WHAT SUTDOWN AND WHEN?

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Summary

Selecting the right equipment to inspect and overhaul at the right time, with the right scope of work, is fundamental to maximising plant performance and integrity in an environment of ever increasing competitive and regulatory pressures. Modern software tools, combined with existing technical assessment and inspection methodologies, are enabling operators to utilise new technology and build on years of experience to develop optimal strategies for the new millennium.

This paper will look at selection of equipment for maintenance and the choice of appropriate maintenance intervals. A case study will demonstrate how Net Present Value savings over 12 years of £2.5 million were identified.

Recent History

Prior to 1989, maintenance on process plants in ICI was often driven by the need to carry out inspections of pressurised systems. This tended to result in major shutdowns at one or two years frequency with as much maintenance as possible carried out during the event.

Maintenance was seen as a cost by management and year on year reductions in fixed cost were demanded. Whilst some condition monitoring was done, there was little use of more advanced techniques.

In 1989, the Pressure Systems and Transportable Gas Container Regulations (PSTGCR) replaced the requirements in the Factories act. The selection of equipment was very similar to existing ICI regulations and resulted in more statutory equipment. They did however allow much greater flexibility in the setting of inspection intervals compared with previous legislation. Initially this flexibility was not taken advantage of because in many cases the status quo was not challenged. Continuing pressure from a poor business environment soon changed this.

ICI’s response in the mid-nineties was to develop a benchmarking process called the Manufacturing Performance Assessment. This looks at both performance in all the key metrics for both batch and continuous process manufacturing, *and* the underlying practices that are required to support sustainable high levels of performance. This valuable database, now containing nearly 300 assessments from a range of companies, enables Eutech to provide a comprehensive and powerful process for benchmarking capability and supporting radical change programmes.

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The demand for improved performance resulted in a drive to increase inspection intervals. However the legislation required a technical justification of interval changes away from the previous values now given advisory status. Some operators used this as an opportunity to use risk based techniques such as Risk Based Inspection (RBI) and Failure Mode, Effects and Criticality Analysis (FMECA) to support the process. Generally these techniques are more detailed and result in a much better understanding of what should be inspected, where to inspect, how to inspect and how often it should be done. Properly carried out they result in less downtime from shutdowns and breakdowns often repaying the investment in less than a year.

One reason that advanced techniques were slow to take off is that Engineers were unable to convince the business managers of their worth. Resources within a company are limited and must be competed for. The method of comparison is likely to be a financial one and hence Engineers must learn to support their proposals on financial grounds.

Two important financial tools are Loss Accounting and Net Present Value (NPV). Loss Accounting looks at the total costs from a breakdown or failure rather than just the repair costs. Often the lost production costs are significantly more than the other costs and this method results in much larger losses being attributed to breakdowns. The higher penalties make it easier to justify spending on techniques which improve reliability. Business managers use NPV to value future benefits in today’s money to ensure that benefits accrued in the future are not exaggerated.

Overview of Maintenance using modern Tools

Eutech's asset care process is shown schematically in figure 1. This paper will explore the use of risk based tools to calculate the optimum time to inspect or maintain equipment and how these support the traditional methods which still have their part to play. Examples of risk based techniques and how they compliment the existing methods is explored in the following sections.

In order to select the equipment which warrants investigation, some form of criticality test is required. This uses agreed criteria to compare equipment on the basis of risk. Risk is a combination of how likely something is to happen and the severity of the consequences. Initially this focused on safety but has now been extended to include environmental damage and business performance. For non critical items it is still advisable to define a maintenance policy but this need not be subject to the same control as the critical items.

Critical items should be subject to further investigation to establish failure modes and effects in order to define the maintenance policy. This can be done using Failure Mode, Effects and Criticality Analysis (FMECA). Under the Pressure Systems Regulation, statutory pressure systems require a scheme of examination. Although it may not be recognised as such, the process is similar to FMECA. From the FMECA analysis the appropriate maintenance policy can be defined and the maintenance tasks and frequencies

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established. The optimal frequency and choice of task can be evaluated using traditional methods and new software which evaluates the cost/risk trade off.

Typical benefits from the asset care process include longer intervals between plant shutdowns, less invasive inspection and reduced costs. Because maintenance is now based on what is likely to happen rather than what used to happen, reliability is not compromised.

The following sections look at the process in more detail.

Criticality Assessment

In order that scarce resources are properly utilised, the equipment most in need of care needs to be identified. Hazop studies carried out when a plant is built give valuable information on criticality but may not be available or have the information in a suitable form on older plants. It is normal therefore to carry out a screening process to select critical equipment. Either Qualitative methods which utilise simple rules and judgement or Quantitative methods which are highly structured but involve considerably more effort may be used. The base resource document API 581 (draft) gives examples of both qualitative and quantitative methods.

Eutech prefer to utilise qualitative methods for criticality and to utilise the experience and skill of their consultants to ensure an acceptable result. The equipment selected by the criticality study can then be subject to further analysis to focus inspection resource on the highest risk items for maximum effect. The equipment covered by criticality studies in Eutech is broken down on functional lines into the following categories:

Pressure Systems
Machines and Pumps
Critical Protective Systems
Plant structures and Pipebridges
Lifting Equipment

Each category has selection criteria appropriate to the type of equipment covered and also takes account of legislation. Experienced professionals ensure that the process is properly applied. The objective is to focus attention on the most critical equipment and so it is important that all equipment is not classified as critical. As an example a risk grid that is being developed for piping is shown in figure 2. Note that the consequence axis does not include business risk at this stage as this must be agreed with the client.

Having selected critical equipment, an appropriate care regime should be specified. This should be appropriate to the risk involved.

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Caring for Critical Equipment

As mentioned previously, a FMECA assessment or similar process is required to identify maintenance tasks. However, maintenance is part of a wider care process. Referring to figure 2, it can be seen that there are a number of controls suggested by the particular combination of likelihood and consequence. For example, the highest consequence combined with the highest likelihood is deemed intolerable and redesign should be considered. On the other hand the highest consequence with the lowest likelihood would suggest that mitigation measures may be more important than maintenance (inspection).

The process for dealing with Critical equipment should include the following elements:

Element	**Requirement**
Design	standards should be approved by a functional expert
Manufacture	Agreed quality standards
Modifications and Repairs	Must be controlled and not compromise the original integrity. Same design standard as original
Maintenance	Maintain and inspect at appropriate frequencies. These may be based on risk based methods
Limits	Safe operating limits should be defined and adhered to
Clear Responsibilities	It must be clear who is responsible for what. Their competence should be verified
Audit	Confirm that the system is being worked to. Define improvement plans

Management systems incorporating the above elements such as that used by Eutech can be used to meet the requirements of standards such as BS 8800, ISO 14001 or OSHA 1910.

Non critical equipment should also be maintained but a less formal system is required and the maintenance programme may be based on templates or experience.

The next step in the care process is to optimise the frequency and content of the maintenance programme to give the solution with the least business impact. Eutech support this process using the Asset Performance Tools software for risk based inspection and risk based maintenance. A simplified explanation of the software is given below.

The Inspection software uses probability methods and curve fitting distributions to evaluate the risk and hence cost of failure with time. The failure point is the point at which the equipment ceases to function. For ductile failure of pressurised equipment for example, Eutech base the failure thickness on factoring methods after NFPA 69. Inspections have inaccuracy and are aimed at detecting deterioration which may not be accurately defined. The software combines these factors to establish how likely equipment is to fail at a particular time since the last inspection. The failure cost is established by range estimating methods and considers both direct costs (e.g. premium working) and penalty costs (e.g. lost gross margin, plant damage) supplied by the client.

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Both Inspection cost and failure cost are expressed per unit time and summed to show how the business impact varies with time. The optimum strategy is when the business impact is minimised.

The inspection software can also evaluate the optimum time to perform failure finding inspections e.g. Relief Valve inspections. Another software package, APT Maintenance enables performance deterioration, operating costs and prolongation (e.g. effect of lubrication intervals) to be modelled as well.

The methodology that sits behind the software takes account of uncertainty in variables and uses sensitivity studies to evaluate the need for more accurate data. Having identified the economic case for change the technical case is evaluated using Eutech's Focused Schemes of Examination product to ensure it is acceptable to the client and regulator. The benefits of Risk based software will be evaluated in the following section.

Case Study to Illustrate Benefits of RBI

The benefits of risk based inspection (RBI) software are best examined using a case study on a continuous process plant operated by a Bulk Chemical Manufacturer. The plant was subject to a biennial shutdown costing £320k with a loss of 21 days production. The purpose of the study was to examine the case for change given that the plant had a very low level of mechanical breakdowns.

The results of the study are summarised in figure 3. It can clearly be seen that the optimum inspection interval would be 4 years with most equipment falling into this category. The study also identified a number of limitations which would need to be addressed to enable a longer interval.

The most limiting vessel was the HCl stripping column which had an optimum inspection interval of less than two years with a rapidly rising failure probability. An alternative material of construction would cost about £20k more but would last much longer. It can be seen (figure 4) that this would enable a longer inspection interval and this would result in a cost saving. Similar material changes to other components would enable a four year interval for them.

The reactor manway had a loose liner which had previously shown an unpredictable life. The benefit of replacing the manway branch using solid material is shown in figure 5 where the business impact of the loose liner is shown to be about £1000 per month.

One of the columns on the plant was packed with sacrificial iron packing. The packing lasts about two years and a longer interval could result in a reduction in performance or jeopardise the other carbon steel parts. The effect of falling performance was investigated using APT Maintenance. This showed that if the plant output reduced by only 1% between two and four years, the optimum maintenance interval would be 3 years. Longer intervals would be very expensive due to the performance loss which may not be detected

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given normal measurement accuracy. Given the relatively small cost of this column, an in line spare with isolation to enable on line repacking was recommended to enable longer intervals.

The smaller piping sizes on the plant have a very short life and Risk based software was found to offer little advantage over careful monitoring of life by the plant engineer. The overall conclusion for this pipework was to change out after a period of service. The smallest sizes would only manage one period of service and a material change should be considered on economic grounds.

Items of equipment in a plant will generally all have different optimal inspection intervals and a number of the pressure systems inspections may be invasive (i.e. need vessel entry) requiring a plant shutdown. The timing of this shutdown needs to be carefully chosen as it will be sub optimal for some items. Generally, as a result of overhauls normally taking place in the warmer months, the frequency is a given number of years. Eutech are collaborators in the European funded MACRO project which has developed the risk based inspection tools referred to. The final piece of software to be developed will enable the optimum shutdown strategy to be developed by grouping together the various inspection and maintenance requirements. This software is about to enter the testing phase and will be available early in 2000. In this study, the potential for a four year interval could be seen from figure 3.

The benefit of studying a complete unit was apparent compared with piecemeal studies of individual items. The cost savings that could be realised from a 4 year shutdown interval were an NPV of £2.5 million over 12 years (figure 6). There are some costs associated with achieving this such as the change of material for the column above. However these are small in comparison with the benefit. The final section of this paper addresses how the benefits from Risk Based Inspection (RBI) of pressure systems are implemented by Eutech.

Risk Based Inspection and Focused Schemes of Examination

As a subsidiary of ICI, Eutech has an operations heritage and many of our staff have experience of running and maintaining process plant. Eutech’s in service inspection division is accredited to the demanding standards of EN14004. As a result we are often involved in implementing the results of studies carried out and ensuring that the benefits are delivered. The implementation of an RBI study results in changes to Statutory Schemes of Examination which are a requirement of the Pressure Systems Safety Regulations (PSSR) 1999. Many of our clients extend the statutory system to include high criticality systems not covered by statute.

Through its RBI process Eutech develops *Focused* Schemes of Examination (FSE) for identified critical pressurised equipment. The RBI/FSE process was recently subject to an external audit by the Health and Safety Executive who are concerned about the increasing use of RBI without a consistent standard. The Eutech study of a complete plant (70+

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vessels, 120 relief streams) was endorsed by the Regulator who was completely satisfied by the approach and decisions taken by the team.

The RBI/FSE review is a team approach and takes account of the past history, the failure mechanisms and rates of deterioration to establish the optimum Scheme of Examination taking account of any legislation and guidance. The review considers whether non invasive techniques can provide adequate assurance of integrity without the need to shutdown the plant and how to most effectively evaluate the integrity of the equipment. The outcome is a Scheme of Examination which will be acceptable to the HSE, maintain reliability and minimise the business impact. The scheme specifies:

- what needs to be examined
- why it needs to be examined
- where it needs to be examined and
- how it can be examined.

Key to the success of Eutech's Focused Schemes product is the mix of experience and knowledge of the people on the study team. The team is lead by a person competent in the process and includes the following inputs:

Plant Engineer	provides data on the equipment and its history
Materials Engineer	provides data on deterioration mechanisms and rates of deterioration
Process Engineer	provides data on the process and operation of the equipment
Inspection Engineer	provides data on the inspection history and inspection methods
Functional experts	provide data on fitness for purpose as necessary

The benefits from FSE may be seen from a recent study on a large process plant with 157 vessels due to be thoroughly inspected. As a result of the study it was found that 76 Vessels could be examined with plant on line and 30 Vessels had a reduced scope of examination specified. The benefit to the client from this study was a cost saving of £720K for a single shutdown. Eutech have completed many other studies of this type which typically have a benefit to cost ratio of ten or more.

Conclusion

Modern maintenance tools enable maintenance staff to identify precisely what work is required and when. This has resulted in large cost savings which have not been accompanied by other adverse effects. Indeed over the period during which the studies described have been conducted, reliability has been steadily improving as the focus changes from reactive to predictive techniques.

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FIGURE 1
EUTECH ASSET CARE PROCESS

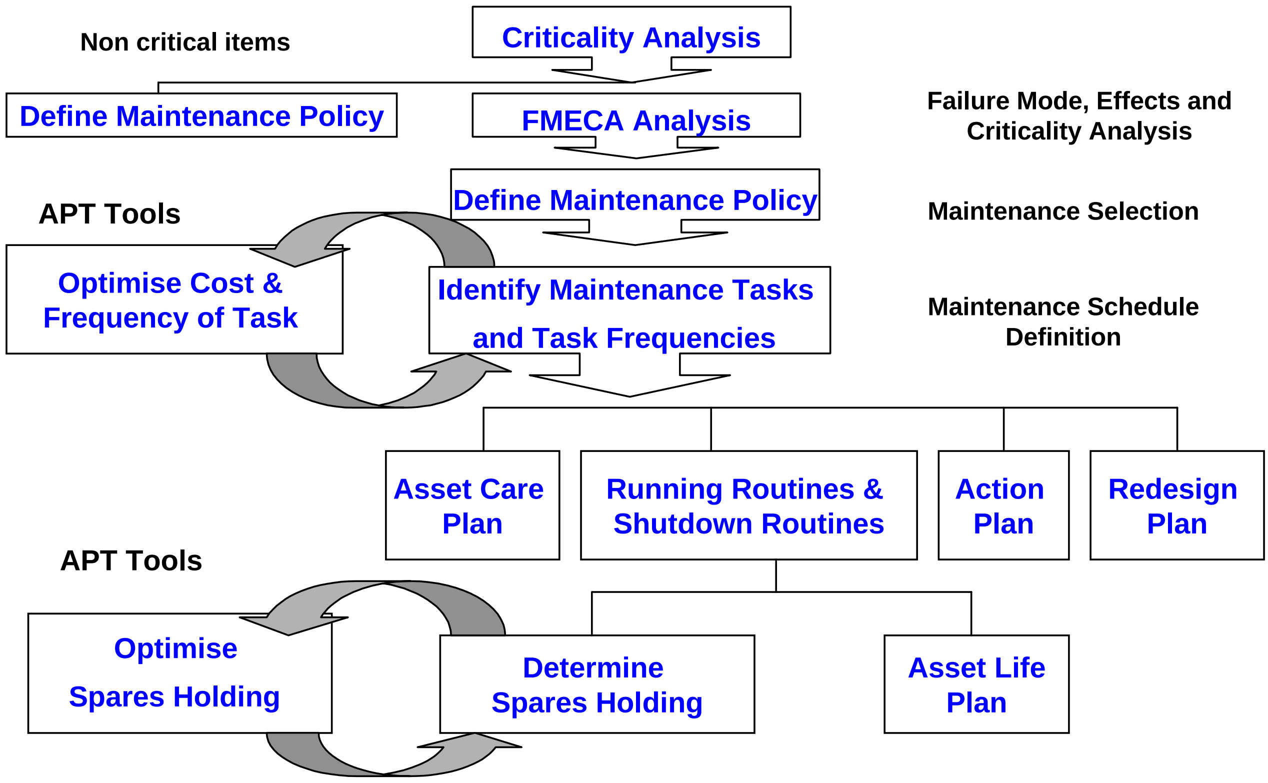

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FIGURE 2 RISK GRID FOR PIPING

CONSEQUENCE	TYPICAL CONTROLS				
Catagory 5 Incident High probability of multiple employee fatalities. Significant probability of off-site fatality. National and possibly international media attention. Long term damage to the reputation to the Company	Apply design verification and control of repairs/ mods procedures.	Apply full Registration Procedure	Apply full Registration Procedure	Apply full Registration Procedure and consider full risk assessment	Carry out full risk assessment
Category 4 Incident Major Hazard incident. Possibly few employee fatalities. Almost certain single employee fatality. Distressing off-site effects and possible off-site fatality. National media attention.	Apply design verification and control of repairs/ mods procedures.	Apply design verification and control of repairs/ mods procedures +periodic inspection and maintenance of protective coatings- as prescribed by Client	Apply full Registration Procedure	Apply full Registration Procedure	Apply full Registration Procedure and consider full risk assessment
Category 3 Incident Low probability of an operator fatality. Distressing off-site effects. Considerable local media attention. Prosecution almost certain. Formal commitment for improvement/prevention of reoccurrence required.	No special precautions	Periodic inspection and maintenance of protective coatings- as prescribed by Client	Periodic inspection- as prescribed by Client	Apply full Registration Procedure	Apply full Registration Procedure
Category 2 Incident Very low probability of an operator fatality. Adverse local media attention. Possible prosecution.	No special precautions	Periodic inspection and maintenance of protective coatings- as prescribed by Client	Periodic inspection- as prescribed by Client	Periodic inspection- as prescribed by Client	Apply full Registration Procedure
Category 1 Incident Operator fatality very unlikely. Nuisance off-site. Complaints from General Public.	No special precautions	Periodic inspection and maintenance of protective coatings- as prescribed by Client	Periodic inspection- as prescribed by Client	Periodic inspection- as prescribed by Client	Periodic inspection- as prescribed by Client or full Registration Procedure.
VULNERABILITY TO FAILURE	**No known history of significant deterioration of piping or supports.**	**No known history of internal deterioration. Protected from external deterioration by well designed, installed and maintained protective coatings.**	**Predictable rate of deterioration. Corrosion allowance may be exceeded during life of plant.**	**Rate and location of deterioration is unpredictable. High risk of leakage/ failure during life of plant.**	**History of high rate of significant deterioration.**
Examples	e.g.Stainless steel , unlagged piping, Process fluid non-corrosive. Pipe hangers not used.	e.g.Stainless steel, lagged piping. Undamaged protective coating under insulation.	e.g.Carbon steel, unlagged piping subject to predictable internal and/or external corrosion.	e.g.Lagged carbon steel operating in vulnerable temperature range and/ or limited data on corrosive properties of process fluid.	e.g.Carbon steel piping subject to high rate of internal corrosion/ erosion.

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FIGURE 3
OPTIMAL INSPECTION INTERVALS FOR CASE STUDY EQUIPMENT

	1 TO 2 YEARS	2 TO 3 YEARS	3 TO 4 YEARS	4 YEARS PLUS
PIPING			1.5" 2,3,4"	6"-36"
VESSELS	C214		E211,E212, E214	C213,E213,E218,R211, T211,C211
RELIEF			ALL DISCS	2" VALVE

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FIGURE 4
HCL STRIPPING COLUMN

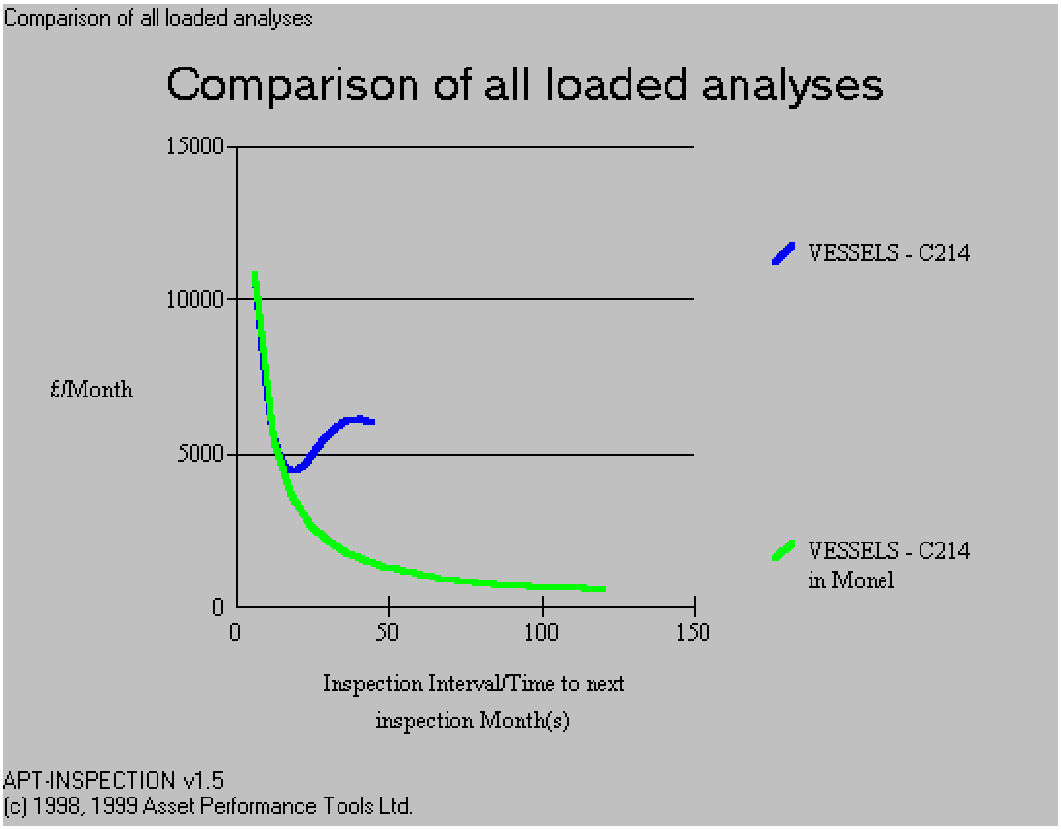

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FIGURE 5
MANWAY LINER

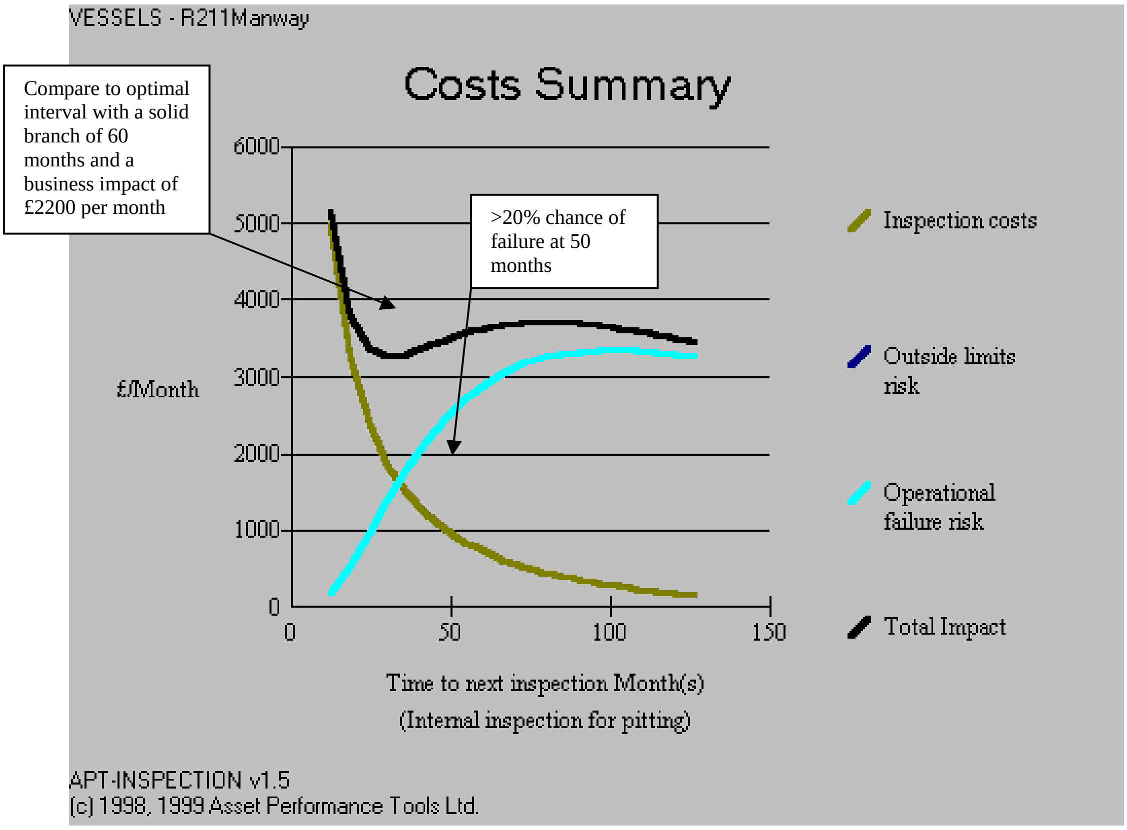

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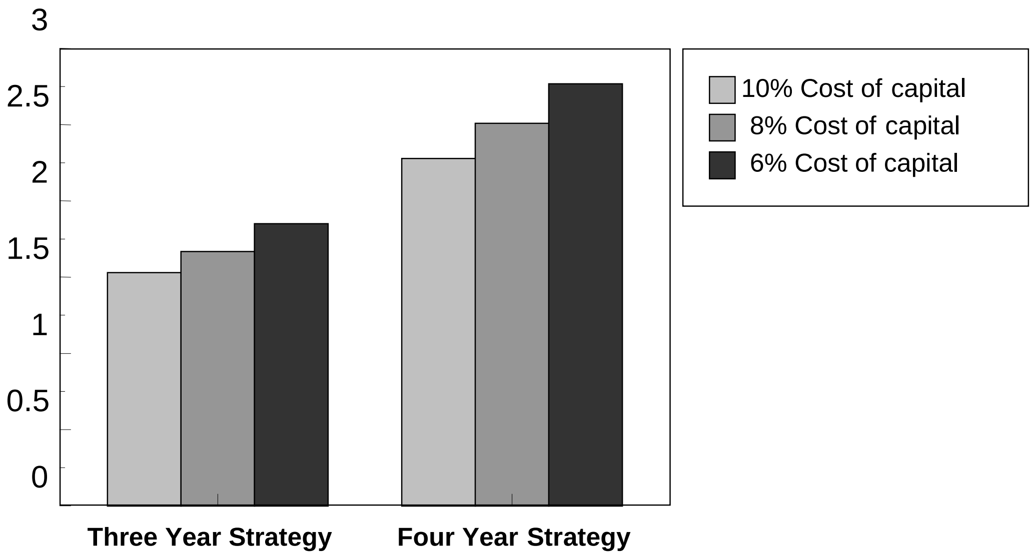
FIGURE 6
SAVINGS RELATIVE TO TWO YEAR INSPECTION INTERVALS



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