Pipework: a pig to clean

Pipe purging technology cuts costs and contamination
Lionel Bisteur.

Pigging is a technology for cleaning pipework efficiently by forcing a scraper or "pig" through the pipe. Its key advantage is that it allows many products to be dispensed through a single pipeline with high accuracy and minimal contamination. This in turn reduces waste and improves safety. Although a pigged system must be carefully designed and is more expensive than a simple pipeline, the payback period for the installation may be less than a year.

The use of pigging systems to clean pipework in paint plants can offer both technical and economic benefits. Pigging is based on the movement of a scraper, called "pig", inside a pipe. It is believed that the process was invented at the end of the nineteenth century, initially within the crude oil industry, purely as a maintenance tool to scavenge the pipeline with a simple leather ball. Since then, pigging technology has developed into a genuine process tool through the use of closed systems able to scavenge the pipe in both directions, giving security and flexibility to the production line (Figure 1). Recent developments have made the systems completely safe, and from waterborne to solvent-based systems and from decorative to automotive paints, a wide range of solutions is available to help paint producers deal with their industrial and development challenges effectively.

The basic functions of pigging

Product transfer
Essentially, pigging enables different products to be transferred in the same line without cross-contamination. Considering a nominal pipe diameter of 80 mm, where up to 5 litres per metre of products could remain inside after use, the basic function of recovering this produces a fast payback. Pigging thus represents an ideal compromise between a conventional "piped" process and the pipeless process in which the vessel moves to the raw material storage area instead of the raw material moving to the dosing or mixing vessel.

Product recovery
By propelling the pig with a liquid (solvent or water) or a gas (nitrogen or air), the entire transferred product can be recovered, thus saving on both product and cleaning media.

Pipe cleaning
By introducing cleaning media into the line in association with a pigging cycle, cleaning operations and the wastes they generate are reduced by approximately 80 - 90%. In addition, bacteriological contamination is considerably decreased.

Flexibility is a key advantage

Piping networks are simplified
It is not always possible to install a dedicated pipe for each raw material inside an existing factory because of a lack of space. Pigging avoids the need to use dedicated pipes which may be difficult or impossible to clean. The piping network and the connections between the process tanks are thus optimised.

Production becomes more responsive to demand
The possible connections to and from a pigged pipe network provide flexibility for the production unit, high availability and easy adaptation to market requirements by facilitating:
- Small batch manufacturing
- Shorter delivery times
- JIT (just-in-time) production.

An example of such a small-batch production installation is shown in Figure 2.

Installation space can be optimised
With pigged systems, the arrangement of the main production equipment can be optimised and rationalised:
- For instance, areas such as production, letdown tanks, raw material storage or filling lines are well defined.
- The area which must be explosion-protected (Ex) can be limited to a strict minimum.
- When updating a plant, it may be quite difficult to properly install new dedicated pipes, and a multi-product pipe would definitely be preferable. Conventional pipelines need a draining angle or fall of at least 1 cm/m to be self-draining, and this requirement may make it difficult to connect them to additional tanks. A pigged line needs no such draining, and also enables upwards transfer, hence making a single level configuration of the production area possible.

Pigging can reduce waste treatment costs by up to 95%
By reducing the quantities of cleaning media, the costs of waste treatment can be cut by approximately 95%. This system avoids leaving quantities of product remaining in the pipe, which could then be degraded by standing in the pipe under high or low temperatures. A pigged line is considered as a closed system. So vapour emissions, or nitrogen used as a propellant, are easily isolated, contained and vented. Using nitrogen as pig propellant helps to modify or reduce the hazardous area classification.

Transfer of incompatible products in the same line
Products such as slurries have to be maintained in movement to avoid sedimentation. Dead zones in the pipe are unacceptable, and circulation lines prevent this phenomenon occurring. However, a pigged line is preferable for long distances in particular, because of the economic benefits of avoiding material remaining in the pipe. Pigging enables different kinds of products to be transferred, whether they are compatible or not, in the same line. From simple processes (one inlet, one outlet) to more complicated ones (multiple inlets and outlets) the modular concept of pigging technology provides a very efficient solution.

Safety and security are improved
Compared with flexible hoses, the fixed connections of a pigged line guarantee the same flexibility with higher safety levels for operators. By controlling the status of the pipeline, the conveyance of toxic chemicals is made safer by pushing them out of the pipe. Transfer operations are much safer with respect to quantities remaining in the pipe and thus to maintenance operations.

Global engineered solution maximises benefits
Pigging technology is not a simple matter of assembling components, but must be considered in terms of a global engineered solution. In addition to giving added value in itself, this technology can produce better organisation and increase the capabilities of a production unit. That is the reason why the process specifications (e.g. process cycle, capacities, utilisation rates, product characteristics) have to be integrated into the overall design.

The mechanical aspects are not the least of the difficulties:
- Routing of pipes (elbows are a particular problem).
- Pipe specification (tolerance and roughness must be taken into account).
- The assembly must be “state of the art”.
- Mechanical and chemical design of the pigs must be taken into account (a compromise between abrasion and chemical resistance).

The best results will be achieved if all these parameters have been taken into consideration. Some results which illustrate what can be achieved are shown for an automotive paint application. In particular, customers have found that the first kilogram of transferred paint should not be contaminated by the previous one after an intermediate pigging sequence. The results in Table 1 show that the level of contamination was less than 100 ppm.

**Different systems meet specific needs**

**Raw material distribution**

When the requirement is to dose all main raw materials at only one feeding or introduction point on the pigging line, the pigged collector shown in Figure 3 is a cost-effective solution for avoiding cross-contamination and allowing a single mass flowmeter to be used for several raw materials, while ensuring compact dimensions.

**Additive and colour paste distribution**

Additives and colour pastes represent a significant part of raw material costs, which can be as high as 80%. Moreover, they are required in large numbers and are highly concentrated. The simple but effective dosing system shown in Figure 4 ensures accurate dosing of small quantities, their transfer and complete recovery inside the mixer without cross-contamination.

**Many products, many routes**

The interconnection unit or manifold (also termed a “Pigged Matrix”), shown in Figure 5 interconnects pigged and dedicated lines when a substantial number of inlets and outlets are required. The manifold replaces multiple flexible hose connections and therefore avoids human interventions and mistakes. Product spillages are eliminated and the working environment is made safer.

**Control systems should match the installation**

Depending on the complexity of the plant, the control mode can be manual or completely automatic. The manual mode, using hand operated valves, mechanical or electrical pig detectors, pressure indicators, push buttons, control switches and lamps, should be used for simple pigging lines, single pigs and systems having few inlets and outlets. Its principal advantage is in reduced investment cost. An automatically operated pigging sequence is implemented wholly by PLC (programmable logic controller), including automatic valves and electrical pig detectors, with monitoring from a flow diagram on a mimic screen (see Figure 6) or a control box. Although the investment cost is increased, the main advantages provided are control safety, no need for a site operator and reliable management of the line status.

**Rapid payback can be achieved**

From a purely economic point of view, pigging is a production technology with one of the most rapid returns on investment (ROI). This can be illustrated by a case history based on a simple pigging line in Scandinavia. Table 2 shows the ROI calculation for the additional costs of a pigged pipeline compared to standard one. Payback of the investment is achieved when the difference in investment costs equals the cumulated difference in operating cost savings, according to:

\[
(\text{IP} - \text{IS}) = t (\text{OS} - \text{OP})
\]

or

\[
t = (\text{IP} - \text{IS}) / (\text{OS} - \text{OP})
\]

where \(t\) is the break-even time (in weeks), \(\text{IP}\) and \(\text{IS}\) are the capital costs for the pigged and standard lines, and \(\text{OS}\) and \(\text{OP}\) the total operating costs per week of the pigged and standard systems, respectively.

With the values from Table 2 (\(\text{IP}\): 41,000 EUR, \(\text{IS}\): 5,335 EUR, \(\text{OS}\): 1,209 EUR/week, \(\text{OP}\): 73 EUR/week), the break-even time is found to be as short as approximately 31 weeks.

Thus, the potential benefits of pigging technology can be summarised in a few key words and phrases which almost every plant manager would like to see applied to his unit: efficiency, economical production, short payback time, environmentally friendly, improved security, greater flexibility, easy adaptation to a changing market and Just-In-Time production systems.

**Results at a glance**

- Pigging is a method of cleaning pipes by forcing an object (the “pig”) through a pipe.
- Pigging has developed from primitive origins in the oil industry to sophisticated computer controlled systems.
- Efficient cleaning of pipes by pigging allows many products to be handled through a single pipeline.
- Product wastage and use of cleaning materials can be dramatically reduced.
- Safety can be improved by more compact plant design and the immediate removal of hazardous materials from pipelines after transfer.
- Although installing pigged lines may be expensive, the savings in materials and cleaning costs can repay the investment very rapidly.

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Figure 1: Example of a modern pipe-cleaning pig
Figure 2: Production unit for small batches, using pigged lines to simplify operations
Figure 3: Pigged collector system, using a single flowmeter to dose many materials into one pigged line
Figure 4: "Dosrac" distribution system for colour pastes
Figure 5: Pigged manifold system - the way to send anything anywhere
Figure 6: Flow diagram for a pigging system as shown on a mimic screen.
Table 5: Specified maximum values for product cross-contamination (expressed in terms of colour deviation) and results actually achieved by supplying materials through a pigged line

<table>
<thead>
<tr>
<th>Customer</th>
<th>Specification</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lightness (dL)</td>
<td>Chroma (dC)</td>
</tr>
<tr>
<td>Customer A</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td>Customer P</td>
<td>0.25</td>
<td>0.5</td>
</tr>
<tr>
<td>Customer H</td>
<td>0.25</td>
<td>0.5</td>
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### Table 2: Comparison of investment and operating costs for standard and pigged lines

<table>
<thead>
<tr>
<th></th>
<th>Standard pipe</th>
<th>Pigging solution</th>
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<tbody>
<tr>
<td><strong>Investment costs:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( I_s = 5,335 ) ( € )</td>
<td>( I_p = 41,000 ) ( € )</td>
</tr>
<tr>
<td><strong>Weekly operating costs:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production changes/pigging cycles</td>
<td>per week</td>
<td>15</td>
</tr>
<tr>
<td>Loss of product</td>
<td>kg/week</td>
<td>15 x 27 = 405</td>
</tr>
<tr>
<td></td>
<td>€/week</td>
<td>932</td>
</tr>
<tr>
<td>Propellant required</td>
<td>€/week</td>
<td>0</td>
</tr>
<tr>
<td>Cleaning solvent required</td>
<td>l/week</td>
<td>642</td>
</tr>
<tr>
<td></td>
<td>€/week</td>
<td>244</td>
</tr>
<tr>
<td>Cleaning solvent emptying</td>
<td>€/week</td>
<td>10</td>
</tr>
<tr>
<td>Cleaning solvent treatment (0.038 €/l)</td>
<td>€/week</td>
<td>24</td>
</tr>
<tr>
<td><strong>Total operating costs</strong></td>
<td>€/week</td>
<td>( O_p = 1,209 ) €</td>
</tr>
</tbody>
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