A Shutdown Story

K W McQuillan
Huntsman Petrochemicals (UK) Ltd

K McGeachie
Huntsman Petrochemicals (UK) Ltd
kenny_mcgeachie@huntsman.com

D Richards
ABB Eutech
dai.richards@gb.abb.com

ABSTRACT

The Huntsman Olefins plant at Wilton International is one of the largest ethylene crackers in the world, with an annual throughput of approximately 1 million Te of hydrocarbons. The plant is shutdown periodically for maintenance work, and the aim of each shutdown is to prepare the plant for reliable operation until the next planned shutdown. Plant shutdowns are major events, and have many significant impacts:

- Shutdowns provide the only opportunity to inspect, clean, repair or modify the majority of plant equipment, assuring reliability for the next operational campaign.

- Shutdowns are expensive, and take a minimum of approximately 45 days to complete. As such, they are by far the most significant cause of plant unavailability.

- Shutting down and starting up the plant is a hazardous activity which can have significant environmental impact. It also subjects the plant to excursions in duty that can impact equipment integrity.
Since commissioning in 1978 the plant has been through six shutdowns. Initially (until 1993) the interval between shutdowns was constrained by legislation to a maximum of three years, but more recently the introduction of new Pressure Systems legislation has provided for longer interval between shutdowns. This paper describes how engineers at Huntsman have tackled the challenge of providing for increased shutdown interval without causing proportionate increases in the workload or duration of the shutdown, and without causing a reduction in plant reliability.

The paper considers four basic categories of shutdown work; cleaning, inspection, repair and modification, and looks at the policies and practices which have been developed or used to specify and control the work in each of these categories. Particular attention will be given to the processes for optimising shutdown inspection work, and ensuring that inspection, particularly where internal access is required, is only undertaken where alternative means of confirming equipment integrity are not available.

The paper will present the result of applying the above policies to the 2002 plant shutdown, scheduled for Mar 2002 and designed to provide for reliable high rate plant operation until 2008. The 2002 shutdown will be compared, both in overall size and by type of work, with earlier events.
CONTENTS

1 Introduction and Background
2 Worklist Preparation
3 Inspection during shutdowns
4 Repairs and Cleaning
5 Engineering Standards
6 Worklist Analysis
7 Contracts and Contractor Management
8 Conclusions
9 References
1 INTRODUCTION AND BACKGROUND

Planned shutdowns are an accepted feature in the operation of almost all large chemical plants; they provide engineers the opportunity to inspect, clean, repair and modify equipment that is otherwise in continuous operation. The impact of shutdowns on the overall plant reliability can be expressed in the equation:

\[
\text{Plant “unavailability”} = \frac{\text{breakdown outage} + \text{shutdown duration}}{\text{shutdown interval}}
\]

From this equation it can be seen that there is a benefit from optimising the work done during a shutdown to:

- Reduce the probability of breakdowns between shutdowns
- Protect future process performance at design throughput / energy efficiency (the above equation is written on the assumption that the plant can run at full rate during an operational campaign)
- Increase the interval between shutdowns
- Reduce the duration of each shutdown

There is a clear conflict in the above issues; it might reasonably expected that efforts to reduce breakdowns, protect throughput and energy efficiency, or to increase shutdown intervals would tend to put more work into each shutdown, thus tending to increase the duration of the shutdown. This conflict makes the overall optimisation of workscope a complex issue.

The Huntsman Olefins 6 plant at Wilton International is one of the largest ethylene crackers in the world, with an annual throughput of approximately 1 million Te of hydrocarbons. The plant is shutdown periodically for maintenance work, and until 1994 the task of optimising the work done during shutdowns was simplified by the
fixing of one of the variables in the above equation. National legislation required that the plant was shut down every three years to provide for inspection of the steam systems, and thus the task facing the engineers in preparation for each shutdown was to identify the work required to allow the plant to run reliably over the three year period between shutdowns. However, the introduction of the Pressure Systems Regulations in 1994 provided flexibility, where technically justified, to vary the shutdown interval, thus exposing the organisation to the full complexity of the optimisation process.

A number of other issues have caused most chemical plant operators to simplify the optimisation process by looking to extend shutdown intervals as far as practical, whilst trying to minimise the increase in the “per shutdown” workload. Some of the key factors driving this trend are:

- There is a minimum fixed duration and cost associated with all shutdowns; the times taken to de inventory and subsequently recommission the plant.

- The process of shutting down and starting up complex chemical plants is hazardous

- The period of plant operation immediately after a shutdown is often characterised by unsteady plant conditions and high levels of equipment breakdown

Since the introduction of the Pressure Systems Regulations in 1994 the Olefins 6 plant at Wilton has moved away from the fixed three-year shutdown interval, with subsequent shutdowns in 1997 and 2002. The aim of the 2002 shutdown has been to prepare the plant for reliable high rate operation for a period of six years until the next planned shutdown in 2008. This paper describes the key issues considered during the preparation and delivery of the 2002 shutdown, looking in particular at:
• The preparation of the worklist and the comparison of the worklist with previous shutdowns.

• The use of a risk based approach to optimise inspection activities, eliminating unnecessary work from the shutdown.

• The use of novel engineering techniques and control of engineering standards.

• The use of incentivised contracts to help align the objectives of the contractors with those of the client organisation.

2 WORKLIST PREPARATION

The stated aim of the 2002 Olefins shutdown was to specify and deliver the work required to support reliable high rate operation of the plant until the next scheduled shutdown in 2008. An unwritten further aim was to ensure that the duration of the shutdown, and therefore the total work undertaken within the shutdown, could be held at approximately the same levels as achieved in previous shutdowns. In order to understand this it is useful to divide the work done during the shutdown into 4 types, as below:

• Repair of defects

• Equipment inspection and testing

• Equipment cleaning

• Modifications
Analysis of the 1993 and 1997 shutdowns shows that modifications are a relatively small part of the total workload. It is reasonable to expect that the workload associated with repairing defects and cleaning equipment will generally be proportional to the chosen shutdown interval, so in order to achieve the aim of delivering a 6 year interval without increasing the overall shutdown workscope it would be necessary to reduce the amount of inspection work in order to compensate for the increase in defect repair and cleaning (section 3). Alternatively, it would be necessary to find more effective ways of making repairs or cleaning equipment (section 4).

<table>
<thead>
<tr>
<th>Work type</th>
<th>1993 shutdown</th>
<th>1997 shutdown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
<td>Percentage</td>
</tr>
<tr>
<td>Repair</td>
<td>56520</td>
<td>36</td>
</tr>
<tr>
<td>Inspect and test Cleaning</td>
<td>80070</td>
<td>51</td>
</tr>
<tr>
<td>Cleaning</td>
<td>7850</td>
<td>05</td>
</tr>
<tr>
<td>Modification</td>
<td>12560</td>
<td>08</td>
</tr>
<tr>
<td>Total</td>
<td>157000</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1 Analysis of work for 1993 and 1997 shutdowns

3 INSPECTION DURING SHUTDOWNS

Historically, shutdown intervals and workscope have been dominated by the statutory and company requirements for routine inspection and testing of key items of equipment, primarily pressure vessels and heat exchangers. These inspections have mainly been delivered by visual internal inspection of the equipment, which coincidentally requires an amount of cleaning in order to provide access to the equipment. Items of equipment covered by legislation were required to be inspected at each shutdown, but for other items the inspection interval could be extended subject to the equipment remaining in good condition. By 1993 the inspection intervals for the equipment on Olefins 6 were as shown in table 2.
This situation allowed the inspection workload to be spread out between shutdowns, but clearly any move to increase the interval between shutdowns would cause a proportionate increase in the inspection workload at each shutdown. The introduction of the Pressure Systems Regulations increased the attention given to the effectiveness of the traditional inspection processes; reliance on visual internal inspection, and it was noted that:

- Most visual internal inspections served merely to confirm the good condition of the equipment. Repairs had been necessary in on 5% of cases, and many of these were as a result of damage caused during inspection.

- In many cases the most significant deterioration mechanism was external corrosion, and yet all inspections depended mainly on visual internal inspection.

- The environment within most pressure vessels is hazardous for the inspector, with significant cleaning and preparation required to provide access.

- Despite the general good condition of the equipment at inspection, occasional “surprise / unforeseen” deterioration had been recorded. In these cases remedial work often causes significant delays to the shutdown.

- Little use was being made of advanced technology in support of equipment inspection.

Table 2  Olefins6 - Equipment Inspection Intervals

<table>
<thead>
<tr>
<th>Interval (years)</th>
<th>% of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>12</td>
<td>50</td>
</tr>
</tbody>
</table>
Driven by the above issues, and by the overriding need to support shutdown interval extension by reducing inspection workload, a process was developed and applied during the 1997 plant shutdown preparations. This process has since been further developed both inside and outside Huntsman, and has become characterised as “Risk Based Inspection”. There are three key features of the process:

1. The amount of effort invested in inspecting equipment should be in proportion to the risk associated with failure of the equipment, where the risk is the product of the probability and consequence of failure. This aspect of RBI has been well recognised by most studies, and software packages are now available to help in the quantification of risk.

2. The inspection of equipment should be knowledge based, underpinned by a clear understanding of the behaviour of the item, the potential failure mechanisms and the consequences of failure, and an evaluation of the associated risk. Inspection should be focussed on high-risk items, and be geared to detection and quantification of deterioration arising from the predicted failure mechanism and vulnerable areas. For example, if the likely deterioration is external corrosion under insulation, then inspecting the equipment internally is not the most appropriate method to use. This aspect of RBI (sometimes known as “focussed schemes”) is often given less attention by some exponents of the RBI process, but in many ways is more important and a fundamental pre-requisite of the assessment of risk (if it is not know how the equipment is likely to fail, how can the failure consequences be established?).

3. The RBI process should be multi-disciplinary, using a mixture of process, plant design, materials and inspection expertise. The RBI review explores the duty and condition of the equipment, establishing what can happen and why. The process can identify opportunities for improvements in process control and design or material selection since it will establish “proximate cause” of an experienced or predicted failure.
The Huntsman approach to RBI was initially developed and applied as a pilot project during the 1997 Olefins6 plant shutdown, and the results of this process are evident in table 1 which shows a clear reduction in inspection workload and an increase in cleaning workload in the 1997 shutdown compared to the 1993 shutdown. Since then the process has been further refined in partnership with ABB Eutech, the Inspection Authority for Huntsman, (Ref. 1). ABB have similar experience with other clients in the process industry sector. The process has been applied in many situations, both in ordinary maintenance and in support of shutdown inspection optimisation.

The impact of the process on the shutdown inspection workload is extremely significant, in that a number of inspections can be carried out with the plant on-line by using non-invasive external inspection as the means of certifying the condition of the equipment. Additionally, the process allows equipment that is likely to have suffered deterioration to be identified so that repair or replacement requirements can be planned into the shutdown, this reducing the likelihood of “surprise” deterioration and unplanned additions to the shutdown workscope. The situation is summarised in table 3.

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of items due for inspection</td>
<td>157</td>
<td>232</td>
</tr>
<tr>
<td>Number of items studied</td>
<td>157</td>
<td>232</td>
</tr>
<tr>
<td>Number of non-invasive inspections</td>
<td>080</td>
<td>188</td>
</tr>
<tr>
<td>Number of SD inspections</td>
<td>081</td>
<td>047</td>
</tr>
<tr>
<td>Number or repair requirements identified prior to shutdown</td>
<td>018</td>
<td>017</td>
</tr>
<tr>
<td>Number of repair requirements identified during shutdown</td>
<td>006</td>
<td>002</td>
</tr>
</tbody>
</table>

**Table 3**  
Impact of Risk Based Inspection on Shutdown Workload
The overall impact of the RBI/focussed scheme process is to optimise the inspection content of the shutdown, by:

- Eliminating unnecessary inspection activity.
- Exploiting the use on on-line non-invasive inspection, thereby reducing shutdown inspection work.
- Ensuring that most likely deterioration is identified prior to the shutdown so that appropriate repair or replacement work can be built into the shutdown plan.
- Ensuring that inspection is a value adding part of maintenance!

4 REPAIRS AND CLEANING

Section 3 described the process used to optimise the inspection content of the shutdown. The two main remaining categories of work are repairs and modifications in support of repair work, and cleaning. In both cases it might be expected that the workload would increase in proportion to the shutdown interval. The following subsections describe some of the approaches taken to limit any growth.

4.1 Repairs
Repair work during shutdowns is dominated by activity to rectify defects identified during plant operation. Significant types of activity include the replacement of defective valves, repacking of valve glands and the replacement of corroded pipework. Most defects arise as a result of normal plant operation, and it would be expected that the total workload would increase in proportion to shutdown interval. Generally it is not possible or cost effective to do the work on-line, so in an effort to control shutdown workload it is useful to look for more effective ways of delivering the work, or technical solutions to avoid / reduce the defect rate on future shutdowns. The most significant saving of this type that was achieved during the 2002 shutdown
was a result of the use of “axial swage pipe connection technology”, Ref 2. This technology uses a fitting that, with the use of hydraulic equipment, establishes a metal to metal interference fit and thus avoids the need for welding and associated costs. Figure 1 shows a sectioned fitting, and figure 2 shows the assembly equipment.

**Figure 1 – Sectioned Swage Fitting**
The fittings can only be used if the parent pipework is in good condition, and use in the 2002 shutdown was limited to service duties only. The fittings were installed by technicians from the shutdown mechanical contractor, and the technicians were trained in the installation process by the supplier of the fittings.

A total of 454 swage fittings were used during the shutdown. Of these, 5 leaked when the plant was recommissioned. In each case the leak was a result of using the fitting on pipework that was in poor condition. The technology provided a significant reduction in the shutdown workload, both by removing the requirement for welding and also by removing the requirement for fire tents and post weld Non Destructive Testing. The savings are estimated at 6500 main trade manhours, plus additional savings in support trade hours. Additionally, the use of the swage fitting technology provides a significant reduction in hot work, thus reducing the risk of fire, and in the requirements for planning and interface management (fire tents, standby men and NDT technicians).
4.2 Cleaning

The impact of the inspection study process described in section 3 was to remove many internal inspection requirements from the shutdown. Coincidentally this also removed the requirement to “clean items in preparation for inspection”. In most pressure vessels this is not a problem, but for heat exchangers and distillation columns lack of cleaning could easily lead to efficiency losses or even rate reductions, especially over a planned 6 year run at potentially high rates. The problem was further compounded by the lack of accurate heat balance data from previous pre / post cleaning heat exchanger operations. It was therefore decided to include identification of cleaning requirements as part of the inspection study, and also to undertake supplementary inspections of items required to be cleaned in order to validate the conclusions of the inspection study. This process generated a list of heat exchangers and columns that were required to be cleaned during the shutdown, together with some pipework that was known to be fouled with polymer.

The traditionally favoured method for heat exchanger cleaning is to blast the tubes with high pressure water. This technique was used on most of the cleaning tasks undertaken during the shutdown, however some improvements were achieved, notably:

- The removal of some bundles from site for chemical cleaning or simply to provide a safer environment for high pressure water jetting.

- The use of hydrokinetic cleaning on suitable duties, see figure 3 and Ref 3. The hydrokinetic process uses acoustic resonance established in a water column within the fouled tube to break the bond between the tube wall and the fouling material. The fouling material is then ejected from the tube by a combination of the water pressure in the column and a plug inserted into the tube as part of the cleaning process. Hydrokinetic cleaning is not suitable for all cleaning applications, but can deliver large cost and duration savings on certain duties.
Use of the Quick Shot Tube Cleaning System, see figure 4. A powerful air and water stream shoots reusable scrubbers through the tubes to remove mud, sludge, algae, and other deposits. The tube scrubbers are loaded into the condenser tubes and propelled through by a stream of air and water via a hand held cleaning gun. Scrubbers consist of a core body and seven scraping discs, which are self-adjusting to the diameter of the tube. Openings at the base of the tips allow passage of water to agitate and advance loosened deposits while maintaining differential pressure to force the scrubber completely through the tube. The scrubber construction assures excellent wear characteristics of the edges without harmful wear to the interior wall of the tube.
5 ENGINEERING STANDARDS

In most chemical plant shutdowns it is necessary to supplement local resource by the use of contractors. In these circumstances control of engineering standards becomes a key issue, particularly where inadequate standards could lead directly to plant integrity problems during testing or start up. Looking at maintenance work during shutdowns, and in particular those aspects that might impact on plant integrity:

- Weld quality is assured by good practise; qualified welders, approved procedures and post weld NDE and pressure testing.

- I/E work is checked by loop checking and trip / alarm testing

- Gasketed joint making, following reassembly of components, is checked by pressure testing and / or leak testing on most systems.

So it could be argued that testing protects against poor standards. However, in the case of gasketed joint making most shutdowns involve many technicians in making hundreds of joints, there is often no traceability of a particular joint to the technicians involved in its assembly, and leaks discovered during leak testing can cause significant and costly delays to the startup.

During leak testing after the 1990 shutdown of Olefins 6 there were major problems with leaks from gasketed joints; approximately 1000 joints had to be retightened and 200 joints were required to be remade. This caused approximately 5 days delay in bringing the plant back on-line, and the investigation after the shutdown concluded that the leaks were mainly caused by poor joint making standards. For the 1993 and 1997 shutdowns a traceability system was introduced, and all technicians were trained in the importance of high standards and the need to identify problems during the maintenance period in order that re-machining etc could be used in a planned way to minimise leaks during testing. This process was extremely effective, reducing the number of leaks to less than 50, and the number of remakes to less than 10.
Traceability was also used during the 2002 shutdown, and as in previous shutdowns the technicians were required to undertake detailed training and validation. The training did not cover the fundamentals of joint making, but focussed on:

- The importance of high standards in joint making.
- The benefits of identifying defects in flange faces or flange misalignment during the maintenance period rather than during leak testing.
- The Olefins joint making procedure, and the use of prescribed torque settings and tightening sequence.
- The requirement for traceability by tagging and the means of achieving this.
- Safety issues and other mandatory requirements (eg the use of new gaskets on all joints).

The training was delivered using a purpose made video, which included statement and demonstration of best practices in mechanical joint integrity. Trainees were required to take a written validation test on completion of the training, and technicians who failed the test were required to repeat the training. The majority of the questions asked in the validation test were covered directly in the training video, but a small number of other relevant questions were also included. The overall pass rate for the validation test was very high, but it was interesting to note that although most candidates could answer correctly the questions covered by the video, there were fewer correct answers to those questions that relied on the technicians general knowledge of joint making.

In order to further improve control of joint making, the requirement to use controlled tightening of all joints was introduced during the 2002 shutdown. HSE Offshore Safety Notice 2/2000 “Bolting of Flanged Joints for Pressurised Systems”, Ref 4, was issued to highlight poor practice in joint making and provide guidance of safe practice in assembly, tightening and inspection. The document emphasises the importance of controlled tightening of gasketed joints. The Olefins joint making procedure was
revised prior to the 2002 shutdown to include the following requirement for controlled tightening:

- All joints with bolts above 1” diameter to be tightened to specified torques using hydraulic torque equipment

- All other joints on hydrocarbon duty to be tightened to specified torques using calibrated hand torque wrenches

- All other joints (service duties with bolts <1” diameter) to be tightened using hand spanners

Guidelines on acceptable levels of flange alignment were also issued, based on the findings of laboratory and site testing work undertaken in cooperation with the gasket supplier, Ref 5. It was established that for spiral wound gaskets misalignment of up to 1 mm was usually acceptable and this figure was incorporated into the joint making procedure.

The revision of the joint making procedure, and the calculation of torque settings, was undertaken in partnership with:

ABB Eutech Suppliers of Design services
Hedley Purvis Suppliers of Design services/Technician Training Centre
and manufacturer of joint making equipment.
Klinger UK Ltd Suppliers of gaskets for the shutdown, Ref 5.

Torque settings for piping flanges were calculated using the Hedley Purvis Infomate Bolting Software System, Ref 6 and 7, and torque settings for heat exchanger and vessel flanges were calculated using BS EN 1591 Part 1 “Flanges and their joints – design rules for gasketed circular flange connections”, Ref 8.
A total of 400 technicians and supervisors were trained and validated in the Olefins joint making procedure, and the application of the procedure was audited during the shutdown. Approximately 7300 flanged joints were made during the shutdown, and 355 flange defects were identified and repaired during the maintenance period. During leak testing and plant commissioning a small number of joints were required to be retorqued, but no joints that had been worked on during the shutdown were required to be remade. This was an excellent performance, and a clear demonstration of the benefits of high standards in gasketed joint making supported by the use of controlled tightening and early identification of flange defects.

6 WORKLIST ANALYSIS

Sections 1 to 5 of this document have described key aspects of the preparation of the worklist for the 2002 Olefins6 plant shutdown, focussing on the need to provide for increased shutdown intervals without incurring proportional increases in workload and shutdown duration. The final worklist for the 2002 shutdown is summarised, in comparison with previous events, in the table below:

<table>
<thead>
<tr>
<th>Work type</th>
<th>1993 shutdown</th>
<th>1997 shutdown</th>
<th>2002 shutdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair</td>
<td>56520</td>
<td>36</td>
<td>91000</td>
</tr>
<tr>
<td>Inspect and Test</td>
<td>80070</td>
<td>51</td>
<td>56000</td>
</tr>
<tr>
<td>Cleaning</td>
<td>7850</td>
<td>5</td>
<td>22000</td>
</tr>
<tr>
<td>Modification</td>
<td>12560</td>
<td>8</td>
<td>15000</td>
</tr>
<tr>
<td>Total</td>
<td>157000</td>
<td>100</td>
<td>184000</td>
</tr>
<tr>
<td>SD interval</td>
<td>4 year</td>
<td>5 year</td>
<td>6 year</td>
</tr>
<tr>
<td>“Per year” hours</td>
<td>39250</td>
<td>36800</td>
<td>27333</td>
</tr>
</tbody>
</table>

Table 4 Worklist analysis including 2002 shutdown
The following key points can be noted:

- The RBI process has delivered a significant reduction in the total workload associated with equipment inspection, despite the increase in SD interval. This is due to the elimination of unnecessary inspection and the extensive use of on-line non-invasive inspection.
- There has been an increase in the cleaning workload, partly due to increases in the shutdown interval and partly due to re-categorisation of work previously undertaken during inspections.
- The modification workload has stayed reasonably constant.
- The repair workload has risen (the high figure in 1997 being due in part to a major planned repair to the main cracked gas header), but the use of novel techniques has a considerable impact in controlling the increase.
- The workload, measured in main trade manhours per year of plant operation, has shown a steady reduction as the shutdown interval has increased.

Table 4 demonstrates that it is possible to achieve increases in shutdown interval without incurring similar increases in the workload and hence the duration of each event. As shown in Table 4 reductions can be achieved in manhours per operational year, and in total event manhours. This has the added benefit of reducing a number of other risks, eg safety performance and Industrial Relations risk, associated with large events.
Once the shutdown workload is established and the planning is complete, it is necessary to deliver the work. The final aspect of this paper is to look at the work done in the 2002 shutdown to deliver a cost effective event, and to attempt to engage the contractors used in support of delivering the shutdown in the overall objectives of minimising the cost and duration of the shutdown.

The plan for the 2002 shutdown showed an overall duration (product to product) of 47 days, with a 28 day maintenance window. The 19 day period of shutting down the plant and preparation for maintenance, followed at the end of maintenance by leak testing and commissioning is effectively fixed by plant design and process conditions and is independent of the shutdown workload. The main scope to deliver improvements in duration and cost provided by optimising the activities undertaken during the 28 day maintenance period.

The key shutdown objectives for the delivery of the specified work were identified as:

- Control of costs.
- EHS performance.
- Achievement of programme.
- Quality of work completed.

Two main contracts were let for the delivery of the event, and in both cases the contracts were designed to focus the efforts of the contractors in supporting the achievement of the above objectives, thus aligning the objectives of the contractors with those of the client organisation. This was achieved as follows:

- A target cost was established for each contract, and the contracts were written so that the contractors and the client organisations would share deviations from the
agreed targets. Thus, if the total cost was within budget there would be a “gainshare”, and if the total cost was above budget there would be a “painshare”.

- Fixed bonuses were agreed for achievement of plan and for achievement of specified EHS targets. Payment of these bonuses would be independent of shutdown cost performance (although in reality there are strong links between cost and programme performance).

- Contractor selection and technician training in support of quality objectives.

The application of the above contracts was analysed after the event, and the key learning is summarised below:

- The use of fixed bonuses for programme and EHS performance worked very well. In particular, on EHS performance, achievement of the bonus was dependent on both input measures (eg auditing compliance) and output measures (eg accident statistics).

- The use of a target cost was less successful, primarily because the targets were subject to variation as a result of emergent work. This was difficult to manage, and although the contractors were efficient at identifying variations that tended to increase cost, it was more difficult to identify or record variations that tended to reduce cost. Ultimately, the use of target man hours in incentivised contracts will only drive the contractors to control and reduce cost if it can be established that the targets are not to be subject to variation after they have been agreed.
8 CONCLUSIONS

This paper has noted that for large Petrochemical plants, there are benefits to be gained from increasing the interval between plant shutdowns, but that these benefits depend on the ability to control shutdown workload and duration. The aim is a strategy which embodies the best combination of low cost and acceptable business risk.

A number of techniques for controlling shutdown workload have been described, and the benefits of these techniques have been demonstrated by examining the history of plant shutdowns on the Huntsman Olefins6 plant at Wilton.

On a given plant it should be possible, by judicious application of RBI techniques and techniques to improve reliability or reduce the work content of cleaning and defect rectification, to reach the position where shutdown intervals are dictated by unavoidable cleaning requirements rather than by mechanical deterioration that triggers the need to inspect equipment. This requires an optimisation of equipment design, focussing on elements in the process chain that suffer from time dependent deterioration that influence the outage frequency. The cost benefits of improvements in engineering design can be optimised to whatever is the desired goal.

Turnarounds are large maintenance events that require detail planning, execution and rigorous controls of event costs and quality of the critical tasks undertaken. All aspects are intrinsically linked. The reliability and continuous safe operation of the plant for the next operational campaign is dependent on all elements of the event described in this paper coming together with the level of assurance appropriate for the hazardous installation being operated.
9 REFERENCES

1 Tony Musgrave, Asset Integrity Manager, ABB Eutech, Daresbury, Warrington, Cheshire, United Kingdom, WA4 4BT Tel: 44(0)1925 741163 E-Mail: tony.musgrave@gb.abb.com

2 Axial Swage Pipe Connection Technology. Deutschlok fittings are available from Trouvay and Cauvin. Contacts Neil Mason (Europe) at ncmason@trouvay150.freeserve.co.uk or Kevin Connor (Pacific Rim) at kevcon1@bigpond.com

3 Hydrokinetic Cleaning. Available from Powerstream Ltd. Contact Richard Walton (Hydrokinetics Manager) at enquiries@power-stream.co.uk

4 HSE Offshore Division Safety Notice 2/2000 “Bolting of Flanged Joints for Pressurised Systems

5 Dr Gavin Smith, Technical Manager, Klinger Limited, The Klinger Building Wharfedale Trading Estate, Bradford, BD4 6SG, email smith.g@klingeruk.co.uk

6 Hedley Purvis Group UK/Norway/Singapore/Malaysia/Perth/Houston Informate 2001 – Bolt Working Software Programme, also JDMS Joint Data Management System as used by Texaco and BP.

7 Hedley Purvis Group are an ECITB accredited Training Provider for the PF015 and PF010 NSDS Units, (Specific to the Preparation and Tightening of Bolted Connections) recognised by UKOOA and the HSE.

8 BS EN 1591 Part 1 “Flanges and their joints – design rules for gasketed circular flange connections”