?
- What is the physical design of the reactor?
- Which work areas will be co-ordinated with other contractors?
- What utilities are available?
- Who is to dispose of the spent catalyst?
- How much time should be allotted for the turnaround?
- Are there any repairs needed to the reactor or its internals?
- What is the loading method (dense or sock)?
- How will the catalyst be packaged?

Once the contractor has been awarded the job, a pre-job meeting is scheduled. In this meeting, co-ordination with the maintenance department, the safety department and others should be well defined and respective expectations fully understood. The following is an explanation of job parameters for the removal of un-regenerated catalyst in a hydروprocessing unit.

The operations department must provide the shut-down and cool-down procedures in order to accomplish an effective removal of hydrocarbons, prevent the generation of carbonyl gases and effectively cool the vessel without metallurgical damage. The maintenance department must provide the necessary piping and blinding to accomplish the shut-down/cool-down procedures. Furthermore, they must organise the logistics of several contractors for the turnaround. The safety department will be concerned about the activities of the various contractors involved, particularly the inert entry involvement by the contractor.

The contractor’s involvement begins with the planning of the shut-down. The pre-job meeting will determine the interfacing requirements with other contractors and the various plant departments. The contractor’s procedures and methods will often be dictated by the allotted time. Since, quite often, a catalyst change-out is on the ‘critical path’, removal of the catalyst must be the primary concern. Removal may be either by dumping from the bottom- or side-dump nozzles or by vacuuming. Dumping into large containers, such as flow bins, is generally the quickest method. If screening of the catalyst is required, the equipment may be located at some offsite location. When vacuuming either the entire bed of catalyst or the residual ‘angle of repose’, the reactor must contain a continuous purge of nitrogen and the exhaust of the vacuum unit must be re-circulated back into the reactor.

Prior to starting the dumping/vacuuming procedure, a checklist should be implemented to ensure safe vessel entry. Typically, the effluent gases released from the opened man-way contain a substantial volume of hydrocarbons, i.e. the lower explosive limit (LEL) is excessive. Vessel entry standards used throughout the industry prohibit entry into an atmosphere of greater than 10% LEL. Many procedures have parameters between 0 and 5% LEL. The correct place for measuring LEL is at the man-way opening, since the instruments that read explosivity operate only when there is oxygen present. The greatest danger of explosion exists at the point where hydrocarbons meet the air. If there are substantial hydrocarbons present in the corresponding effluent gas, there is a danger of fire. However, proper shut-down procedures and a sufficient nitrogen purge will prevent this occurrence.

Monitoring of the gases in and around the reactor openings, as well as throughout the vessel, is an important step in the catalyst change-out process. The shut-down procedure involves a hot hydrogen strip, nitrogen purge circulation of light cycle oil or some type of passivating chemical. Upon opening the reactor, certain checks are made to determine the presence of hydrogen sulphide, carbon monoxide, carboxyls and the LEL of hydrocarbons. Some hydrocarbons are igniteable when mixed with as little as 7% oxygen. This procedure is important regardless of the type of shut-down procedure.

Once the pre-determined percentage of the LEL measured at the man-way opening is satisfactory and entry into the reactor is permissible, continuous monitoring should occur. If the reactor is purged with nitrogen, the LEL should be continually monitored at the man-way opening and oxygen content should be monitored inside the reactor. Oxygen content is monitored throughout the vessel as well as where the personnel are working or where the re-circulated nitrogen is entering the reactor. Nitrogen purging and re-circulation of the nitrogen, as a general rule, should produce an environment in which no more than 5% oxygen be allowed to accumulate. In most instances, oxygen levels are inside the vessel and re-circulation systems are maintained at 0%.

It is important to understand that the high LEL inside a nitrogen-purged reactor is not bad if the oxygen content is maintained at less than 5% (preferably 0%). It is only when high amounts of oxygen are present that an ignitable condition can exist. In fact, it is safer to work in an environment that can be made inert and maintained inert. In a confined space where air is the primary environment, a possibility exists that hydrocarbons can invade the space. Such is the case when reactors are dumped in an air atmosphere, even if the catalyst has been wetted with oil or an oil/chemical mixture.

In the end it is not ‘new technology’ that is the key to catalyst handling, but rather the planning, training and safety procedures. With these steps in place, success is guaranteed on any catalyst change-out.