HOW TO INTEGRATE INHERENT SHE IN PROCESS DEVELOPMENT AND PLANT DESIGN

The CEC *INSIDE* Project
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The concept of 'inherently safer' plant has been around for many years, yet a recent study by the HSE indicated that few companies are using inherently safer principles in process development and plant design. This pilot study is now being built on by a major CEC co-funded joint industry project, the *INSIDE* Project. The objectives of this are to promote the use of inherent safety, health and environmental (SHE) protection across Europe and to develop tools to enable chemists and engineers to optimise processes and designs using the 'inherent' principles.

This paper describes the findings of the first phase of the project, a European wide review to assess the current status of inherent SHE in the onshore and offshore process and chemical industries.

Key Words: inherent safety, environmental protection, process development, plant design, integrated Safety Health and Environment (SHE), process optimisation.

1 THE *INSIDE* PROJECT

The concept of "inherently safer" plant has been with us now for many years (Ref 1), but despite its clear potential safety, health, environmental (SHE) and cost benefits, there have been few deliberate or recognised examples of its application in chemical plant design.

In March 1992 a pilot study was started by AEA Technology on behalf of the UK Health and Safety Executive to establish the current status of inherently safer approaches to plant design within the UK Chemical Industry, and to identify possible means of progressing the application of these concepts in industry. The findings of this study have recently been published (Ref 2). However it quickly became clear that a larger project with the active involvement of industry was needed to develop practical guidance and tools to help chemists and engineers make best use of inherent approaches in process development and plant design. It was also recognised that an integrated approach to safety, health and environmental issues was required to handle the conflicts and mutual benefits that can arise. This reflects the growing view of industry that an integrated approached is required for SHE.

In August 1994 the resulting joint industry project, "The *INSIDE* Project",[1] commenced with co-funding from the CEC under the 1990-1994 Environment Programme. Its objectives are to promote the use of inherent SHE in industry and to develop tools for the practical integration of inherent SHE approaches into process development and plant design.

The project has 3 Phases:

Phase 1 - Review of current status of inherent SHE in industry
Phase 2 - Framework/tool development
Phase 3 - Pilot applications of tools in industry

Phase 1 is now nearing completion and this paper summarises the findings of the review and draws from this a number of practical ways of integrating inherent approaches into the development and design process. The paper also describes the basic framework that will be used to develop the tools in Phase 2 of the project starting in the summer of 1995.

2 INHERENT SHE AND ITS POTENTIAL BENEFITS

If the hazard potential of the plant can be reduced or even eliminated by careful selection of the process together with good design of the plant, then the need for "add on" safety systems and detailed management controls is reduced. The plant can be said to be "inherently safer" because its safety performance is less reliant on "add on" engineered systems and management controls which can and do fail. In practice of course many of the processes we operate do require hazardous materials to be held sometimes in considerable quantities, or pose the threat of runaway reactions. The question to be asked therefore is "can we change the process or the equipment to make it inherently safer?". Kletz (Ref 3) sets out the routes by which we can achieve an inherently safer plant:

- intensification - *reducing the hazardous inventories;*
- substitution - *substituting hazardous materials with less hazardous ones (but recognising that there could be some trade-offs here between plant safety and the wider product and life cycle issues);*
- attenuation - *using the hazardous materials or processes in a way that limits their hazard potential eg. dissolved in a safe solvent, stored at low pressure or temperature; and*
- simplification - *making the plant and process simpler to design, build and operate hence less prone to equipment, control and human failings.*

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[1]The *INSIDE* Project is a joint industry - CEC Industrial Safety research project to progress the adoption of inherently safer approaches to chemical process development and plant design. This research is being carried out by a team drawn from AEA Technology Consultancy Services, TNO, VTT Manufacturing Technology, Eutech Engineering Solutions, Inburex, and Kemira under the Major Industrial Hazards research programme of the Commission of the European Communities, DGXII, (Contract No. EV5V-CT94-0416). We are also grateful for the additional financial support from the UK Health and Safety Executive, the Dutch Ministry of Employment and Social Security and the BMFT, Germany.

Adopting an "inherent safety" approach such as that described above offers several advantages. Minimising the inherent hazard of the plant offers savings by reducing the need for expensive safety systems and instrumentation, easing the burden on personnel and procedures, and simplifying on-site and off-site emergency plans. In the extreme the hazards and risks may be so low that many of these controls may not be required at all.

Reducing complexity reduces the need for instrumentation and operator supervision, and cuts the maintenance bills. Smaller inventories may mean smaller plant and storage facilities, hence possibly cheaper equipment costs and less land to put it on. Substitution for less harmful chemicals or processes could reduce the environmental impact of any wastes produced. With all these potential benefits, it was considered surprising that inherent safety had such a low profile, and so a review was undertaken to assess the true extent of inherent safety in industry.

3 THE PHASE 1 REVIEWS

A number of reviews were carried out to try to assess the current status of inherent SHE approaches in the process and chemicals industries. These included a literature review, interviews with a representative sample of companies in these industries, a review of past lessons from risk assessments (QRAs) and accident investigations and a review of some of the main regulations and standards for process development and design.

These together enabled a good overview to be gained of the current status of inherent SHE technology and application, and highlighted a number of areas that will be followed up on the project. The findings of these reviews are summarised in the following sections.

3.1 Literature Review

Searches of open literature and other sources available to the project members unearthed a large number of papers and publications on inherent SHE. In all over 100 references were found and reviewed. These covered the principles of inherent SHE, example applications, discussions of the main hurdles and drivers affecting the way SHE issues are addressed and possible methods and tools to address inherent SHE. Authors such as Kletz, Englund and Hendershot were responsible for many of the papers. The review found that many of the references repeated the same points and examples, often adding little to the early publications by Kletz, although Kletz's main principles of inherent SHE have been extended/expanded by some authors (Ref 4,5,6,7) to include segregation and leak path minimisation.

These aspects were also highlighted in the QRA and accident reviews, where the number of leak paths provided by pipe fittings, connections and sample points tend to dominate overall leak frequencies, and where the plant layout and siting often plays a major part in the consequences of any hazardous leak both in terms of its potential for escalation, the number of people subject to the hazard, and the range of environmental effects.

In general most papers concentrated on inherent safety. Several papers mentioned inherent environment and health, but few offered any detail or discussion in these areas. Surprisingly, in light of the current emphasis on environmental issues, few papers were found tackling an integrated inherent approach to environmental risk management. Most environment papers tended to focus on specific measures such as waste minimisation and effluent treatment rather than present an overall framework to minimise environmental impact.

Although the references often listed some of the hurdles to adopting inherent SHE approaches, few related any practical experience of how best to overcome these. The overall impression was that inherent SHE approaches are still in the early stages of development, supported by a small number of safety specialists but not generally recognised or accepted by the industry at large. As a result few of the papers could offer any practical, tried and tested, advice on how to promote the use of inherent SHE.

Several authors put forward ideas for methods and tool to address inherent safety (and some health and environment aspects), but again these do not appear to have been applied in practice. The tools range from systematic open methods such as 'what if' analysis (Ref 8)) and 'critical examination' (Ref 9), through to detailed checklists (Refs 8,11,12,13,14). Several authors have suggested the use of indices to measure the degree of inherent SHE of a process, either using existing methods such as the DOW/MOND indices (Refs 15, 16) or specific indices for inherent SHE (Ref 17).

More recently Hendershot (Ref 18) has proposed the use of decision analysis techniques to help address the economic, engineering and SHE factors that need to be addressed when optimising route selection and plant design. Similar approaches are being considered or used by other leading companies. These tool ideas have been fed into the Phase 2 tool development stages of the *INSIDE* Project. Overall the literature review gave the impression that there has been little substantial progress on inherent SHE theory or practice over last 18 years.

3.2 Lessons from QRAs and Accident Investigations

Experiences with QRAs both onshore and offshore show that safety efforts tend to be directed towards the provision of reliable safety systems rather than by tackling the hazards at source. In most plants the inventories of hazardous materials are large enough to present a major hazard to the workers and often the adjacent public as well.

Recent advances in consequence analysis, driven primarily by the needs of the offshore industry, have led to the increased use of passive protection systems (eg. fire and blast walls, protective coatings), and better layout arrangements and segregation. Whilst these may improve safety, they do not tackle the fundamental hazard.

Leak frequencies estimated in QRAs tend to be driven by pipe fittings and small bore connections. These provide the most likely failure points in the process containment. Reducing the need for valves, gaskets, sample points, and instrument connections by careful design and the use of welded connections can make a difference to the risk levels.

This provides an effective means of demonstrating the safety benefits of simplification. It is known that some companies are now placing considerable emphasis on this type of simplification due to the considerable capital cost and maintenance savings it can offer. Recent offshore minimum facilities and subsea production facilities depend heavily on this type of simplification to make them practicable.

Onshore plant risks to the public tend to arise from catastrophic events, and the handling of liquefied gases or vapours above their boiling point is shown to be a key source of hazard that should be avoided where possible.

Overall, QRA can provide a useful means of assessing inherent safety and, more importantly, it can point towards areas where risk can be reduced at source. The benefits from this type of analysis can only be realised if the QRA is performed early in the design when major changes can be identified and made.

Accident investigations have been rarely found to go into the detail required to find how inherently safer approaches could have helped prevent or mitigate the accident. Most concentrate on the immediate failures of the containment and control or safety systems concerned. Key lessons from some of the major disasters often point to a lack of appreciation of the hazards and their causes at the design stage. Inherent safety cannot help here, you need to know the hazards first. The same design shortcomings often appear time after time, eg. poor plant segregation and siting, inadequate containment, and failures in protective systems. However the main factors in the accidents are inevitably the large inventories of hazardous materials, or presence of very reactive materials in an unstable state, often due to some process deviation or human intervention.

The main lesson from accidents seems to be the need to learn from past experience! That said, inherently safer approaches provide a good way of minimising the hazard potential of a plant, but cannot make up for a lack of detailed understanding of the hazards. Perhaps incident reports should be required to make specific comments on how inherently safer practices or design could have prevented or mitigated the consequences of the accident.

3.3 Review of Regulations and Standards

Some of the more influential regulations, codes and standards affecting process development and design were reviewed to see to what extent they encouraged an inherent SHE approach. Regulations and codes are seen by industry as by far the main influence on how they manage SHE. If inherent SHE principles are not embodied in regulations, then it is unlikely that they will ever come into widespread use. Equally, emphasising the role of inherent approaches in regulations would probably be the best way to ensure such approaches come into common use.

OSHA 1910 (Ref 19), and the Seveso Directive (Ref 20) are two of the main major hazard safety requirements. Both these use inventory based threshold quantities. This can drive a company to reduce inventories from just above the threshold level to below it, but it has little impact in the majority of cases.

In some cases inventories have been reduced at receipt or dispatch facilities, leading to an increased risk from transport and transfer operations. These regulations are generally goal setting in approach and would permit inherently safer approaches. However they do not mention the concept of inherent safety or its principles and do not encourage an inherently safer approach. These regulations also focus on the plant as operated rather than on its design, and so may fail to influence the early part of design so crucial to inherent SHE.

In contrast, the recent UK regulations for Offshore Installations (Ref 21) brought in following the Piper A disaster specifically ask for a design safety case to be drawn up. This case must state how the principles of inherent safety have been implemented in the concept and detailed design. This has increased awareness of inherent safety design issues in an industry that has traditionally tried to use segregation and simplification as a key part of its hazard management strategy. Further, the principles of inventory reduction and simplification can bring major capital and operating cost savings by reducing topside weight, equipment costs, and maintenance and operating requirements. The regulations show that inherent SHE principles can form a key part of a successful goal setting regulatory regime which benefits both safety and the industry as a whole.

In the UK the COSHH regulations (Ref 22) provide the main framework for occupational health and safety. These do not mention 'inherent safety' specifically but do place a real emphasis on its principles of substitution, inventory reduction and attenuation. As a result they probably provide the best example of regulations aimed at persuading industry to deal with the hazards at source rather than to rely on add on safety.

There has also been a trend in recent years throughout the EC to regulate activities which have the potential to pollute the environment. In particular there have been a number of initiatives to ensure that the control of polluting activities is undertaken in an integrated way. Some EC members have already established integrated pollution laws. The EC has also recognised the need to adapt existing environmental pollution controls to incorporate the strategies of integrated pollution control; the Commissions' thoughts on the subject have been published as a proposal for a directive on Integrated Prevention Pollution Control (IPPC) (Ref 23).

The philosophy of IPPC is goal setting; it encourages industry to prevent pollution and, if that cannot be achieved, to minimise it. Emission limits are likely to be set for many substances, and industry will be encouraged to better these by the use of 'best available technology'. Whilst the IPPC Directive may not specifically mention 'inherent approaches' and its principles, its approach is compatible, and may encourage the use of inherent SHE approaches through its emphasis on prevention.

In contrast to more recent goal setting regulations, many older safety and environmental regulations, engineering standards and codes of practice are very prescriptive in nature, and can prevent the use of inherently safer approaches. Some pressure protection regulations are a good example, where relief valves are required even if the vessel can be designed to take the maximum foreseeable pressure. The relief valve not only provides a source of leaks and unreliability, but also presents a vent management problem.

In some cases there can be real conflicts between safety and environmental requirements especially in the areas of relief venting, and leak/spill management. For example it may be safer to dilute and wash away some plant spillages, but concerns over environmental effects may mean that the material needs to be contained and kept in high concentrations for recycle or separation. Also fitting vent capture systems can lead to overpressurisation problems. These conflicts place increasing pressures on designers and operators, and prescription may mean that novel or alternative solutions are not implemented.

To conclude, older regulations and standards tend to be prescriptive in nature and prevent or hinder the application of inherent SHE approaches. More recent 'goal setting' regulations often permit inherent SHE but do not actively encourage its application. Some of the latest regulations and some future legislation are recognising the role inherent SHE principles can play and are encouraging its use.

3.4 Industry Interviews

A review of current process development and plant design practices was carried out by interviewing over 20 companies across Europe. The companies were selected to represent a broad spectrum of the process and chemical industry, including production companies from the hydrocarbon, pharmaceuticals, bulk chemicals, fine chemicals, agrochemicals, plastics, fibres and polymers sectors. Large, medium and small companies were represented. A number of major design & engineering contractors and a process licensor were also included.

These interviews provided a key insight in to the way SHE issues are addressed in process development and design, and the status of inherent approaches in these. They also gave the opportunity to find out industry's views on the role of regulations and standards and inherent approaches.

Although no clear divisions emerged in the approach to process development and plant design, some typical characteristic types indicated were:

• an informal team approach with chemists and engineers working together and most of the SHE expertise residing in the group. This was typical of the smaller companies or divisions, or those developing many products utilising existing or modular plant.

• a clear distinction between the development and design activities with less communication between these and possible conflicts of objectives. This was typical of most medium and larger companies who had separate engineering and R&D functions or used contractors for the design and engineering. SHE expertise could reside within the group or be sought from a separate department.

• projects where both the process development and design was carried out by the process design function. This was typical of engineering contractors or engineering departments in the heavy chemicals and petrochemicals sectors. The projects tend to be large and complex and involve many design disciplines working in a very formal and structured way. Most use separate SHE functions to liaise with the design and development teams.

Although there were a few differences in the status and views of inherent SHE between these different types of organisation, the main findings were common to all sectors of industry and types of organisation.

3.4.1 Addressing SHE Few organisations had any formal SHE specialist involvement at the process development stage, relying on the skills of the development team themselves to be aware of SHE issues. SHE techniques used in the development stages included Life Cycle Analysis, process hazards analysis/review and calorimetric studies, but few organisations did more than one of these. By the design stage around a third of the companies had brought in a SHE specialist, but for many the HAZOP of the detailed design schemes was the first structured safety review, and by that time it is too late to make significant changes.

However most companies were generally content with the way they addressed SHE in process development and design, although a significant number thought they could make worthwhile improvements, especially in the area of inherent SHE.

It was noted that the UK Offshore industry, and some of the leading chemical manufacturers were now starting to address inherent SHE specifically in their projects. This will have an impact on service organisations, engineering contractors and process licensors who work with these companies. The idea of a concept design safety case may be something else that is carried over as an example of good practice from the offshore and nuclear industries into the onshore process industries.

3.4.2 Role of procedures Most companies had some form of development and design procedures and these usually covered most or all SHE aspects. However only around a quarter of these procedures mentioned inherent SHE or any of its underlying principles. Inventory reduction and substitution were the two most commonly mentioned. A few of the procedures asked for alternative options to be considered at the development stage, though few criteria or objectives were offered to help selection.

3.4.3 Awareness Awareness of the inherent SHE principles was mainly confined to SHE specialists, with only around one fifth of companies indicating any significant awareness in their development or design departments. This perhaps reflects the level and type of training, with only a small proportion of organisations including inherent SHE in their training programmes (Fig 1). The Trevor Kletz/I Chem E video was one training/awareness mentioned.

3.4.4 Benefits Despite this lack of awareness, many of those interviewed thought that inherent SHE approaches would offer a competitive advantage and be worthwhile following. Several of the companies thought it could help reduce plant lifecycle costs, and the majority thought that it would improve SHE performance. Other benefits could be improved plant performance and public image. It was recognised that these benefits would best be achieved by considering inherent SHE at the earliest stages of any project.

Several of those interviewed expressed reservations about the cost effectiveness of inherent SHE, and suggested that some good case studies would be needed to persuade them of the benefits of introducing inherent SHE into their organisation.

3.4.5 Key pressure on development and design Companies were asked what pressures they felt had most influence on the way they approach the development and design activities, and the way SHE is addressed within this.

The most common pressure was the need to drive down costs of the development, design and plant installation. Plant lifecycle costs are also becoming a factor, and these can take account of the trade-offs between higher capital costs and lower running costs that some inherent safer designs may offer. Companies are also under increasing pressure to get products to the market place ahead of the competition, and this is reducing the programmes for development and design, increasing the need for parallel working and giving less time to think about alternatives, or make late changes. The case for inherent SHE therefore needs to be able to demonstrate that time and effort spent at the early stages of the project can produce greater savings later on by reducing the need for costly changes or remedial action late in design. The need for flexibility in manufacturing and products to react to market demands was also mentioned as a key pressure in some sectors.

One company noted that increasing pressures to produce 'friendly' **products**, meant that some of the manufacturing **processes** were becoming more hazardous due to the need to use more active reagents. In many ways this may be 'inherently safer' overall since it ensures the more serious hazards are on the plant where they can be dealt with effectively, and not at large in society.

3.4.6 Hurdles to inherent SHE The main hurdles to adopting inherent SHE were considered to be the lack of awareness, and conservatism in the design and general management (Fig 2). Prescriptive regulatory requirements and cost and time pressures were also cited as problems. The different approaches of the various agencies responsible for safety, health and the environment in member states may also hinder an integrated approach by industry to these aspects.

One of the key aspects relating to awareness was that of the education of chemists and engineers, and this point was made specifically by some of the people interviewed. They considered that SHE management principles are not given sufficient attention during degree or equivalent courses, and that even when SHE topics are taught, they are treated as a separate subject, and not as an integral part of plant development and design. This aspect of awareness will be tackled in a later stage of this project (see section 5).

The nature of the relationship between client and contractor was also noted as a key influence on SHE. More open relationships may be needed to encourage the dialogue between the contract engineers and client chemists, and to ensure the contractor takes steps to evaluate design options and optimise accordingly.

Many companies noted that a lot of effort was currently going into modifying and extending existing plants, rather than building new ones. These situations place constraints on the design which can inhibit the adoption of inherent SHE. However there should still be many opportunities to use inherent SHE principles for modifications, and revamps often provide the opportunity to upgrade the process and its ancillaries to take account of the latest advances in production and SHE performance.

Of course some speciality chemical manufacturers use the same plant to make a wide variety of products, and in these cases the chemistry and process need to be evaluated to check that the manufacture can be carried out safely in the plant. Attention needs to be focused on the generic inherent SHE design of the equipment, and the inherent SHE chemistry and processing measures that can be taken for that specific batch.

3.4.7 Suggested initiatives to encourage inherent SHE Interviewees were invited to offer their suggestions for improving the use of inherent SHE in industry. The main factor was seen as the attitude of the regulators, and the need to influence them in the direction of inherent SHE.

Some good case studies and example applications may be needed to persuade some senior managers of the benefits of inherent SHE, and to help overcome some of the conservative attitudes of project leaders and designers. It was also felt that university courses and industry groups could do much more to promote the use of inherent SHE. Many recognised that in practice some form of systematic method would be needed to integrate inherent SHE in to the development and design activities, and that these would have to start at a very early stage in a project to be worthwhile.

4 HOW TO BUILD INHERENT SHE INTO THE DEVELOPMENT AND DESIGN PROCESS

The findings to-date highlight a number of current practices and ideas in industry that are helping to encourage the use of inherent SHE in its R&D and design teams. The fundamentals seem to be:

• Management commitment and support to the adoption of inherent SHE and the implications this may have for training, programmes, project organisation etc.

• introducing and maintaining a good level of awareness of the inherent SHE principles and applications amongst the chemists and design engineers

• setting aside time in the development and design programme to identify and evaluate alternatives, recognising that this should save time later by reducing the need for changes

• providing opportunities for the chemists, designers and operators to discuss and ideas at all stages of the development and design process

• providing some methods or tools to help lateral thinking and encourage innovation

• addressing S, H and E aspects in an integrated way to establish the trade-offs and conflicts these can bring

These activities together should help foster a culture that rewards good innovation and clear thinking, and one which recognises the importance of doing things well and early. It would also appear that these initiatives need to go hand-in-hand, and companies who have just tackled one or two of these together have found that it has not been very effective, either having limited effect or quickly loosing impetus.

Some of the more practical tips include:

• having an enthusiastic senior manager appointed to 'champion' inherent SHE

• including inherent SHE in the safety introduction training package for new recruits

• having regular informal lunchtime sessions on issues relevant to work, and including something on inherent SHE once in a while

• including inherent SHE objectives in the kick off meeting on new projects

• asking for a statements at various stages of the project on how inherent SHE principles have been incorporated into the process route development, concept design and detailed design

• including a review of inherent SHE as part of the end of project appraisal, and passing on any lessons or suggestions onto the design and development team

• setting up a development team at the early stages of process development which includes an experienced process engineer and operator (preferably those who will go on to design and operate the plant) so design and operation implications can be discussed as the process develops

• appointing a SHE specialist to each development and design project with the time and remit to co-ordinate SHE aspects and promote the adoption of inherent SHE

• using checklists or HAZOP style guidewords to identify process or design alternatives at various stages of each project. These could form part of the design SHE procedures, and take the form of formal study groups or be used by small teams or individuals as part of their ongoing work. Similarly some indices could be used to measure the improvement in inherent SHE, or to compare options

• reviewing existing plants and processes to look for good examples of inherent SHE which can be copied, and to provide any evidence of benefits to support the case for inherent SHE

This list is by no means exhaustive, but should give a flavour of how inherent SHE can be encouraged within industry. Perhaps regulators could also appoint someone to 'champion' inherent SHE, and to review proposals for new regulations to see how they could be formulated to encourage inherent SHE.

5 FURTHER WORK ON THE APPLICATION OF INHERENT SHE

The findings of the reviews are being used to formulate the objectives for the final task in Phase 1, to find ways of encouraging the use of inherent SHE, and the wider industry and society factors influencing this. The aim of the task will be to develop ways for the successful introduction of inherent SHE approaches in industry, including the integration of inherent SHE with existing hazard and SHE management programmes. Issues to be tackled include:

• the role of education and vocational courses, training, research organisations, industrial organisations and professional institutions in raising awareness of inherent SHE

• the relationships between clients, engineering contractors and equipment suppliers and how these can be structured to encourage more innovation, better information to base decisions on and clearer objective setting

• the role of licensors, patents, FDA requirements and other potential barriers to change

• project management strategies and the need for time to consider options at the early stages on fast track projects

• the role of legislators and regulators at national and European level in encouraging inherent SHE.

• QA and TQM implications

This work is to be carried out during the summer of 1995.

6 TOOL FRAMEWORK

A framework for the tools has been developed based on the ideas and suggestions for tools found in the literature and from discussions with industry. The key aim is to provide those at the workface (chemists and engineers) with some simple practical methods and tools to promote identification and adoption of inherently SHE options. The tool development will focus on two key stages:

- process route development
- front end plant design

These two activities contain almost all the major decision stages relating to the performance of the plant and its processes, be these SHE performance, product quality, reliability, capital cost or running costs. These stages set down the process chemistry, the raw materials, the waste streams, the plant throughput, the control philosophy, the basic unit operation, equipment selection and plant layout / siting. As a result these stages are the most critical to the project, and provide the best opportunities to identify and select inherently SHE options. By considering these matters early on, it is possible to make major changes to the process or plant to optimise performance without incurring significant cost or programme penalties.

The basic tool framework proposed consists of a number of elements which latch into more conventional hazard identification and decision support tools. The overall framework is presented in Figure 3, and each element is described in more detail in the following sections.

6.1 Hazard Identification

The framework links into existing methods of information gathering and hazard identification regarding the process which, depending on the stage, could include the preparation of hazardous properties data sheets, reviews of past experience, laboratory chemical and thermal assessment, HAZOPs and other guideword led studies. This datafile of process characteristic and hazards would provide the knowledge of the hazards and other problems that is needed to assess if any alternatives generated are safer or whether they could make matters worse.

6.2 Option Generation

The next stage is an option generator that prompts chemists and engineers to identify alternatives (materials, routes, process conditions, unit operations, equipment depending on the stage) which can then be evaluated. The option generator consists of a number of guideword based analysis tools that:

- challenge the basis of the initial proposal to clarify the fundamental purpose / functionality of any step or item and prompts the identification of other ways to achieve this purpose. This approach is intended to stop the natural inclination to adopt previous or "accepted" solutions without thinking it through, or seeking any alternatives.

- prompt the consideration of deviations from the initial proposal to identify alternative options

The structure of the framework will allow other tools and examples to be used if the assessment stalls. These would include formal techniques to help identify the key functions or purpose of any item or step (functional analysis, critical examination) where these are complex or not obvious and relevant examples of inherent SHE which might be tried or which may promote another line of thinking.

6.3 Screening of Options

Initial screening of the options is carried out to identify the options which offer inherent SHE advantages and appear practicable. The form of screening proposed is a rapid individual or team evaluation against a number of principles and criteria which enable the relative merits of alternative options to be judged. This simple screening approach would only be able to detect clear favourites, and a more detailed decision method will be provided for situations where the advantages and disadvantages of a number of options needs to be assessed, especially where options may include conflicts between safety and environmental performance. It may be possible to provide some help as part of the screening tools and to identify or warn of some of the more common conflict situations that can arise.

6.4 Decision Support

Work on the more detailed decision method is yet to start but the method is likely to be based on classic multi-attribute decision support tools, and will include suggested criteria to evaluate the inherent SHE and other important technical and business factors. Methods of ranking the inherent S, H and E performance of options to allow a consistent basis for comparison will be a key feature of the decision support tools.

7. CONCLUSIONS

The *INSIDE* Project is now nearing the end of its first phase. The reviews it has carried out have shown that inherent SHE approaches are not widely known or recognised in industry, or the regulatory bodies, however there is a general view that such approaches are worthwhile and could offer advantages in terms of improved SHE performance, reduced capital and operating costs and improved operability.

Some recent regulations are now trying to encourage inherent SHE, and some of the leading companies are looking towards inherent SHE as a means of improving their competitive edge. The outlook for inherent SHE is therefore very positive.

The main hurdles seem to be the general lack of awareness, the lack of tools and methods, and the need for some hard proof of the benefits. It is hoped that this project will go some way to addressing these key needs by raising awareness through its activities and publications, developing tools in Phase 2, and finally producing hard evidence of the benefits and disbenefits of inherent SHE from case studies of the trials to be carried out in Phase 3 of the project.

The project also has close links with the CEC and some national regulatory bodies, and hopes to use these to encourage the development of flexible future legislation which encourages, or at least permits, inherent SHE approaches.

Progress on the *INSIDE* Project will be reported via our Newsletter and we hope to present further papers during the remaining 14 months of the project.

Finally this project is just one of a number of initiatives working in the area of inherent safety, and its activities are being monitored to maximise the synergy this permits. The IPSG have recently released a Video Training Package on inherent safety which should provide a cost effective way of improving awareness for many companies. The CCPS are also working on a guideline document on inherent safety, to provide a framework to integrate inherent SHE into process development, plant design and operation. Loughborough University are also developing an inherent SHE index to assist with the measurement and optimisation of process alternatives. If there is anyone else out there working in this field we would be pleased to hear from you!

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Figure 1 - SHE Training for Chemists and Engineers

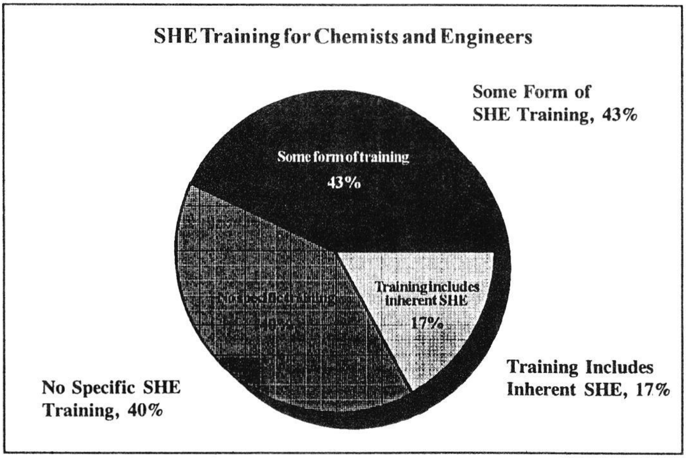

Figure 2 - Main Hurdles to Adopting inherent SHE

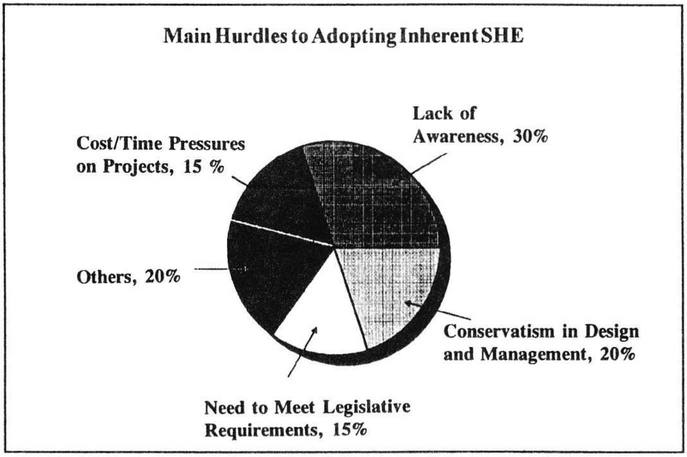

Figure 3 - Inherent SHE Tool Framework

HAZARD / PROBLEM IDENTIFIER
* uses existing company datasheets / hazard studies
* hazard / problem file to track hazards

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OPTION GENERATOR
* set structure for analysis
* sets objectives
* guideword / brainstorm methods
  - prompt deviations
  - question functionality
  - prompt different means to achieve same function

↓

INITIAL SCREENING
* compares options against key success factors
* rapid screening to find best options
* warn of possible conflicts between S,H and E

↓

DECISION AIDS
* used where no clear best option identified
* ranking index for inherent S,H and E
* multi-attribute analysis to aid decision making
* includes "musts" and "wants" criteria
* includes provision for cost, feasibility, and other decision criteria
* provides stand-alone decision support tool or can feed in to existing company decision support tools

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SUPPORTING TOOLS
* provide support at each step in the framework
* situation specific assistance to tackle problems or stimulate / provide ideas
* functional analysis
* alternative perspectives from which to view systems / problems
* generic and specific detailed examples of ways to make processes and plant more inherently SHE