

LESSONS FROM GRANGEMOUTH

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The year 2000 was not a good year for the BP Grangemouth complex: three major incidents and a major internal investigation, culminating in two fines totaling £1M and the publication of a public report by the Competent Authority (CA). This paper will describe how the site has quickly and effectively responded to the first two "key lessons for industry" in the CA report, and what lessons may be learnt from the experience.

INTRODUCTION

The BP Grangemouth complex (Figure 1) is located on the south side of the Firth of Forth, some 25 miles west of Edinburgh. The core site covers 700 hectares, straddling a major public road and two watercourses, and currently employs some 1400 people. It is adjacent

Figure 1. Photograph of BP Grangemouth complex

to the town of Grangemouth with a population of 20000, and other nearby population centres at Polmont, Bo'ness and Falkirk. The site borders on several Sites of Special Scientific Interest.

The BP Grangemouth facility is one of the largest petrochemical facilities in Europe and is a top tier establishment as defined by the COMAH Regulations. It is unique within BP because the three major production segments of BP — BP Oil, BP Chemicals and BP Exploration — all have processing facilities on the site. At the time of the incidents, the site was in the process of bringing these different manufacturing operations under a single management structure.

Between 29th May 2000 and 10th June 2000, the site experienced three serious incidents: a major electrical failure following work to install a new cable; a catastrophic failure of a steam main; and a pipework failure on the Fluidised Catalytic Cracker leading to a plant fire. The incidents caused concern within the site and within the local community, with questions being raised about the competence of the workforce and the ability of the site to manage its operations safely.

The root causes of the incidents were investigated both by BP and by the Competent Authority (Health and Safety Executive and Scottish Environment Protection Agency). As a separate response to the incidents, the site's management systems were subjected to a rigorous "root and branch" audit by a team of over 36 engineers and safety experts from inside and outside BP.

The intention of this paper is not to re-examine the root causes of the incidents. These are covered in the Competent Authority report[1]. This paper will share some of the experience that the Grangemouth site has had in addressing the first two Key Lessons for Industry presented in the Competent Authority report:

Key lesson 1: "*Major accident hazards should be actively managed to allow control and reduction of risks. Control of major accident hazards requires a specific focus on process safety management over and above conventional safety management.*"

Key lesson 2: "*Companies should develop key performance indicators (KPI's) for major hazards and ensure process safety performance is monitored and reported against these parameters.*"

The particular themes of the paper are around the management system structure, site governance, risk management and performance measurement. The first three address the first Key Lesson; the last addresses the second Key Lesson.

LESSONS FOR THE MANAGEMENT SYSTEM STRUCTURE

At the time of the incidents, the site was in the process of bringing together the heritage management systems from the combined BP Oil/BP Exploration operations and the BP Chemicals operations. The safety management systems used on the site had been

[1]Health and Safety Executive and Scottish Environment Protection Agency, 2003, Major Incident Investigation Report — BP Grangemouth Scotland: 29th May–10th June 2000

derived from ISRS but had developed in different ways. However, a common feature of both systems was that focus was more strongly on occupational safety than on major accident safety.

The CA report identifies several gaps that were present in the major accident hazard management system. The internal management system audit also concluded that while many elements of a good process safety management system were present across the complex, there were important gaps. As a result, one of the specific recommendations of the internal management system audit was that the site should adopt minimum process safety management standards derived from the U.S. regulation OSHA 1910.119 *Process Safety Management of Highly Hazardous Substances.*

The purpose of this paper is not to compare U.S. major accident hazard regulation with the European and in particular the U.K. regulations. It is the authors' opinion that when considered against the wider view of a complete management system outlined in HS(G)65, the OSHA 1910.119 expectations have some gaps. These are particularly in the areas of engineering design and standards, site governance and the need to consider the organisation as a whole for competence and management of change, rather than just the plant operators and contractors. The guidance to Schedule 2 of the COMAH Regulation discusses these issues.

However, even with gaps, the OSHA 1910.119 regulation is a very useful basis for a major accident hazard management system, with the particular advantage of using terms that engineers understand. It identifies some areas where the guidance to Schedule 2 of COMAH is less definitive — for example the need to be very specific about identifying and maintaining key engineering documentation, and the need for periodic formal revalidation of existing process risk assessments.

Simply by running through the OSHA 1910.119 elements as a set of prompts and asking what should lie behind them, it is possible to appreciate the enormous range of activities that has to be managed and to see how many parts of the site organisation and management system are involved. Exposure to sixteen years of CIMAH and nine of *Successful health and Safety management*[2] HS(G)65 had not led to the same clarity.

In the experience of the Grangemouth site, even if there are gaps and quibbles over detail, the OSHA 1910.119 regulation lays out in very clear terms a set of core expectations for a major accident management system with which it is hard to take issue. At a high level it provides a set of "lenses" through which the site's performance can be examined, and a common language for major accident hazard management issues.

Within the Amoco Refining organisation, which in 1999 merged with BP, the gaps in the OSHA 1910.119 expectations outlined above had been recognised and a more extensive set of expectations had been derived. These have been adopted by the BP Oil refineries worldwide and have been used as a basis for a detailed gap analysis of the Grangemouth site's major accident hazard management system. For Grangemouth the expanded set of expectations is a key component in how the site meets the expectations for the Safety Management System required under COMAH.

[2]HSE Books, 1991, Successful health and safety management, HS(G)65

Since the internal audit findings were delivered, the site has expended a great deal of effort in closing the gaps. This has been achieved during a period of considerable organisational change, with almost 1000 posts being removed from the site. It may be counter-intuitive, but the increased clarity on roles and responsibilities within the organisation, together with the ongoing simplification of the management system that such reorganisations make possible, has allowed the site to deliver enormous structural changes at the same time as a four-fold improvement in occupational safety performance.

From Grangemouth's experience, here are some points for other manufacturing sites to consider:

- How explicit is your management system in laying down clear expectations for major accident management? Is it simply a collection of high-level objectives or does it contain clear and auditable detail?
- When did your site last have a detailed audit of its management systems that looked critically at the major accident hazard management content and performance?
- When you look at level of compliance with your site's management system, what deficiencies are you tolerating?

GOVERNANCE

An effective major accident hazard management system is made up of many components. When operating properly, these collectively create a system of barriers to major accidents. At the time of the incidents in 2000, governance for major accident hazard management at Grangemouth was fragmented with no formal means of overviewing the performance of the entire system. As a result, the BP internal audit team recommended that Grangemouth should develop a governance structure to focus on major accident hazard management.

At Grangemouth the creation of an effective governance structure has been key to achieving an improvement in major accident hazard management performance. On reflection, the site felt that the major accident safety and occupational safety agendas were so different that two separate bodies were required to provide effective governance. Therefore in September 2000 the site formed a Process Safety Committee (PSC) chaired by a senior manufacturing manager to oversee the development and implementation of the major accident hazard management system. The initial PSC membership followed an Amoco Refining template and represented the different site heritages, key manufacturing and technical disciplines, and trades unions.

The initial PSC laid the ground-work for subsequent developments. It provided process safety awareness training for the site leadership, engineering population and part of the shift population. It developed new standards to close gaps in the existing management system. It established the PSM elements as the language of major accident hazard management on the site. It started the development of major accident Key Performance Indicators (KPI's) to allow assessment of the performance of the management system.

However, after about 18 months it became clear that despite a lot of effort and the delivery of many of its initial objectives, there were problems with the structure of the

committee. While many of the committee members were leaders in their technical field or had some local control over resources, the committee as a whole was too divorced from the senior line-management of the manufacturing organisation for it to make effective decisions.

The years 2002 and 2003 saw major reorganisations at the Grangemouth site. The PSC took the opportunities these presented to restructure itself so that it could make authoritative decisions. The committee is now much more aligned with those who either have the responsibility and/or the resources to deliver change, whilst ensuring it maximises linkages with other stakeholders and networks in the complex. The current site Process Safety Committee membership is outlined in Table 1.

The key interfaces the new Committee membership addressed were with:

- The Site Leadership Team;
- The managers responsible for "licence to operate" issues in the manufacturing areas;
- The plant managers;
- The Process Safety technical community;
- The Engineering disciplines;
- The shift supervisors and workforce.

Figures 2 and 3 show the remodeled governance structure and the key linkages to other site networks on the site. It is important to note the parallel structure between the site HSSE committee, which deals with "occupational" issues, and the Process Safety Committee, which deals with major accident issues. The local committees are an essential means of getting more local ownership of process safety issues and of bridging the communications gap between the central committee that sets policy and the local areas that implement it.

The Process Safety Committee is neither a traditional consultative committee nor a technical talking shop. Its role is to frame policy, set standards and make sure they are implemented. By selecting appropriate KPI's, the PSC can monitor the health of the major accident hazard management systems on the site and intervene where appropriate.

The PSC now meets monthly for a half-day, although for a long period it met fortnightly. The typical workscope for the committee includes:

- Review of Site's top risks and progress in implementing associated improvement plans;
- Oversight on compliance with site equipment inspection programme and regular overview of corrective action plans to address backlogs;
- Review of proposals to defer inspections;
- Analysis of leaks from pipework and equipment, including root cause analysis and requirement for action plans to address root causes;
- Monitoring implementation of major accident hazard management procedures;
- Identification of specific actions or changes in site standards required to address analysis of incidents and audit findings;
- Regular updates on improvement projects sponsored by the PSC;

Table 1. Current (2004) Process Safety Committee membership

PSC Post	Role of this post	Linkage to Site Management and Network Structure
Senior Manufacturing Manger	Chairman of the PSC.	Link to Grangemouth Leadership Team
HSSE Manager	Provides an overview of the Site Governance Committees: ensures overlaps are avoided and gaps are covered.	Link to Site HSSE Committee Additional link to Leadership Team Link to external BP HSE Managers network.
"Licence to Operate" Managers in manufacturing areas	Provides linkage with the Line Management structure and linkage to the local area improvement plans.	Chairs the Local Process Safety Committee.
	These roles are the focal point within manufacturing areas for the "Licence to Operate issues", and have access to the resources to implement the delivery of PSM.	Link to manufacturing area line management and local PSM governance/ implementation structure.
Process Safety Specialist	Provides the Technical expertise in PSM.	Chairs the Site network of Process Safety Engineers Link to national and international process safety networks in BP and industry
Plant Manager	Provides input from the Operations community	Link to the site Plant Managers network
Site Engineering Authority	Post provides the connection to the Site Engineering Assurance and standards-setting process.	Link to the Engineering Authorities Committee as Chairman Link to the Engineering community

(*Continued*)

Table 1. *Continued*

PSC Post	Role of this post	Linkage to Site Management and Network Structure
Site Inspection Authority	Provides direct feedback on mechanical integrity a part of PSM, including inspection and monitoring of plant condition.	Link to Inspection Engineers Additional link to the Engineering community
Shift Manager	Provides feedback from shift workforce including supervisors and emergency response team. They provide feedback on the exercising of the Site's Emergency Response Plans.	Link to the Shift population Link to the Emergency Response structure
Safety Representatives (2)	The two posts provide the connection to the technician population and their role in the Safety Management System.	Link to the Site Safety Representatives. Link to Technician population.

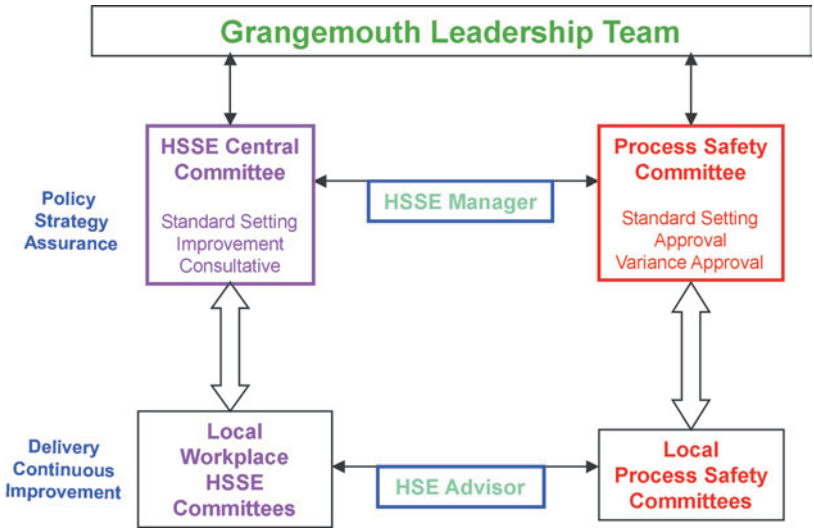

Figure 2. Overview of HSSE governance at Grangemouth

- Feedback from local areas;
- Review of KPI's;
- Regulator correspondence.

Grangemouth has found that a well-organised governance structure is vital if the site is to deliver its objectives in major accident hazard management. In setting up a governance body for process safety, the most important points are that:

- A senior Manufacturing Manager who is part of the site leadership team should lead it;
- The committee should have delegated authority from the site leadership;
- The membership should be senior enough for its decisions to count;
- The focus should be on setting expectations and standards for local line management to implement;
- The committee membership should link directly with the line management structure of the groups that need to implement the policies and standards;
- It should develop appropriate KPI's to monitor progress;

From our experience, here are some points for manufacturing sites to consider:

- Major accident hazard management safety covers a vast range of issues. Where in your organisation does it all come together?
- How is your site organised to deliver process safety? Does it match your governance structure?

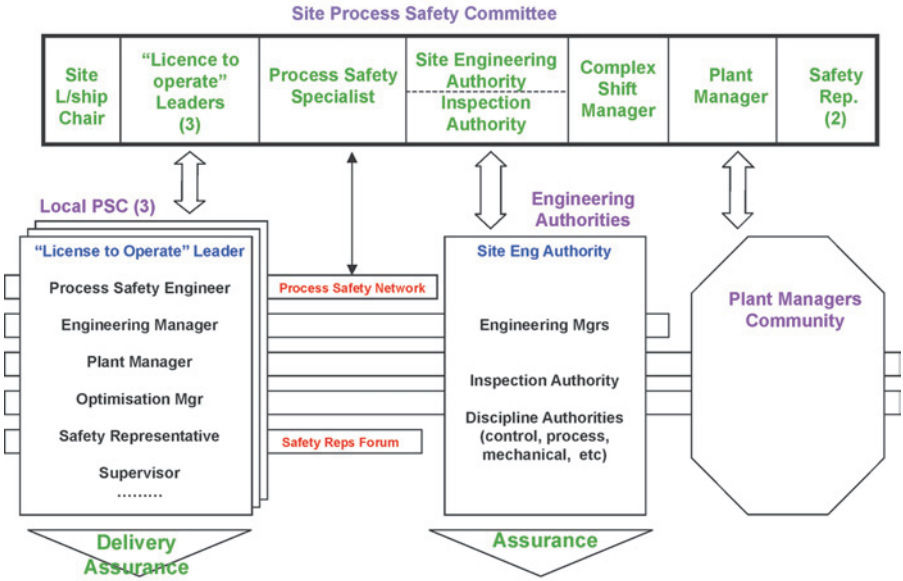

Figure 3. Make-up of Process Safety Committees

- Is there a body on your site to drive the process safety agenda? If you rely on a single HSSE governance body, is the membership appropriate for major accident safety and how much of the agenda does major accident safety occupy?

The governance structure described here is not offered as an exact solution for all circumstances. However, the authors believe that process that Grangemouth has gone through offers lessons that should be useful to other sites that are trying to establish a governance structure of their own for major accident safety.

RISK MANAGEMENT

At their highest level, the COMAH regulations want to drive the linkage between the hazards associated with a manufacturing organisation and the safeguards in place to manage those hazards. One of the exercises that Grangemouth undertook during 2001, in common with the other refineries in BP, was to assemble a list of the top 5–10 major accident risks for its operations. For Grangemouth, as well as COMAH risks, these include major cross-country pipeline routes, an offshore platform and marine-loading activities. The questions being asked at the time were: what operations is the site carrying out that could be a show-stopper if they went wrong, and how is the site managing the risk?

For a site like Grangemouth, with the experience of gathering hazard and consequence information over many years for CIMAH and COMAH, it was not difficult to identify the top issues. In general terms they included:

- Operations handling bulk toxics
- Major losses of containment on plants leading to an explosion
- Certain pipeline operations
- Pollution from marine loading operations
- Bulk LPG storage

Although the process of assembling the list was straightforward, the impact of having to identify such a list was significant in a number of ways:

- First, it brought focus on the overall risk profile of the site: which were the main contributors, how did they compare and how were they controlled?
- Secondly, it promoted increased "mindfulness" of what could go wrong.
- Thirdly, it became a vehicle for discussing major accident risk outside the site: the list was regularly discussed at the site's supervisory board meetings.
- Fourthly, it challenged the site's portfolio of activities: were all the site's activities still worth doing when the risk exposure was considered? As a result of asking this question the site has pulled out of one of its operations.
- Finally, were any interventions necessary to promote further understanding of the risks or sponsor further risk reduction. In the event, the list supported the programme of risk reduction the site was already undertaking.

Following this first-pass study, the site carried out a more detailed assessment during 2003, to provide a more complete risk-ranked overview of the site's activities.

This review confirmed the initial assessment of the most significant risks, but also identified other significant areas of the site's operations. By repeating this assessment periodically, the site can maintain an evergreen list of the top contributors to its residual risk profile. It also promotes a continuing review of the top contributors to confirm that no further risk reduction can be justified and that existing risk reduction activities are focusing on the right areas — in essence at a high level it forms part of the overall ALARP demonstration for the site.

The site is now starting to use the top risks approach to inform its assurance process. It is an instructive exercise at both a governance and operational level to ask what the key safeguards are that manage the principal hazards, and how assurance can be provided that these safeguards are working properly.

Grangemouth is using its understanding of the site's top major accident risks to align its work with that of the Competent Authority. The site has shared its analysis of the relative risks from different operations on the site, and this has led to an open dialogue of how the site and the Competent Authority can meet their complementary objectives based on a shared understanding of the priorities.

Some points for manufacturing sites to consider:

- What major accidents could shut your site down or jeopardise its licence to operate? What would you put in a "top-5" list?
- Do you know the key safeguards that allow you to manage your top major hazards? How do you know they are working effectively?
- Is your site running risks that aren't worth the commercial reward?
- Does your assurance process focus in the right areas? Is it proportionate to the weight you are placing on the management system to deliver the required risk reduction?

PERFORMANCE MEASURES

Since the incidents in 2000, Grangemouth has actively contributed to industry and regulatory discussions on major accident hazard KPI's. The site contributes to UKPIA discussions on measures and is one of the contributors to the CIA Scotland voluntary reporting scheme with the Health and Safety Executive.

Within the site, the Process Safety Committee has developed a set of major accident hazard KPI's that allow it to monitor continuing performance and progress in implementing certain key improvement activities. Outside the primary KPI set, the Process Safety Committee measures performance in other elements of the overall management system.

Table 2 shows the 2003 process safety KPI set in use at Grangemouth. The number of overdue inspections and "integrity" leaks formed part of the site's 2003 performance contract.

During 2003, the PSC also monitored compliance with the emergency exercise programme, implementation of standards and the frequency of Local Process Safety Committee meetings. For 2004, the KPI-set has been updated to include a broader measure of the state of Process Safety Information across the complex, compliance with COMAH improvement plan objectives and the site audit programme.

Clearly the particular set of KPI's in use will depend on the circumstances and priorities at the site in question. They should ideally represent a combination of both input and output measures. At Grangemouth the OSHA 1910.119 elements have been used as a checklist to ask what measures should be used to assess ongoing performance across the management system and to measure progress in implementing improvement plans.

To illustrate the benefits of measuring performance and setting improvement goals, Figure 4 shows how the site has progressed in reducing the number of hazardous fluid leaks of all sizes — mostly pinholes — from its process equipment since the start of 2001. The definition of leaks for this measure is where the fabric of the equipment has lost containment as opposed to a leak through a flanged joint or seal. The purpose of this measure is to give an output measure of the success of the inspection programme to complement the compliance with the inspection programme — an input measure.

The graph shows a considerable reduction in the number of hazardous fluid leaks from the start of 2002, which reflects progress in a number of areas: tackling the inspection backlog, dealing with vulnerable pipework, and tackling corrosion-under-insulation.

Table 2. 2003 major accident KPI-set at Grangemouth

Measure	Comment
Number of Process Safety significant incidents	Defined against BP internal reporting standard
Personal injury frequency	Defined against OSHA definition
Overdue inspections	For all primary containment and protective systems
Number of "integrity" leaks	Defined against site definition — excludes flange and seal leaks
Process Hazard Analysis plan compliance	Compliance with site timetable
Audit action closure	Completion of high priority actions
Staff trained in major accident awareness	Delivery of major accident awareness training to all staff and detailed training to operating and engineering personnel
COMAH reports issued	Compliance with statutory requirements
Overdue updates to documentation from plant modifications	Key to getting up-to-date Process Safety Information
Operating envelopes developed	Defines clear boundaries (integrity and operational) within which equipment should be operated

However, by the end of 2003 the number appeared to be reaching a plateau, so the Process Safety Committee asked the inspection team to provide an analysis of the root causes of the ongoing leaks. This indicated that the underlying causes of the majority of leaks was fatigue of small-bore pipework and corrosion-under-insulation. As a result, the Process Safety Committee asked the engineering community to develop plans to address the root causes.

Other KPI's have allowed similar focus to be brought on areas that needed improvement:

- The site has a greatly reduced number of overdue inspections of any kind, with clear focus being brought to bear on the outstanding items. Where appropriate, the Process Safety Committee has asked for detailed risk-prioritised action plans to show how the number of overdues is to be brought to zero. This is not a substitute for local management identifying and addressing the issues for themselves, but is part of responsible governance for the Process Safety Committee to make sure on behalf of the site leadership that the issue is being properly addressed and managed.
- The site has given detailed training in major accident awareness and management to over 1100 operating technicians and engineers. The aim was to provide a means for

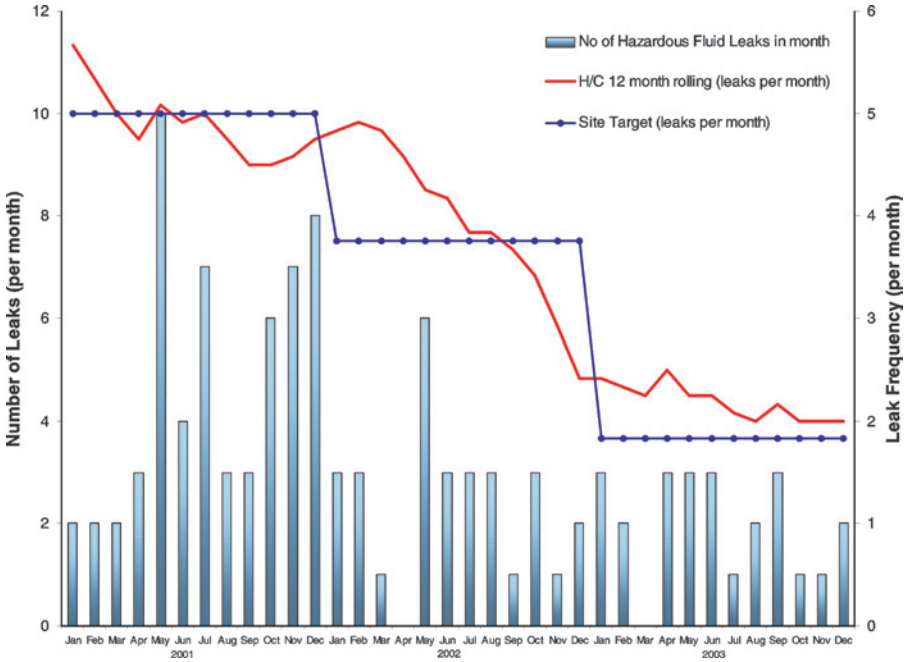

Figure 4. Progress in reducing leaks from equipment

consultation with the workforce and to help site personnel understand their COMAH reports and what their role is in preventing major accidents.

- The site had a large backlog of documentation that needed to be updated following plant modifications. Responsibilites were clarified and the number of overdue document updates reduced by over 50% within a year, with ongoing plans to reduce the number to zero across the site.

The combination of appropriate performance indicators supported by a suitable governance system is crucial for a site to establish and maintain control over its major accident management system.

DEVELOPMENTS WITHIN BP

The incidents at Grangemouth, together with other incidents elsewhere within BP, led to an increased awareness of the significance of major accident hazard management and the need for increased focus through the management system. In 2001 BP introduced a Process Safety and Integrity Management Standard that applies to all its operations

worldwide. In many respects this complemented the work that the Grangemouth site was already undertaking in applying the OSHA PSM framework and developing its governance model. As a further development, BP is in the process of developing and implementing high-level functional standards that collectively address major accident hazard management.

CONCLUSIONS

Successful management of major accident hazards is a huge exercise as it touches on almost every area of an operating site's activities. The incidents at Grangemouth, together with others around the world, have shown that traditional approaches to safety management based on occupational safety do not deliver successful major accident hazard management.

This paper has highlighted some of the main factors that have enabled Grangemouth to move forward in major accident hazard management from the incidents in 2000. In summary these are:

- The need for a comprehensive management system for major accident safety;
- The need for an effective governance structure to drive the major accident safety agenda;
- The need for a clear understanding of risk to drive improvement and inform assurance;
- The need for appropriate performance measures.

The Grangemouth site is not perfect: there are still many areas for improvement. However, the steps that the site has taken in standards and governance have allowed it to establish and maintain control over its major accident management system and so improve its management of major accident risk. The authors hope that the experiences shared in this paper will help other operators develop their own processes for major accident hazard management and make progress on the same journey.