Accidents and Agenda

An examination of the processes that follow from accidents or incidents of high potential in several industries and their effectiveness in preventing further accidents

Full Sector Reports

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Industry Sector Reports

Transverse Sector Reports

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Aviation – Jeff Jupp FREng

1. Synopsis

1.1. Civil aviation is relatively young in comparison to other modes of transport and has been perceived as technically complex and potentially dangerous from the outset. As a consequence, it has developed in a highly regulated framework with, in the UK, an independent accident investigation authority. The Air Accident Investigation Branch (AAIB) commands a worldwide reputation for excellence in accident investigation, not only in aerospace, but also in the transport industry in general. The jurisdiction of the AAIB is deemed to cover the period from the crew entering the aircraft to leaving it. Outside this period, any accident is treated more in the way of any routine industrial accident, with the HSE having responsibility, and is not dealt with in this report.

1.2. The requirements of the International Civil Aviation Organisation (Annex 13 of the Chicago Convention) govern the work of the AAIB and are embedded in the requirements of the UK Civil Aviation (Investigations of Air Accidents and Incidents) Regulations 1996. Independence from regulators and judiciary is achieved by the head of the AAIB reporting directly to the Secretary of State for Transport. The AAIB's investigations and recommendations are for the sole purpose of establishing the reasons for an accident and ensuring the continued safety of the public with the minimum of disruption to the ability to continue travelling. Their work is integrated with that of the Coroner and Judicial Inquiries etc. as necessary. Good working guidelines have been established (published, reference 1), which ensure that the AAIB Inspectors lead and control any investigation work at the crash/incident site except in the most exceptional circumstances. However, further clarity in this area would be valuable.

1.3. It has been clearly established in law that no evidence given to the AAIB can be used directly in other actions to the detriment of the providers of that evidence. This ensures the maximum exposure of potentially important witness information as to the cause of the incident.

1.4. The AAIB's responsibility covers the complete field of civil aviation, from paragliding and private aircraft to major international incidents such as the Lockerby Boeing 747 disaster. Different levels of response can be invoked depending on the severity of the incident, the procedures for which are summarised in reference 1 and 2, along with the guidelines for integration with the other "Authorised Personnel" from the police, the emergency services etc. who must legitimately have access to the incident.

1.5. Although not in its formal terms of reference, the AAIB puts a very high priority on the interests of the survivors of incidents and the dependants of any fatalities, in terms of their need to be kept informed and rehabilitation.

1.6. The results of the AAIB's investigations and its recommendations are publicly reported and it is then for appropriate parties, including the CAA as regulator, to take action as necessary. Progress on such recommendations is reviewed between the CAA and the AAIB on an annual basis. Accident prevention is strictly outside the scope of this report but is obviously closely linked, as investigation findings and recommendations may obviously involve actions which, had they been carried out previously, could have prevented the occurrence. There are formal and informal mechanisms discharged by the AAIB, the Regulator, the Airlines and the Aircraft Manufactures to keep all operators informed of any significant findings from an accident investigation AS SOON AS POSSIBLE. This can vary from just keeping all informed, through to a formal instruction from the Regulator to ground the relevant fleet of aircraft until findings are confirmed. The latter is, however, a rare occurrence, and requires firm evidence that continued operation could be unsafe. Good mechanisms are therefore in place for communicating learning from incidents/accidents. What is done about it as a safety management issue is a different subject.

1.7. The work of the AAIB was recently audited by ICAO representatives (a world first). This confirmed the respected position of the AAIB world wide, with no major learning points arising from practices in other countries, such as the NTSB/FAA in the USA. The only recommendations referred to relatively minor internal organisational and resourcing matters. Given the authority delegated to the AAIB as a single investigating body, this recent development is to be welcomed, particularly if used as an example for other sectors.

1.8. As an example of an Aviation accident investigation, the Concorde crash in Paris in July 2000, although carried out by a foreign authority, included a major input from the AAIB and the UK manufactures. Although a “high visibility” event rather than routine, it showed that the accident investigation procedures embodied in the AAIB should be maintained and not allowed to be derailed by the current trends towards litigation and the “blame culture”. In this case, the technical investigation was severely compromised in timescale, if not (in the end) in result, by the agents of the parallel French judicial inquiry. The dangers of investing the authority in a single investigative agency, if that agency does not maintain full transparency and openness to advice from all relevant expertise, were also apparent (the above comment on audit mechanism clearly being relevant.)

1.9. In the Author’s view, the processes established in the UK for air accident investigation are correctly seen as “best practice”. However, it is also appropriate to acknowledge that this practice is not necessarily totally applicable to either other transport media or other national cultures where the regulatory or social framework differs from that of Civil Aviation.

2. Mounting and Conducting Major Inquiries

2.1. The United Kingdom is a signatory to the Convention on International Civil Aviation (The Chicago Convention) and the International Civil Aviation Organisation, which was formed to administer its principles. All EU Member States are signatories; hence the European Union as a whole accepts them. Air Accident Investigation through an independent body is a requirement of the Convention, with the policies and procedures set out in Annex 13 to the Convention on International Civil Aviation – Aircraft Accident and Incident Investigation (reference 3). This is carried into EU law by Council Directive 94/56/EC of 21 November 1994 “establishing the fundamental principles governing the investigation of civil aviation accidents and incidents” (reference 4). These are flowed down into UK law through the Statutory Instrument 1996 No. 2798, CIVIL AVIATION – The Civil Aviation (Investigation of Air Accidents and incidents) Regulations 1996 (reference 5). The latter are then the current statutes defining the procedures to be followed in the investigation of aircraft accidents and the powers of the Inspectors of Air Accidents.

> **“The sole objective of the investigation of an accident or incident under these Regulations is the prevention of accidents and incidents. It is not to the purpose of this activity to apportion blame or liability.”**

3. The AAIB accident investigation procedures and levels of response

3.1. Much of the following information is abstracted from a guidance brochure for the police and emergency services (reference 1) which demonstrates the attention paid by the AAIB to integrating the investigation with the requirements of other responsible agencies. More details are also repeated in reference 2.

3.2. Notification of accidents

3.2.1. The legal responsibility for notification of an accident or serious incident rests first with the commander of the aircraft or, if he be killed or incapacitated then the operator. If the accident occurs on or adjacent to an aerodrome, then the aerodrome authority is also required to notify the accident. In practice the first information usually reaches the AAIB from the police force dealing with the incident. The notification is required to be passed to the Department for Transport (in effect the AAIB) by the quickest means.

3.2.2. The person reporting the accident to the AAIB is also required to inform the local police of the accident and the place where it occurred. This may be the first information received by the police, although it is more likely that it will have already come to them through an emergency call. The police should immediately telephone the AAIB and pass on as much information as is available. Police Forces should also inform the Civil Aviation Area and Terminal Control Centre in case air traffic restrictions are necessary.

3.2.3. In the event of an aircraft being reported missing or overdue, the police may be alerted by a local aerodrome authority, an Air Traffic Control Centre (ATCC) or Aeronautical Rescue Coordination Centre (ARCC). When this happens it is essential that the closest liaison is established and maintained with the ARCC.

3.3. AAIB response

3.3.1. The notification is passed to the AAIB Duty Co-ordinator who will decide what action to take. There are more than 350 reportable accidents every year but fortunately the majority of these are relatively minor and are usually be investigated by correspondence and telephone.

3.3.2. The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996 provides for the Chief Inspector to determine the form and conduct of the investigations carried out by the AAIB. Three levels of investigation are in use, as follows:

a) Inspector’s Investigation. An Inspector’s Investigation is carried out whenever the Chief Inspector considered it appropriate, usually a major accident or serious incident to a passenger carrying public transport aircraft. At the end of an Inspectors Investigation, a formal accident report is submitted to the Secretary of State;

b) AAIB Field Investigation. An AAIB Field Investigation will determine the main circumstances of an accident in order to enable the Chief Inspector to decide whether to order an Inspector’s Investigation, or to complete the investigation as an AAIB Field Investigation (see below) with the publication of a report in the AAIB Bulletin;

c) Aircraft Accident Report Form (AARF). An AARF is required for all reportable accidents and serious incidents, which are not the subject of an AAIB Field Investigation. (see reference 2 for further information of “minor” accidents).

3.3.3. For the more significant accidents or serious incidents (approximately 50 to 70 every year) a team of AAIB Inspectors will be despatched to carry out a Field Investigation. It is most important that the site is kept secure prior to the arrival of the AAIB Inspectors and until the wreckage has been removed. The Inspectors have powers to require evidence to be produced and to retain it.

3.4. Accident site security and safety

3.4.1. The regulations specify that:

> **"...where an accident or serious incident occurs in or over the United Kingdom and an aircraft involved in that accident or serious incident is withdrawn from service by its operator, no person other than an authorised person shall have access to that aircraft and neither the aircraft not its contents shall except under the authority of the Secretary of State be removed or otherwise interfered with."**

3.4.2. Apart from AAIB Personnel, authorised persons include any constable or any officer of Customs and Excise.

3.4.3. It being vital that an accident site be identified and sealed off as soon as possible; only people required for rescue and fire-fighting are allowed access to the wreckage. The guarding of a site is not always easy. For example, the wreckage trail can be hundreds or thousands of yards long - in December 1988 the wreckage trail of the Boeing 747 which broke up over Lockerbie at 31,000 feet was 80 miles long and covered an area of 845 square miles. The number of people in and around the wreckage needs to be kept to an absolute minimum. It is all too easy for vital evidence to be destroyed by well intentioned persons climbing over the wreckage, trampling equipment into the ground, or moving switches and controls from their original positions. The press, in particular, will be well represented and it requires some effort to keep them away from the wreckage. However, press photographs taken soon after an accident, albeit from a distance, can provide a useful record of the wreckage distribution or the local weather conditions. It is the responsibility of the police to guard the wreckage and provide security for the accident site.

3.4.4. Overall responsibility for the safety at the site usually resides with the authority in control, i.e. the Fire Service, Police or the AAIB. However, organisations working at the site will retain responsibility for the safety both for their own personnel and for others working under their direction. To ensure that a high level of safety management is maintained during site operations, it is important that organisations co-operate and co-ordinate their activities. At major accident sites for example, a risk management group will be formed to assist with the safety management process. Initiation and chair of the group is likely to be co-ordinated by the local authority emergency planners (the AAIB may initiate this action if required). Group members should include safety co-ordinators from the main organisations involved, including the AAIB, Police, Fire, Emergency Planners, Environment Agency, contractors, etc.

3.4.5. Upon completion of the fire-fighting and rescue phase, the AAIB will assume responsibility for investigation and recovery operations at site. At this stage, AAIB personnel will undertake an assessment of safety hazards posed by damaged aircraft cargo, buildings and other structures at site. The advice of the senior Fire or Police Officer will be sought to establish information on hazards previously identified.

3.4.6. Some incidents may have implications for public safety and, given the extent and duration of site operations in major accidents, may also have a significant impact on the daily routine of the local population. Past experience has shown that the involvement of the Local Authority, and in particular the Emergency Planning department, is essential for the effective co-ordination of non-investigation activities at and around major accident sites. The AAIB will seek to maintain a close liaison with the Local Authority to provide advice and assistance where required.

3.5. Organisation of the investigation

3.5.1. With the increasing complexity of the aviation environment, e.g. flight operations, aircraft systems, and air traffic control, it has become necessary for the AAIB to call on outside specialists to assist the Branch in particular aspects of specific investigations. These personnel can be co-opted from the airline operator involved, the manufacturers of the aircraft, its engines and equipment, or other government agencies. They will be formed into working groups under the direction of AAIB Inspectors. Thus the maximum use is made of available expertise (both during the on-site investigation and the subsequent analysis), but without overburdening the AAIB with permanent resources. None-the-less, that expertise is under the full direction of the AAIB during the specific investigation. The number and scope of the groups depends on the site and complexity of the specific accident. An Investigator-in-Charge will be appointed by the Chief Inspector of Air Accidents and will be responsible to him for the overall organisation, conduct, and control of an accident investigation. The Investigator-in-Charge will decide which specialist working groups are required and will co-ordinate and direct the efforts of the groups. The Investigator-in-Charge will also ensure that regular liaison is maintained between the AAIB, the police incident commander and the Coroner or Procurator Fiscal.

3.6. Preservation of evidence

3.6.1. Modern aircraft systems are complex and there is an ever present risk of destroying vital evidence as a result of an inadvertent action by members of the emergency services. The important point is that, after the initial emergency response phase, the accident site must be disturbed as little as possible until the arrival of the AAIB investigation team. The evidence remains under the responsibility of the AAIB.

3.7. Firefighting

3.7.1. There have in the past been occasions where the Fire Service has allowed the post-impact fire to burn itself out thus causing unnecessary damage to the wreckage and destroying evidence. It is vital that the fire is extinguished as soon as possible and, as soon as all has been done to save life and minimise injury, that the wreckage is then disturbed as little as possible.

3.8. Photographs and videos

3.8.1. It is often necessary for wreckage to be moved for the purpose of rescue or removal of bodies before the AAIB Inspectors arrive. It is, therefore, very important that, wherever practicable, a comprehensive record is made of the original situation by photograph or video. Coverage should include an overall view of the site and close-up of the wreckage, especially the cockpit area, and of the bodies.

3.9. Eye-witnesses

3.9.1. The police can assist the AAIB a great deal by compiling a list of witnesses, their addresses and telephone numbers and taking their initial statements. It is important that statements be strictly confined to a record of the facts as seen by the witnesses. Although the police may need these statements for their own purposes, it is important that they be made available to the AAIB. In cases where it is necessary to try and establish the final flight path of an aircraft, the number of witnesses and the area covered by them can be more important than the individual quality of their evidence. Specialist aviation knowledge on the part of a witness is no guarantee of accuracy. It is not unusual for witnesses to have photographs or video recordings of an accident, particularly at air displays. Copies of these (preferably the originals) should be requested from witnesses. They will be analysed by the AAIB Inspectors and then returned to the owners.

3.9.2. Passengers are requested to complete a copy of a standard questionnaire, ideally with the assistance of a police officer or a member of the support agencies, who should then ensure that it is given to an AAIB Inspector on site or, failing that, is returned to the AAIB.

3.10. Flight recorders

3.10.1. Large passenger aircraft carry flight data recorders (FDR) and cockpit voice recorders (CVR), which work on an electromagnetic principle. After an accident the retrieval of the recorders is of prime importance, but electromagnetic devices of the mine-detector type should not be used to search for these recorders because these can erase the recorded information. Unskilled handling after a crash can cause unnecessary damage, which might lead to loss of recorded information, or delay in interpreting that information.

3.11. Wreckage recovery

3.11.1. Recovery of the wreckage of public transport aircraft will normally be coordinated by the AAIB, usually with assistance from the Royal Air Force Aircraft Recovery and Transportation Flight.

3.11.2. In all accidents, the prevention of pollution or further damage to land, water course, buildings, etc. will be a significant consideration from an early stage. The AAIB will advise and assist the Emergency Services, Environment Agency, utility companies, etc in gaining access to the site to limit any environmental effects. At major accident sites, Local Authorities are likely to act as the co-ordinating body for this aspect of site operations. At most accident sites, representatives of the aircraft operator/insurers will also attend site at an early stage to assess liabilities and plan restoration/remediation activities. Where complex or extensive restoration work is required, agents will be appointed by the insurers to manage the project.

3.12. Aviation Pathology

3.12.1. In the United Kingdom the AAIB team may include a specialist in aviation pathology, usually seconded from the RAF. From the AAIB standpoint, it is important for the pathologist dealing with an air accident to have a knowledge of aviation and aviation medicine.

3.12.2. Whilst the cause of death following an aircraft accident is generally obvious in the broad sense, the standard autopsy report may not meet the requirements of the aircraft accident investigation. In some cases the AAIB Inspector requires as much information from the pathologist's examination of the bodies of the occupants of the aircraft as he does from the engineering examination of the aircraft structure.

3.12.3. Normally, two pathologists cover an aircraft accident autopsy, the Coroner's pathologist being in charge and the aviation pathologist, although formally being present as an observer, taking an active part. The aviation pathologist is normally willing to act on behalf of the Coroner (or Procurator Fiscal in Scotland) when they so desire. In Scottish Law two pathologists are necessary to conduct an autopsy where there is a possibility of criminal proceedings. Wherever possible one of these will be the aviation pathologist.

3.13. Consideration of the survivors and dependants where fatalities have occurred

3.13.1. Although not in their formal terms of reference, the AAIB regard it as an important responsibility to consider the well being of survivors and dependants where fatalities have occurred, in terms of keeping them informed of the progress of the investigation. Further details are given in reference 2.

3.14. Relationship with other Investigating Authorities

3.14.1. Various relevant aspects have already been addressed in the above paragraphs. The following overall points are of note: -

3.15. Liaison between the AAIB and Police Inquiries

3.15.1. The purpose of the Police inquiry and that of the investigation conducted by the AAIB are very different. The AAIB investigation's purpose is to establish the circumstances and causes of an accident to ensure that safety action is taken to prevent that accident occurring again. This is an international obligation placed on a State by the Convention on International Civil Aviation (The 'Chicago Convention'). It is the AAIB's responsibility, after an accident or incident to ensure that urgent safety action is disseminated world-wide so that the safety of the travelling public is assured. The police role is to establish whether there is sufficient evidence to justify criminal proceedings. The purpose of any prosecution being not to establish the circumstances of an accident or incident but to prove beyond reasonable doubt that an offence has been committed. Increasingly in recent years, this may be paralleled by investigators to support civil proceedings to apportion blame and liability.

3.15.2. The Lord Chancellor has provided guidance on the relationship between the Police inquiries and the technical investigations conducted by bodies such as the AAIB. This guidance is entitled "Disasters and the Law - Deciding the form of Inquiry". In this Memorandum the Lord Chancellor states that:

> **"It would require firm indications of serious criminality to justify a criminal investigation taking precedence over an inquiry held in public (or at least whose results are to be made public) where otherwise the public interest requires that such an inquiry be held. Colleagues will wish to bear in mind that the holding of such an inquiry in advance of criminal proceedings may adversely affect the ultimate prospects of a successful prosecution, but nevertheless, unless the criterion mentioned in the previous sentence is met, this is likely to be justified."**

3.15.3. The AAIB will make every effort to establish and maintain good liaison and cooperation with the Police throughout the technical investigation. The aim is to ensure that both the Police and the AAIB investigations can proceed in parallel without either body obstructing the other.

3.16. Liaison with HM Coroner (In Scotland the Procurator Fiscal)

3.16.1. A Coroner, or in Scotland the Procurator Fiscal, is required to inquire into all the circumstances of a sudden, violent or unnatural death, which includes aircraft fatalities. Whilst the AAIB is strictly concerned with the cause of the accident, the two aspects of a fatality are inseparable. In practice, the Coroner's Officer and the AAIB Inspectors collaborate in the investigation. Normally, the Coroner or Procurator Fiscal will be in touch with the progress of the inquiries and may consult the Inspector in deciding which witnesses should be called. In Scottish Law the Procurator Fiscal is responsible for investigating any accident, whether fatal or not, resulting from a criminal act. In cases of possible criminality the Procurator Fiscal, police and the AAIB Inspectors collaborate in the investigation and care is taken to fulfil the requirements for corroboration of all material aspects of the evidence including the recovery of parts of the aircraft.

3.17. Reporting

3.17.1. As already noted, for lesser accidents where a field investigation was appropriate, the facts will be summarised in an AAIB Bulletin. Preliminary findings and urgent recommendations are issued in AAIB "Special Bulletins". Where a full Inspectors Investigation was carried out, then a full report will be submitted to the Secretary of State. In the latter case, before the report can be finalised the Investigator in Charge is obliged under the applicable regulations to consult the aircraft commander, the operator and any other person whose reputation is likely to be adversely affected by the report and to take into consideration any representations they may make. The final report is then submitted by the Chief Inspector to the Secretary of State and it is then published.

3.17.2. Safety recommendations arising out of any investigation are passed to the relevant authority or organisation and responses to these are summarised in progress reports by the CAA and reviewed annually. All AAIB publications are available publicly and are also published on the internet.

3.17.3. It should also be noted that, as well as the formal AAIB reporting mechanisms, there are formal and informal mechanisms discharged by the Regulator, the Airlines and the Aircraft Manufactures to keep all operators informed of any significant findings from an accident investigation AS SOON AS POSSIBLE. This can vary from just keeping all informed, particularly those other operators with the same type of aircraft, through to a formal instruction from the Regulator to ground the relevant fleet of aircraft until findings are confirmed. The latter is, however, a rare occurrence, and requires firm evidence that continued operation could be unsafe.

3.18. The ICAO audit mechanism

3.18.1. A recent development has been the initiation by ICAO of auditing the compliance of national Accident Investigation Agencies (as well as national Regulatory Authorities) with the requirements of Annex 13, including sharing of best practice and recommendations for improvement. The recent audit of the AAIB was in fact the first. The results (reference 5) confirmed the respected position of the AAIB worldwide, with only one relatively minor finding of a procedural nature and particularly noting the level of experience of the permanent staff (average 15 years), which is crucial to the efficient investigation and analysis of accidents to complex transport vehicles. Recommendations were made, however, on the level of support staffing etc., to ensure the timely issue of final reports and to ensure adequate response to a potentially increasing number of accidents (due to traffic growth) of an increasingly complex nature as technology advances. As always where a high level of delegation is given to a single party, the introduction of a value adding audit mechanism is to be welcomed.

3.19. Accident Prevention

3.19.1. Accident prevention is strictly outside the scope of this report but is obviously closely linked, as investigation findings and recommendations may obviously involve actions which, had they been carried out previously, could have prevented the occurrence. In the Civil Aviation sector, major transport operators (e.g. British Airways) and Manufacturers (e.g. Airbus) operate confidential incident reporting systems and Safety Boards which ensure appropriate action is promulgated in terms of changed procedures or (often) reminders of existing procedures. There are also mandatory reporting systems to the Regulator (the CAA) for significant incidents, such as "Near

Misses", which apply to the whole user population (including smaller private aircraft). As noted in the section "The AAIB accident investigation procedures and levels of response, (a) Notification of Accidents", a serious incident must also be reported to the AAIB (for example when significant damage to an aircraft is incurred, but when there are no injuries or fatalities). As for accident follow up, the Manufacturers, Regulators, Airlines and the AAIB have formal and informal routine procedures for keeping all relevant parties informed of incident occurrences and any urgent findings and necessary actions.

3.19.2. There are, then, good mechanisms in place for communicating learning from incidents/accidents. What is done about it as a safety management issue is a different subject.

4. Accident Examples

Two example accidents are referred to, the "Lockerbie" Boeing 747 disaster, briefly, and the Concorde Paris 2000 crash in more detail.

4.1. Boeing 747 disaster at Lockerbie, December 1988

4.1.1. The details of this incident are well known and are not gone into here. One aspect has already been referred to in that the wreckage trail was spread over a huge area and it was absolutely paramount that all debris was recovered for analysis. (This is likely to be much more an issue for Aviation accidents than for other transport sectors.) Importantly, this is an example where all aspects of the investigation needed to be fully integrated, since the forensic investigation would have needed to be even more detailed than the technical investigation. The AAIB needed to go as far as showing that the cause of the accident was an explosive device, where it was positioned and how powerful it was. Recommendations followed on possible measures for research and measures into "hardening" cargo containers/compartments against such blasts. The criminal investigation then needed to discover the details of the device and any other clues to its origins etc. This integration was indeed achieved, with the results that are well known.

4.2. The Concorde Crash at Paris Charles de Gaulle, July 25th 2000

4.2.1. The crash of Air France Concorde F-BTSC at Gonesse shortly after take-off from Charles de Gaul airport on 25th July 2000 was widely reported about the world. The aircraft struck a metal strip on the runway, causing the explosive destruction of a tyre. The subsequent impact caused the expulsion of a piece of wing skin (by a previously unknown mechanism) and a massive fuel leak. The fuel ignited and the subsequent fire led to the final crash with the loss of all on board and four people on the ground. The investigation was led by the Bureau Enquetes-Accidents (BEA), the French equivalent of the AAIB, assisted by Airbus France, one of the joint original manufactures. The AAIB was also involved in accordance with the ICAO regulations (representing the joint state of manufacture) along with representatives from Airbus (UK) and Rolls-Royce (Bristol). British Airways, as the only other operator of Concorde offered assistance as well. Full details of the accident are given in reference 2.

4.2.2. Almost as soon as the technical investigation was underway, the French Minister for Transport demanded that Air France withdraw Concorde from Service. Under normal circumstances, no recommendation on the safety of an aircraft type would be made until a fleet-wide technical issue had been established, and British Airway kept operating Concorde normally accordingly (certificates of airworthiness were properly withdrawn at a later stage in the investigation and the fleet was grounded).

4.2.3. As well as the BEA technical investigation, an immediate judicial inquiry was launched and the Transport Minister convened his own panel of experts to advise him personally. Thus three inquiry teams were competing for access to physical evidence and the French Police had taken control of crash site on behalf of the Judiciary.

4.2.4. Although the facts of the accident were eventually established, there was a lack of cooperation between the BEA and the Police. The police controlled access to the site and debris and did not allow open access to the evidence to the BEA, let alone the AAIB, in direct contravention of the Chicago Convention.

4.2.5. At the date of writing, the French Judicial inquiry had still not been completed. When Air France stopped Concorde services in July 2003, the French judiciary subpoenaed one Concorde when it arrived in Toulouse to enter a museum. They then had a runway test carried out recreating a technical fault with the undercarriage of F-BTSC. This maintenance oversight on the aircraft had been discounted by the BEA technical inquiry as being a significant factor in the accident and the test, although expensive, merely confirmed the findings of the technical report.

4.2.6. A particular technical point is of relevance to the conduct of the BEA. Regarding the reason for the massive fuel leak being ignited, the BEA commissioned a report from a French university, which claimed that torching from the afterburners was feasible, and in an interim report this was given as the most likely cause, apparently supported by the firemen witness statements (which had not been made available to the UK participants). From the start, fire experts advising the AAIB and Airbus UK felt this was not likely (and had so advised the BEA), with the flame front unable to advance from downstream, against the speed of the airflow relative to the aircraft, to lock on to the rear of the landing gear bay as a flame holder (where it was clearly visible in photographs obtained from the public of Concorde just after take-off). Airbus UK commissioned tests in a “fire-tunnel”, with a representation of the relevant parts of the aircraft etc., which in the end showed that the flame front would not have come forward and that electric sparking from damage electric circuits was the most probable cause. **This was acknowledged in the BEA final report, which would otherwise have come to the wrong conclusions, with the wrong safety actions possibly resulting**. (Although the personal view of the Author, who has not seen this explanation in print, it is probable that in fact the fuel first released from the aircraft was torched by the afterburners downstream of the aircraft, leading to the flame reported by the firemen, but then electric sparking caused the upstream ignition which established the flame under the aircraft.)

4.2.7. Key points which are illustrated by this example:

a) There was interference with the technical inquiry by agents of the Judiciary and poor co-ordination of the investigations. The attention of the French Authorities had to be drawn to the fact that they were acting in contravention to Annex 13 of the Chicago Convention.

b) Access to the crash site for authorised expects was restricted.

c) Evidence from the scene of the incident and the subsequent crash was removed before full technical investigation.

d) Access to material evidence by authorised experts was restricted/delayed, leading to a delay on confirming the causes of the accident and adequate measures for returning the fleet to service.

e) The BEA did not appear to have the full confidence of experts advising the Judicial inquiry. For example the 2003 ground run of Concorde with the “spacer” missing recreating the maintenance oversight discovered on F-BTSC.

f) There were in effect three technical expert teams involved, those acting for the BEA, the Judiciary and the French Transport Minister.

4.2.8. This accident gave a clear example of what can happen when there is a lack of co-operation and respect between the investigatory powers. However, in the end the correct outcomes were reached (subject to the final outcome of the Judicial Inquiry), but significant time was wasted in reaching the conclusions. Concorde’s return to service was nearly compromised, as British Airways’ deadline for retaining the large team involved in the Concorde operation had just been passed when the Certificates of Airworthiness were returned. The Concorde fleet was relatively small and hence the numbers of passengers affected was limited. For another aircraft type the damage in terms of travel restrictions or the commercial viability of the aircraft type could have been more serious.

4.2.9. On the other hand, it also gave an example of what may happen if the responsible (single) independent accident investigation authority does not discharge its investigation in an open way and does not accept constructive criticism to its views. In this respect, an audit mechanism becomes important, the more that responsibility is delegated to a single team/authority. The relatively recent development of ICAO extending its audits of Regulatory Authorities to the Independent Accident Investigators is therefore a welcome development.

5. Concluding remarks

5.1. This report has outlined the responsibilities and processes for accident investigation in civil aviation, which has already been held up as a “best practice” example of how accident investigation can and should operate in the environment of a technically complex transport system. In the Author’s opinion, there is very little to question or improve upon in the way civil aircraft accident investigation is carried out in the UK.

5.2. Some key further points of note are:

- The conduct of aircraft accident investigations is covered by international law. This is increasingly important for other transport sectors such as Maritime and Railways.

- The leadership of Civil Aircraft Accident Investigation is delegated to a single independent body (the AAIB) whose sole objective is to discover the causes of the accident and to ensure the continued safety of the travelling public as quickly as possible. The AAIB is a respected, independent, technical authority, which is allowed full “ownership” of the accident site and unfettered access to relevant evidence.

- Clear delineation, but cooperation, between technical and criminal inquiries. In this case, the safety of the travelling public takes precedence over criminal proceedings and hence the technical inquiry takes precedence over criminal investigations. Guidelines have been issued by the AAIB to other “authorised personnel” (e.g. the police) to ensure understanding of the procedures and the appropriate integration of all avenues of enquiry.

- The international agreements mean that investigation teams can be quickly drawn together from many interested countries and all involved should have a clear understanding of procedures and practices.

- It is important that the Accident Investigation body has the right expertise and experience to discharge the authority delegated to it. The UK independent AAIB has established a worldwide reputation and respect. In other cultures and in other circumstances where this respect has yet to be won, the Author can see potential problems in empowering such an independent agency, relative to, for example, the requirements of the Police to gather and guard evidence for potential criminal proceedings.

- In view of the preceding remark, the example of the UK AAIB, whilst an excellent precedent, may not be universally appropriate. Also, as has recently happened, the introduction of an Audit mechanism is to be welcomed.

References

1. Air Accidents Investigation Branch, Department of Transport. “Guidance for the Police and Emergency Services in the Aftermath of an Aircraft Accident.”

2. RAE “Accidents and Agendas”, Working Paper – “Aviation”

3. ICAO International Standards and Recommended Practices. Annex 13 to the Convention on International Civil Aviation Aircraft Accident and Incident Investigation. Ninth Edition July 2001.

4. Council Directive 94/56/EC of 21 November 1994.

5. Establishing the Fundamental Principles Covering the Investigation of Civil Aviation Accidents and Incidents.

6. Statutory Instruments 1996 No. 2798. The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996. Air Accidents Investigation Branch, Department of Transport.

7. ICAO December 2002. Review of Legislation, Procedures and Facilities for Aircraft Accident Investigation – Air Accidents Investigation Branch, United Kingdom

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Chemical and Allied Industries – Prof Trevor Kletz FREng

1. Synopsis

1.1. This body of this report is in three sections. Section 2 describes the procedures in outline. Section 3 describes the results of an investigation while the third and most important section describes the common weaknesses in investigation procedures. No investigation displays all of them but most display some of them and many display most of them. The accident described in the second section has been chosen because it illustrates one of the most common and serious: superficiality. In the following, "accidents" include dangerous occurrences or so-called "near misses" (really near accidents) in which, by good fortune, no one was injured or damage was trivial.

2. Mounting and Conducting Major Inquiries

2.1. The procedures depend on the seriousness of the accident. Minor accidents may justify no more than a hand-written report by the foreman, more serious ones are formally investigated by a panel chaired by a manager whose seniority depends on the seriousness of the accident. The measure of "seriousness" is often the number and nature of the injuries but in the more responsible companies what might have happened and the value of the incident as a learning experience are give equal weight.

2.2. Many accidents have by law to be reported to the Health and Safety Executive (HSE) (or in some cases to the Environment Authority [EA] instead or as well). The HSE (and EA) may carry out their own investigations, which may be followed by the issue of Improvement or Prohibition Notices or prosecution. However, HSE, unlike their opposite numbers in some other countries, prefer to help companies prevent accidents rather than prosecute afterwards and much of their resources are spent giving advice. However, as a result, it seems, of political pressure HSE now prosecutes more often than in the past.

2.3. In a very few cases, less than once/year, HSE publish a report on the results of an investigation into a chemical accident. These reports are always clearly written and bring out lessons of wide applicability. All data of possible relevance are described so that readers with different interests and background can sometimes draw additional lessons that HSE have missed. Brief summaries of incidents appear in some of their other publications. Public inquiries have been held into a very few major incidents, such as Flixborough (1974) and Piper Alpha (1988).

2.4. As published HSE reports are so few it is difficult to generalise from them and so an accident investigated internally is described in the next Section.

2.5. The degree of formality in accident investigation varies greatly between companies and is at its greatest in public inquiries and when the police are involved. Greater formality does not result in greater effectiveness, in fact the reverse. What really happened is most likely to be discovered when people are allowed to ramble on in a relaxed atmosphere. It is better to hold meetings in the familiar atmosphere of the plant rather than in the main office. In general, however, the collection of evidence and the discovery of the course of events is usually carried out competently. The weaknesses occur in the interpretation of the evidence, as discussed in Section 4.

3. The Process Illustrated by Example

3.1. A crude oil distillation unit was being started up after a major turnaround. Stocks of product were low and it was important to get the unit on-line as soon as possible. The unit manager, a young graduate who had joined the company only a year before, therefore decided to be present throughout the night so that he could deal promptly with any problems that arose. Perhaps also his presence might discourage delay.

3.2. The distillation column was warming up. The reflux drum was half-filled with water with a layer of light oil containing some liquefied petroleum gas (LPG) on top. Some water was always produced but as the column had been washed out the production of water was greater than usual. Two pumps were connected to the reflux drum as shown in Figure 1. The water pump took suction from the bottom of the drum and sent the water to a scrubber for purification and discharge to drain; the oil pump took suction from a point about 30 cm (1 foot) above the bottom and provided reflux and product take-off. Neither pump had been started up.

3.3. The foreman asked an operator to start up the water pump. He discovered that a slip-plate (blind) had been left in the suction line to the pump on the drum side of the isolation valve (Figure 1). All the branches on the drum had been slip-plated during the turnaround to isolate the drum for entry. The other slip-plates had been removed but this one had been overlooked by the fitter who removed them and this was not noticed by the process foreman when he accepted back the permit-to-work.

3.4. The manager estimated that shutting down the furnace, allowing it to cool, fitting a flex to the spare branch on the reflux drum, draining the contents to a safe place, removing the slip-plate and warming up again would result in 24 hours delay. The maintenance foreman, a man of great experience, who was also present, offered to break the joint, remove the slip-plate and remake the joint while the water ran out of it. He could do it, he said, before all the water ran out and was followed by the oil; he had done such jobs before.

3.5. After some hesitation the manager agreed to let the foreman go ahead. He dressed up in waterproof clothing and watched by the process team, unbolted the joint and removed the slip-plate while the water sprayed out. Unfortunately he tore one of the gaskets, half of it sticking to one of the joint faces. Before he could remove it and replace it, all the water ran out and was followed by the oil. The foreman abandoned the attempt to remake the joint.

3.6. The furnace was only 30 m (100 feet) away. As soon as the oil appeared, one of the process team pressed the button that should have shut down the burners. Nothing happened. The process team had to isolate the burners one by one while the oil and vapour were spreading across the level ground towards the furnace. Fortunately, they did so without the vapour igniting.

3.7. Afterwards it was discovered that the trip system on the furnace had given trouble a day or two before the turnaround started. The process foreman on duty therefore took a considered decision to by-pass it until the turnaround, when it could be repaired. Unfortunately this late addition to the job list was overlooked.

3.8. Although there was no injury or damage, both could easily have occurred. The incident was therefore thoroughly investigated, as all dangerous occurrence and near-misses should be. The first two sets of recommendations described below were made at the time. The others were made later when the incident was selected for discussion by groups of 12-20 people, from works managers to senior foremen, as part of a training programme. The various recommendations are not alternatives. All are necessary if a repeat of the accident is to be prevented and all apply widely, not just to the unit, factory or company where the accident occurred.

3.9. Key points relating to the example incident:

3.9.1. **The slip-plate was the key:** The incident was due to the failure to remove the slip-plate before the start-up. The internal inquiry made several detailed recommendations (see Appendix 1) to prevent this happening again.

3.9.2. **Better control of protective systems:** The second technical cause was the failure to shut down the furnace. Appendix 2 summarises the recommendations.

3.9.3. **Don't rush:** The discussion groups contained people with a wider range of knowledge and experience than the investigating panel, which was composed of people with detailed knowledge of the plant. They therefore saw additional ways of ways of preventing the accident. They felt it was due in part to a rushed decision by the manager. Few problems on a large plant are so urgent that we cannot delay action for 15 minutes while we talk them over. If those concerned had paused for a cup of tea they would have realised that removing the slip-plate was more hazardous than it seemed at first sight and that there were other ways of avoiding a shut-down.

Removing the slip-plate was more hazardous than seemed at first sight because the gauge pressure at the slip-plate, due to the head of liquid, was nearly 0.7 bar (10 psi) higher than the pressure in the reflux drum (a gauge pressure of about 1 bar (15 psi). This might have been realised if those present had given themselves time to talk over the proposed course of action. Simple calculations could have avoided many other accidents.

A shutdown could have been avoided with less risk by freezing the water above the slip-plate with solid carbon dioxide (dry ice) or by injecting water into the reflux drum via the spare branch shown in Figure 1 so as to maintain the level. Another possible way of avoiding the shut-down would be to remove the pump, pass a drill through the valve and drill through the slip-plate. This method could, of course, only be used if the valve was a straight-through type.

As a general rule, when we have to decide between two courses of action, both of which have disadvantages, there are often alternative actions that we have not considered.

3.9.4. **Who was in charge?:** The discussion groups saw the accident as due to the failure of the young manager to stand up to the maintenance foremen. The manager's situation was difficult. The foreman was a strong personality, widely respected as an experienced craftsman, old enough to be the manager's father, and he assured the manager that he had done similar jobs before. It was 3 am, not the best time of day for decisions. The manager could not be blamed. Nevertheless sooner or later every manager has to learn to stand up to his staff, not disregarding their advice, but weighing it in the balance. He should be very reluctant to overrule them if they are advocating caution, more willing to do so if, as in this case, they advocate taking a chance.

The maintenance foreman felt partly responsible for the non-removal of the slip-plate. This made him more willing than he might otherwise have been to compensate for his mistake by taking a chance. A more experienced manager would have realised this.

The company's policy was to teach mangers to swim by pushing them in the deep end. This is excellent training for the mangers, as I can testify by experience, but is not always good for the plant.

3.9.5. **The climate in the works:** Finally some discussion groups went deeper than the others and saw the incident as due to a failure to give sufficient emphasis to safety throughout the organisation. What would the factory manager have said the next morning if he found that the start-up had been delayed? Would he have commented first on the low stocks and lost production or would he have said that despite the low stocks he was pleased that no chances had been taken?

The young unit manager was not working in a vacuum. His judgement was influenced by his assessment of his bosses' reactions and by the attitude to safety in the company, as demonstrated by the actions taken or remarks made in other situations. Official statements of policy have little influence. We judge people by what they do, not what they say. The factory manager carried a large share of responsibility for setting a climate, probably inadvertently, in which his staff felt that risk-taking was legitimate.

Did the unit manager feel that he had been given, by implication, contradictory instructions, in this case to get the plant back on line as soon as possible and, at the same time, to follow normal safety procedures? Junior managers and foremen often find themselves in this position. Senior mangers stress the importance of output or efficiency but do not mention safety. So their subordinates assume that safety takes second place. They are in a 'no-win' situation. If there is an accident they are blamed for not following the safety procedures. If the required output or efficiency are not achieved they are blamed for that. Managers, when talking about output and efficiency should bring safety into the conversation. What we don't say is as important as what we do say.

It may be right, on occasions to relax the safety rules, but if so this should be clearly stated, not hinted at.

How, if at all, did the young manager's training in the company and at University prepare him for the situation in which he found himself? Probably not at all. Today, in the UK, all undergraduate chemical engineers receive some training in loss prevention though it is unlikely to cover situations such as that described.

3.9.6. **Other comments:** The accident, like most accidents, was not the fault of a single person. Many people shared responsibility: those who failed to remove the slip-plate, those who by-passed the furnace trip and then failed to make sure that it was repaired, the young manager, those responsible for his training and guidance, the maintenance foreman, the works manager. Any of these people, by doing their job better, could have prevented the incident. At the operating level, those concerned were following custom and practice, and the greater responsibility is therefore that of the factory manager and his senior colleagues who either failed to recognise the deficiencies in their procedures or failed to do anything about them. See the extract from the Robens Report, that led to the Health and Safety at Work Act and the setting up of HSE, in Appendix 4.

4. Issues Arising from Major Inquiries

4.1. There is an old story about two manufacturers of shoes who sent representatives to an African country to look into sales opportunities. One reported, “No business here. People don’t wear shoes”. The other said, “Great opportunities here. People don’t wear shoes”. Both representatives had the same data but their interpretations of it were different and told us more about them than about the opportunities for sales. Similarly, different accident investigators can draw different conclusions from the same evidence and propose different actions. The ten major opportunities summarised below are frequently missed, the first seven during the preparation of a report and the other three afterwards. Having paid the “tuition fee”, we should learn the lessons. Failures should be seen as educational experiences. The evidence is usually collected adequately; the weakness lies in its interpretation

4.2. Accident investigations often find only a single cause

4.2.1. Accident reports often identify only a single cause, though as in the accident described above, many people, from the designers, down to the last link in the chain, the mechanic who broke the wrong joint or the operator who closed the wrong valve, had an opportunity to prevent the accident. The single cause identified is usually this last link in the chain of events that led to the accident. Just as we are blind to all but one of the octaves in the electromagnetic spectrum so we are blind to many of the opportunities that we have to prevent an accident. But just as we have found ways of making the rest of the spectrum visible, so we need to make all the ways of preventing an accident visible.

4.3. Accident investigations are often superficial

4.3.1. Even when we find more than one cause**,** we often find only the immediate causes, as in the initial investigation of the accident described above. We should look beyond the immediate causes or triggering events for ways of avoiding the hazards, such as inherently safer design (such as, could less hazardous raw materials have been used?) and for weaknesses in the management system (such as, could more safety features have been included in the design or were the operators adequately trained and instructed?) If a mechanic opened up the wrong piece of equipment, could there have been a better system for identifying it? Were previous incidents overlooked because the results were, by good fortune, only trivial? The emphasis should shift from blaming the operator to removing opportunities for error or identifying weaknesses in the management systems or in the design.

4.3.2. When investigators are asked to look for underlying or root causes some of them simply call the causes they have found root causes. One report quoted corrosion as the root cause of equipment failure but it is an immediate cause. To find the true root causes we need to ask if corrosion was foreseen during design and if not, why not; if operating conditions were the same as those given to the designer and if not, why not; if regular examination for corrosion had been requested, and if so, if it had been carried out and the results acted upon, and so on. Senior managers should not accept accident reports that deal only with immediate causes.

4.3.3. The causes listed in accident reports are like Rorschach inkblots; they tell us more about the investigators’ beliefs and background than about the accidents. One company had recognized that failure to learn from past experience (see para 4.11.1) was a major cause of accidents and were making strenuous efforts to improve their learning from experience. However, none of their accident reports or the annual summary of them mentioned this as a cause. The members of the investigating panels did not know that similar accidents had happened before.

4.3.4. People close to the job naturally look for the immediate causes as they want to get the plant back on line. Outsiders on the investigating panel or the senior managers who review the report are better able to see the underlying causes. Also we can hardly expect investigators to tell their bosses that their actions could have prevented the accident (see part 5 of para 3.9.5).

4.4. Accident investigations list human error as a cause

4.4.1. Human error is far too vague a term to be useful. We should ask, "What sort of error?" because different sorts of error require different actions if we are going to prevent the errors happening again[1].

- Was the error a mistake, that is, one due to poor training or instructions, so that the intention was wrong? If so, we need to improve the training and instructions and, if possible, simplify the task. While instructions tell us what to do, training gives us the understanding that allows us to handle unforeseen situations. However many instructions we write, we will never foresee everything that might go wrong.

- Was the error due to a violation or non-compliance, that is, a deliberate decision not to follow instructions or recognized good practice? If so, we need to explain the reasons for them as we do not live in a society in which people will uncritically do what they are told. We should, if possible, simplify the task as if an incorrect method is easier than the correct one it is difficult to persuade everyone to use the correct method; we should check from time to time to see that instructions are being followed and never turn a blind eye. Many violations occur when people are trying to help: they think they have found a better way of doing the job.

- Was the task beyond the ability of the person asked to do it, perhaps beyond anyone's ability? If so, we need to redesign the task.

- Was it a slip or lapse of attention? In contrast to mistakes, the intention may have been correct but it was not fulfilled. It is no use telling people to be more careful as no one is deliberately careless. We should remove opportunities for error by changing the design or method of working.

4.4.2. Designers, supervisors and managers make errors of all these types though slips and lapses of attention by designers and managers are rare as they usually have time to check their work. Errors by designers produce traps into which operators fall, that is, they produce situations in which slips or lapses of attention, inevitable from time to time, result in accidents. Errors by managers are signposts pointing in the wrong directions.

4.5. Accident reports look for people to blame

4.5.1. In every walk of life, when things go wrong the default action of many people is to ask. “Who is to blame?” However, blaming human error for an accident diverts attention from what can be done by better design or better methods of operation. To quote

James Reason, “We cannot change the human conditions but we can change the conditions in which humans work.” Even when managers ask, “What did we do wrong?” they often find the wrong answer. They find that the instructions were perhaps not clear enough, rewrite them in greater detail and at greater length and thus reduce the probability that anyone will read them.

4.5.2. In recent years the tendency to blame operators has decreased in many industries but there is now a greater willingness to blame managers. The press and politicians argue that accidents occur because managers put costs and output before safety. The vast majority do not do so. Managers are not superhuman. Like everyone else they make errors because they lack knowledge, do not realise they could do more, cannot do everything at once and so on. These weaknesses extend to the highest levels.

4.5.3. No individuals were blamed in the company report on the accident described in Section 3.

4.6. Accident reports list causes that are difficult or impossible to remove

4.6.1. For example, a source of ignition is often listed as the cause of a fire or explosion. But it is impossible on the industrial scale to eliminate all sources of ignition with 100% certainty. While we try to remove as many as possible it is more important to prevent the formation of flammable mixtures.

4.6.2. Another unhelpful cause is to blame someone’s attitude. But we cannot measure attitude. All we can do is deduce it from people’s actions and if their actions are ineffective we should help them to act differently, by better training, instructions, persuasion etc, depending on the details of each case

4.6.3. Instead of listing causes we should list the actions needed to prevent a recurrence. This forces people to ask if and how each so-called cause can be prevented in future.

4.7. We may go too far

4.7.1. Sometimes after an accident people go too far and spend time and money on making sure that nothing similar could possibly happen again even though the probability is low. If the accident was a serious one it may be necessary to do this to re-assure employees and the public, but otherwise we should remember that if we gold-plate one unit there are fewer resources available to silver-plate the others.

4.7.2. UK law does not require everything possible to prevent an accident but only what is “reasonably practicable”. This legal phrase recognizes the impracticability of removing every hazard and implies that the size of a risk should be compared with the cost of removing or reducing it, in money, time and trouble. When there is a gross disproportion between them it is not necessary to remove or reduce the risk. In recent years HSE has provided detailed advice on the risks that are tolerable and the costs that are considered disproportionate[2]. In most other countries the law is more rigid and, in theory, expects companies to remove all risks. This, of course, is impossible but it makes companies reluctant to admit that there is a limit to what they, and society, can afford to spend even to save a life. If this sounds cold-blooded, remember that we are discussing very low probabilities of death where further expenditure will make the probability even lower but is very unlikely to actually prevent any death or even injury.

4.8. We change procedures rather than designs

4.8.1. There are several different actions we can take after we have identified a hazard as a result of an accident (or in some other way) to prevent it causing an another accident or to mitigate the consequences if it does: Our first choice, whenever "reasonably practicable", should be to remove the hazard by inherently safer design. For example, can we use a safer material instead of a toxic or flammable one? Even if we cannot change the existing plant we should note the change for possible use on the next plant.

4.8.2. If we cannot remove the hazard then our next choice should be to keep it under control by adding passive protective equipment, that is, equipment that does not have to be switched on or does not contain moving parts. The third choice is active protective equipment that is, equipment switched on automatically; unfortunately the equipment may be neglected and fail to work or it may be disarmed.

4.8.3. The fourth choice is reliance on actions by people, such as switching on protective equipment; unfortunately the person concerned may fail to act, for a number of reasons, such as forgetfulness, ignorance, distraction, poor instructions or, after an accident, because he or she has been injured.

4.8.4. Finally, we can use the techniques of behavioural science to improve the extent to which people follow procedures and accepted good practice. By listing this as the last resort I do not intend to diminish its value. Safety by design should always be our aim but is often impossible and experience shows that behavioural methods can bring about substantial improvement in the everyday types of accident that make up most of the lost-time and minor accident rates. However, the technique has little effect on process safety. Behavioural methods should not be used as an alternative to the improvement of plant design or methods of working when these are reasonably practicable.

See Appendix 3 for some simple examples.

4.9. We do not let others learn from our experience

4.9.1. Many companies restrict the circulation of incident reports, as they do not want everyone, even everyone in the company, to know that they have blundered but this will not prevent the incident happening again. We should circulate the essential messages widely, in the company and elsewhere, so that others can learn from them, for several reasons:

a) *Moral:* if we have information that might prevent another accident we have a duty to pass it on.

b) *Pragmatic:* if we tell other organizations about our accidents they may tell us about theirs.

c) *Economic:* we would like our competitors to spend as much as we do on safety.

d) *The industry is one: every accident effects its reputation*. To misquote the well-known words of John Donne,

"No plant is an Island, entire of itself; every plant is a piece of the Continent, a part of the main. Any plant's loss diminishes us, because we

are involved in the Industry: and therefore never send to know for whom the Inquiry sitteth; it sitteth for thee."

4.9.2. Even when accident reports are published they often contain so much inessential detail that they lack impact. As they are intended for busy people the main messages should be apparent at a glance. Otherwise the reports will be put aside to be read later and we know what that means.

4.9.3. When information is published people do not always learn from it. A belief that "Our problems are different" is a common failing. The accident described in Section 3 was described in a published paper and later in a Chapter of a book

4.10. We read or receive only overviews

4.10.1. This opportunity is one missed by many senior people. Lacking the time to read accident reports in detail they consume pre-digested summaries of them, full of generalisations such as, "There has been an increase in accidents due to inadequate training". They describe this as taking a helicopter view. However, from a helicopter we see only forests. To understand the causes of accidents we need to land the helicopter and look at individual trees or even twigs and leaves. As already mentioned, the identification of underlying causes can be very subjective and is influenced by people's experience, interests, blind spots and prejudices. Senior people should read a number of accident reports regularly to see if they agree with the assignment of underlying causes.

4.11. We forget the lessons learned and allow the accident to happen again

4.11.1. Even when we prepare a good report and circulate it widely, all too often it is read, filed and forgotten. Organizations have no memory[3]. Only people have memories and after a few years they move on taking their memories with them. Procedures introduced after an accident are allowed to lapse and ten years later the accident happens again, even on the plant where it happened before. If by good fortune the results of an accident are not serious, the lessons are forgotten even more quickly.

4.11.2. Appendix 5 describes some actions that can prevent accidents occurring again and thus negate the whole investigation process. Unless we take actions such as these nothing will happen except a repetition of the accident. The main purpose of an accident investigation is to prevent it happening again. If it is allowed to happen the investigation was a waste of time. We should remind people that "It is the success of engineering which holds back the growth of engineering knowledge, and its failures which provide the seeds for its future development"[4].

4.11.3. Because the accident described in Section 3 was selected for discussion as part of a training programme it was remembered for a number of years. I doubt if it is now that the factory has been sold to another company.

Appendix 1 – Recommendations made to prevent slip-plates being left in position after maintenance

- All slip-plates should be listed on a permit-to-work. It is not sufficient to say "Slip-plate (or de-slip-plate) all branches on reflux drum". Instead their positions should be listed and identified by numbered tags. "All" is a word that should be avoided when writing instructions on safety matters
- When a maintenance job is complete the process foreman, before accepting back the permit-to-work, should check that the job done is the job he wanted done and that all parts of it have been completed.
- In addition, all slip-plates inserted during a shut-down should be entered on a master list and a final inspection made, using this list, before start-up.
- If the slip-plate had been inserted below the isolation valve it would have been possible to remove it with the plant on-line. Nevertheless we should continue to insert slip-plates on the vessel side of isolation valves as if they are fitted on the far side liquid might be trapped between the slip-plate and a closed valve and then slowly evaporate while people were working in the vessel. Such incidents have occurred.

Appendix 2 – Recommendations made to prevent plants opening when unknown protective equipment is not operable

- Protective equipment should not be by-passed or isolated unless this has been authorised in writing by a responsible person.
- If it is by-passed or isolated this should be signalled to the operators in some way, for example by a light on the panel. A note in the shift log is not enough.
- All trips should be tested after a major turnaround and all trips that have been repaired or overhauled should be tested before they are put back into service
- The ground should have been sloped so that any liquid spillage flowed away from the furnace. In general, spillages should flow away from equipment, not towards it.

Appendix 3 – Avoiding hazards is better then keeping them under control

Consider a simple but common cause of injury and even death, particularly in the home: falls on the stairs:

The inherently safer solution is to avoid the use of stairs by building a single story building or using ramps instead of stairs.

If that is not reasonably practicable a passive solution is to install intermediate landings so that people cannot fall very far or to avoid types of stair, such as spiral staircases, which make falls more likely. An active solution is to install a lift. Like most active solutions it is expensive and involves complex equipment that is liable to fail, expensive to maintain and easy to neglect.

The procedural solution is to instruct people to always use the handrails, never to run on the stairs, to keep then free from junk and so on. This can be backed up by behavioural techniques: specially trained fellow workers (or parents in the home) look out for people who behave unsafely and tactfully draw their attention to the action.

Similarly, if someone has fallen into a hole in the road, as well as asking why it wasn't fenced or why someone removed the fence or if the lighting should be improved, we should ask if there is a reasonably practicable alternative to digging holes in the road. Could we drill a route for pipes or cables under the road or install culverts for future use when roads are laid out? Must we run pipes and cables under the road instead of overground?

In some companies the default action after an accident is to start at the wrong end of the list of alternatives and recommend a change in procedures or better observation of procedures, often without asking why the procedures were not followed. Were they, for example, too complex or unclear or have supervisors and managers turned a blind eye in the past? Changing procedures is, of course, usually quicker, cheaper and easier than changing the design, but it is less effective.

Today designers often consider inherently safer options but the authors of incident reports do so less often. Perhaps it goes against the widely accepted belief that accidents are someone's fault and the job of the investigation is to find out who it was. Having identified the culprit we are less likely to blame him or her than in the past; we realize that he or she may not have been adequately trained or instructed, and that everyone makes occasional slips, but nevertheless his or her action or inaction caused the incident. In some companies they blame a piece of equipment. It is hard for some people to accept that the incident is the result of a widespread practice in design and operations.

Operators provide the last line of defence against errors by designers and managers. It is a bad strategy to rely on the last line of defence and neglect the outer ones. Good loss prevention starts far from the top event, in the early stages of design. Blaming users is a camouflage for poor design.

Appendix 4 – An Extract from the Robens Report*, Health and Safety at Work: Report of the Committee 1970-1972*, HMSO, 1972, paragraph 261.

> "The fact is - and we believe this to be widely recognised - the traditional concepts of the criminal law are not readily applicable to the majority of infringements which arise under this type of legislation. Relatively few offences are clear cut, few arise from reckless indifference to the possibility of causing injury, few can be laid without qualification at the door of a single individual. The typical infringement or combination of infringements arises rather through carelessness, oversight, lack of knowledge or means, inadequate supervision, or sheer inefficiency. In such circumstances the process of prosecution and punishment by the criminal courts is largely an irrelevancy. The real need is for a constructive means of ensuring that practical improvements are made and preventative measures adopted."

Appendix 5 – Some actions that can prevent accidents occurring again.

- Include in every instruction, code and standard a note on the reasons for it and accounts of accidents that would not have occurred if the instruction etc had existed at the time and had been followed. Once we forget the origins of our practices they become "cut flowers"; severed from their roots they wither and die.

- Never remove equipment before we know why it was installed. Never abandon a procedure before we know why it was adopted.

- Describe old accidents as well as recent ones, other companies' accidents as well as our own, in safety bulletins and discuss them at safety meetings.

- Follow up at regular intervals to see that the recommendations made after accidents are being followed, in design as well as operations.
- Remember that the first step down the road to an accident occurs when someone turns a blind eye to a missing blind.
- Include important accidents of the past in the training of undergraduates and company employees.
- Keep a folder of old accident reports in every control room. It should be compulsory reading for recruits and others should look through it from time to time.
- Read more books, which tell us what is old, as well as magazines that tell us what is new.
- We cannot stop downsizing but we should make sure that the remaining employees at all levels have adequate knowledge and experience.
- Devise better retrieval systems so that we can find, more easily than at present, details of past accidents, in our own and other companies, and the recommendations made afterwards. We need systems in which the computer will automatically draw our attention to information that is relevant to what we are typing or reading.

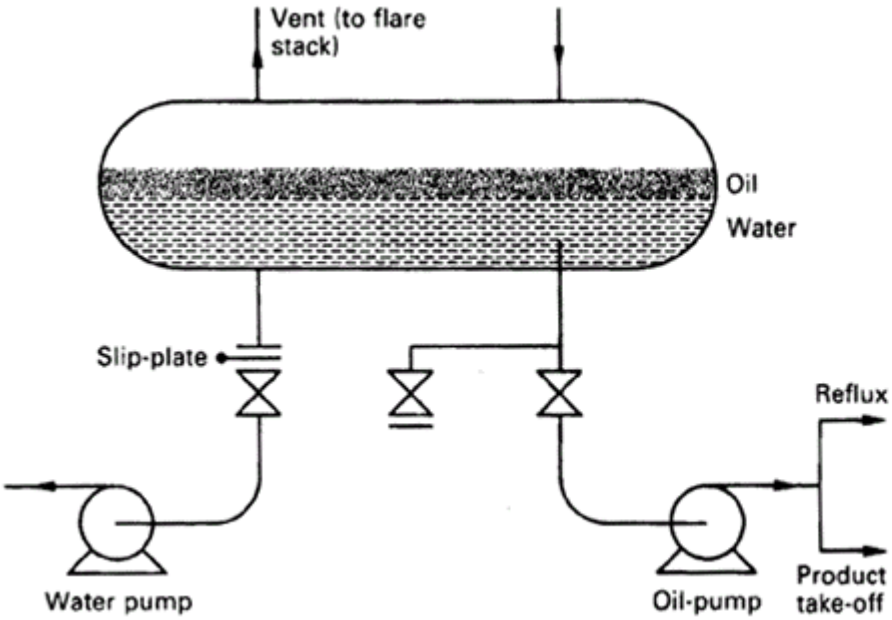

Figure 1 The reflux drum showing the position of the slip-plate which should have been removed before start-up. The vessel is further above the slip-plate than shown so that the pressure at the slip-plate was about 0.7 barg (10 psig) higher than in the reflux drum.

Event **Recommendations for Prevention/Mitigation**

Fire (by good fortune did not occur)
|
Furnace failed to trip
|
|----------------------------------Do not disarm trips without authority.
| Signal if disarmed.
| Test after repair and after turnarounds.
Spread of oil towards furnace
|
|----------------------------------*Slope ground so that spillages flow other way.*
|
Oil leak
|
|----------------------------------*Add water to reflux drum to keep level steady*
| *or freeze the pipeline.*
|
Decision to remove slip-plate
while water runs out
|
|----------------------------------*Do not rush decisions.*
| *Try to think of alternatives, e.g. freezing line.*
| **Provide better training for young managers.**
Slip-plate left in
|
|----------------------------------Better control of slip-plating procedures.
|
Decision to "push new managers in at deep end"
|
|----------------------------------**Good for the managers but not for the plant.**

General recommendations: Audit management procedures and rectify weaknesses.
Establish a climate in which more attention is given to safety.

Ordinary type 1st layer: Immediate technical recommendations

Italics *2nd layer: Avoiding the hazard*

Bold type **3rd layer: Improving the management system**

Figure 2 Summary of events leading to accident and actions that could have prevented it

References

1. Kletz, T.A., An Engineer's View of Human Error, 3rd edition, (Institution of Chemical Engineers, Rugby UK and Taylor & Francis, New York), 2001.

2. Health and Safety Executive, Reducing Risks, Protecting People – HSE's Decision Making Process, (HSE Books, Sudbury, UK), 2001.

3. Kletz, T.A., Lessons from Disaster - How Organisations have No Memory and Accidents Recur, (Institution of Chemical Engineers, Rugby UK and Gulf, Houston, TX), 1993.

4. Blockley, D.I. and Henderson, J.R., Proceedings of the Institution of Civil Engineers, Part 1, 68:719, 1980.

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Construction Industry – Norman Haste FREng

1. The Organisation of the Industry

1.1. The UK Construction Industry has the worst accident record of all industries considered in this study. The industry is fragmented in its organisation with thousands of companies involved and over 90% employing less than six people. The work ranges from the design and construction of major engineering projects, such as bridges, power stations, etc. to the simple house extension. Despite this fragmentation the industry contributes significantly to the UK GDP and when material suppliers are included with Architects, Structural Designers and Contractors, then it becomes easy to see the wealth created by the Industry.

1.2. The Industry has moved from the dark days of "lump labour" to labour agencies which, while more respectable, differs little in the context of Health & Safety management. The poor accident record in construction has, and continues to be, the subject of new legislation and new advice from those bodies concerned with Health & Safety at Work. The legislation governing the management of Healthy & Safety in the construction industry is the Health & Safety at Work Act, which is administered by the Health & Safety Executive (HSE). The HSE works hard at helping Industry to improve its performance through advice on training, reporting statistics and through the punitive measures of fines.

1.3. There are now moves to prosecute directors of companies individually for breaches of good health and safety management by their companies. The use of fines to achieve improvement is questionable. It was reported on 9th January 2004 that Cleveland Bridge & Engineering had been fined £15,000 for an incident which occurred in March 2002 when a large piece of steelwork was dropped 70m because of unsatisfactory lifting eyes attached to the steelwork. Given the time it has taken to come to court and the size of the fine, it would seem that the cost of making the prosecution would have been considerably more than the financial hardship suffered by Cleveland Bridge.

2. The Process for Reporting Accidents

2.1. Like all companies in any Industry there is a requirement in the construction industry for over 3 days lost time injuries to be reported to the Health & Safety Executive. Accidents ratios are used for monitoring Health and Safety performance on the basis of the number of reportable accidents (3 days lost or more) per 100,000 man hours. This ratio is called the AFR or Accident Frequency Ratio. This ratio is not reported across the industry but each company is encouraged to use it and kit is the major players who do so with greatest accuracy. The national monitor is based on the number of accidents per 1000 employees. The fragmented nature of the industry is such that the system is open to abuse by some people using a lost time accident of 3 days or more as a means of seeking compensation, although cases of this are not frequent.

2.2. Accident reporting in the construction industry is routine but when there is major incident or fatality involved then apart from recording the occurrence the process of finding the cause of the accident or incident becomes long and drawn out.

2.3. The Aviation Industry has its Air Accident Investigation Branch and now the Rail Industry has a similar body which is able to get to the root cause of an accident quickly and therefore enables others to learn from the mistakes of its neighbour(s).

2.4. Fatalities and major incidents in the construction Industry are investigated by the Health and Safety Executive. The HSE has the powers to stop operations through the imposition of a Prohibition Notice which enables an investigation to be carried out before work can resume. This should assist the investigation by leaving the site of the accident undisturbed and should also help in finding the cause quickly. There is however, an underlying fear of culpability on the part of individuals and companies alike which can make it difficult for the cause of an accident to be found quickly and for legal reasons the cause is often not communicated to bodies who would wish to learn from it.

2.5. It is often the case that the real cause of a major accident or incident is not fully known until the case comes to court which can be several years after the incident occurred. The HSE often pursues prosecution of companies as the major priority and this fear of culpability causes companies and individuals to resist questioning even if it is designed to enable others to learn, thereby avoiding a similar accident occurring.

3. Examples of the Reporting Process and its Shortcomings

3.1. The following three examples illustrate the shortcomings of the reporting process in terms of preventing rapid dissemination of the cause of an accident or incident.

3.2. Severn Bridge Gantry Failure 1990

3.2.1. The accident resulted in four men losing their life. The HSE imposed a Prohibition Notice on the use of all other gantries on the Severn Bridge pending the outcome of the Investigation. There were nine companies involved in the design, construction or operation of the failed gantry. The HSE attempted to prosecute all nine companies. The fear of culpability resulted in none of the companies speaking to each other and the investigation to find the root cause was thus hampered. The cases against the nine companies came to court two years later and the judge threw out the case against each company one by one. The sad thing was that the root cause of the accident was not known early after the accident and the lack of wide communication of the causes of failure prevented real learning so that a similar occurrence could be avoided in the future.

3.3. Avonmouth Bridge Gantry failure 1998

3.3.1. As was the case with the earlier Severn Bridge gantry failure, this albeit temporary gantry was being moved just before the accident occurred. Again fatalities were involved and although there was a successful prosecution by HSE the real shame was that the lessons learnt from the Severn Bridge incident eight years earlier were not taken on board.

3.4. Heathrow Express Tunnel Collapse 1994

3.4.1. During the driving of the tunnels at Heathrow Airport using the Sprayed Concrete Lining method of ground support, there was a serious ground movement which caused collapse. There were no fatalities but the incident was so grave that the centre of the Airport suffered major subsidence and had to be closed for several days whilst emergency measures were put in place.

3.4.2. At the same time as the Heathrow Tunnels were being constructed the Jubilee Line Extension in Central London was also under construction using the same method, i.e. sprayed concrete lining (SCL). There followed a detailed investigation of the Heathrow incident during which work on the Jubilee Line was suspended for 6 months. The HSE brought a case to court arising out of the Heathrow experience and a final report on the incident was published in 2000, some 6 years after the incident had occurred.

3.5. These examples indicate how much better it would have been if the investigation to establish their causes could have been carried out quickly within a legal framework but outside the area where prosecutions may ensue.

4. Proposals for the Future Investigation of Accidents in the Construction Industry

4.1. The diversity and scale of the industry is such that the ability to learn from accidents is dependent on the quality of communication arising out of a rapid investigation to establish the root cause of the accident. Also because of the diversity of the industry the skills and responses needed would make it difficult and costly to set up an Accident Investigation Branch along the lines of that which is established for Air accidents or Rail accidents.

4.2. There is however, a strong case for commissioning consulting engineers under a chairman who would report directly to the Deputy Prime Minister or a Secretary of State, to carry out an investigation into the causes of an accident for the specific purpose of passing on the learning to the relevant parts of the industry. The objective would be to produce a report within just a few weeks. The parties involved in the accident would be required by law to respond to the investigation and answer the questions posed by the Investigating Engineer. The report would establish cause and would not seek to blame any party. The report could and would be used by the Health & Safety Executive in any further investigation which may lead to prosecution of one or more parties. The Investigating Engineer would have to work closely with the police where a fatality was concerned and where the possibility of a criminal act may exist.

4.3. Experience has shown that there are real benefits to be gained from a more rapid and accurate reporting of the causes of an accident or incident. Communication would best be achieved through circulation of the report direct to companies involved in the field in which the accident occurred. It would not be difficult given today's technology to establish who those companies are.

4.4. Organisations do exist to share information on a confidential basis. The Institutions of Civil and Structural Engineers jointly support the Standing Committee On Structural Safety (SCOSS) As well as sharing information within industry SCOSS advises Government particularly on the safety of buildings. The Institution of Structural Engineers has also developed guidelines for the inspection and structural integrity of Bridge maintenance gantries following the Severn Bridge accident in 1990.

4.5. The Health & Safety Executive would expect companies to strive for the designing out of potential hazards within a risk management philosophy. Most companies would support this approach but it should be remembered that the construction Industry is "dynamic" in the sense that nothing looks the same tomorrow as it does today or did yesterday. Residual risks, therefore, have to be managed by procedure which involved human intervention. The learning from accidents needs to be transposed into training for the future and the communication of causes of accidents must be timely which can only be achieved through rapid investigation.

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Nuclear – Sir Robert Hill FREng

Introduction

1. Nuclear accidents arising from the operation and decommissioning of civil nuclear power plants are very rare and the number of deaths (both known and estimated) is very small. However, such are the potential economic consequences of a nuclear accident that exceptional measures are taken to prevent them.

2. An important method employed to reduce the likelihood of a nuclear accident is the detailed investigation of much lesser events and incidents. Understanding the root causes of these and learning from the associated corrective actions is important to the development of a strong safety culture. Accordingly, such investigations form an important part of work in the nuclear field.

Aim

3. The aim of this paper is to describe the processes and procedures used for the investigation of accidents and incidents in the operation and decommissioning of civil nuclear power plants in the UK as a contribution the Royal Academy of Engineering study of the various approaches taken by different industries.

Scope

4. The paper is primarily concerned with nuclear power plants and the processes of investigation and their consequences. However, because this can overlap with the arrangements covering any possible nuclear emergency, the paper also outlines the detailed planning and exercising of responses to nuclear accidents. [1, 2, 3]

5. The paper does not cover the following: the medical use of radioactive isotopes; uranium mining, extraction and enrichment; nuclear chemical plant; nuclear weapon fabrication; the manufacture of reactor cores for nuclear powered submarines; the manufacture of fuel for civil nuclear power plants; the collection and storage of radioactive waste (other than when located at civil nuclear power plants); the transport of radioactive materials; and the operation of submarine nuclear power plants

Government Departments

6. The lead government departments are the DTI (England and Wales) and the Scottish Office (Scotland). Under certain circumstances the Department of Transport or the Department of the Environment, Food & Rural Affairs (DEFRA) may also be involved. The regulator is the Nuclear Installations Inspectorate (NII) of the Nuclear Safety Department (NSD) of the Health & Safety Executive (HSE).

[1] Arrangements for responding to nuclear emergencies.
1994, HSE books ISBN 0 7176 0828 X

[2] Civil nuclear emergency planning; consolidated guidance. Prepared by the Nuclear Emergency Planning Liaison Group. "The Blue Book". Department of Trade and Industry.

[3] Dealing with disaster. Revised Third Edition. Cabinet Office. ISBN 1-874447-42-X

The Nature of the Nuclear Hazard

7. The nuclear hazard exists because ionising radiation damages living cells. Only in the case of very large exposure to radiation will it cause death within days or weeks. Otherwise, cell damage due to ionising radiation, if the damaged cells are not eliminated by the body's defence mechanism, may result in cancer[4]. Effects may also occur in the descendants of the exposed individual, although there is little evidence for this in practice. As a benchmark, the typical early effect of a single exposure of 200 millisieverts (mSv) is detectable chromosome changes in blood cells. Table 1 below gives examples of typical kinds of exposure in daily life [5]:

Dose (mSv)	
About 20	Annual doses received by individuals from radon in certain areas of the UK [6]
5 - 15	Annual doses received by some maintenance workers in the nuclear industry
2	Typical x-ray examination of the lumbar spine
2	Average annual dose from the natural background
1	Average annual dose received by nuclear workers as a consequence of their work
0.1	25 hours in a jet aircraft at cruising height
0.05	Chest x-ray (single exposure)
0.001	Annual dose (averaged over whole population) from radioactive wastes

Table 1 Typical exposures in daily life (millisieverts)

8. The process of nuclear fission gives rise to fission products which are highly radioactive, some of which have very long half-lives. The reactor is designed to retain the hazardous fission products within the fuel can and there are two further barriers that prevent the release of fission products should the fuel can fail (e.g. due to overheating), namely the reactor pressure vessel and primary coolant loop and, in most cases, the containment building. Nuclear safety is thus provided by ensuring the integrity of the fuel can and these further barriers.

[4] "That a cancer could be induced by very low doses (less than 10mSv) is a possibility that cannot be discounted, but all the available biological data indicate that at very low doses the combination of the failure to repair the DNA damage leading to cell death (apoptosis) and error-free DNA repair should make this risk minimal or non-existent." André Auengo et al. 30 March 2005. *Dose-effect Relationships and Estimation of the carcinogenic Effects of Low Doses of Ionising Radiation, para 6.3.7*. Académie des Sciences - Académie Nationale de Médecine, France.

[5] The tolerability of risk from nuclear power stations. 1988 revised 1992, HSE books ISBN 0 11 886368 1

[6] "It is important to note that the rates of cancer in most populations exposed to low-level radiation have not been found to be detectably increased, and that in most cases the rates appear to have decreased" - *Evaluation of the Linear-Nonthreshold Dose-Response Model for Ionising Radiation*. (Report 136, National Council on Radiation Protection and Measurements, Bethseda, MD, 2001, in Chaplin et al, *Nuclear Power Plants and Their Fuel as Terrorist Targets*, SCIENCE Vol 297 20 September 2002. http://www.sciencemagazine.com

9. The design, manufacture and operation of nuclear power plants is highly regulated, such that for a member of the public the additional risk of a fatal cancer due to normal operation **plus** that conceivably due to a nuclear accident is very low indeed.

10. Thus a nuclear accident has the following characteristics:

   a. The hazard is radioactivity. Injury or death due to conventional causes such as fire, fall, collision, etc may also occur concurrently and their treatment may be complicated by the circumstances, but they are not categorized as nuclear injuries.

   b. Except in the most extreme cases, the consequences would be a small number of additional cases of cancer, later in life.

   c. The accident may be expected to develop gradually, following some malfunction and further errors or events.

   d. It generates exceptionally high level of public concern over wide area in the vicinity. Individual stress a major factor, possibly with physical symptoms. (See Annex C - Three Mile Island).

   e. It generates exceptionally high level of media interest, at home and abroad and exceptionally high level of political interest and involvement.

   f. The consequences, in terms of the spread and activity levels of radioactive material, are readily measurable.

The INES Scale [7, 8, 9]

11. In order that the scale of an event may be better understood, particularly by people outside the industry, the International Atomic Energy Agency and the Nuclear Energy Agency of OECD have drawn up the International Nuclear Event Scale (INES) which has been adopted by 48 countries, including the UK. The scale ranges from INES 0, described as having no safety significance, to INES 7 - a major accident involving a major release of radioactivity causing acute health and long term environment effects. (e.g. Chernobyl). The scale, dating from the early 1990s, is described more fully in Annex A.

12. Nuclear operators have procedures that require the investigation of untoward events well below even INES level 0. Also, regulatory authorities, notably the NII and the Environment Agency (EA) (SEPA in Scotland), require certain types of events to be reported to them by licensees and also themselves conduct investigations into events.

Every Incident a Learning Opportunity

13. As is typical throughout the nuclear industry, the UKAEA uses the Bird Triangle to emphasise the importance of reporting, investigating and correcting the causes of even minor events. A UKAEA Bulletin[10], describing their new (2003) management of an unusual occurrence system (UNOR), states that research carried out by Frank E Bird who investigated 2,000,000 accidents showed that for every event leading to major injury there can be as many as 10 causing minor injury, 30 causing property damage

[7] http://www.ukaea.org.uk/dounreay/pdf/ines.pdf
[8] http://www.british-energy.co.uk/pagetemplate.php?pid=130
[9] http://www.iaea.or.at/ns/nusafe/images/ines.gif
[10] http://www.ukaea.org.uk/contract_org/index.htm

and hundreds that resulted in neither injury or damage. This is usually illustrated by Bird's triangle.

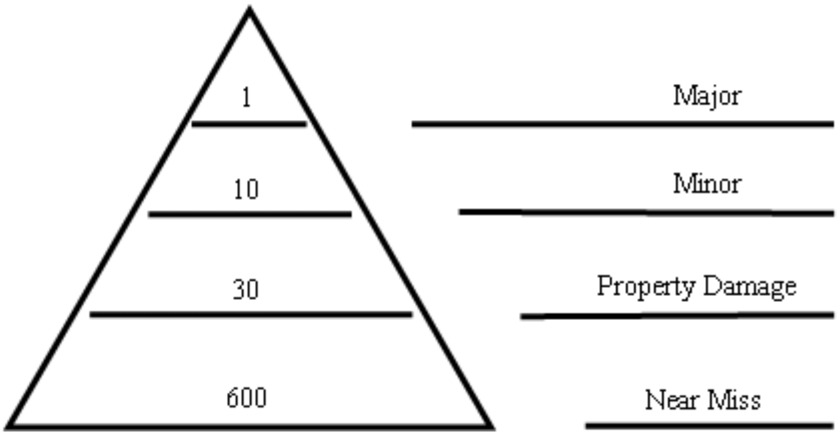

Figure 1 Bird's triangle

14. In principle, Bird's triangle can be extended downwards to encompass lesser events and occurrences in ever larger numbers. The nuclear industry is therefore assiduous in investigating relatively minor untoward occurrences with a view to taking corrective action and preventing more serious incidents and accidents. The level of the investigation generally reflects the seriousness of the event, unless an adverse trend indicates the need for more senior and thorough investigation than would otherwise be adopted.

15. British Energy Generation instructions for reporting, classifying, investigating and correcting events and incidents (described as "adverse conditions") at its Advanced Gas Cooled Reactor (AGR) and Sizewell B Pressurised Water Reactor (PWR) sites[11] form part of a single corrective action programme (CAP) dealing with all such events, from minor suggestions for improvement through to significant events affecting plant safety and output.

16. Condition Reports (CR) are assigned one of 3 priorities. Priority 1 CRs are subject to Significant Adverse Condition Investigations by an investigator or investigation team whose composition and degree of independence from the site Licence holder reflects the seriousness of the CR. The process involves comprehensive root cause analysis. Lesser CRs are subject to Adverse Condition Analysis, conducted on the same principles but without such detailed, formal root cause analysis; while the third category comprises CRs suggesting material or process improvements.

17. British Nuclear Fuels plc, the parent company of Magnox Electric Ltd which owns the Magnox gas cooled reactors, has equivalent instructions[12]. The principles of its Event Reporting, Recording, Investigation and Learning system are:

- Abnormal events shall be promptly reported as required and graded according to their severity and impact in accordance with local regulatory requirements.

[11] Implementing Effective Operating Experience (OPEX) Programme. May 2004. Integrated Company Practice BE.G./ICP/OPSV/OPEX/001; Implementing An Effective Corrective Action Programme (CAP). February 2005. Integrated Company Practice BE.G./ICP/OPSV/CAP/001; Conduct of Significant Adverse Conditions Investigations (SACI). June 2004. Company Specification BE.G./SPEC/OPSV/CAP/002; Conduct of Adverse Conditions Investigations (ACIN). May 2004. Company Specification BE.G./SPEC/OPSV/CAP/003.

[12] Event recording, reporting & investigation. BNFL Group. EH&S Manual.

- Abnormal events shall be investigated and root causes identified to a level consistent with the agreed grading.

- Corrective or preventive actions shall, where appropriate, be tracked to completion and periodically reviewed.

- The learning and improvement opportunities from events shall be openly communicated wherever possible within the company and where appropriate to other organisations.

- In investigating and responding to events, the opportunity will be taken to review how others have dealt with similar issues and maximum use will be made of their experience and solutions.

18. As well as the results and recommendations of an event report being reported and acted upon within the company, a report will, according to severity, be made to the UK nuclear plant event reporting system (NUPER) and by them, if appropriate, to the World Association of Nuclear Operators (WANO) who judges those that might be valuable for other operators to learn about and issues notices accordingly. Equally, reports from other companies are studied assiduously as they come in, since this greatly expands the database of experience.

19. Throughout the nuclear industry, the importance of open reporting is stressed, in order that low significance untoward events are exposed and lessons may be learnt which help to prevent similar and worse occurrences in future. To have a large number of low level events being reported and investigated is viewed as a good thing and not to be discouraged. By such means the number of INES Level 2 events, and worse, are kept very low.

20. The aim is create a virtuous circle of operating experience - benchmarking - corrective actions - self assessment, illustrated in this British Energy graphic:

21. Should an organisation ever become complacent, it would risk experiencing a failure of its safety culture and systems. Should this happen, then even if there had been no significant accident or event, this decline in safety culture would result in action by the regulator as addressed in the next section.

Investigations by the Regulators

22. Just as the licensees have their procedures for incident investigation so, too, the Nuclear Safety Directorate (NSD) of HSE has procedures for investigating incidents,

progressing and reviewing a prosecution case and for the conduct of investigations.[13] In the event of death or serious injury, the police become involved and a protocol exists for liaison between investigating authorities.[14]

23. Key to the process is the work of the NSD Site Inspector. NSD Inspectors are authorised by virtue of their warrant under the HSW Act s20(2)(d) to make "such examination and investigations as may in any circumstances be necessary ……. ". Part of the decision-making process relating to investigations is conditioned by NSD confidence in the licensee's arrangements for classifying, reporting, investigating and remedying the causes of incidents in the first place. The decision whether or not to carry out an investigation will also be influenced by whether the licensee is carrying out its own investigations and follow up actions with due seriousness and urgency. Thus the factors taken into account are:

- Whether significant actual harm or injury has occurred
- Whether there was clear potential for harm or injury
- Whether the INES rating is greater than Level 1
- The licensee's track record
- The licensee's response
- The level of public/media or other interest
- The implications for other licensees
- Whether there is a serious breach of HSWA/relevant statutory provisions.

24. The regulator shares with the licensee the motivation to ensure that lessons are learnt which will avoid the recurrence of the same or similar events. In the case of the regulator, the NSD Inspector bears in mind the possible need for enforcement or prosecution and takes appropriate action when collecting and recording evidence.

25. In the first instance, however, the NSD Inspector, in consultation with the relevant Superintending Inspector, decides whether the incident meets the HSE Major Incident criteria. If the 3-person HS Executive so classify the incident, matters proceed in accordance with that procedure.[15] A Major Incident (NB. not particular to the nuclear industry) is defined as:

> " ……*a significant event which demands a response beyond the routine. Significance is determined by the severity of the incident, the degree of public concern and the nature and extent of HSE's previous involvement with the duty holders; though the nature and extent of previous involvement would not alone trigger a major incident investigation."*

[13] Investigations, Progress and Review of Prosecution Cases. 2003. Nuclear Safety Directorate INS/012 Issue 002. Technical Inspection Guide: Investigations. 2003. Nuclear Safety Directorate TINS/052 Issue 001

[14] Work-related deaths: a protocol for liaison. http://www.hse.gov.uk/enforce/index.htm

[15] Document G - Major incident response and investigation policy and procedures. Issue No. 5. April 2001. http://www.hse.gov.uk/enforce/index.htm

26. Given the nature of the nuclear hazard, INES Level 4 and above would certainly be treated as a Major Incident and Level 3 might be so treated, depending on the circumstances.

Investigation of a Nuclear Accident

27. In the event of a nuclear accident being so classified, the HSE Major Incident Group would be activated, under which an Investigation and Prior Role Inquiry Board is formed. This comprises HSE Senior Staff and is supported by external members. Board members responsible for the Prior Role Inquiry Team are drawn from outside the Directorate responsible for the duty holder (in this case the nuclear licensee). Under the direction of the Board, two teams are formed:

    a. An Investigation Team.

    b. An Inquiry Team.

The Investigating Team

28. The Investigation Team is formed under an investigation manager with no operational responsibility for the site. Members would be drawn from HSE/NII inspectors, an inspector from a different division, the technology division, the health and safety laboratory, and from external consultants.

29. The investigation covers technical causes, organizational causes and legal considerations. The outputs from the investigation are:

    a. A report, with industry wide lessons for improvement of safety.

    b. Possible enforcement action.

    c. Review by the HS Commission.

The Inquiry Team

30. The Inquiry Team is formed from HSE staff from outside the directorate responsible for the duty holder (i.e. from outside the NSD). The purpose of the inquiry is to establish the effectiveness of HSE's regulatory and operational practices relevant to the incident.

31. The outputs of the inquiry are:

    a. A report, made available to the public.

    b. Action by the HS Executive to deal with any deficiencies identified.

    c. Review by the HS Commission.

32. Throughout the investigation and inquiry, the Commission and the Executive oversee the process to ensure that:

    a. There will be rigour in exposing failings, by duty holder or by HSE.

    b. Ministers can be advised.

    c. Action is taken on emerging findings and lessons learnt.

    d. Decisions can be taken on the timing of information release to the public.

Other Investigations

33. Given the huge public concern inevitably generated by a nuclear accident it is highly likely that Government would see the need for some higher level investigation or inquiry. In the case of Three Mile Island, for instance, as described in Annex C, the President of the USA found it necessary to order a Commission on the accident - the Kemeny Commission.

34. Furthermore, as well as investigation and inquiry activities covering the causes of the accident and HSE's regulatory and operational involvement, there will need to be investigations into the handling of the accident and the emergency response. It is not clear whether this investigation will fall to HSE or some other authority.

35. In the case of a nuclear accident, the matter of a higher level inquiry has been addressed by the DTI and various alternatives considered, namely:

a. Statutory Inquiries under the HSW Act 1974 (amended); or the Nuclear Installations Act 1965; or Acts relating to Public Health and Environment; or under Local Acts (numerous and various).

b. Non-Statutory Inquiries; typically ordered by Ministers without specific statutory authority.

c. Inquests. Available only in the event of death and limited in scope.

d. Tribunals of Enquiry. These are set up under the Tribunals of Enquiry (Evidence) Act 1921 by resolution of both Houses of Parliament to enquire into a matter of urgent public importance.

36. A "1921 Act Enquiry" is probably the most likely form that a public enquiry would take after a nuclear accident. However, this has not been pre-determined and nothing is allowed to be done that would commit the DTI in advance in any way on a matter which would be for decision by the Secretary of State.

Response and Investigation Overlap

37. Given the likely duration of a nuclear accident, it is probable that investigations and inquiries by the operator and by the HSE/C will be established and commence their work even as the Emergency Response is in progress. Quite apart from the need for investigations to commence before the trail goes cold and information is lost, the technical and operating causes of the accident will need to be established as part of the process of determining its likely course. Furthermore, early identification of cause is essential for determining whether action is needed to safeguard plants of similar design or vintage.

Emergency Response

38. Although not the main subject of this report, for completeness the response to a nuclear emergency is outlined in Annex B. From this account it will be noted that:

a. A large number of national and local authorities are involved.

b. Detailed plans exist for responding to a nuclear emergency.

c. Responsibilities are clearly defined.

d. Plans are regularly exercised.

Example of a Nuclear Accident

Three Mile Island, USA - 1979 [16, 17, 18, 19, 20]

39. The accident began at about 4:00 a.m. on 28 March 1979 and extended over some 3 days. It is described in Annex C which concludes:

a. Every aspect of the TMI accident has been exhaustively analysed with a view to learning its lessons and avoiding a repetition of anything similar.

b. Resulting from the event, the most significant realisation was that however good the technology and the physical and engineered safety features, it is human performance that has the most significant effect on safety. This is the message that was picked up by INPO whose mission and methods have been devoted to discovering and prescribing error prevention tools.

c. The importance of Operational Experience Feedback (OEF), conservative decision taking, pre-job briefing, peer review, the identification and rectification of plant defects, adherence to well devised written procedures, and clear accountability for nuclear safety are continually stressed among a range of other INPO principles.

d. INPO has been hugely successful in improving the safety performance of US power plants and along with improved safety performance has come lower (not greater) operating costs. INPO's methods have been exported to the UK and other nations through WANO. This stands as the single greatest benefit to arise from the accident.

e. The accident at Three Mile Island caused very little if any effect on health, other than through stress, but nevertheless it is identified throughout the world as an example of the hazards of nuclear power generation

f. Some commentators explain this by attributing people's worries to the association with atomic bombs coupled to fear of radiation as an invisible hazard. However, a main contributor to the damage to public confidence was done by the poor emergency response, described in the Kemeny Report as

"….. dominated by an atmosphere of almost total confusion. There was lack of communication at all levels. Many key recommendations were made by individuals who were not in possession of accurate information, and those who managed the accident were slow to realize the significance and implications of the events that had taken place."

[16] Fact sheet on the accident at Three Mile Island. U S Nuclear Regulatory Commission http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html

[17] Report of the President's Commission on the accident at Three Mile Island. "The Kemeny Commission". http://stellar-one.com/nuclear/commission_recommendations.htm

[18] The TMI 2 accident: Its impact, its lessons. Account by the Nuclear Energy Institute. http://www.nei.org/doc.asp?docid=455

[19] History's lessons for our future challenges. 2002. The Honorable Jeffrey S Merrifield, Commissioner, U S Nuclear Regulatory Commission. http://www.nrc.gov/reading-rm/doc-collections/commission/speeches/2002/02-008.html

[20] Three Mile Island: The Judge's ruling. Excerpt from the official court summary covering Judge Rambo's decisions on the key questions. 1996. http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/tmi.html

g. There is no doubt that, together with the accident at Chernobyl, 7 years later, the most damaging consequence of TMI was to undermine, seriously, public confidence in the safety of nuclear power.

Example of a Nuclear Incident

Wylfa, UK – 1993 [21, 22]

40. The incident at Wylfa power station in the UK in July 1993 is an example of a nuclear event rated INES level 2. The incident resulted in the company, Nuclear Electric plc, being taken to court by NII/HSE. The incident is described in Annex D which concludes as follows:

a. It was fortunate that the affected fuel channel was low rated in that the fuel in the channel was relatively new and in a low flux region. Had the detached component fallen into a highly rated channel, the fuel can would almost certainly have melted. The design and the safety case allow for such an occurrence and the operator would have been alerted by the fuel channel monitors. But it would have been a more serious event.

b. As in the case of Three Mile Island, the underlying causes of the event were human performance failings. In this case they occurred at all stages: in design, in manufacture, in inspection, in store room procedures and in operation of the reactor itself. The main benefit to emerge was the change towards conservative decision taking, maximising safety margins, providing defence in depth and stopping in the face of indecision, as opposed to reliance on engineered safety features.

c. Criminal proceedings, with the attendant drama of seeking to hold persons or companies liable for the consequences of accidents, tend to attract the press and other media to a greater extent than the methodical processes of inquiry. It is important for those involved, particularly the prosecuting team, to avoid exaggerated or emotive language which can be misinterpreted by the press and used by pressure groups in a manner which the facts do not justify.

Summary

41. Summarizing:

a. The nuclear hazard exists because ionising radiation damages living cells and may result in cancer. Only in the case of very large exposure to radiation will it cause death within days or weeks. (para 7).

b. The design, manufacture and operation of nuclear power plants is highly regulated, such that for a member of the public the additional risk of a fatal cancer due to normal operation plus that conceivably due to a nuclear accident is very low indeed. (para 9)

c. A nuclear accident may be expected to develop gradually, following some malfunction and further errors or events. (para 10c)

[21] Before Mr Justice Morland: Regina v Nuclear Electric plc. Transcript of the Verbatim Record. 1995. Ref. No. T95/0026

[22] Failure of refuelling machine grab and consequent shutdown of Reactor 1. Nuper report WYL00322. 1993.

d. It generates exceptionally high level of public concern, media interest, political interest and involvement. (para 10 d - f)

e. In order that the scale of an event may be better understood, the INES scale has been devised, ranging from level 0 (no safety significance) to level 7 (a major accident involving a major release of radioactivity causing acute health and long term environment effects. (para 11. Annex A)

f. To have a large number of low level events being reported and investigated is viewed as a good thing and not to be discouraged. By such means the number of INES Level 2 events, and worse, are kept very low. (para 19)

g. The aim of corrective action programmes is to avoid complacency leading to failure by creating a virtuous circle of operating experience - benchmarking - corrective actions - self assessment. (para 20)

h. Should an organisation experience failure of its safety culture and systems, the regulator becomes closely involved. (para 21)

i. The investigation by HSE/NII of a nuclear accident (INES level 4 and above, perhaps some level 3) would be in accordance with procedures covering all major HSE incidents. (paras 27 - 33)

j. It is highly likely that Government will see the need for some higher level investigation or inquiry. A "1921 Act Enquiry" is probably the most likely form that a public enquiry would take. However, this has not been pre-determined and nothing is allowed to be done that would commit the DTI in advance in any way on a matter which would be for decision by the Secretary of State. (paras 35, 36)

k. Detailed plans exist and are regularly exercised for responding to a nuclear emergency. (para 38. Annex B)

l. The accident at Three Mile Island caused very little if any effect on health, other than through stress, but nevertheless it is identified throughout the world as an example of the hazards of nuclear power generation. Arguably, the main damage to public confidence was done by the poor emergency response. (para 39. Annex C)

m. The greatest single benefit to arise from the TMI accident has been the formation of INPO which has been hugely successful in improving the safety performance of US power plants and along with improved safety performance has come lower operating costs. INPO's methods are being exported to the UK and other nations through WANO. (para 39f. Annex C)

n. As in the case of TMI, the underlying causes of the Wylfa "near-miss" event were human performance failings. The main benefit to emerge was the change towards conservative decision taking. (para 40. Annex D)

o. In criminal proceedings, it is important for those involved, particularly the prosecuting team, to avoid exaggerated or emotive language which can be misinterpreted by the press. (para 40. Annex D)

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ANNEX A

The International Nuclear Event Scale (INES)

1. Forty-eight countries, including the UK, use the International Nuclear Event Scale to categorise radiological events in the nuclear industry. This creates a common understanding of nuclear events among the nuclear community, the media and the public, in a similar way to the Richter Scale for seismic events.

2. The scale was drawn up by the International Atomic Energy Agency and the Nuclear Energy Agency of OECD. Though most events at nuclear facilities are below scale or Level 1, they often draw intensive media coverage, so the INES is a useful tool for rapid communication of the significance of an event.

   Level 0 - Below scale. No safety significance.

   Level 1 - Anomaly. Variation from permitted procedures.

   Level 2 - Incident with potential safety consequences on site but with sufficient safety defences remaining. Insignificant release of radioactivity off site.

   Level 3 - Serious Incident. Very small release of radioactivity. Radiation exposure off site a fraction of the prescribed limits. Local protective measures unlikely except for some food monitoring and control. Possible acute health effects to a worker.

   Level 4 - Accident with minor release of radioactivity. Radiation exposure off site of the order of prescribed limits. Local protective measures unlikely except for some food monitoring and control. Significant plant damage. Fatal exposure of a worker.

   Level 5 - Accident with off site risks. Release of radioactivity. Severe plant damage. Partial implementation of local counter measures, e.g. Windscale fire, Three Mile Island.

   Level 6 - Serious accident. Significant release of radioactivity. Full implementation of local counter measures.

   Level 7 - Major accident. Major release of radioactivity. Acute health and long term environment effects, e.g. Chernobyl.

3. The INES Scale came into effect in the early 1990s. Events prior to the introduction of the scale were rated as they would have scored, had the scale existed at the time.

4. The accident at an RBMK reactor at the Chernobyl nuclear power plant, in the former Soviet Union in 1986, had widespread environmental and human health effects and was rated as level 7.

5. The accident at the Three Mile Island nuclear power plant in the United States in 1979 resulted in a severely damaged reactor core. The event was rated at level 5 on the basis of the onsite impact.

6. In 1957, in the early stages of development of the UK nuclear programme, an accident occurred at Windscale in Cumbria that involved an external release of radioactive fission products. On the basis of the off-site impact, it was rated at level 5, the highest rated accident that has occurred in the United Kingdom.

Response to Nuclear Emergencies

Introduction

1. It is a condition of licence that operators should have and should exercise arrangements for responding to a nuclear emergency. Licensees' emergency policies and practices accord with HSE arrangements[23]. This Annex, which is not specific to any particular operator or site, describes the general principles and methods of response in the case of a civil nuclear power plant. The arrangements in the case of other nuclear facilities are similar, although the lead departments and detailed arrangements may differ.

2. The arrangements nationally are devised by the Nuclear Emergency Planning Liaison Group (NEPLG)[24]. This is a forum on which some 25 organizations are represented which aims to identify, discuss and find solutions to common problems and decide how these issues should be taken forward.

3. Most accidents at a nuclear power plant would be expected to develop gradually over a period of several hours and, depending on severity, the emergency may be expected to last for many hours or even days. Thus many organizations and authorities become involved even as the emergency is developing.

General Principles

4. The following general principles govern the response:

    a. The control of the plant begins and remains with the operator, who is responsible throughout for bringing the plant under control and for reducing off-site consequences.

    b. Protecting members of the public will be the responsibility of the Chief Officer of Police who will coordinate the work of the local authorities and emergency services for the area concerned.

    c. Advice and support will be provided by the Nuclear Installations Inspectorate (NII), the National Radiological Protection Board (NRPB) and by government departments responsible for various aspects of public protection.

    d. If off-site consequences exist or are likely, a Government Technical Adviser (GTA) will be appointed by the Department of Trade and Industry (DTI) to provide an authoritative source of advice and media briefings. The GTA will be a Deputy Chief Inspector of the NII, one of whom is always on duty in case of a nuclear emergency. Provision of a GTA is an emergency response measure that is unique to the nuclear industry.

    e. The GTA will be supported by a Senior Government Liaison Representative (SGLR) to provide a communications link between central government and local agencies.

[23] Arrangements for responding to nuclear emergencies.
1994, HSE books ISBN 0 7176 0828 X

[24] Civil nuclear emergency planning; consolidated guidance. Prepared by the Nuclear Emergency Planning Liaison Group. "The Blue Book". Department of Trade and Industry.

f. Response to the emergency will be controlled from a pre-determined off-site facility local to, but some distance from, the nuclear site. Adjacent to the off-site facility is provided a media briefing centre.

g. Site nuclear emergency arrangements dovetail with local and national emergency plans that exist to deal with a wide range of emergencies and disasters, described in Reference 4. This is the so-called "principle of extendibility".

5. Principles 2d, e, f and g above arose out of lessons learnt from the Three Mile Island event described in Annex C.

Control Centres

6. For the Reactor: On site, the plant itself continues to be controlled from the normal Control Room or, if this has to be evacuated, from an alternative shutdown room, provided with appropriate controls and instrumentation to enable reactors to be tripped and the plant to be monitored.

7. For the Station: The response within the Station is controlled by the operator's Site Emergency Controller from the Emergency Control Centre (ECC). Also attending the ECC would be:

a. The NII (the site inspector)

b. The local police, lest there be any death or serious injury involved in the accident.

c. The fire brigade - to attend any fire associated with the accident and to assist the station emergency response team with search and rescue activities

d. The ambulance service, to take any injured people to hospital.

8. Off-Site: The Off-Site Facility which may, for example, be established at a local police station, is the centre from which all off site activities are controlled and is the place where official media briefings are held. It is attended by:

a. The police GOLD (strategic) Commander

b. The GTA

c. The SGLR

d. The site operator

e. Local authority

f. Health authority

g. Environment Agency

h. Water company

i. Fire and ambulance services

9. Other National Centres: The principal authorities involved in the emergency will also establish their individual (headquarters) centres in order to be able to monitor the evolving situation and provide authoritative advice to their people at the Off-Site Facility. Thus, centres will be established by:

a. The DTI [the Nuclear Emergency Briefing Room at 1 Victoria Street]

b. Scotland (if appropriate): [The Scottish Executive Emergency Room]

c. The NII [a particular concern will be to consider the implications for other operating nuclear power stations]

d. The NRPB

e. The Food Standards Agency (FSA)

f. The Department for Environment, Food and Rural Affairs (DEFRA)

g. The Department of Transport.

The Phases Of An Emergency

10. A nuclear emergency has 3 main phases, defined by the various responsibilities and activities of the organizations involved:

a. The immediate phase

b. The emergency phase

c. The recovery phase

The Immediate Phase

11. In the event of an untoward occurrence resulting in a hazardous condition, the operator will declare:

a. A Site Incident: a hazardous condition which is confined in its effect to within the site security fence; or

b. A Nuclear Emergency: a hazardous condition which results or is likely to result in a radiological hazard outside the security fence.

12. During this phase the operator establishes the ECC and takes appropriate action to protect people on site from hazard, while notifying external authorities. In general, the fire service is likely to attend the site in all such cases, while other services and authorities will attend according to the nature and scale of the incident.

13. In the event of a nuclear incident, the response remains within the site, although outside authorities are alert to the possibility of escalation to a Nuclear Emergency, in which case the Emergency Phase follows:

The Emergency Phase

14. In the event of a nuclear emergency, site personnel and others are alerted, according to a predetermined list, extensive use being made of automated alerting using pagers. The off-site facility is established.

15. With the arrival of the GTA (normally coincident with the arrival of his DTI letter of appointment), he takes over from the operator the responsibility of advising the police GOLD commander, leaving the operator to concentrate on controlling the plant and the site. Other authorities arrive, and appropriate groups may be formed (e.g. Health

Advisory Group) to formulate advice to the Gold Commander, who chairs the strategic co-ordinating group during this phase.

16. Depending on the circumstances and the nature and scale of the hazard, the public are advised through the media and through police and local authorities of appropriate action for their safety and protection.

17. The media centre is established and a programme of media briefings by the GTA is instigated.

18. A Recovery Working Group is set up to plan the Recovery Phase.

The Recovery Phase

19. The recovery phase begins when conditions have stabilised and control of events has been achieved. For the Recovery Phase, the police GOLD Commander hands over to the Local Authority.

20. Even for a serious accident the amount of decontamination and restricted access measures to protect the public from direct radiation exposure is likely to be limited. The need for widespread decontamination is only likely to arise for the most severe accidents.

21. The International Commission on Radiological Protection (ICRP) principles for intervention following nuclear accidents are:

    a. The justification for intervention: The proposed intervention should do more good than harm.

    b. The optimisation of intervention: The form, scale and duration of intervention should be optimised so that the benefit of the reduction of dose is maximised.

22. Using principles such as these and having information from radiation monitoring and population densities etc. a recovery plan is formulated and progressed.

23. The following types of activity might be undertaken during the recovery phase:

    a. Decontamination

    b. Clean up, removal of barriers.

    c. Reoccupation of premises

    d. Compensation

Countermeasures to Protect the Public

24. A release of radioactive material to the environment presents a risk of radiation exposure to an individual in 3 different ways:

    a. From direct exposure to radiation emitted by airborne and deposited particles

    b. From exposure by inhalation of airborne materials

    c. From exposure by ingestion of contaminated food or drinking water.

25. Countermeasures to protect the public, during the Emergency and/or Recovery phases may, therefore, take the form of sheltering (i.e. remaining in doors), evacuation, or taking stable iodine tablets (if the main risk is from the Iodine 131 isotope), decontamination, shielding.

26. The form and scale of the accident, the prevailing wind and weather conditions, and the location and movement of people will affect the countermeasures deemed appropriate.

Exercises

27. Every nuclear licensed site exercises its emergency plan as follows:

- Each operating shift of a nuclear power station - annually, of which one is chosen to test
- Whole station on site arrangements - annually (Level 1 exercise)
- Offsite arrangements - every 3 years (Level 2 exercise)

28. Each year, selected from all operators, one scheduled level 2 exercise is upgraded to Level 3 to test arrangements more extensively.

Three Mile Island

1. The nuclear accident at Three Mile Island power station in Pennsylvania, USA in 1979 is an example of a nuclear accident rated INES level 5. The account which follows, paragraphs 2 to 11, is taken from the U S Nuclear Regulatory Commission fact sheet[25].

The Event

2. The accident began at about 4:00 a.m. on 28 March 1979, when the plant experienced a failure in the secondary, non-nuclear section of the plant. The main feedwater pumps stopped running, caused by either a mechanical or electrical failure, which prevented the steam generators from removing heat. First the turbine, then the reactor automatically shut down. Immediately, the pressure in the primary system (the nuclear portion of the plant) began to increase. In order to prevent that pressure from becoming excessive, the pressurizer relief valve (a valve located at the top of the pressurizer) opened. The valve should have closed when the pressure decreased by a certain amount, but it did not. Signals available to the operator failed to show that the valve was still open. As a result, the stuck-open valve caused the pressure to continue to decrease in the system.

3. Meanwhile, another problem appeared elsewhere in the plant. The emergency feedwater system (backup to main feedwater) was tested 42 hours prior to the accident. As part of the test, a valve is closed and then reopened at the end of the test. But this time, through either an administrative or human error, the valve was not reopened - preventing the emergency feedwater system from functioning. The valve was discovered closed about eight minutes into the accident. Once it was reopened, the emergency feedwater system began to work correctly, allowing cooling water to flow into the steam generators.

4. As the system pressure in the primary system continued to decrease, voids (areas where no water is present) began to form in portions of the system other than the pressurizer. Because of these voids, the water in the system was redistributed and the pressurizer became full of water. The level indicator, which tells the operator the amount of coolant capable of heat removal, incorrectly indicated the system was full of water. Thus, the operator stopped adding water. He was unaware that, because of the stuck valve, the indicator can, and in this instance did, provide false readings.

5. Because adequate cooling was not available, the nuclear fuel overheated to the point where some of the zirconium cladding (the long metal tubes or jackets which hold the nuclear fuel pellets) reacted with the water and generated hydrogen. This hydrogen was released into the reactor containment building. By March 30, two days after the start of the chain of events, some hydrogen remained within the primary coolant system in the vessel surrounding the reactor, forming a "hydrogen bubble" above the reactor core.

6. The concern was that if reactor pressure decreased, the hydrogen bubble would expand and thus interfere with the flow of cooling water through the core. Over the next few days, the bubble was reduced by "degassing" the pressurizer -- adjusting air and water pressure. Without water to cool it, and with the top of the reactor core uncovered, the primary damage to the reactor occurred two to three hours into the accident.

[25] Fact sheet on the accident at Three Mile Island. U S Nuclear Regulatory Commission http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html

Although no "meltdown" occurred in the classic sense of the word, in that fuel did not "melt" through the floor beneath the containment or through the steel reactor vessel, a significant amount of fuel did in fact melt. Radioactivity in the reactor coolant increased dramatically, and there were small leaks in the reactor coolant system which caused high radiation levels in other parts of the plant and small releases into the environment. Shortly after the accident began, some of the water, carrying fuel debris and fission products, escaped from the reactor coolant system and flowed into the reactor building basement. By the time the accident had ended, the water in the basement had been heated by residual heat from the reactor vessel, evaporated, condensed on the walls, and drained down onto the floors and back into the basement. The radionuclides then permeated into the porous surfaces of concrete and layers of iron which later became corroded (this area of the plant became a major focus of the subsequent clean-up and decontamination).

The Response

7. Response to the accident was swift. The NRC's regional office in King of Prussia, Pennsylvania, was notified at 7:45 a.m. on March 28. By 8:00, the NRC headquarters in Washington, D.C. was alerted and the NRC Operations Center in Bethesda, Maryland, was activated. The regional office promptly dispatched the first team of inspectors to the site and other agencies, such as the Department of Energy, and the Environmental Protection Agency, also mobilized their response teams. Helicopters hired by TMI's owner, General Public Utilities Nuclear, and the Department of Energy were sampling radioactivity in the atmosphere above the plant by midday. A team from the Brookhaven National Laboratory was also sent to assist in radiation monitoring.

8. At 9:15 a.m., the White House was notified and at 11:00 a.m., all non-essential personnel were ordered off the plant's premises.

9. From the early stages of the accident, low levels of radioactive gas, mostly in the form of xenon, continued to be released to the environment. At the time, efforts to halt the releases were unsuccessful and there was some fear of an explosion from the build-up of hydrogen - fortunately, this did not occur. However, on Friday, March 30, Governor Thornburgh of Pennsylvania ordered a precautionary evacuation of pre-school children and pregnant women from within the 5-mile zone nearest the plant, and suggested that people living within 10 miles of the plant stay inside and keep their windows closed. Advice to the public was delayed and confusing, resulting in many people simply deciding to evacuate, whatever the situation. Most evacuees had returned to their homes by April 4. By that time, the situation at the reactor had been brought under control.

10. The American Nuclear Insurers, an organization made up of nuclear insurance firms, had already begun distributing checks to evacuees to cover hotel and meal expenses, and was beginning to handle claims for property and liability losses.

Health Effects

11. Detailed studies of the radiological consequences of the accident have been conducted by the NRC, the Environmental Protection Agency, the Department of Health, Education and Welfare (now Health and Human Services), the Department of Energy, and the State of Pennsylvania. Several independent studies have also been conducted. Estimates are that the average dose to about 2 million people in the area was about only about 1 millirem[26]. To put this into context, exposure from a full set of

[26] As this account is drawn from US sources, radiation exposure is given in rem. For comparison with the SI units used elsewhere, 1Sv = 100rem; 1millirem = .01 mSv

chest x-rays is about 6 millirem. Compared to the natural radioactive background dose of about 100-125 millirem per year for the area, the collective dose to the community from the accident was very small. The maximum dose to a person at the site boundary would have been less than 100 millirem.

12. In the months following the accident, although questions were raised about possible adverse effects from radiation on human, animal, and plant life in the TMI area, none could be directly correlated to the accident. Thousands of environmental samples of air, water, milk, vegetation, soil, and foodstuffs were collected by various groups monitoring the area. Very low levels of radionuclides could be attributed to releases from the accident. However, comprehensive investigations and assessments by several well-respected organizations over the 24 years since the accident have concluded that in spite of serious damage to the reactor, most of the radiation was contained and that the actual release had negligible effects on the physical health of individuals or the environment.

Accident Investigations

13. Investigations into the accident were carried out by the industry, by the NRC and by a number of other commercial and governmental organisations, covering every aspect of the event. Considerable public concern at the accident did not start to abate until, two weeks after the event, President Carter appointed a 12-member commission under John Kemeny, then President of Dartmouth College, a mathematician and co-inventor of BASIC computer language, to investigate what had happened and its possible impact on the health and safety of the public and plant personnel.

The Kemeny Commission Findings

14. The following extracts, taken from the Overview of the Kemeny report [27], illustrate the main thrusts of a very comprehensive report:

a. On the causes:

"Other investigations have concluded that, while equipment failures initiated the event, the fundamental cause of the accident was "operator error." It is pointed out that if the operators (or those who supervised them) had kept the emergency cooling systems on through the early stages of the accident, Three Mile Island would have been limited to a relatively insignificant incident. While we agree that this statement is true, we also feel that it does not speak to the fundamental causes of the accident."

"Popular discussions of nuclear power plants tend to concentrate on questions of equipment safety. Equipment can and should be improved to add further safety to nuclear power plants, and some of our recommendations deal with this subject. But as the evidence accumulated, it became clear that the fundamental problems are people-related problems and not equipment problems"

b. On the mindset of the industry:

"The most serious "mindset" is the preoccupation of everyone with the safety of equipment, resulting in the down-playing of the importance of the human element in nuclear power generation. We are tempted to say that while an enormous effort was

[27] Report of the President's Commission on the accident at Three Mile Island. "The Kemeny Commission". http://stellar-one.com/nuclear/commission_recommendations.htm

expended to assure that safety-related equipment functioned as well as possible, and that there was backup equipment in depth, what the NRC and the industry have failed to recognize sufficiently is that the human beings who manage and operate the plants constitute an important safety system."

c. On the response to the emergency

"The response to the emergency was dominated by an atmosphere of almost total confusion. There was lack of communication at all levels. Many key recommendations were made by individuals who were not in possession of accurate information, and those who managed the accident were slow to realize the significance and implications of the events that had taken place. While we have attempted to address these shortcomings in our recommendations, it is important to reiterate the fundamental philosophy we stated above: One must do everything possible to prevent accidents of this seriousness, but at the same time assume that such an accident may occur and be prepared for response to the resulting emergency. The fact that too many individuals and organizations were not aware of the dimensions of serious accidents at nuclear power plants accounts for a great deal of the lack of preparedness and the poor quality of the response."

d. On the seriousness of the accident:

"Just how serious was the accident? Based on our investigation of the health effects of the accident, we conclude that in spite of serious damage to the plant, most of the radiation was contained and the actual release will have a negligible effect on the physical health of individuals. The major health effect of the accident was found to be mental stress."

e. On the management of the plant:

"There were significant deficiencies in the management of the TMI-2 plant. Shift foremen were burdened with paper work not relevant to supervision and could not adequately fulfil their supervisory roles. There was no systematic check on the status of the plant and the line-up of valves when shifts changed. Surveillance procedures were not adequately supervised. And there were weaknesses in the program of quality assurance and control.

……... We, therefore, recommend the development of higher standards of organization and management that a company must meet before it is granted a license to operate a nuclear power plant."

f. On prevention:

"To prevent nuclear accidents as serious as Three Mile Island, fundamental changes will be necessary in the organization, procedures, and practices -- and above all -- in the attitudes of the Nuclear Regulatory Commission and, to the extent that the institutions we investigated are typical, of the nuclear industry."

g. On the need for change:

"We are convinced that, unless portions of the industry and its regulatory agency undergo fundamental changes, they will over time totally destroy public confidence and, hence, they will be responsible for the elimination of nuclear power as a viable source of energy."

Recommendations and Changes Resulting From the Accident

15. The following summary (paragraphs 15 to 21) of the recommendations and the changes that followed the accident is taken from the account by the Nuclear Energy Institute [28].

The Kemeny Recommendations

16. The commission's report on its investigation, issued in October 1979, contained many detailed recommendations. Among them were:

- The industry must set and police its own standards of excellence.
- Within each utility, a single organization with the requisite expertise must be accountable for nuclear operations.
- Every nuclear plant must systematically gather, review and analyze operating experience.
- Agency-accredited training institutions must be established for nuclear plant operators and immediate supervisors of operations.
- The nuclear industry must dramatically change its attitudes toward safety and regulations.

17. The industry, the NRC and the White House all praised the report, endorsing the recommendations.

Resulting Changes

18. Within nine months of the accident, the industry had formed the Institute of Nuclear Power Operations (INPO), whose mission was to promote the highest levels of safety and reliability in the operation of nuclear power plants. INPO developed an assortment of tools to do the job:

- Performance objectives and criteria for overall nuclear plant operations and for corporate management support of nuclear programs. These documents set the benchmarks for excellence in safety and reliability and are the basis for INPO's on-site evaluations of plant performance and corporate support.
- Guidelines and "Good Practice" documents that define one method of meeting INPO performance objectives in specific areas. The guidelines establish the basis for sound programs in selected areas of nuclear plant operation. The "Good Practice" documents identify techniques, programs or processes that have been proven particularly effective at one or more nuclear plants.
- Regular evaluations of nuclear plants and periodic evaluations of corporate support of operating plants. After each evaluation, INPO supplies the utility with a formal report, giving its findings and recommending improvements. Follow-up visits ensure the recommendations are implemented.

[28] The TMI 2 accident: Its impact, its lessons. Account by the Nuclear Energy Institute. http://www.nei.org/doc.asp?docid=455

- Special assistance visits at the request of member utilities. These visits, conducted by qualified INPO personnel and industry peers, are designed to help utilities deal with specific technical issues.

19. In 1985, INPO formed the National Academy for Nuclear Training, which reviews and accredits nuclear utilities' training programs for all key positions at each plant.

20. INPO has had a profound impact on the way nuclear plants are managed and operated. The proof is the steady improvement in plant performance over the past 20 years. INPO started monitoring performance indicators in 1981. Today, INPO compiles data on U.S. nuclear plants and generates industry averages for 10 World Association of Nuclear Operators performance indicators. It also generates industry goals, based on individual utility goals. Plants use the indicators to compare their performance with the industry as a whole. Some of the indicators are:

    a). Unit capability factor, which is the percentage of maximum energy generation a plant is capable of supplying. It has risen from 62.7 percent in 1980 to 88.7 percent in 1999.

    b). Unplanned automatic scrams, which are plant shutdowns caused by some imbalance in operations. The number has fallen from 7.3 per plant in 1980 to virtually zero in 1999 per 7,000 hours of operation (about one year).

    c). Industrial safety accident rates, which have been cut by more than 85 percent since 1980 and now number 0.34 industrial accidents per 200,000 work hours.

21. In March 1989, 10 years after the TMI accident, INPO issued a report on the industry's responses to the Kemeny Commission recommendations. The report detailed what the industry had done to comply with the commission's recommendations and noted that the industry "has demonstrably altered its posture toward nuclear safety and has embraced standards of excellence for nuclear plant operation."

22. On the occasion of the 10th anniversary of the accident, John Kemeny, chairman of the commission, said of the INPO report: "[It] clearly shows that the Commission's commendations have stood the test of time and have served as a catalyst for significant change." He added: "The [industry's] improvements over the past decade have been impressive and are very reassuring."

Further Changes

23. In accordance with Kemeny recommendations, significant changes were made to the structure and *modus operandi* of the Nuclear Regulatory Commission, releasing the industry from regulatory shackles that were the initial response to the accident and instituting a regulatory regime that assesses the safety performance of stations, has objective criteria and adjusts the degree of regulatory oversight to the observed safety performance.

The World Association of Nuclear Operators (WANO)

24. INPO provides self regulation and improvement of the industry in the USA. Following the very serious (INES level 7) accident at the Chernobyl plant in 1986, the World Association of Nuclear Operators (WANO) was formed to provide a similar function for nuclear power plants outside the USA. WANO draws heavily on INPO practices, procedures and personnel.

UK Effects

25. In the UK, as throughout the rest of the world, considerable attention was paid to understanding and learning from the TMI accident. In particular, TMI:

a. Had a major impact on the Layfield Inquiry (1983 to 1985) preceding the construction of Sizewell B power station.

b. Demonstrated the need to identify and provide off-site facilities for the effective response to a nuclear accident.

c. Gave rise to the role of Government Technical Adviser (GTA) - see Annex B.

d. Demonstrated the need for "extendability" - i.e., the linking of nuclear site emergency plans to the broader Local Authority emergency plans.

Civil Lawsuits

26. There were, of course, civil lawsuits in the wake of TMI. The following is taken from an account of the Pennsylvania district court hearings (Reference 22) which finally put an end to those lengthy proceedings:

a. On March 28, 1979 Reactor 2 at the Three Mile Island nuclear power plant suffered a partial meltdown. Within weeks attorneys filed a class action suit against Metropolitan Edison Company (a subsidiary of General Public Utilities) on behalf of all businesses and residents within 25 miles of the plant.

b. Over 2,000 personal injury claims were filed, with plaintiffs claiming a variety of health injuries caused by gamma radiation exposure. The Pennsylvania district court quickly consolidated the claims into ten test cases.

c. Over the next 15 years, the case went to the Supreme Court and back, and through various district and appeals courts. Finally, in June 1996 district court judge Sylvia Rambo dismissed the lawsuit granting summary judgment in favour of the defendants[29].

Commentary

27. Every aspect of the TMI accident has been exhaustively analysed with a view to learning its lessons and avoiding a repetition of anything similar. Together with the accident at Chernobyl, 7 years later, perhaps its most damaging consequence was to undermine, seriously and perhaps for ever, public confidence in the safety of nuclear power.

28. Resulting from the event, the most significant realisation was that however good the technology and the physical and engineered safety features, it is human performance that has the most significant effect on safety. This is the message that was picked up by INPO whose mission and methods have been devoted to discovering and prescribing error prevention tools. The importance of Operational Experience Feedback (OEF), conservative decision taking, pre-job briefing, peer review, the identification and rectification of plant defects, adherence to well devised written procedures, and clear

[29] Three Mile Island: The Judge's ruling. Excerpt from the official court summary covering Judge Rambo's decisions on the key questions. 1996.
http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/tmi.html

accountability for nuclear safety are continually stressed, among a range of other INPO principles.

29. INPO has been hugely successful in improving the safety performance of US power plants and along with improved safety performance has come lower (not greater) operating costs. INPO's methods are being exported to the UK and other nations through WANO. This stands as the single greatest benefit to arise from the accident.

30. The accident at Three Mile Island caused very little if any effect on health, other than through stress, but which nevertheless is identified throughout the world as an example of the hazards of nuclear power generation. It is as if the human psyche suffered a permanent and irreversible dislocation. Why is this so?

31. Commentators generally attribute people's worries to the association with atomic bombs coupled to fear of radiation as an invisible hazard. Arguably, however, the main damage to public confidence was done by the poor emergency response, described in the Kemeny Report as dominated by an atmosphere of almost total confusion.

Specific Answers to Royal Academy of Engineering Questions

1. Q: What was actually done differently afterwards?

    A1. INPO was created bringing strong, determined self-regulation to the nuclear power industry in the USA, subsequently extending this worldwide through WANO, with the emphasis on excellence in human performance, accountability, protecting the core and training. Error prevention tools devised.

    A2. The NRC was reorganized and its approach to regulation was fundamentally changed.

2. What set of prior decisions was found to have been at fault?

    A1. Failure to make known an earlier (near miss) event, very similar in nature, on a similar plant in similar circumstances. [Failure of Operational Experience Feedback (OEF)].

    A2. Emergency arrangements were revealed as inadequate and unrehearsed.

    A3. Operator training was revealed as deficient.

    A4. In the power station, there were organizational deficiencies and lack of accountability for nuclear safety.

3. How have these been prevented in similar and related areas of work?

    A1. OEF: Better databases have been created and events made widely known. OEF stressed in INPO/WANO plant evaluations. As a result, there is free sharing by operating companies across the world of vast amounts of nuclear event information and the sharing of good practice. This is to an extent unequalled by any other industry or activity.

    A2. Emergency plans have been extensively modified and are regularly exercised.

    A3. In the USA: Operator training is subject to inspection by the INPO National Academy of Nuclear Training.

    A4. In the course of INPO/WANO plant evaluations, the inspecting teams look for clear evidence of accountability for nuclear and radiological safety.

4. How did the interests of the various parties fare? How did the wider community benefit?

    A1. The nuclear power industry: Suffered very serious repercussions and constraints from which it has slowly emerged stronger and with very much higher standards. It remains, however, generally feared and distrusted.

    A2. The nuclear regulator: Emerged from reorganization with a superior approach and methods and has regained the respect of the industry.

    A3. The wider community: Remains deeply scarred by the event. Few accidents have caused so little actual physical harm to people and yet so great damage to public confidence in an industry.

5. Is the useful experience extracted from the incident is easily accessible to future generations? Is this knowledge actively promoted? Is it widely accessible?

    A1. Affirmative on all counts. References 18 to 22 are but a small sample of readily available information about the accident and its consequences.

6. Are such accidents really less likely as a result of the processes described? How was this achieved by the process?

    A1. Yes, such accidents are less likely, largely but not exclusively as a result of the Kemeny Commission and the resulting establishment of INPO, then WANO and the changes to the NRC.

Wylfa

1. The incident at Wylfa power station in the UK in July 1993 is an example of a nuclear event rated INES level 2. The incident resulted in the company, Nuclear Electric plc, being taken to court by NII/HSE.

The Incident

2. On the evening of the 31 July, 1993, during normal on-line refuelling operations, a component of one of the refuelling tools, 34 inches long and weighing 130 lbs, detached itself and fell possibly up to 45 feet down a refuelling chute connecting the refuelling machine and the core. It lodged itself in the upper part of a fuel channel, effectively blocking the channel. This created the risk that the Magnox cans containing the fuel would overheat and the cladding would melt because of the non-circulation of the coolant gases.

3. The part which fell was the lower part of a component known as a "parasol grab" whose purpose was to put in place and subsequently to remove a drive tube which bridged the gap between the refuelling machine and the reactor charge chute.

4. At 1920, the operator noticed on TV that the parasol grab was not complete (it was known to have been complete at 1600 that day). Efforts were made to locate the missing component. Everyone in authority was notified and came to the station. By 2120 it was established that the missing component was not in the refuelling machine itself, or in the magazine where the parasol grab was housed when not in use.

5. Throughout this time the reactor was operating entirely normally. All the sensors which were being carefully monitored, indicated no overheating and nothing to suggest any melt of a fuel clad.

6. Because the missing component was not in the refuelling machine, there were only two places where it could be: it could be stuck somewhere in the charge chute or obstructing a fuel channel, having passed down the charge chute. This latter alternative was erroneously rejected because of the entirely normal operation of the reactor.

7. Reactor operation continued while further assessments were carried out which, given the geometry of the parasol grab, suggested that the missing component might be lodged within the charge chute assembly, a major engineered feature above the reactor core.

8. All the senior, expert, experienced people on the site at the time, after prolonged discussion and evaluation, individually and collectively, wrongly came to the conclusion that the missing component was in the charge chute.

9. The reactor was shut down in a controlled manner terminating at 0431 on 1 August. Several days later, after cooling and depressurizing the reactor, a TV inspection identified that the missing component was lodged in the top of the fuel channel. The top graphite bricks of the fuel channel had been fractured and distorted by the force of the falling component, allowing some emission of coolant gas through the top of the fuel channel. Additionally, the coolant gas was able to circulate through the designed gaps between the graphite blocks. The coolant gas flow thus permitted had prevented the overheating of the fuel can to the point of can melting.

10. The component became detached from its parent body due to the failure of a single tack weld, intended to prevent the two sections, threaded together, from coming apart.

The Court Case [30]

11. The case went to court in September 1995, more than 2 years after the event. The case for the prosecution was:

   a. The component should have been designed to prevent detachment of the two parts, and the component should have been of a larger size to prevent it being able to enter the reactor channels.

   b. The component should not have been put into use in a defective condition (i.e. with a cracked weld). [A second parasol grab, located in the station store, was found also to have a cracked and defective securing weld].

   c. As soon as the operators saw that a part was missing, they should have commenced reactor shut down.

12. This case translated into 5 counts. Count 1 concerned the design of the component and was not pursued. It was a design of the late 1960's procured by a predecessor nationalised industry, the CE.G.B.

13. Count 2 set out a criminal offence under section 2 of the HSW Act, which occurs when the risk of hurt or injury to employees is created. (The Crown accepted that there was no actual danger of hurt or injury).

    Counts 3, 4 and 5 referred to specific breaches of the Nuclear Installations Act to which the Company pleaded guilty.

14. On the first day, in the course of presenting the case for the prosecution, Mr Carlisle QC inappropriately used the words "melt-down" to describe the possible consequences of the event. This was avidly picked up by the press and resulted in lurid headlines in the next day's newspapers. Opening the second day's hearings, the judge made a strong statement refuting the possibility of such a serious accident.

15. In his judgment, Mr Justice Morland

   a. In referring to the defective component, stated: "*In my judgment, it is totally inadequate to rely upon inspection by independent experts before delivery, however eminent the reputation of the independent experts may be."*

   b. Stressed that in the nuclear industry safety in depth must be maintained so as to prevent lapses [due to human failing, error or misjudgement] causing actual danger.

   c. Viewed the lapses that occurred and the events to be very serious indeed *"because they involved not only lowly operatives but top local management and upper management generally"*

16. In mitigation, he recognized that *"Generally the defendants have maintained the highest standards of safety and observe, in practice, the principle of the paramouncy of safety."*

[30] Before Mr Justice Morland: Regina v Nuclear Electric plc. Transcript of the Verbatim Record. 1995. Ref. No. T95/0026

The Fine

17. *"I impose a fine of £250,000 on Count 2. There will be no separate penalty on Counts 3, 4, or 5. Additionally, the defendants will pay the costs of the Crown agreed at £138, 000."*

Commentary

18. It was fortunate that the affected fuel channel was low rated in that the fuel in the channel was relatively new and in a low flux region. Had the detached component fallen into a highly rated channel, the fuel can would almost certainly have melted. The design and the safety case allow for such an occurrence and the operator would have been alerted by the fuel channel monitors. But it would have been a more serious event.

19. As in the case of Three Mile Island, the underlying causes of the event were human performance failings. In this case they occurred at all stages: in design, in manufacture, in inspection, in store room procedures and in operation of the reactor itself. The main benefit to emerge was the change towards conservative decision taking, maximising safety margins, providing defence in depth and stopping in the face of indecision, as opposed to reliance on engineered safety features.

20. Criminal proceedings tend to attract the press and other media to a greater extent than the methodical processes of inquiry. It is important for those involved, particularly the prosecuting team, to avoid exaggerated or emotive language which can be misinterpreted by the press and used by pressure groups in a manner which the facts do not justify.

Specific Answers to Royal Academy of Engineering Questions

1. Q: What was actually done differently afterwards?

   A1. Operation of nuclear power plants in the UK was re-oriented towards conservative decision taking, maximising safety margins and defence in depth, and stopping in the face of indecision, as opposed to reliance on engineered safety features.

   A2. The concept of “Intelligent/informed customer" was developed, for contracted out goods and services.

2. What set of prior decisions was found to have been at fault?

   A1. In the design of components, the potential hazard of fuel channel blocking had not been considered.

   A2. Faulty manufacture was not picked up either by the 3rd party inspectors or by the operators.

   A3. Quality Assurance and Stores procedures were not properly followed

   A4. Reactor shut down was not commenced as soon as there was doubt about the whereabouts of a missing component.

3. How have these been prevented in similar and related areas of work?

   A1. The design of the component was changed

   A2. Quality Assurance and Stores procedures were overhauled and reinforced

   A3. Inspection regimes were tightened

   A4. Conservative decision taking was emphasized by an industry workshop and by adoption of INPO/WANO principles in training and simulators.

   A5. All nuclear power stations were required by the operating company to address the key issues, including reviewing the potential for channel blockage from failures of any components which enter or are used in the reactors.

4. How did the interests of the various parties fare? How did the wider community benefit?

   A1. HSE/NII: The regulator’s role and status were emphasized. The regulator was shown to have teeth and to be prepared to use them.

   A2. The operating company: Being taken to court was a salutary experience. Principles of operation were redirected towards conservative decision taking, increasing operating margins, and readiness to shut down in the case of uncertainty. Today, Wylfa is a high safety, high performing power station.

   A3. The wider community: Rather than being reassured, the inappropriate use by prosecuting counsel of the words "melt-down", greedily picked up and exploited by the press in lurid headlines after day one of the trial, probably further increased by another notch public fear and dislike of nuclear power.

5. Is the useful experience extracted from the incident is easily accessible to future generations? Is this knowledge actively promoted? Is it widely accessible?

   A1. Affirmative on all counts. The event left a strong impression on operators (now British Energy and BNFL) and is still quoted. The information is readily accessible on the industry's event database [31]

6. Are such accidents really less likely as a result of the processes described? How was this achieved by the process?

   A1. Such accidents are less likely. Refuelling continues to be affected by combinations of defects and human performance deficiencies, but it is now absolutely normal practice for refuelling to be suspended and for safe conditions to be restored if abnormal circumstance arises. This has been achieved by the incessant focus on conservative decision taking.

[31] Failure of refuelling machine grab and consequent shutdown of Reactor 1.
Nuper report WYL00322. 1993.

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Offshore Oil and Gas – Richard Snell FREng

1. Synopsis

1.1. The Offshore Oil & Gas Industry in the United Kingdom Continental Shelf (UKCS) experienced a major accident on 6th July 1988 when the Piper Alpha platform experienced a sequence of explosions and fires and was destroyed. There were 226 people on the platform at the time of the accident. 163 of the platform staff and 2 rescue craft staff were killed.

1.2. A public Inquiry was commissioned chaired by Lord Cullen. This published its findings in October 1990.

1.3. The Inquiry recommended that a Safety Case Regime be introduced requiring that the design and operation of a platform be controlled by a Safety Case which demonstrates and documents the safety of a platform. This was applied to both new platforms and retrospectively to existing ones.

1.4. The Oil & Gas Industry responded with a very large investment in research to enhance understanding, modifications to platforms and operating procedures and organisation.

1.5. There have been no further major incidents in the UK. Many of the lessons learned have been applied internationally.

2. Mounting and Conducting Major Inquiries

2.1. The Offshore Oil & Gas Industry in the UK has only had one major incident and public inquiry. With just one major accident in the UK there is no standing inquiry practice specific to the Offshore Oil & Gas Industry and it is to be expected that should a further accident occur the precedent set by the Piper Alpha Inquiry would be considered as a basis for a new inquiry. The Piper Alpha Inquiry was seen to have been fair and the findings have stood the test of time and been hugely influential worldwide. There is therefore no basis on which to suggest significant improvements. It was conducted in Aberdeen and apart from the opening and closing phases often not under the spotlight of the national media.

2.2. Inquiries have been held in other countries, for instance after the Alexander Kjelland accident in Norway and Ocean Ranger accident in USA. The major international oil companies have a strong culture of investigating accidents and disseminating and adopting the findings of accident inquiries wherever they may occur into globally applied Industry Standards and Guidance thus repetition of major accidents has largely been avoided.

3. The Piper Alpha Inquiry

3.1. Description of the Piper Alpha Facility

3.1.1. The Piper Alpha field is 110 miles NE of Aberdeen. The platform comprised wells, separation, gas compression, gas conservation, utilities and accommodation modules supported on a steel frame structure in 144m water depth with piled foundations. It started producing oil in 1976. Occidental Petroleum (Caledonia) Ltd was the Operator. The platform provided the facilities to drill wells and extract and process the reservoir fluids. Gas and water were separated from the oil in production separators. Gas condensate liquid was separated from the gas by cooling and was then re-injected into the oil to be transported with it by a 128 mile pipeline to the shore terminal at Flotta.

3.1.2. The Piper Alpha platform was linked by pipeline to three other platforms. The Claymore platform oil export pipeline was tied into the Piper Alpha oil export line to Flotta. A 16 mile gas pipeline from Piper Alpha exported gas to Claymore. Tartan platform exported oil via a 24 mile pipeline to Claymore and gas via an 18 mile pipeline to Piper Alpha. Piper Alpha exported gas by a 34 mile pipeline to MCP-01. The inventory of hydrocarbons in these pipelines was a factor in the escalation of the accident.

3.2. Cause of the Accident

3.2.1. The cause of the accident was a combination of events. The first event was an explosion in the gas compression module at about 22.00 hours and was due to the ignition of a cloud of gas condensate. The leak that caused the condensate cloud resulted from steps taken by night-shift personnel with a view to restarting a condensate pump that had been shut down for maintenance. Unknown to them a pressure safety valve had been removed from the relief line of that pump. A blank flange assembly, which had been fitted at the site of the valve, was not leak-tight. This explosion caused extensive damage and a fire in the separation module, which then extended into the gas compression module. This fire was fed by oil from the platform and also from a leak from the main oil line to Flotta to which the pipeline from Claymore and Tartan were connected.

3.2.2. At about 22.20 a second large explosion occurred when the oil fire caused the gas riser from the pipeline from Tartan platform to rupture. The fire was then further intensified by rupture of the other gas risers to Claymore at about 22.50 and MCP-01 at about 23.20.

3.2.3. The fire fighting and process system controls were damaged in the initial fire. The scale of the fire and smoke made the planned evacuation options of helicopter and lifeboat impractical and the survivors escaped to the sea by jumping or using ropes or hoses.

3.2.4. The platform was completely destroyed by the accident.

3.3. Industry Response to the Inquiry Findings

3.3.1. Since the late 1960's the Oil Industry has been largely self-standing in the development of engineering standards for it's specific requirements supplementing general industrial standards where necessary. These were initially developed for application in US Gulf of Mexico operations where the Offshore Industry first started and still has by far the largest number of platforms. Most of these standards address hydrocarbon plant and drilling and are applicable worldwide. When the Industry started developing in N W Europe the UK Health and Safety Executive (HSE) and the Norwegian Petroleum Directorate prepared Guidance Notes with additional design requirements primarily on structural design for the harsh conditions in NW European waters. These standards and national Guidance Notes emphasised sound design requirements but a complex and often modified facility such as an offshore platform also has to be operated correctly in order to maintain the safe intent of the designer. One of the most important lessons from the Cullen Inquiry related to control of maintenance and operation on a complex and modified facility and indicated that improved procedures were needed if consistently sound operation of a large number of complex facilities is to be attained.

3.3.2. There is a considerable difference in the scale and complexity of the platforms in the UKCS. Fixed platforms vary from small throughput unmanned gas platforms in 25m water depth the Southern North Sea to some of the largest man made structures in the world with large numbers of staff on board in 180m water depth the Northern North Sea. Floating systems range from itinerant drilling semi-submersibles with no production duty to permanently moored floating production systems using a variety of hull form some with a large inventory of oil on board. Prescriptive rules for the design and operation of such a diverse range of facilities would be very complex and it is doubtful that they would genuinely result in the improved safety that was required. Of particular concern was the ability of prescriptive rules to address the complexity of operational tasks on a big facility.

3.3.3. The Oil & Gas Industry proposed to Lord Cullen that a Goal Setting regime be used to regulate the safety of UKCS Oil & Gas operations. Under this regime the safety of the design and operation of a platform would be controlled by a Safety Case, which demonstrates and documents the safety of the platform.

3.3.4. The Safety Case system, which came into effect on 31 May 1993, places a legally enforceable obligation on the Duty Holder to prepare and comply with a documented design and operation procedures that demonstrates an acceptably safe facility. The Duty Holder is normally an Oil & Gas Company for production platforms and a Drilling Contractor for a drilling facility. Some production systems are leased and in this instance the owner would normally be the Duty Holder. The UK HSE reviews all Safety Cases to ensure that they are adequate and has the legal power to require non compliant facilities to be improved and if not improved ultimately shut down. The Duty Holder has to re/submit the Safety Case for review every 3 years.

3.3.5. The objective of the Safety Case is that the design and subsequent operation has to be demonstrably safe. There is a finite limit to safety and this is assessed using the “as low as reasonably practicable” (ALARP) principle. Safety performance is measured from the time staff step on a helicopter to transit to a platform to the time they are back onshore.

3.3.6. The Safety Case approach was applied retrospectively to existing installations as well as new platforms.

3.3.7. Following the Cullen Inquiry the Oil & Gas Industry invested heavily in understanding how to design safer platforms including extensive research into blast and fire design including near full-scale experiments to validate theoretical work. Substantial platform modifications to existing and new platforms and improvements in operating practice were made costing in excess of $1 billion.

3.3.8. The safety measures applied were both physical and organisational. A key requirement is to limit the scale of any hydrocarbon inventory that can be released in an accident and to minimise sources of ignition. Typical measures to minimise the frequency and magnitude of a hydrocarbon release are to maximise the use of welded connections in place of flanges wherever possible and using emergency shut down valves able to control the inventory of large pipelines. Gas tight enclosures around all sources of ignition were installed.

3.3.9. Platforms were toughened against fire and blast with the aim of ensuring that in the event of a major accident no further hydrocarbon release occurs, the process system is safely closed down and the staff are safe in positive pressure ventilated fire and blast toughened accommodation until they can be evacuated by helicopter or lifeboat.

3.3.10. Blast & fire toughening comprised developing light but very strong blast walls able to retain integrity under highly non linear deformation, ventilation and sub-division designed to reduce the build up of large accumulations of hydrocarbons and improved understanding of the performance of structures subject to fire and fire suppression systems.

3.3.11. In addition to physical toughening of platforms considerable attention has been paid to minimising the exposure of platform staff to potential hazards. This has included automation to minimise manning and centralising control systems to reduce the time of exposure of staff to hydrocarbon containing areas.

3.3.12. Platform Operating Procedures and Management of Change Procedures have been developed to ensure that the intent of the Safety Case is observed and is not invalidated by any platform modifications. Intensive attention to safety training for all staff ensures that the revised safety measures are correctly applied. Key service contractors operating equipment that itself has a safety risk such as helicopter and supply vessel operators were required to enhance their safety performance in line with the safety Case intent. Platform maintenance contractors were required to adopt safety training programmes similar to the Operators.

3.4. Post Piper Alpha Industry Performance on Offshore Platform Safety

3.4.1. With the perspective of some 15 years of operation after the Piper Alpha accident the Industry would generally agree that the improved approach to safety has been successful and is very strongly supported by the Oil majors. There have been no further major incidents in the UK. There have however been some significant gas releases that did not ignite. The fact that gas releases have not been eliminated reinforces the requirement for continued vigilance. Whilst it was expensive to apply it retrospectively to existing platforms when incorporated into the design and operation from the very beginning of a new platform it is not unduly expensive and provides very valuable capital asset protection as well as greatly enhanced safety. The HSE is generally considered to have been tough but fair in its review of Safety Cases.

3.4.2. Approximately 10 years after its introduction the HSE is currently reviewing the operation of the Safety Case system and is inviting comment from the Oil & Gas Industry. The changes are likely to aim to ease the operation of the system.

3.4.3. The major oil companies have taken the knowledge gained from this accident and the response (working within the legislation of the host government) into their global operations with a significant consequent improvement in global oilfield safety.

3.4.4. Some major accidents have occurred to national companies overseas within the last 15 years and they too are adopting safety approaches that are broadly comparable to the Safety Case philosophy.

4. Issues arising from Major Inquiries

4.1. A large corporation operates in a very complex world with extensive regulation and legal obligations. To be successful it has to innovate and operate facilities as efficiently as possible. Risk management processes are used to identify and intervene when risks rise above remote levels. Sound design and operating standards are the most effective means of managing risk. A key component of the findings of an inquiry needs to be sound guidance on how to minimise the risk of a re-occurrence. The Guidance is most directly helpful and applicable if given in the context of improvements to design and operating practice.

4.2. The focus on safety following Piper Alpha was on improving offshore platform design and operating procedures. The Industry, whilst not in any way reducing their effort on Offshore Facility Safety Cases, has to address the whole spectrum of potential accidents. Whilst there have been no major accidents in the UKCS since Piper Alpha there have been accidents to individuals mostly due to accidents on the road, during lifting, getting caught between moving objects and slips trips and falls. Avoiding this type of accident is often a matter of influencing the behaviour of employees and making them take responsibility for their individual safety behaviour in addition to platform design and operating procedures. Most of the oil majors have training programmes designed to significantly reduce accidents of this type.

4.3. Safety behaviour training translates differently across different cultures and can sometimes clash will local cultural attitudes. As an example driving standards vary considerably and for an international company typically road traffic accidents can be the biggest component of the global accident statistics. The effort some international corporations expend improving the safety behaviour of their employees, wherever they may be, is often under recognised.

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Rail – Dr Peter Watson FREng

1. Introduction

1.1. This document focuses on rail accident investigation, and is a brief report summarising current practices and commenting on its strengths and weaknesses. It also considers the likely impact of the introduction of the Rail Accident Investigation Branch (RAIB).

1.2. The approach used has been to review relevant Railway Group Standards and company standards/procedures in parallel with interviewing a wide range of individuals and organisations who are, or have been, closely involved in the process.

1.3. This report is arranged as follows:

Industry Investigations describes the processes applied by Railway Group Members when investigating railway incidents.

Other Investigations considers the effect that investigations by either the Health and Safety Executive (HSE) or British Transport Police (BTP) have on the process.

Public Perceptions discusses how public perceptions affect the investigation process, and how the rail industry engages with and involves interested parties.

Rail Accident Investigation Branch considers how investigations by the RAIB will relate to and affect existing processes.

Summary summarises the main points from the preceding sections and draws a number of conclusions.

1.4. Throughout the report, observations from recent accident investigations are included to illustrate specific points.

2. Industry Investigations

2.1. The railway industry has a long history of investigating and learning from railway incidents. Public inquiries, following major rail accidents, attract much public interest and often result in fundamental changes in the way the industry manages safety, but this is only the tip of the iceberg. The railway industry investigates thousands of incidents per year. It typically carries out around 500 formal investigations and 20 formal inquires annually, each of which results in recommendations that are recorded and tracked by the industry. This section of the report describes the process by which a rail incident is investigated; investigations involving external organisations (i.e. the HSE and BTP) are considered in Section 4.

2.2. Incident Management

2.2.1. Section M5 (Managing Accidents) of the Rule Book sets out how railway staff should respond to an accident. Having made the site safe, summoned emergency services and looked after the safety and welfare of anyone involved, staff are required to ensure that evidence is not disturbed unless this is necessary to gather perishable evidence[1], which must be done immediately.

2.2.2. As infrastructure controller, Network Rail has a pivotal role in managing incidents. Having been notified of the incident, Network Rail's Control Centre will immediately designate a local person to take charge of the site until the incident is over or they are relieved by a qualified Rail Incident Officer (RIO).

2.2.3. The RIO is appointed by Network Rail and is responsible for on-site communication and decision making between railway organisations, and for liaising with Network Rail Control, the BTP and any other emergency services involved. In particular, the RIO is responsible for control of the site to prevent unauthorised people disrupting the recovery and gathering of evidence. Network Rail Control works closely with the RIO and has protocols for contacting organisations needed to support accident investigations and recovery operations.

2.2.4. The RIO often has a very demanding job. Incident sites are often confused, can be spread over a wide area (especially in the case of derailments) and involve large numbers of railway organisations and other agencies. For this reason, significant effort is put into selecting, training and reviewing the competencies of RIOs. Those surveyed were found to have a high regard for the quality of RIOs, although it was acknowledged that this varied from incident to incident, especially in areas where RIOs see few incidents. To address this problem, Railway Group Standard GO/RT 3471 requires Railway Group Members (RGMs) to prepare and test incident response plans for reasonably foreseeable incidents.

2.2.5. These plans should cover:

- Evacuation, rescue and the establishment of a safe situation.
- Command and control strategies and protocols for working with different agencies.
- Alternative working, recovery and return to normal.

2.2.6. Acknowledgement is made of the fact that ultimately an investigation into the causes of the incident will be undertaken and the protocols are required to include details on the protection, collection and preservation of evidence.

2.3. Evidence Gathering

2.3.1. The most important evidence to collect first is that which may be lost over time. The RIO is required to collect perishable evidence as soon as possible (during the rescue effort if possible). The RIO then has a responsibility to determine what other on-site evidence is of relevance to any future investigation and to protect this so that it can be examined properly. These decisions require the RIO to take advice from technical and operational specialists.

2.3.2. Third party independent investigation teams are often involved in this process and in complex investigations their work needs to be carefully controlled to prevent them disturbing evidence that other parties may be interested in collecting.

2.3.3. A number of interviewees with on-site experience suggested that immediately after an incident those involved are much more likely to talk openly about what happened than they are at inquiry hearings, especially if they have then taken legal advice.

2.4. Restoration of Services

2.4.1. There is inevitably a tension between those responsible for collecting evidence as part of a structured investigation process, and those responsible for restoring the railway service. Incidents which are only being managed by a RIO (with no involvement from the BTP or HSE) are the ones where there is greatest risk that the evidence collection process is compromised by the desire to restore a service. Whilst those interviewed provided no evidence that this was a significant issue, anecdotal comments suggest that site restoration work does often happen without all the evidence being captured, or before independent third parties have been able to confirm that it has.

At a recent derailment at Aberystwyth (2003) the RIO decided that the cause of accident was self evident (the train was derailed by the prop shaft/final drive falling off). Although the set of points outside the station had been damaged this was considered to be as a result of the derailment, and since he needed to get the station back into commission again as quickly as possible he authorised the damaged points to be removed before the derailment investigation team had reached the site. Whilst this did not directly impact on the inquiry findings, it was frustrating that only one photo of the incident site was taken before the track was repaired.

2.5. Learning from Incidents

2.5.1. There are now three principal methods for carrying out internal railway inquiries. These developed from British Rail's procedures, and have been modified and revised during the privatisation process and as a result of recommendations from Lord Cullen's second report into the Ladbroke Grove accident. Railway Group Standard GO/RT3473 (Formal Inquiries, Formal Investigations and Local Investigations) defines which method should be undertaken when and the process that should be carried out. The standard places a duty on Railway Group Members (RGMs) to:

- Investigate the circumstances of accidents/incidents for the purpose of identifying ways to prevent, or reduce the risk of, reoccurrence

- Cooperate with each other to investigate accidents/incidents involving more than one RGM

- Share and use information arising from such investigations to maintain and improve railway safety

2.5.2. It requires each RGM to identify at least one Designated Competent Person (DCP) who will determine whether an incident warrants an investigation or inquiry and at what level:

- The DCP at the Rail Safety and Standards Board (RSSB) shall consider whether a formal inquiry is required and if so RSSB will act as the lead organisation.

- Where a formal inquiry is not required, RGMs involved in the incident shall determine which member should act as the lead investigator (in 95% of cases this is Network Rail[2]). The DCP of the lead organisation shall then determine if a formal investigation or a local investigation is required. In the case of disagreement RSSB will determine the type of investigation to be carried out.

2.5.3. The following sections describe, briefly, how the three types of investigation are conducted.

Formal Inquiry

2.5.4. RSSB establishes about 20 formal inquiries every year, and the DCP will normally decide to do so if:

- There has been a fatality or multiple major injuries

- RSSB expects to draw important safety lessons from the inquiry

2.5.4.1. The DCP has considerable discretion when considering this second category, and usually consults with other RSSB managers and DCPs of involved RGMs in such cases.

Many derailments are unique events and so are very much of interest. One recent incident was caused when track tamping left a kink in the track. An inquiry was carried out to discover why the tamping caused this defect and why the processes for checking the work carried out did not ensure the track was left in an acceptable condition.

2.5.4.2. The aim of a formal inquiry is to establish the immediate and underlying causes of an incident so that all the relevant lessons can be learnt. It is not intended to establish blame or liability, although in practice failures in process and people's application of process/rules and standards are often identified.

2.5.4.3. A formal inquiry is carried out to a defined remit, which is drafted by the DCP for consultation with the proposed chairman of the inquiry panel and the principal companies involved. The remit will always name the chairman and panel members, and define the inquiry's scope and timescales for reporting.

2.5.5. **Panel Members:** RSSB maintains a register of independent people considered suitable to chair formal inquiries and will select one of these based on the experience required for the incident in question. The quality of the chairman is important and they need to have a wide range of:

- Analytical skills, to ensure that the correct evidence is sought, examined and distilled to establish the true events and their causes

- Personal skills, to manage the panel and observers, to ensure witnesses feel comfortable giving evidence and the question and answer sessions are conducted properly and (where appropriate) with sensitivity

- Management, negotiation and diplomacy skills, to ensure potentially opposing organisations cooperate with each other and the inquiry process.

2.5.5.1. Great care is taken when appointing chairmen to RSSB's register and training is provided to ensure that they have and maintain the necessary skills.

2.5.5.2. The rest of the panel is usually made up of senior managers from the organisations involved, chosen to provide a broad base of operational and engineering experience. Their role is primarily to bring their experience and specific technical knowledge rather than to represent their respective companies.

2.5.5.3. In the case of large or sensitive incidents a completely independent panel can be convened (usually comprising a number of the independent chairmen). There have been four recent instances of this: Ladbroke Grove, Hatfield, Great Heck and Potters Bar

It was decided to not only select a fully independent panel for the Potters Bar (2002) formal inquiry, but to choose an Operator as chairman (to be independent from the technical railway disciplines) and to support him with appropriate rolling stock, track and signalling panel experts.

2.5.6. **Observers**: Observers to the inquiry are allowed, although the HSE and BTP are specifically excluded since their presence could discourage witnesses from being open about the true causes of an incident. RSSB always invites union representation; representatives of other bodies such as the Association of Train Operating Companies (ATOC) and the Rail Passengers' Council (RPC) are also invited as appropriate. In addition, the panel has access to advice and testimony from expert witnesses and often draws on such experts, especially for human factors issues.

2.5.7. **Support Facilities:** Support and facilities for inquiries are normally provided by the lead RGM. Typically it provides a room, recording facilities, and support staff to organise the witnesses and other evidence. For fully independent inquiries RSSB provides the facilities, which in addition to the above would include an office, witness room, and clerical support team.

2.5.7.1. Counsellors are also provided for witnesses (both before and after they give evidence) as they are often required to relive traumatic incidents.

2.5.8. **Process**: The chairman will usually convene a pre-inquiry meeting with the panel, at which a decision is made on how to proceed and which witnesses to call.

2.5.8.1. The inquiry panel will usually visit the site as soon as possible to get a feel for the working environment, sighting distances, line speeds etc. Typically an inquiry will take 2-3 days to carry out the witness interviews (usually around 10-15 witnesses are called), with several weeks required to complete the report. However, major inquiries can take much longer due to the quantity of evidence and complications due to the sensitivity of the incident.

2.5.9. **Witness Interviews**: The panel interviews each witness in turn and the proceedings are taped.

2.5.9.1. Typically there is a lead questioner appointed for each witness with a prepared set of questions. As evidence emerges additional lines of questioning may be followed, and all panel members have an opportunity to clarify or ask additional questions at the end of this process. Whilst the Railway Group Standard does not require it, the chairman often gives an opportunity for observers to ask questions through the chair, and this is often found to provide valuable insights into particular incidents, although it does need to be controlled to prevent abuse.

2.5.9.2. An inquiry panel has scope to commission technical investigations. Although the budget has to be approved by RSSB or the lead organisation, no one questioned could remember such a request ever being refused.

During the inquiry into a recent derailment at Aberystwyth (2003) it was determined that the initial cause was failure of the prop shaft on the final drive gear box. To determine the underlying causes the inquiry panel commissioned AEA Technology to dismantle the gear box. This identified a bearing failure which was traced to an inappropriate assembly process in the Doncaster workshop, where staff had not complied with the workshop procedure to check residual torque settings.

2.5.9.3. Formal inquiries rely heavily on local investigations and on-site investigations as well as testimony from those involved.

2.5.10. **Witness Cooperation and Representation**: RGMs have a duty to cooperate with an inquiry but this duty cannot be passed onto employees, and European legislation prevents forced cooperation. Nevertheless, it was suggested that RGMs do cooperate and provide information when requested, and that in the vast majority of cases witnesses are happy to give evidence. If a witness does refuse to attend, the chairman has a limited range of options:

- Write to the witness asking them to reconsider
- Write to their employer to see if they can persuade them
- Ask the witness if they are willing to answer written questions
- Proceed without their testimony

This process was followed during the Hatfield Inquiry when a large number of witnesses from Railtrack refused to appear. In addition the inquiry chairman wrote to the Lord Advocate to see whether immunity from prosecution could be granted but this was not successful. In the end all but one of the witnesses provided answers to written questions, although their answers were generally not considered to be very helpful.

2.5.10.1. Sometimes non-attendance is related to the trauma associated with a witness's involvement in an incident, and the panel has discretion to take evidence in other ways in these instances.

Almost all witnesses to a particular track worker fatality managed to leave the incident without giving a statement. In particular the driver was keen to get his train away on time. He was subsequently reluctant to give evidence because he was traumatised, and the panel accepted evidence on his behalf from his line manager, to whom he had already given an account.

2.5.10.2. If witnesses decide to attend, they are not allowed direct representation during questioning but some take legal advice beforehand. In addition, contractual obligations between the parties involved mean that there can be major financial implications associated with the inquiry's findings and this too can have a detrimental effect on the level of openness and cooperation.

2.5.11. **Reporting**: The chairman is responsible for producing the report and this should usually be submitted within 16 weeks of the incident[3]. In order to ensure consistency a template structure is defined in GO/RT3473. The report must include details of:

- The immediate causes of the incident
- The underlying causes of the incident
- Any other safety issues which have been uncovered during the inquiry (even if they are unrelated to the incident)
- Recommendations to prevent, or reduce the risk of, the incident reoccurring
- Recommendations to mitigate any outcomes should the incident reoccur.

2.5.11.1. Although individuals are not named in reports, their roles are and there is concern that this often provides sufficient information to identify individuals.

2.5.11.2. If an inquiry discovers a serious issue which is likely to be replicated elsewhere they can issue an immediate advice notice through RSSB before the final report is issued.

The Hatfield Inquiry uncovered the fact that track inspection had been carried out by a patrolman walking on the ballast to the side of the two tracks he was inspecting which prevented him from having a clear view of the canted track at the accident site. This was found to be a regular practice and an immediate advice notice was issued to ensure the practice was stopped elsewhere.

2.5.11.3. The draft report is circulated to the panel for comment. All panel members have to sign that they agree with the conclusions and recommendations. If no agreement is reached, it is possible to issue a minority report, but this is avoided if at all possible.

One inquiry chairman mentioned an instance when a minority report had to be issued because a panel member did not feel able to agree with one identified underlying cause, although during the inquiry they had been in agreement. The chairman suspected that they had been 'leant on' by their organisation.

2.5.11.4. Once a report is issued it is signed off by the DCP against the remit. RSSB then publishes the report and distributes it to the panel, all RGMs, BTP, HSE, the unions and any other inquiry observers. Reasonable requests from other parties are considered but all copies are supplied on the basis that they are not released into the public domain. Instead RSSB publishes a synopsis on its website.

2.5.11.5. RSSB has in the past received requests for the full report from legal firms representing bereaved/casualties. Such requests are often granted but on the basis that the inquiry process was intended to identify causes only and not to indicate blame, and that evidence has been given in the light of this understanding.

2.5.11.6. Despite instructions to keep the contents of inquiry reports confidential, information sometimes leaks into the public domain. This can result in a distorted view and encourages the perception that the industry has something to hide. The majority of people interviewed suggested that, whilst releasing the reports into the public domain could result in more scrutiny from external groups, it would help demonstrate that the inquiry process is rigorous and fair.

Formal Investigations

2.5.12. The DCPs are required to monitor Network Rail's incident log to identify incidents that should be investigated. If an incident is likely to be subject to a formal inquiry, the DCP will liaise with RSSB. Otherwise, they should liaise with the DCPs of other RGMs involved in the incident to determine whether a formal investigation is merited. Network Rail's National Investigations Manager also reviews the incident log and has a 'Top 20' list of events which is used as a starting point for considering whether a national investigation is appropriate.

2.5.13. The process of formal investigation then continues in a similar manner to a formal inquiry, with the relevant DCP issuing a draft remit for consultation with interested RGMs who have 48 hours to respond. The DCP then issues the remit and chooses a lead investigator (rather than an independent chairman) who puts together a team of two or three people who are usually drawn from the other organisations involved.

2.5.14. Since Network Rail is the lead RGM in 95% of cases, one of its DCPs is usually responsible for establishing formal investigations[4]. A regional investigator would be appointed unless Network Rail felt that a national investigation was merited or the other RGMs requested a national investigator to ensure a measure of independence.

2.5.15. The investigation team must decide how to proceed, which witnesses to call, and what evidence needs to be reviewed etc. In most cases they will set-up a hearing to do this, although the panel does have scope to use alternative approaches such as reviewing documentation and one-to-one interviews (if someone cannot attend a hearing).

2.5.16. Network Rail draws on third parties to support investigations. For example AEA Technology Rail is often called in to investigate the causes of a derailment, and signalling experts are asked to look at signalling issues (especially wrong side failures).

2.5.17. The lead investigator will write the formal investigation report and, as with formal inquiries, a standard template is used to ensure consistency. The draft report is sent out to all involved parties for a two-week consultation period which allows the investigation's independence to be tested. The lead investigator then has one week to include responses, before the DCP signs off the report against the remit.

2.5.18. As with formal inquiries, a copy of the final report is circulated to all RGMs, other involved parties and to the HSE. It is not published in the public domain, although a summary may be issued if requested.

Local Investigations

2.5.19. Local investigations are carried out for any minor incident that does not warrant a formal investigation or inquiry. They tend to be carried out by a local manager to a company procedure, which does not necessarily follow the detailed approach suggested in GO/RT3473, although a reasonably structured approach is generally adopted.

2.5.20. On the whole, local investigations are still focussed on determining immediate and underlying causes, rather than apportioning blame, and staff are generally forthcoming. The most significant factor in limiting how willing people are to speak about what actually happened is fear of disciplinary action, since the investigations are often conducted by line managers who staff suspect could use their testimony as part of formal disciplinary proceedings.

2.5.21. The competency and experience of the local manager is recognised as one of the most significant factors for the success of local investigations, and there are established courses and competency levels for people who carry them out. Individual duty holders are responsible for reviewing manager's performance to ensure they retain their competence, and this is especially important where managers are rarely called upon to investigate incidents.

2.6. Effect of Prosecutions

2.6.1. As stated earlier, the formal investigation and inquiry process is not designed to apportion blame or liability, and no prosecutions are brought directly as a result of them occurring.

2.6.2. However, consideration of the underlying causes can inevitably lead to the identification of failures in process and people's application of process/rules and standards. Whilst the BTP and HSE are excluded from the proceedings, factual information uncovered by the process can be passed to them, and they also received a copy of the final report.

2.6.3. It is therefore possible for the BTP and HSE to use their statutory powers to collect evidence themselves, and some witnesses do perceive that they could find themselves subject to the threat of prosecution as a result of cooperation with an industry investigation or inquiry. Statements by the police about its intention to prosecute have contributed to this fear, along with the perception that the HSE would seek to bring individual prosecutions (despite evidence to the contrary examined in Section 4.1).

2.6.4. These issues are acknowledged as being significant and have led to an increased reluctance for some witnesses to appear at all. Growing reliance on legal advice prior to an inquiry appearance is also a factor, since lawyers will usually point out that there is no legal requirement for witnesses to give evidence.

Of the 16 witnesses from Railtrack called to the Hatfield Inquiry, 14 refused to attend following advice from an independent lawyer that they were not compelled to appear. This reluctance was driven primarily by fear of prosecution.

2.7. Tracking of Recommendations

2.7.1. All inquiries' and investigations' recommendations have actions (with an identified owner and timescales) and the identified parties are required to indicate whether they accept or reject any recommendations.

- If they accept a recommendation they have to send an action plan indicating how and when they intend to implement it, and they should also send periodic progress reports to RSSB.

- If they reject a recommendation they have to provide a formal documented reason why, and provide alternative solutions where possible.

2.7.2. RSSB has a section of people dedicated to the tracking of recommendations from formal inquiries on behalf of the whole industry. They also track any recommendations on RSSB from public or HSE inquiries.

2.7.3. Duty holders are also required to have people responsible for tracking recommendations on them from formal and public inquiries as well as local and formal investigations.

2.7.4. Formal inquiries can generate a range of both specific and generic recommendations and have recently started to include timescales. RSSB reviews the action plans submitted by RGMs in response to inquiry recommendations and monitors the resulting periodic progress reports.

2.7.5. RSSB has no ability to force compliance with formal inquiry recommendations. It can, however, comment on the adequacy of response and an RGM's understanding of the issues, and reveal continued non-compliance as part of a safety case review.

2.7.6. Similarly, while failure to close out formal investigation recommendations is reviewed regularly, there is no ultimate sanction other than the possibility that an audit of the duty holder's safety case will identify general non-compliance in this area.

2.8. Repeat Recommendations

2.8.1. It is not uncommon for an inquiry/investigation recommendation to have been made before, and RSSB tracks these in particular. In addition chairmen/lead investigators are often encouraged to identify previous similar incidents, which often highlight these issues.

2.8.2. A regular recommendation has been that signallers should have ordinance survey grid references for signals and other lineside features to facilitate the process of getting emergency services to site.

3. Likely Changes

3.1. Improving Incident Scene Management

3.1.1. Since formal investigations and inquiries are carried out by people who have had no direct involvement in the incident, they are heavily reliant on the professionalism and competence of on-site investigation work.

3.1.2. As discussed earlier, the RIO plays a key role in ensuring that evidence is protected following an incident, and that suitable evidence collection is undertaken. Whilst the role of the RIO/local management on-site is well described in GO/RT3472 (Incident Management and Evidence Gathering), it is recognised that this is a potential area of weakness especially in complex/unusual incidents occurring in areas which do not have many incidents. Network Rail is actively considering how to improve the management of incidents and their subsequent investigation through closer incorporation of the role of RIO within the formal investigations process.

3.2. Risk Based Decision Making

3.2.1. Network Rail is becoming more proactive in its investigations, and is starting to consider a wider range of incidents to investigate, especially if it believes it has spotted a trend. In particular:

3.2.2. Some CIRAS5 reports (which currently trigger a local regional investigation) may soon result in a national level investigation.

3.2.3. Some technical investigations (which are currently fundamentally about ‘diagnose and fix’) are being considered for formal investigation, since a large amount of avoidable risk could be uncovered in these too.

3.2.4. Network Rail is starting to look at ‘financial loss’ as well as ‘safety loss’, in particular investigating incidents when performance is badly affected.

3.2.5. The principal driver for a risk based approach is to improve the match between the focus and level of investigations and the actual risks associated with incidents.

3.2.6. Where a significant performance event (one with more than 8000 delay minutes) occurs the residual risks associated with such an event are often sufficient to justify a formal investigation. Including such events allows aspects which are not normally considered (such as the train plan and its ability to cope with perturbations) to be investigated which in turn could uncover underlying safety risks.

3.2.7. A recent cracked crossing on the approach to Liverpool Street resulted in all trains reduced to 5mph and generated significant delay costs (which is a key business risk to Network Rail). However additional safety risks were also generated:

- Track workers had to be on-track to investigate and monitor the situation.
  - Increased worker exposure to risk of being hit
  - Increased out-of-course events for driver to observe
- More red signals were shown to slow trains down

- Increased SPAD/collision risk

• Lots of out-of-course communications going on

- Increased risk of miscommunication or misunderstanding

• Signaller stress raised due to out-of-course running

- Increased risk of mistakes

3.2.8. As Network Rail considers expanding the scope of events/incidents which are appropriate for formal investigation, it is also having to consider how to manage the available resource.

3.2.9. Currently Network Rail has resources to carry out around 500 formal investigations annually, of which investigations into Signals Passed at Danger (SPADs) typically account for about 80%. All Category A SPAD incidents are considered important enough to undergo a formal investigation because overall they contribute 40% of Network Rail's catastrophic risk. However, incidents on Level Crossings contribute 20% of this risk, and yet at the moment only 1% of these incidents undergo formal investigation.

3.2.10. Network Rail is considering doing fewer formal investigations into Category A SPADs (using a local investigation instead for those incidents which are considered to have posed a lower risk) and instead concentrating resources on those incidents which pose a higher overall risk to the railway. Network Rail already uses the risk ranking of SPAD incidents to determine the scope of any investigation carried out, with higher risk events having additional elements added to the remit.

4. Other Investigations

Section 2 described the industry's own arrangements to manage and investigate incidents. In practice, higher-profile incidents will involve other agencies, and this introduces further complexity and new tensions.

4.1. Health and Safety Executive Investigations

4.1.1. Railway organisations (as with other industries) must inform the HSE about all safety related incidents and accidents through the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR), and the HSE has a duty to ensure that a proper investigation is carried out following an incident. This may simply involve the HSE satisfying itself that the industry process is working properly, and reviewing the outcomes, but in the case of more serious accidents it has powers to carry out its own investigation.

4.1.2. An HSE investigation will be undertaken by either a single inspector or a team depending on the scale and circumstances of the incident. As with industry investigations, the principal aim of such an investigation is to establish the immediate and underlying causes so that recommendations for the improvement of safety can be made. However, the HSE must also consider if a breach of the Health and Safety at Work Act (HSWA) has occurred and, if this is the case, whether it is appropriate to prosecute the organisations or individuals involved.

4.1.3. Typically less than 5% of HSE investigations result in prosecution and the majority of these are against organisations rather than individuals, because in most cases the significant cause is found to be a failure of the safety management system, rather than an individual act of negligence.

4.1.4. In either case the HSE has powers under Section 20 of the HSWA to require witnesses to give testimony and to protect evidence, which usually involves ensuring that any evidence is not entrusted to an implicated party.

4.1.5. HSE investigations by themselves should not affect the ability of the industry to pursue its own investigation processes. The HSE has an interest in ensuring the established safety management systems are applied, that immediate and underlying causes are established, and that important safety lessons are learnt. There is therefore no reason for it not to provide access to or share evidence collected as part of its own investigation. However, there is a perception within the railway industry that this is not always the case, and this has led at times to a less than satisfactory relationship between the various parties. It is possible that the HSE's use of external third party organisations to carry out analysis of evidence and its unwillingness to release any results until a full report has been completed has contributed to this perception.

4.1.6. If both the BTP and HSE determine that an investigation is necessary they will act jointly (with the BTP acting as the lead party) until it is determined that police involvement is no longer required. Thus the HSE can appear to significantly restrict access to an incident scene (generating problems discussed further below) but in most cases this is due to the BTP's involvement.

4.1.7. On a more positive note, HSE interaction is rarely a problem at the formal investigation level, and generally the presence and influence of HM Railway Inspectors on-site can be helpful in ensuring that other investigators are able to carry out their work properly, resisting pressure to restore services until the necessary evidence has been collected.

4.1.8. Following the derailment at Southall East (2002), the TOC was keen to start running trains over the crossover adjacent to the incident site. AEA Technology Rail and the HSE resisted this request as they suspected that the crossing could have been important to the investigation process. Instead they pressed for it to be removed for further investigation and it was later determined that it had in fact played a crucial role in the incident.

4.2. British Transport Police Investigations

4.2.1. The BTP will always be involved if it is notified of an incident. This must happen if there has been a fatality or the emergency services are involved (in which case it has an important co-ordinating role), but can also occur if the BTP is notified for any other reason. Whenever the BTP is in attendance, it will take overall control of the site management, relying on the RIO to co-ordinate the activities of the RGMs involved and their representatives. Where Gold, Silver and Bronze command structures are put in place by the emergency services, the RIO acts at the Silver level with additional strategic off-site Gold support and co-ordination being provided by a Rail Incident Commander (RIC).

4.2.2. The BTP has a duty to investigate incidents on behalf of the Crown Prosecution Service (CPS) if it considers that a crime has occurred, and on behalf of the coroner (in England or Wales) and the Procurator Fiscal (in Scotland) if there has been a fatality. As a result it will always regard an incident site as a 'crime scene' until there is sufficient evidence (or lack of it) to decide otherwise.

4.2.3. This results in the process of evidence collection being heavily controlled, and has a significant effect on the activities of other incident investigators. BTP investigations appear to be more cautious, because it is looking for higher levels of evidence integrity in order to achieve a successful prosecution, and if third party evidence collection is authorised, it will be conducted in the presence of BTP officers to ensure its integrity. The BTP has authority to either confiscate evidence or ensure it is retained by a trusted third party.

4.2.4. In the last 10 years or so there has been a growing tendency for the BTP to consider the possibility of manslaughter as well as murder. Since it is difficult to rule this possibility out without completing a thorough and more prolonged investigation this had led to an increase in the number of accidents where BTP investigation has had a significant effect on associated industry investigations. Recent statements by the BTP, however, suggest that this trend is being reversed.

4.2.5. In addition, the BTP has a number of roles to play when on-site and, unless there is good dialogue between the RIO and the BTP incident manager, the processes involved in restricting site access can result in perishable evidence not being collected quickly enough.

4.2.6. At Hatfield (2000) there was a double ring of security. All railway personnel were initially excluded from site partly because the police had received an earlier bomb threat and the first indications were that this was a possible cause of the accident. When investigators were finally allowed access 'perishable' evidence had been lost.

4.2.7. In addition, the identification of relevant evidence often requires detailed technical knowledge or railway operational experience, and there have been a number of recent incidents when it is believed that:

- Time has been wasted collecting evidence that was unlikely to be relevant
- Important evidence was not initially protected through lack of appropriate knowledge.

4.2.8. At Hatfield (2000), the police did a finger tip search the day after the derailment as they considered it to be a 'crime scene'. Significant time was wasted from the railway industry's point of view because the BTP did not have sufficient experience or take advice about what might be relevant evidence.

4.2.9. At Potters Bar (2002), whilst the tips of the switch mechanism were protected and covered, the back-drive mechanism (some 30 feet away) was not. This part of the switch operating mechanism could have had a significant part to play in how the switch blades moved under the train and needed to be part of any investigation.

4.2.10. BTP officers are trained to treat train-crew both as victims and as being potentially responsible for some incidents. It is therefore particularly important to identify and protect the driver, and carry out drug testing quickly and sensitively. This is usually in the driver's best interests (to eliminate this as a possible cause) and also prevents the 'post-accident hip flask' defence as happened following an incident at Tattenham Corner.

4.2.11. Once the BTP officers have determined that no crime has occurred they revert to providing assistance to other organisations. They are then required to balance the interests of gathering evidence against the disruption to services and the BTP has a remit to ensure that the public interest is best served by helping to restore services as soon as is practicable.

4.2.12. There have been occasions when the BTP has reverted to an assistance role on site when, in retrospect, it would have been helpful to continue maintaining it as a 'crime scene'. Such incidents are rare and are usually when people die some time later (so evidence is needed for the coroner's inquiry) or a subsequent inquiry discovers that there were underlying causes which resulted from significant failures of responsibility.

4.2.13. Following a derailment at Bexley (1997) the BTP determined that it was not a police incident (there were no fatalities and the derailment appeared to be caused by the gauge spreading due to rotten sleepers) so it reverted to scene management. However, the subsequent railway inquiry determined that one of the significant underlying causes was one of the wagons being 20 tonnes over-weight and there was also a suspicion that the train was travelling too fast.

4.2.14. On the whole, it would appear that it is the involvement of the BTP in an incident and subsequent investigation that causes the most problems for industry investigations. Whilst the BTP/CPS are investigating or pursuing a potential prosecution, there tends to be a reluctance to make some evidence available to wider scrutiny in order to avoid the possibility of the prosecution failing. Since any HSE investigation in these cases would be carried out jointly with the BTP it can appear that the HSE is involved in such decisions, a perception not helped by the recent decision by the BTP/CPS to prosecute a number of individuals involved in the Hatfield accident, some of these prosecutions being brought under the HSWA.

4.2.15. Following the Southall collision (1997) the Uff inquiry was postponed for 2 years because the CPS had started manslaughter charges against the driver and First Great Western. Any reporting was thought to possibly prejudice this prosecution.

4.2.16. Whilst, there is frustration within the railway industry about restrictions imposed in the immediate aftermath of an incident, which can slow down the initial process of evidence gathering, there are clear guidelines for how such incidents should be managed when multiple agencies are involved. It is recognised that working relationships did not function very well during the incident management and investigation process following the Southall rail crash in 1997, but all parties have made significant efforts to improve these relationships through closer contact and improved protocols for working together and sharing evidence. More recent incidents suggest that all parties appear to work much better together now.

4.2.17. One additional impact of BTP and HSE investigations is that witnesses can be asked to testify a number of times. This can be a traumatic experience for those involved and has at times resulted in their reluctance to cooperate fully at later hearings.

4.3. Public Inquiries

4.3.1. The Health and Safety Commission (HSC) has powers to carry out its own investigations by getting the HSE to conduct a more formal panel-led investigation. This approach ensures greater independence amongst the panel members, and enables an objective consideration of whether the safety regulation role of the HSE has contributed to an incident.

4.3.2. In cases of extreme sensitivity, or national interest the HSC can make a recommendation to the Secretary of State for Transport that a public inquiry is undertaken under the terms of the HSWA.

4.3.3. Public inquiries usually occur some time after the incident and have no effect on how the incident is managed or the evidence is collected. Two such inquiries have been carried out in recent years (Professor Uff's inquiry into the Southall crash and Lord Cullen's inquiry into the accident at Ladbroke Grove).

5. Public Perceptions

Public perception is an important factor that affects the overall climate in which railway accident investigations are carried out. This section considers a number of important factors that interviewees identified.

5.1. Independence of Process

5.1.1. Public understanding of how the railway industry carries out investigations into incidents is not good. This is hardly surprising since the process is not particularly well documented in the public domain, and whilst it is very comprehensive (and includes an increasingly appropriate level of independence at each stage) it can appear complicated and insufficiently independent.

5.1.2. The skills and experience needed to carry out a proper investigation require someone who has worked at a senior level within the railway industry. This can lead to the perception that the industry is investigating itself.

5.1.3. The BTP and HSE are not immune from these perceptions. The BTP is ultimately funded by individual railway companies, and the HSE can (in complex cases which have been caused by a failure in safety systems and their implementation or management) find itself investigating how well the safety regulation process works.

5.1.4. Internal formal inquiry and investigation reports are not currently published in the public domain, although a summary of the findings are. A number of parties consulted felt that they should be published in full, because:

5.1.5. It would help to demonstrate how internal investigations operate and that they provide a serious examination of what went wrong and how it can be prevented in the future.

5.1.6. It would ensure a balanced view is presented, since parts of a report often reach the public domain anyway, either through leaks or more general exposure caused by the wide circulation amongst quite diverse groups.

5.2. Regular Calls for Public Inquiries

5.2.1. In addition to the lack of knowledge about the existing investigation processes and the general lack of confidence in the industry, there is also a perception that, since privatisation, railway companies have become much more interested in making (or saving) money at the expense of safety.

5.2.2. It is not surprising, therefore that in cases of extreme sensitivity, or national interest there have been increased calls for public inquiries to investigate accidents.

5.2.3. It is disturbing to discover, therefore, that there is a broad consensus amongst the industry, those heavily involved in running public inquiries, and independent observers that the public inquiry process rarely adds to the industry's understanding of what went wrong. Whilst public inquiries do demonstrate considerable openness, this is usually only achieved at great expense to the tax payer.

5.2.4. Further, because of the broad scope of such inquiries, the fact that they are not required to consider the cost implications of any suggestions, and the wide range of stakeholders involved often raise their particular concerns, they can result in recommendations that the industry believes are technically impracticable or far too expensive for the resulting safety benefit. Under such circumstances it is reasonable for to question these recommendations, but doing so further undermines the industry's reputation for putting safety first.

5.2.5. This is not to say that public inquiries do not provide a valuable spur to the industry at times, by creating a climate in which fundamental changes are possible. Lord Cullen's recommendations to establish an independent Rail Industry Safety Board and a Rail Accident Investigation Branch are two such examples.

5.3. Involvement with the Injured and Bereaved

5.3.1. One of the key strengths of the Air Accident Investigation Branch (AAIB), which was cited by a number of those interviewed, is the way it keeps the injured and bereaved informed and involved in the process of investigation.

5.3.2. Whilst the BTP and individual railway companies have made significant strides in involving and communicating with the injured and bereaved, it is notable that the internal railway investigation process has not addressed this directly.

5.4. Site Visits

5.4.1. The most common activity is for the railway companies (usually through the BTP) to offer relatives the opportunity of a site visit. The Train Operating Companies (TOCs) in particular have been heavily influenced by the aviation industry where US law requires airlines to have a high level of care for those involved.

5.4.2. Take up for such visits has risen to over 50% recently, due to a more open acceptance that it is a helpful part of the bereavement process and a general increase in the process of 'memorialisation'. A site visit will usually be at a prearranged point (a remote viewing point is used if the actual site is not safe), and be free of media involvement. The intention is always to provide access to as much information as possible, although very often "we don't know yet" may be the only appropriate answer for many questions. This does not seem to be a problem, as a willingness to be open and to communicate is often all that is required to build trust.

5.4.3. It is also important to be aware of the impact that a site visit may have on those involved in the clear-up and investigation process, since those people often deal with the situation by de-personalising it. The introduction of people who have been significantly affected by the incident can bring home the true human impact of the incident.

5.4.4. At Great Heck (2001), one of the visitors to site was the young son of one of the drivers. As well as having to be mindful of his reaction, the BTP was also aware that his presence significantly affected some site workers.

5.4.5. If the BTP has been involved then it is common for a family liaison officer to be appointed and they will generally keep relatives informed of planned press coverage and briefing. There is now increasing continued involvement by the TOCs and Network Rail.

5.5. Formal Inquiries/Investigations

5.5.1. Set against this, the industry's formal inquiry/investigation process does not engage with the bereaved and injured (unless they are called as a witnesses). Whilst it is unlikely that additional evidence would be uncovered as to the immediate or underlying causes, some form of engagement (either by allowing observation of the process or providing copies of the final report) could help to improve the understanding of how and why formal investigations are carried out and help to reduce unfavourable perceptions.

5.6. Bereaved/Victim Faith Issues

5.6.1. One final issue that the railway companies and the BTP are having to manage is the need to be aware of and accommodate the beliefs and faith of victims and the bereaved.

5.6.2. Separation of body parts can be a significant issue for some faiths, as well as the need to carry out some form of service/ritual. This often needs to be done at site.

5.6.3. At Potters Bar (2002) some victims were Buddhists and it was important for their relatives to have a service on site (at a particular location) to release the spirits of those killed.

5.7. Passenger Priorities

5.7.1. One factor that came out a number of times during the interviews was that the travelling public does not have a homogenous view. This generates significant problems for the industry when trying to determine how to respond.

5.7.2. The HSE has done a large amount of work to measure the real levels of societal concern when presented with well argued statements of fact. Such surveys of public attitudes to the important issues surrounding railway operation usually find safety comes near the top of the list. However, when asked what the key areas for improvement in the railway industry are, safety comes well below other issues. The aspects of safety that people have most concern with are almost always to do with personal safety, such as fear of assault, rather than the possibility that they are at risk from a train accident. Lack of staff, poorly lit stations and car parks, and the presence of threatening characters are much more important issues for most people.

5.7.3. There are a number of organisations which have formed as a result of recent accidents such as the Paddington Survivors Group and Safe Trains Action Group. These groups are usually made up from survivors and relatives of those who have been killed, and they act as a focus for both support and campaigning. By their very nature they are actively concerned with calling for lessons to be learnt from accidents, but they also tend to be primarily focussed on the specific issues associated with the accident they were involved with. On the positive side, politicians and the news media are very sensitive to the perceptions of survivor groups and they can often achieve significant changes. On the negative side, whilst the groups are recognised by the railways as having a level of moral authority to speak out, the industry has sometimes found them hard to actively engage with because they often operate as pressure groups for a particular view or course of action, rather than channels through which constructive debate can be conducted.

5.7.4. The Rail Passengers Council (RPC) on the other hand is often accused of being an apologist for the railway industry, and too tolerant of its failings. Over the years the RPC has developed a particular role of ‘candid friendship’, having found that simply standing on the sidelines hurling abuse does not achieve long term results. Instead, drawing on the views of their local councils (which comprise hundreds of regular travellers who take a lively interest in the industry, and who are recruited to ensure a cross section of age/gender/ethnicity/disabilities) they have been able to demonstrate a level of objectivity which has resulted in the RPC being acknowledged as the recognised channel through which public/passenger interests and perspective is brought into the debate. The downside of this is that to an external observer they may not appear to be a fully independent observer.

5.7.5. The RPC has been actively involved in formal and public inquiries for almost 20 years, and have an important steering role within a number of industry bodies and organisations. Their views are considered to be extremely helpful in allowing the railways to address issues which concern a wide range of railway users.

6. Rail Accident Investigation Branch

In his second report into Ladbroke Grove, Lord Cullen concluded that the industry's arrangements for the investigation of accidents needed to be changed, and recommended the formulation of an independent rail accident investigation body, the RAIB. This is in the process of being established, and while full details about its role and the scope of its operations are not formally developed and published, this section comments on the known intentions and plans, how these will affect existing arrangements and whether it will address some of the issues identified.

6.1. Proposed Role

6.1.1. The Government issued a consultation document in July 2002 entitled 'Establishing a Rail Accident Investigation Branch'. At the time the rail industry expressed strong general support for the new arrangements and the enabling Railways and Transport Safety Bill received Royal Assent in July 2003. The Bill was drafted so that the creation of the RAIB would be in accord with the European Directive on Rail Safety which is likely to become European law next year (and has to be implemented by member states within 3 years). Secondary legislation will be required to support and enable the RAIB's operation and development of this is currently underway.

6.1.2. Whilst the RAIB is part of the Department for Transport its activities will essentially be independent of all other organisations. Its function will be to improve the safety of railways by preventing railway accidents and its purpose will be to establish the cause of rail accidents and incidents, making recommendations for remedial action. As with formal inquiries and investigations it will not be concerned with issues of blame or liability, and investigations will be kept separate from any criminal or civil prosecution.

6.1.3. The Act says that the RAIB may investigate any accident or incident on any heavy rail system, light rail or heritage railway within the whole of the UK and the UK section of the Channel Tunnel (if invited by the Channel Tunnel Commission). It is under a duty to investigate serious accidents on all railways except tramways where the RAIB has discretion to allow the police to investigate if it is a road accident and that is deemed more appropriate.

6.1.4. The RAIB will consist of a core team of expert engineers and operators who will be the front line response team and leaders of the investigations. Specialist skills and competencies which are beyond the core team (due to the size or complexity of an investigation) will be contracted in and will receive the necessary training to work with and for the RAIB. Arrangements for access to additional facilities will also be made.

6.2. Impact on Current Processes

6.2.1. The RAIB will have a significant impact on the existing processes. Although the RAIB is currently drawing up its proposal for the type of incidents that it will investigate they are likely to be:

6.2.2. Those accidents arising from operations that are peculiar to the railways

6.2.3. Where recommendations are likely to improve the safety of the railways

6.2.4. Where an organisation with rail accident investigation expertise is the most appropriate organisation to handle the investigation.

6.2.5. Accordingly, serious accidents involving rail vehicle derailment and collisions would be investigated by the RAIB; a fire in a retail outlet on a station concourse would not.

6.2.6. It is anticipated that the RAIB is likely to take on investigations at about the same level as the railway formal inquiry; it is unclear whether this means that formal inquiries will no longer be required.

6.2.7. The RAIB may also investigate incidents which are currently dealt with at the formal investigation level, but it will almost certainly not replace this process completely. The process of local investigation is less likely to change although the RAIB has powers to monitor how these are carried out and to establish the approach and required competencies.

6.2.8. The most significant impact, though, is that the Act gives the RAIB powers to require or prevent persons taking specific actions in connection with an investigation. In other words, when it is involved the RAIB has overall command of an investigation and if other parties (such as the BTP and HSE) wish to collect evidence beyond that required by the RAIB then the Act provides for the RAIB to be able to manage how and when this evidence is taken so it does not obstruct its own investigation.

6.2.9. The BTP will continue to investigate on behalf of the CPS or coroner, and the HSE will have a continued role in the investigation of accidents on the railways in order to fulfil its statutory obligations to enforce health and safety law. The RAIB will share technical information with both these organisations. However, the identity of witnesses and their statements made to the RAIB will be confidential and will not be made available to other parties except by Court Order.

6.3. Strengths

6.3.1. As well as enabling the RAIB to take overall control of an investigation and therefore establishing that learning safety lessons should take precedence over establishing blame, the Act also provides for the RAIB to specify the scope of industry investigations. It may direct industry bodies to carry out an investigation and the manner in which they do it. In addition, it can supervise and review these industry investigations and will require the industry to report their findings and outcomes.

6.3.2. The Act specifically states that the RAIB's investigations shall be accomplished independently of any judicial inquiry, and it will be able to publish its reports even if civil or criminal proceedings are in progress. This specifically addresses some of the concerns raised by a number of parties about the way in which BTP and HSE investigations have in the past significantly delayed or compromised an industry investigation.

6.3.3. There is also a duty placed upon the RAIB to keep all parties (including the injured and bereaved, staff representatives and owners of damaged property) informed about the progress of an investigation, and to make private briefings (if appropriate) to the injured and next of kin prior to publication of the RAIB report.

6.4. Weaknesses

6.4.1. Whilst one of the RAIB's prime deliverables will be recommendations for improving safety and avoiding accidents in the future, they have already identified that there appears to be no single measure or process which prioritises the introduction of any recommended changes to standards or processes either from the RAIB, the HSE or the duty holders' own investigations. The RAIB is already looking at how to resolve this issue with the industry parties, which is important if it is to achieve identified improvements in railway safety as quickly as it may wish.

6.4.2. In addition, whilst the establishment of the RAIB defines who has overall control of investigations, it does not reduce the number of organisations who might carry out such investigations. There is potential for the lack of simplification of the process to result in confusion or continued public misconceptions, which may become particularly relevant if the different parties do not come to similar conclusions as to the cause of an incident.

6.4.3. It is therefore important that RAIB develops well defined working relationships and protocols with the BTP and HSE, and that once the precise nature of the RAIB's role is established existing industry processes are modified to be complimentary.

6.5. Opportunities

6.5.1. The proposals for the establishment of the RAIB provide the rail industry with an opportunity to not only improve the existing arrangements for learning from accidents, but also to benefit from quicker investigation processes and legal powers which support the primacy of 'no blame' investigations.

6.5.2. All RGMs (and RSSB and Network Rail in particular) have not only welcomed the proposals but have been actively working with the RAIB to share information about processes and competency levels. Such cooperation further demonstrates a willingness to engage in open and independent investigation processes and to address some of the misconceptions that sometimes plague the industry.

6.5.3. Whilst the BTP and HSE have broadly welcomed the establishment of the RAIB, there is much work to do to ensure that protocols for how the three parties will interact and work together are established. This is a great opportunity to establish closer relationships and improved processes.

6.6. Threats

6.6.1. As has already been discussed, there is a growing tendency for witnesses to decline to give evidence because of the risk of self incrimination in the event of subsequent criminal proceedings. It is unclear whether the proposed confidentiality of witnesses and their statements given to an RAIB investigation will offer a sufficient safeguard to ensure that relevant information is not withheld, since there is always the possibility that a judge may determine that disclosure of such testimony is in the public interest. Experience in the aviation industry suggests that this is not a significant concern. Similar judgements on AAIB evidence have always determined that the public interest is best served by maintaining confidentiality. If such an order were made it is likely that the effectiveness of subsequent investigations would be seriously impaired.

6.6.2. Further, it is not clear at the moment how the RAIB's investigation role will replace the need for public inquiries or the Railway Group's formal inquiry process. There are currently benefits of both these inquiry processes which some parties are concerned may be lost if the RAIB's remit is wide, but its approach is more restrictive. Two particular issues have been highlighted:

6.6.3. The possibility that the RAIB will carry out investigations in private, when previously a public inquiry would have been undertaken, thus reducing the openness which is appreciated by a wide range of interested parties.

6.6.4. The possibility that the RAIB will not allow observation by interested parties. It has already been noted that the ability of observers to be able to ask questions (at the discretion of the chairman) is often helpful to the process not only for allowing engagement with the observers but to improve the questioning process and hence the findings of the inquiry.

6.6.5. The RAIB has a difficult task ahead in ensuring witnesses feel able to contribute openly to an investigation without fear, and in achieving other stakeholders' desires for a rigorous and transparent process.

7. Summary

7.1. Industry Investigations

7.1.1. The railway industry has a long history of accident investigation, and has developed a set of clearly defined industry processes for managing and investigating incidents. The Rule Book clearly sets out railway employees' responsibilities to preserve evidence following an incident and Railway Group Standards define duty holders' responsibilities to:

- Prepare for incidents
- Manage incidents so that evidence is protected
- Carry out a structured investigation afterwards

7.1.2. The overall system is designed to establish the causes of accidents, rather than apportion blame or liability, so that lessons can be learnt, and recommendations made to prevent (or reduce the risk of) reoccurrence.

7.2. External Investigations

7.2.1. The HSE and BTP also have a duty to become involved in incident management and investigation in certain circumstances, and they both have powers to affect how this process is carried out.

7.2.2. The HSE has a duty to ensure that the industry's accident investigation process is working properly, but also has powers to investigate in its own right. Its primary aim is to establish root causes, but it must also consider whether a breach of the HSWA has occurred and, if so, whether to prosecute. Prosecution is very rare, and is almost always focussed on the company rather than an individual.

7.2.3. The BTP is always in charge of site management when it attends an incident, and has a duty to investigate on behalf of the coroner if there is a fatality, or the CPS if it suspects that a crime has occurred.

7.2.4. HSE investigations by themselves should not affect the ability of the industry to pursue their own investigation processes, although there are perceptions within the industry that this is not always the case. While the BTP considers the site to be a 'crime scene' on-site evidence collection is carefully controlled, and any decision to pursue a prosecution can restrict the exposure of evidence to wider industry scrutiny for fear of damaging the prosecution case.

7.2.5. There is a growing fear amongst witnesses that evidence they provide to railway investigations or inquiries could result in self-incrimination leading to possible prosecution by the BTP or HSE. Growing reliance on legal advice prior to an inquiry appearance contributes to this situation. These factors are eroding the willingness of staff to present themselves to industry inquiries and the value of what they say if they do.

7.3. Public Inquiries

7.3.1. Public inquiries fulfil an important role in demonstrating complete openness into the process of investigation, enabling broader consideration of related issues, and consultation and engagement with a wide range of stakeholders. Whilst they are usually long and costly affairs which have added little to the overall understanding of the causes behind the incidents under review, they can provide a valuable spur to the industry, creating a climate in which fundamental changes are possible. Lord Cullen's recommendations to establish an independent Rail Industry Safety Board and a Rail Accident Investigation Branch are two such examples.

7.4. Rail Accident Investigation Branch

7.4.1. The proposal to create a Rail Accident Investigation Branch (RAIB), along similar lines to the Air Accident Investigation Branch and Marine Accident Investigation Branch, will address a number of the deficiencies of the current arrangements. These proposals will provide the industry with an opportunity to not only improve the existing arrangements for learning from accidents, but also to benefit from quicker investigation processes and legal powers which support the primacy of 'no blame' investigations. The RAIB will:

- Have full oversight and control of the industry accident investigation process
- Have primacy in all investigations
- Be able to investigate and report independently from any judicial inquiry
- Have a duty to engage with and inform the injured and bereaved

7.4.2. The BTP will continue to investigate on behalf of the CPS or coroner, and the HSE will have a continued role in the investigation of accidents on the railways in order to fulfil its statutory obligations to enforce health and safety law. The RAIB will therefore share technical information with the BTP and HSE, but the identity of witnesses and statements made to the RAIB will remain confidential and will not be made available to other parties except by Court Order. It is anticipated that this will provide sufficient legal protection for witnesses, but it is likely to take some time before trust in these arrangements is established.

7.4.3. Whilst there are processes in place to track investigation recommendations, there is currently no enforceable mechanism to prioritise or ensure adoption of recommendations from existing industry or future RAIB investigations. This needs to be resolved. In addition, RAIB investigations will supersede some of the existing arrangements and so, when its role has been fully defined, it may be necessary to modify the industry's accident investigation procedures.

7.4.4. It is important that the RAIB's approach to investigations does not reduce the level of openness that previous inquiry processes have achieved and which is appreciated by a wide range of interested parties. Similarly, it is also important that it does not disenfranchise interested parties who are currently able to observe and (at the discretion of the chairman) contribute to the success of existing industry investigations.

Appendix 1: Sources

Documents reviewed

The following documents were reviewed during the preparation of this report:

Railway Rule Book - GE/RT8000 (in particular Module M5)

Railway Group Standards

GO/RT3471 (Incident Response Planning)

GO/RT3472 (Incident Management and Evidence Gathering)

GO/RT3473 (Formal Inquiries, Formal Investigations and Local Investigations)

Network Rail Company Standard – RT/LS/P002 (Management of Inquiries and Investigations and their Recommendations)

Lord Cullen's Second Report into Ladbroke Grove

Various RAIB related publications, in particular:

"Establishing a Rail Accident Investigation Branch" – DfT consultation paper

Response to DfT Consultation paper by HSC

Response to DfT Consultation paper by LTUC/RPC

"Ahead of Steam", IMechE Railway Division Chairman's Address by Carolyn Griffiths, Chief Inspector, RAIB

Web searches were also carried out for background information about rail accidents, public inquiries and railway inquiry findings.

Organisations Interviewed

In order to discuss the arrangements for rail accident investigation, and to gather opinions and helpful examples, a series of structured interviews were carried out with the following organisations:

AEA Technology Rail

British Transport Police

Health and Safety Executive (Her Majesty's Railway Inspectorate)

Network Rail

Rail Passengers Council

Rail Safety and Standards Board

Other more informal conversations were conducted with contacts in the RAIB, train operators, freight operators, infrastructure maintenance companies, and technical support organisations.

Other Sources Considered

A number of accident survivor groups were contacted, but none responded to the requests for cooperation.

Three unions were also approached, but only one responded and it was unable to provide a contact who was available to be interviewed in the time available.

Views were also sought from two internet discussion groups, but this did not provide any particularly helpful or insightful comment.

References

1. Perishable evidence (also known as 'short-life' evidence) is that which can change or disappear over time such as wheel-tyre and brake block temperatures, and brake-gauge readings.

2. Following Lord Cullen's report Railtrack (now Network Rail) reviewed and revised its internal company standard (RT/LS/P/002) to meet, and in many areas exceed, the requirements of GO/RT3473. In addition it established two teams of staff with responsibility for managing investigations and their subsequent recommendations.

   A Railtrack **Investigations Team** was established to remove the need for line managers to carry out investigations. The team now comprises 23 regional investigators whose role it is to lead general investigations, and seven HQ-based investigators who lead investigations that have greater national significance (or where some level of independence from the regions/zones is required). A mixture of internal and external appointments was made, in order to combine existing railway investigation experience with skills and experience from other industries/sectors as well. Minimum competency levels were specified, and additional training was provided through a combination of an established training course and enhanced modules.

   Similarly, a Railtrack **Recommendations Team** was created, with responsibility to identify and close out existing inquiry recommendations. Some 10,000 recommendations were found to be outstanding and the team built a database of these recommendations, enabling the majority of them to be visibly tracked to closure. A local manager was appointed in each zone/region to facilitate this process. The number outstanding now is manageable and part of the normal process.

3. If the process is going to take longer then a preliminary report should be issued at 10 weeks detailing:

   - The scope of inquiry so far
   - Any preliminary findings
   - Causes/areas which have been eliminated
   - The timescale for further reports. These may include a provisional report if completion of the final report will exceed 24 weeks.

4. The Safety and Environmental Performance Manager in each of Network Rail's regions/zones is identified as the relevant DCP, and 50% of their job is assigned to this role. As noted earlier Network Rail has designated national and regional teams to perform formal investigations.

5. CIRAS is the rail industry's confidential incident reporting system.

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Marine – Paul Frieze (following work by Prof Douglas Faulkner FREng)

1. Synopsis

1.1. The investigation of marine accidents in United Kingdom waters, or to UK vessels worldwide, is performed by the Marine Accident Investigation Branch (MAIB), a separate branch of the UK Department of Transport. The powers of the MAIB inspectors, and framework for reporting and investigating accidents, are laid out in the Merchant Shipping Act 1995. The Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 put the framework into effect. These pieces of legislation provide guidelines for the definition of what constitutes an accident, the reporting of accidents and the investigation of accidents.

1.2. The defined objective of the legislation relating to the investigation of accidents is the improvement of safety of life at sea and the avoidance of future accidents. These aims should not be substituted by the process of seeking to apportion liability, nor, except where it is fundamental to the understanding of the causes of the accident, to apportion blame. By laying out such goals, it is hoped that investigations will be co-operated with by all parties for the future improvement of safety.

1.3. An example is provided of the processes that might be expected to follow a marine accident. The *M.V. Derbyshire* sank off Japan in 1980, the largest United Kingdom registered merchant vessel ever lost. The vessel sank without trace during a typhoon with all hands, leaving little idea of the causes of the vessel's sinking. In the absence of evidence, no formal investigation was instituted. However, following pressure from a relatives group, studies were commissioned to propose likely scenarios for the sinking. The resultant official conclusions were controversial and eventually, following incidents involving sister vessels of the *Derbyshire*, a formal investigation was held. In the absence of the wreck of the vessel, the conclusions of the formal investigation remained subject to widespread criticism. Some years later a privately sponsored expedition found the wreck, enabling a reopening of the formal investigation, the first time this had occurred. This resulted in more widely accepted conclusions regarding the sinking and the proposal for a range of actions to prevent the occurrence of further losses of similar vessels.

1.4. The long running and controversial nature of the *Derbyshire* investigation provides a number of examples of how investigation of marine accidents could be improved. In particular, the consultation with, and involvement of, the families and other parties affected by the incident in the investigation process would help to improve confidence in the process and the outcome of the investigation. The *Derbyshire* investigation resulted in a number of recommendations, which offer the possibility of improving the safety of ships at sea. In order for the international shipping community to benefit of these proposals, the UK government must act to see them adopted internationally by standards organisations.

1.5. Prior to consideration of the UK investigation procedure and a review of the *Derbyshire* case, some statistics of vessel losses and fatalities worldwide will be examined to help put the magnitude of these into perspective.

2. Vessel Loss and Fatality Data

2.1. At the opening of the IMO Maritime Safety Committee meeting in June 2003, the General Secretary, in his address to delegates, highlighted that shipping "is in a much better state, from the safety and pollution prevention viewpoints, than it was a decade ago." This conclusion was apparently based on statistics issued by Lloyd's Underwriters Marine Intelligence Unit for the period 1991 to 2001 which showed a "very clear and sustained decline" in the number of ships over 500 gross tons[i] lost each year, from over 180 units in 1991 to less than 80 units just ten years later. During the same period, the decline in terms of aggregate gross tonnage lost each year is from 1.75 million gross tons in 1991 to less than 0.75 million lost in 2001.

2.2. Translating these losses to a day rate basis, the rate of loss has fallen from one every 2.0 days to one every 4.6 days. However, a different rate is realised if the vessel range considered is increased. . For example, Spouge found from a survey of Lloyd's World Casualty Statistics of losses of vessels exceeding 100 gross tons from 1995 to 2000[1] that an average of 215 total vessel losses were recorded each year of which 90 were general cargo ships, 54 fishing boats, 19 dry bulk carriers, 11 oil tankers, and 10 passenger ships. Ignoring fishing vessels, one total loss occurs every 2.25 days with general cargo ships every 4.0 days, dry bulk carriers every 19 days and oil tankers every 33 days. He determined the corresponding total loss rate per 1000 ship years for general cargo ships to be 5.4, for dry bulk carriers 3.2 and for oil tankers 1.5.

2.3. Spouge unfortunately does not directly compare the results with those from earlier times. He does, however, present some loss rates for the years 1949 to 1966 for dry cargo ships and oil tankers. He acknowledges that the dry cargo vessel category will include bulk carriers but expects these to be relatively few in number. The average loss rate for dry cargo vessels for the period is found to be 7.1 per 1000 ship years whilst that for tankers was some 2.3 per 1000 ship years. Without further analysis of these figures of further evidence on vessel losses, these three sources of data cannot be directly compared. However, the judgement would be that losses have reduced over the last few years but, up to the beginning of the decade referred to by the Secretary General, little improvement seems to have been made since the early 1950s.

2.4. Spouge also addresses fatalities for the period 1995 to 2000. He again finds general cargo ships to have the worst record with 170 fatalities or 37% of all fatalities during total vessel losses, approximately equal to the combined fatalities for oil tankers, bulk carriers and Ro-Ro ferries including passengers. Assuming crew to spend 50% per year on board a vessel, the risk of death rate is 3.7 x 10-4 per year. Notably this figure only relates to deaths where a total vessel loss occurs and does not include occupational deaths occurring in other circumstances. Spouge examines some statistics relating to occupational hazards on coasters and concludes that the combined risk of a fatality on general cargo ships approximates 10-3 per year.

2.5. Spouge attributes the higher loss and fatality rates demonstrated by the general cargo ship fleet to a combination of two main causes. Firstly, smaller general cargo vessels involved in coastal operations have a higher occupational fatality rate whilst, secondly, older vessels (20 years or more) are more vulnerable to total loss.

2.6. Spouge also notes, based on findings of the Swedish Club, an international mutual marine insurance company, that the implementation of the IMO International Safety Management Code (ISM) to passenger ships, oil tankers, chemical tankers, gas carriers, bulk carriers and high speed cargo shops of 500 GT and over[ii] in 1998 resulted in a 30% reduction accidents and thus claims. The ISM Code was introduced for all other cargo ships and mobile offshore drilling units of 500 GT and over on 1st July 2002. Spouge expects this action, plus the introduction by the International Association of Classification Societies (IACS), also in 2002, of unified requirements for close-up surveys on general cargo ships to lead to improvements similar to those noted by the Swedish Club.

3. Mounting and Conducting Major Inquiries

3.1. Accident Reporting and Investigation Regulations

3.1.1. The Marine Accident Investigation Branch (MAIB) examines and investigates all types of marine accidents to or on board UK ships worldwide and other ships in UK waters.

3.1.2. The powers of MAIB inspectors and the framework for reporting and investigating accidents are set out in the Merchant Shipping Act 1995, which consolidated the various Merchant Shipping Acts legislated between 1894 and 1994 and other enactments relating to merchant shipping. The Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 put the framework into effect. These regulations apply to merchant ships, fishing vessels and (with some exceptions) pleasure craft. They define accidents, set out the purpose of investigations and lay down the requirements for reporting accidents.

3.1.3. The Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 state that:

> *"The fundamental purpose of investigating an accident under these Regulations is to determine its circumstances and causes, with the aim of improving the safety of life at sea and the avoidance of accidents in the future. It is not the purpose to apportion liability, nor, except so far as necessary to achieve the fundamental purpose, to apportion blame."*

3.1.4. There is a Memorandum of Understanding between the Health & Safety Executive (HSE), the MAIB and the Maritime and Coastguard Agency as to which organisation will take the lead in investigations where they share a common interest, particularly at the ship/shore interface.

3.1.5. The Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 (henceforth referred to as "the Regulations") provide the basis for the operations of the MAIB. The following sections detail the provisions of the Regulations, as they apply to the investigation of marine accidents.

3.1.6. Definition of an Accident

3.1.6.1. The Regulations provide a detailed definition of what constitutes an accident. An "accident" is defined as being any contingency caused by an event on board a ship or involving a ship whereby:

- There is loss of life or major injury to any person on board, or any person is lost or falls overboard from, a ship or ship's boat.
- A ship causes any loss of life, major injury or material damage; is lost or presumed lost; is abandoned; is materially damaged by fire, explosion, weather or other cause; grounds; is in collision; is disabled; or causes serious harm to the environment.
- Any of the following occur: a collapse or bursting of any pressure vessel, pipeline or valve; a collapse or failure of any lifting equipment, access equipment, hatch cover, staging or boatswain's chair or any associated load-bearing parts; a collapse of cargo, unintended movement of cargo or ballast sufficient to cause a list, or loss of cargo overboard; a snagging of fishing gear which results in the vessel heeling to a dangerous angle; a contact by a

person with loose asbestos fibre except when full protective clothing is worn; or a escape of a harmful substance or agent.

3.1.7. Obligations to Report Accidents

3.1.7.1. The Regulations state that in the event of a prescribed accident occurring, the master of the vessel involved must send a report to the Chief Inspector of Marine Accidents ("the Chief Inspector"). This report should contain as much information as possible regarding the identity of the vessel, its owners and the master, the time and location of the accident, the weather conditions at the time of the accident, the number of persons killed or injured and brief details of accident.

3.1.7.2. In cases where the vessel is lost or presumed lost or is abandoned, then the requirement to submit a report of the accident falls to either the owner, master or most senior surviving officer.

3.1.7.3. In addition to the requirement to submit a report immediately upon the accident occurring, the master of the vessel is required to examine the circumstances of the accident. This report should be provided to the Chief Inspector on request (or in the case of serious injuries within 14 days) and will give the findings of the examination that has been carried out by the master and stating any measures that have been taken or are proposed to take place to prevent a similar accident occurring.

3.1.8. Ordering of Investigation

3.1.8.1. An investigation may be ordered into any reported accident. Following notification of an accident, inspectors will start to collect evidence and the decision whether or not to conduct a preliminary examination (PE) will start. A PE identifies the cases and circumstances of an accident to see if they meet the criteria required to warrant an MAIB investigation and its publicly available report.

3.1.8.2. If it is decided by the Chief Inspector that an investigation is warranted, the master or owner of the vessel should be notified of this investigation within 28 days of their initial accident report having been received by the Chief Inspector. In aiding the decision as to whether to investigate the accident, the Chief Inspector may require the master or owner of the ship and any other relevant person or corporate body to provide whatever information is considered necessary. This information will cover both the accident and any remedial action taken and must be to the best of the ability and knowledge of the providers. In addition, public notice may be given of the investigation, inviting interested members of the public with relevant information to present it within a specified time period.

3.1.8.3. In the latest version of the regulations, issued in 1999, the provision has been included that if the Chief Inspector initially decides that an investigation is not warranted, this does not prevent the ordering of an investigation at a later date if the Chief Inspector is satisfied that there is good reason to do so. This change could justifiably be interpreted as a response to the issues raised by the sinking of the *Derbyshire* and subsequent investigations (see Section 4).

3.1.8.4. In addition, the latest regulations allow the Secretary of State to require the Chief Inspector to expand the scope of any investigation to examine any further consequences of an accident, including salvage and pollution aspects. This investigation into the further consequences may be conducted by the Chief Inspector as a completely separate and distinct investigation from that into the initial incident.

3.1.9. Preservation of Evidence

3.1.9.1. In the event of an accident, all charts, log books, voyage data, electronic and video records and other documents that might reasonably be considered relevant to the accident must be kept. No alterations may be made to recordings or entries in any of the data. Any equipment which might reasonably be considered relevant to the investigation must, as far as practicable, be left undisturbed until either notification is received from the Chief Inspector that no investigation is to take place, 28 days has elapsed since the receipt of the accident report by the Chief Inspector and no notification of an investigation has been given, or the Chief Inspector or the Inspector carrying out the investigation indicates that they no longer require them.

3.1.9.2. In the period pending an investigation, an inspector may prohibit access to the ship or other equipment involved in the accident.

3.1.10. Reports of Investigation

3.1.10.1. At the completion of an accident investigation the Chief Inspector is required to make the report publicly available in the shortest time possible in the manner that they see fit. However the Chief Inspector will not release the report publicly until any person or organisation whose reputation is, in the opinion of the Chief Inspector, likely to be adversely affected by the report, are informed of its findings. They may make written representations to the Chief Inspector within 28 days of notification of the reports findings, which will be considered by the Chief Inspector prior to the public release of the report. These written representations may result in the Chief Inspector amending the report in any manner that they think is appropriate.

3.1.10.2. Three times a year, the MAIB produces a Safety Digest - a collection of short anonymous reports on the lessons learned from examinations and investigations. From time to time the Chief Inspector may publish a report highlighting specific safety trends or other issues he feels should be brought to the attention of the maritime community and the public.

3.2. Formal Investigations Regulations

3.2.1. As for the Accident Reporting regulations, the process for the initiation of Formal Investigations is laid out in the Merchant Shipping Act 1995. The Merchant Shipping (Formal Investigations) Rules provides the framework for the application of the contents of the Act relating to Formal Investigations.

3.2.2. The Merchant Shipping (Formal Investigations) Rules (henceforth referred to as “the Rules”) prescribe the procedure to be followed at any formal investigation into a shipping casualty or incident. The authority for the ordering of a Formal Investigation lies with the Secretary of State for Transport. Where the Secretary of State determines that a Formal Investigation into the circumstances of an accident is required, they have the power to order that an investigation be carried out by a wreck commissioner in accordance with the Rules. The wreck commissioner is required to be assisted by one or more assessors, who are appointed by the Lord Chancellor.

3.2.3. Notice of Investigation

3.2.3.1. Once a Formal Investigation has been ordered, the responsibility for organising the investigation and notifying the parties to the investigation falls to the Attorney General. The Attorney General is required to provide a “notice of investigation” to any persons who, in the opinion of the Attorney General, ought to be made a party of the Formal Investigation.

3.2.3.2. The notice of investigation is required to contain:

- A statement of the facts giving rise to the formal investigation, and
- A statement of the questions which the Attorney General intends to raise during the Formal Investigation.

3.2.3.3. However, the Attorney General may amend, add or omit any of the questions contained in the notice of investigation at any time before or during the hearing of the Formal Investigation.

3.2.4. Evidence and Procedure

3.2.4.1. The Rules lay out the procedure for Formal Investigation, beginning with an opening statement by the Attorney General. This is followed by, at the discretion of the wreck commissioner, brief speeches on behalf of the other parties to the investigation.

3.2.4.2. At the end of the opening statements, the proceedings are to continue with the cross examination of witnesses by the parties to the investigation. The Attorney General will then put to the wreck commissioner the questions for which answers are sought in relation to the accident under investigation. In framing these questions, the Attorney General may make modifications to, additions to and omissions from those questions set out in the notice of investigation as the Attorney General sees fit.

3.2.4.3. A party to the investigation who does not appear in person at the Formal Investigation and is not represented, may make representations in writing to the wreck commissioner. These representations may be read out during the course of the investigation by of behalf of the wreck commissioner. If, in the course of the investigation, a person faces substantial criticism, that person must be given the opportunity to present a defence of their actions, either in person or using a representative.

3.2.4.4. At the completion of the formal taking of evidence, any of the parties to the investigation may, on the basis of the presented evidence, address the wreck commissioner in relation to that evidence. In addition, the Attorney General may address the wreck commissioner in reply to the whole case that has been presented as to the cause of the accident. After the Attorney General's reply, any officer whose conduct has received substantial criticism during the Formal Investigation may, at the discretion of the wreck commissioner, be permitted to make a final statement as to why his certificate of competency should not be suspended in the event of his conduct being found to have contributed to the accident.

3.2.4.5. At the end of the Formal Investigation the wreck commissioner is required to report on the following aspects of the case:

(a) Where an officer's certificate is an issue, the wreck commissioner must give his findings in public.

(b) The wreck commissioner must make a report on the case to the Secretary of State including the findings as to the reasons for the accident and any particular matters relating to it, including the conduct of any persons implicated in the causes of the accident and the reasons for the suspension or cancellation of any officer's certificate.

4. Example of Investigation Process

4.1. Sinking of *M. V. Derbyshire*

4.1.1. On or about the 9th of September 1980, the Oil-Bulk-Ore (OBO) carrier *M.V. Derbyshire* was lost in the western Pacific Ocean, southeast of Japan. The vessel was carrying a cargo of 158,000 tonnes of iron ore from Canada to Japan.

4.1.2. The *Derbyshire* was the last of a class of six OBO carriers designed by Swan Hunter at their Wallsend Yard in 1969 and built in the period 1970-1976 at the Haverton Hill Shipyard on the River Tees. She was classed with Lloyd's Register of Shipping and delivered to Bibby Bros. of Liverpool. The particulars of the vessel were as follows:

Length	281.94 m	Service Draught	17.04 m
Beam	44.20 m	Summer Draught	18.46 m
Depth	24.99 m	Displacement	203,800 te
Block Coef.	0.84	Deadweight	173,200 te

4.1.3. The vessel was lost whilst riding out Typhoon Orchid with 44 crew on board. There was no distress signal from the vessel, apparent evidence of the speed with which the vessel sank. This vessel remains the largest United Kingdom registered merchant vessel ever lost at sea.

4.2. Initial Response to Sinking of *Derbyshire*

4.2.1. The sinking of the *Derbyshire* occurred without any distress signal being given and there was no wreckage found during the subsequent search for the vessel. The Department of Trade and Industry completed a preliminary examination into the loss of the ship in November 1980 but the inspector concluded that, in the absence of any direct evidence, he could not draw any firm conclusions as to the cause of the vessel's loss. It was subsequently decided that a formal inquiry would not be held, because a court could not reasonably be expected to establish the cause of the casualty.

4.2.2. However, approximately 18 months after the sinking of the *Derbyshire*, a sister ship the *Tyne Bridge* developed severe cracking of the deck structure just forward of the vessel's superstructure. This cracking occurred in the region of frame 65, one of the primary transverse frames in the vessel's structure.

4.2.3. The classification society which had classed the *Derbyshire*, Lloyd's Register, inspected two further sister ships, *Casi Kittiwake* and *Sir Alexander Glen*, in the summer of 1982 and both were found to have identical problems with the design and workmanship of critical structural members around frame 65. The common defect in all three ships involved a pair of longitudinal bulkheads (girders) that ran nearly the length of the ship and served as main strength members. Contrary to the originally intended design, the two longitudinal bulkheads were cut at frame 65 and butt welded to the transverse bulkhead that marks the end of the line of cargo holds. Furthermore, the longitudinal bulkhead sections forward and aft of frame 65, which should precisely align to preserve continuity and maximum hull strength, were misaligned by 25 to 45 millimetres.

4.2.4. The Derbyshire Family Association (DFA), set up to represent the interests of the families of the lost crew, gathered together mounting evidence of possible misalignment and bad workmanship of the vessels of the *Derbyshire*’s class, both in the as-built and repaired conditions. In response to pressure from the DFA, the

Department of Transport (DoT) initiated studies to examine the likely causes of the *Derbyshire* sinking, the results of which were incorporated in a report issued in 1986[2].

4.2.5. The DoT report offered opinions on five of the most likely causes of the loss of the ship:

1) *Explosion* - less likely as the vessel had not carried oil since October 1979 and had been tank cleaned.

2) *Shift of Cargo* - could result from an ingress of water into holds thereby causing liquefaction of the cargo.

3) *Failure of Hatch Covers* - deck flexing could “spring” the covers, followed by water entry and rapid flooding and foundering.

4) *External Hull Damage* - ship struck by submerged or partially submerged object.

5) *Structural Hull Failure* - failure of part of the hull could lead to water ingress, etc.

4.2.6. This report pointed out that some of these scenarios would have been apparent to the crew and consequently a distress signal from the vessel would have been expected. Among the other points made were:

- Any misalignment at frame 65 was significant only for local strength aspects: nevertheless, more consideration should be given to the alignment of these intersections.

- The series of assumptions and events that would lead to a massive hull failure at or about frame 65 were contentious (and not considered further).

- Four of the five sister ships had not (as of 1986) suffered any major structural distress: the fifth, the Tyne Bridge, also survived and the brittle cracking to its upper deck was not considered relevant to the loss of the *Derbyshire*.

4.2.7. The report ended with the conclusion that “in the last analysis the cause of the loss of the *Derbyshire* is, and will almost certainly remain, a matter of speculation”.

4.2.8. Although this was the conclusion of the final report, an earlier draft prepared in July 1985 had a substantially different conclusion. It stated that the most likely cause of the sinking was “total structural failure”, resulting from defective design and/or construction at the frame 65 connection. Unfortunately, a copy of this report, not captioned “draft”, was leaked to the media and subsequently released by the DoT, without consultation with either the builder or Lloyd's Register. This report was regarded as being seriously in error on many points. The subsequent release of the official document, with its different conclusions, naturally lead to accusations of a “cover-up” and was met with a furious response by the DFA.

4.2.9. Less than 6 months later, *Derbyshire’s* sister ship *Kowloon Bridge* grounded on rocks in Bantry Bay following steering gear failure. This occurred following a voyage across the Atlantic in which she had sustained deck cracking just forward of the superstructure, which had necessitated stopping in Bantry Bay for repairs. Despite salvage attempts, she could not be dislodged from the rocks and eventually the stern section broke off near frame 65. As a result of this, and no doubt fuelled by pressure from the media and the DFA, the Government ordered a Formal Investigation into the loss of the *Derbyshire*. In the opinions of some[3], this investigation was “inevitably biased toward a fuller assessment of the frame 65 loss scenario”.

4.3. Original Formal Investigation

4.3.1. A Formal Investigation into the sinking of the *Derbyshire* was instigated in 1989. The result of the investigation was the Decision of the Wreck Commissioner and his three Assessors that "the Court finds that the *Derbyshire* was probably overwhelmed by the forces of nature in Typhoon Orchid, possibly after getting beam on the wind and sea…". The "Summary of Conclusions" of the Court[4] was:

- the *Derbyshire* was properly designed, properly built and constructed from material of approved standard
- no inference can safely be drawn from the absence of any distress signal
- the condition of the cargo when loaded and its loading were within the existing recommended parameters
- the *Derbyshire* was caught in the worst part of Typhoon Orchid and may have encountered local freak weather beyond what can be hindcast
- the actions of her Master were not unreasonable
- the possibility that the ship was lost as a result of torsional weakness in her hull was extremely low
- the combination of circumstances necessary to postulate separation of the hull at frame 65 is very unlikely, though some element of doubt must remain
- it is improbable that immediate or even sudden structural failure of the forward hatch covers caused rapid sinking
- sequential flooding of holds is a possible cause of loss, but not thought probable
- if cargo liquefaction did occur, which is doubtful, it still cannot be concluded that it was the prime cause of the loss
- if the ship got beam-on to the weather, structural failure and/or cargo shift would have become much more likely; it is quite possible that that happened, but it cannot be proved.

4.3.2. Nevertheless, the DFA were unhappy with the lack of a firm conclusion regarding frame 65, despite the subject occupying around 40% of the proceedings.

4.4. Events Subsequent to Original Formal Investigation

4.4.1. Following the publishing of the results of the original Formal Inquiry, debate still continued as to the causes of the sinking of the *Derbyshire*. A paper presented in the Transactions of the Royal Institution of Naval Architects[5] argued that loss of the *Derbyshire* was due to a poor construction and high stresses at the frame 65 connections. However, the conclusions of this study were later rebutted[6] because of factual inaccuracies in the paper and further analysis of the supposed high stresses in the region of frame 65.

4.4.2. The DFA continued to lobby for a reopening of the Formal Investigation. This request was rejected in 1991. In the meantime, the DFA, assisted by the International

Transport Workers Federation (ITWF), continued to raise the funds necessary to mount an expedition to discover the wreck of the *Derbyshire*.

4.4.3. In 1994 the DFA was able to mount a survey. During this survey the location of the wreckage of the *Derbyshire* was found and sonar recordings made of the locations of the larger pieces of the wreck. A remote operated vehicle was sent down to the seabed for a 6 hour period and was able to take a few images of the bow of the vessel and elements of the extensive debris field. On the basis of this limited information in was concluded that the extensive fragmentation of the hull and observations of some brittle fracture suggested that the vessel was subject to very rapid structural collapse during sinking. It was believed this validated the theories regarding the structural strength of the vessel.

4.5. Rehearing of Formal Investigation

4.5.1. In 1995, Lord Donaldson was asked by the Secretary of State for Transport to assess the likely benefits and costs of further underwater surveys of the wreck of the *Derbyshire*. The Terms of Reference of the assessment could be summarised as:

- To assess what further work is needed to learn more of and, if possible, make a judgment about the cause of the loss

- For each option determine the likely costs, the probability of success and benefits to ship safety.

4.5.2. Lord Donaldson concluded that only a further, more extensive, but final examination of the wreck site would satisfactorily resolve the mystery. He considered the likely cost of about £2 million to be fully justified because of the potential benefit to ship safety.

4.5.3. Lord Donaldson's positive recommendations led to UK Government and European Union funding for further surveys of the *Derbyshire* wreck site. Three Assessors were appointed to oversee the survey and report upon the results, two of whom represented the UK and the third representing the EU.

4.5.4. It was the role of the assessors to both oversee the conduct of the survey and to report on its results and whether or not sufficient new information had been obtained. The nature of this second survey had by now become highly politically charged. The suggestion was made in the House of Lords[7] that, as the Government was now liable for compensation claims arising from the sinking of the *Derbyshire* (a result of a deal agreed during the privatisation of the shipyard which built the vessel), there was an interest in seeking conclusions which would clear the construction of the ship from blame. Furthermore, one of the UK assessors was asked to resign following the publication of a technical article in conjunction with a technical assessor representing the shipyard which promoted the theory of hatch cover failure being responsible for the *Derbyshire*'s loss. This alleged presupposition of the results of the Formal Investigation angered political figures and his resignation was called for by the then Minister of Transport. In addition, the DFA was upset that they were not involved in the planning process for the survey, only attending meetings with assessors in order to be kept informed of developments.

4.5.5. The results of this second survey proved to be much more detailed than those of the original DFA/ITWF survey, including more than 135,000 individual images and some 200 hours of continuous video footage. The two remaining assessors concluded on the basis of the photographic evidence that the vessel's loss had been caused by seawater entering the bow section which caused the vessel to develop a forward trim, thereby exposing its No.1 hatch covers to wave heights great enough to impose loading in excess of their collapse strength. Water then poured into the large empty space above the cargo in the No.1 hold. That put the vessel further down by the bow until No.2 and No.3 hatch covers sequentially suffered the same fate. The vessel would then sink.

4.5.6. However, the disturbing aspect of this Report was that the main reason for entry of seawater into the bosun's store in the first place was found to be the failure of the crew to secure the lid to the hatch on the foredeck. This conclusion clearly involved the imputation of serious negligence against the officers and crew, deeply upsetting the DFA. In addition, the conclusion also acquitted the design and construction of the vessel in way of frame 65 of any causal contribution to the loss.

4.5.7. It was considered that the information obtained from the survey and subsequent assessors report constituted, in the words of the Merchant Shipping Act 1995, "new and important evidence which could not be produced at the original investigation". On that basis the Deputy Prime Minister ordered that the Formal Investigation be re-opened.

4.5.8. The terms of reference for the Re-Opened Formal Investigation were determined in part on the basis of public submissions. These were sought by the Secretary of State of the Department of Environment, Transport and the Regions (DETR) when announcing the Re-Opened Formal Investigation. Submissions were sought on whether the Formal Investigation should be re-opened in whole or in part, what questions it should address and whether the re-hearing should be held by a Wreck Commission or by the High Court.

4.5.9. It was announced on the 17th of December 1999 that the whole Formal Investigation would be re-opened and would take place in the High Court. The terms of reference for the inquiry were to cover questions relating to the following areas:

- **Causation**

  1) What were the most probable cause(s) of the loss of the *Derbyshire*?

  2) What possible causes (previously considered by the Formal Investigation or Lord Donaldson's Assessment) can be eliminated in the light of the new evidence of the wreckage of the *Derbyshire*?

  3) What other possible causes of the loss of the *Derbyshire* remain open?

- **Fore-end flooding**

  4) In so far as material to the loss of the *Derbyshire*, was the design of the *Derbyshire* in way of her fore-end (from frame 339 forward - including her hull, bow height, deck, deck openings and fittings) in accordance with the standards applicable at the time she was built?

  5) Is the design satisfactory in the light of what is now known?

  6) In so far as material to the loss of the *Derbyshire* in way of her fore-end? If so:

     a. what repairs were carried out?

     b. was her condition satisfactory after such repair?

- **Hatch Covers**

7) In so far as material to the loss of the *Derbyshire*, was the design of the hatch covers of the *Derbyshire* in accordance with the standards applicable at the time she was built?

8) Is that design satisfactory in the light of what is now known?

- **Standards**

9) At the time when the vessel was:

   a. designed; and

   b. built;

   were the regulations and classification society rules for:

   i. assignment of freeboard;

   ii. design of her fore-end (from frame 339 forward – including her hull, bow height, deck, deck openings, and fittings); and

   iii. design of her hatch covers

   inadequate in any respect material to the loss in the light of the then current state of knowledge and what ought reasonably then to have been known or anticipated?

- **Seaworthiness**

10) When the *Derbyshire* sailed on her last voyage from Sept-Isles was she in all respects seaworthy for her contemplated voyage to Japan in so far as material to her loss?

11) Did she cease to be seaworthy in any respect material to her loss at any time prior to her loss, and if so in what respects where and when?

- **Frame 65**

12) a) Is there any evidence of defective design, construction or repair of the structure in way of frame 65 in the wreckage of the *Derbyshire* which would materially impair the safety of the vessel or those on board her?

   b) Are the present-day classification society rules and instructions to surveyors adequate as regards the quality of design, construction and repairs of the structure in way of frame 65?

- **Navigation**

13) a) Was the information and advice provided to the *Derbyshire* by Oceanroutes Inc. adequate and appropriate in the circumstances?

   b) If not, then did the inadequacy or inappropriateness of such advice and information cause or contribute to the *Derbyshire*'s close encounter with typhoon “Orchid”?

c) Did the master navigate appropriately in the light of the weather information available to him?

- **Recommendations**

14) a) What steps should be taken to avoid a similar loss in the future?

b) Should the current regulations or current classification society rules or instructions to surveyors be amended to avoid a similar loss in the future?

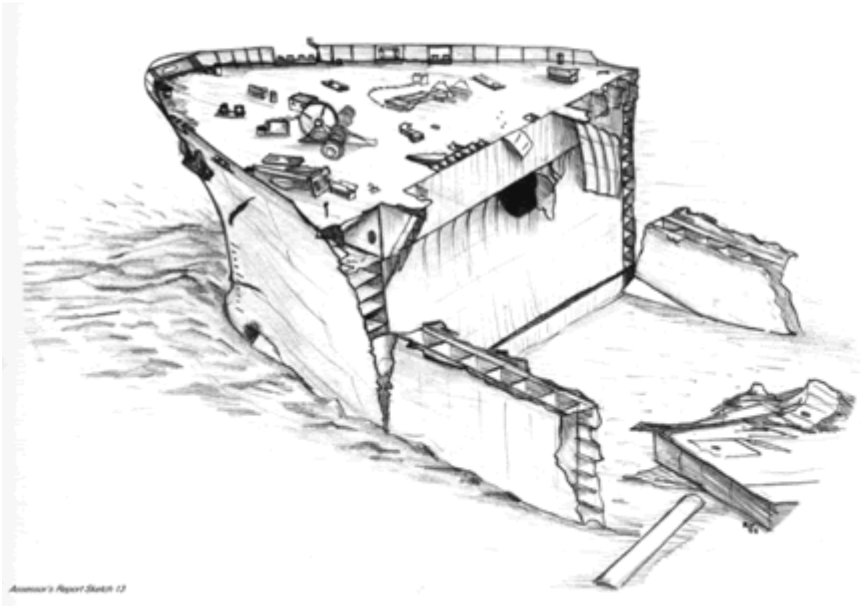

Figure 1: Sketch of bow of *Derbyshire* on seabed.

4.6. Outcomes of Reopened Formal Investigation

4.6.1. The Re-Opened Formal Investigation commenced on Wednesday 5 April 2000 before Mr Justice Colman and lasted for 54 days, concluding on 26th July 2000. Twenty scientific and technical experts, six master mariners and five other witnesses gave oral evidence. The parties to the Investigation were:

- The *Derbyshire* Families Association
- Bibby Tankers Ltd, the ship owner
- SHSE.G.L Realisations Ltd, the successors to Swan Hunter, the shipbuilders
- Lloyd’s Register of Shipping
- The Department of the Environment, Transport and the Regions (DETR).

4.6.2. The result of the Formal Investigation was that the initiating cause of the loss was determined to be the destruction of the ventilators and air pipes on the fore deck by continuous green water loading over many hours on the 8th and 9th September 1980. The seas then flooded the bosun's store and the forward ballast tank. It was found that the previous judgment by the assessors that this flooding resulted from the inadequate securing of a hatch cover on the forward deck by the crew was not supported by the evidence available.

4.6.3. The flooding of the forward compartments caused the ship to trim down by the bow and eventually sink. This trim was not perceptible from the bridge because it would have been obscured by the extremely poor visibility that was likely at the time due to driving wind and spray. Also the bridge was over 260 metres (850 feet) from the bow. The sea started crashing onto No 1 hatch cover as the bow dropped lower in the water. No 1 hatch cover was not designed to withstand such enormous pressures and eventually gave way. This caused No 1 hold to flood and so the bow went down even more. The same thing then happened to the other hatches, one after the other, until each hold filled with water and the ship finally sank. The Court also concluded that it was most unlikely that the ship had been lost due to any other cause - including faults at frame 65. The Court believed that it was most unlikely that she ever went beam on to wind and sea as was suggested in the Formal Investigation held in 1987-1988.

4.6.4. The report included four recommendations on hatch cover strength and permissible freeboard, five on navigational matters and fifteen on additional matters, mostly research projects to be carried out by the International Association of Classification Societies (IACS), the International Maritime Organisation (IMO) and the UK Government. These would seek to develop improved water tight integrity of ship weather decks and improved casualty reporting methods, including the installation of "black box" voyage data recording systems.

4.6.5. The recommendation with the greatest potential impact on the world's bulk carrier owners concerned the relationship between cargo hatch cover strength and the height of bow freeboard, which the judge said should be totally re-evaluated. Mr Justice Colman found the existing international hatch cover strength requirement, contained in the International Convention on Load Lines 1966 (ICLL 66), to be “seriously deficient”. He also found that the current increased IACS standard, UR S21, might also be inadequate although “at worst it may not fall very far short of what might reasonably be required”.

4.6.6. This finding was considered likely to involve the world's merchant fleets in considerable additional expenditure. In particular, it was proposed that such changes to the rules governing the design of bulk carrier vessels should be applied both to new vessels and retrospectively to existing vessels. This would require modifications to existing ships to strengthen their hatch covers and increase the freeboard, the latter through either increasing the fore deck height or operating at reduced draught (i.e. carrying less cargo).

5. Issues Arising from Major Inquiries

5.1. The investigation of the sinking of the *Derbyshire* provides an indication of some of the issues that can arise following a significant vessel loss. Among the important aspects are:

5.1.1. Establishment of Incident Investigation:

5.1.1.1. The response to the sinking of the *Derbyshire* was complicated by the fact that the location of the wreck of the vessel was not known. On this basis it was concluded that it was not possible to carry out a Formal Investigation into the causes of the loss. This response was, unsurprisingly, not accepted by the families of the 44 people who died on board.

5.1.1.2. The decision as to whether or not a formal investigation is warranted following an accident should ideally take into account the loss of life involved and the desire of the families of those lost to determine the cause of the incident. The fact that no Formal Investigation was held initially following the sinking meant that the families of the crew of the *Derbyshire* felt it necessary to form their own pressure group (the DFA) to try and force the establishment of such an investigation.

5.1.2. Involvement of Families of Victims:

5.1.2.1. The initial study performed by the DoT to determine the cause of the *Derbyshire* sinking was in part prompted by pressure from the DFA. However, the during the study the DFA was not involved. This meant that when the draft document was subsequently leaked and the differences between it and the official final report became apparent, there was a not unexpected suggestion that vested interests were responsible for the changes. The resultant publicity undoubtedly affected public confidence in the investigation process.

5.1.2.2. To involve representatives of the victims in the reporting process would help to prevent such situations from occurring. When the Formal Investigation was reopened, funding was provided to the DFA to employ their own technical assessors who were involved in the investigation process.

5.1.3. Appointment of Marine Accident Inspectors:

5.1.3.1. The Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 provide for the appointment of inspectors of marine accidents by the Chief Inspector to carry out a Formal Investigation. These inspectors should act impartially and should not have a previously stated view on the likely outcome of the investigation.

5.1.3.2. Goals of Investigation: The purpose of any Formal Investigation should be in accordance with the requirements of the Merchant Shipping (Accident Reporting and Investigation) Regulations 1999, in that it does not seek to apportion blame but rather to determine the circumstances of the accident and to help prevent similar accidents from occurring in the future.

5.1.4. Recommendations of Investigation:

5.1.4.1. Sufficient authority must be brought to bear by the Government to ensure that the recommendations that arise from a Formal Investigation are incorporated into relevant regulations. In particular, the greatest benefit from these recommendations is likely result from their incorporation in the guidance of international organisations such as IACS and the IMO.

Footnotes

i. Gross tonnage (GT) = K1 V where V is the total volume of all enclosed spaces of a ship in cubic metres and K1 = 0.2 + 0.02 log10 V. GT values of 100 and 500 correspond to volumes of 397 and 1883 respectively.

ii. The ISM Code establishes safety-management objectives and requires a safety management system to be established by "the Company", which is defined as the shipowner or any person, such as the manager or bareboat charterer, who has assumed responsibility for operating a ship.

The following vessels and their owners/operators must have Safety Management Certificates for their ships and Documents of Compliance for their offices by 1st July 1998:

- All passenger ships including passenger high speed craft.
- Oil tankers, chemical tankers, gas carriers, bulk carriers and high speed cargo craft of 500 gross tonnage and over.

ISM certification will be mandatory by 1st July 2002 for all other cargo ships and mobile offshore drilling units of 500 gross tonnage and over.

References

1. Spouge, J R, The safety of general cargo ships, Trans. RINA, IJME, Vol 145 (2003) Part A4.

2. Department of Transport, A report into the circumstances attending the loss of the m.v. *Derbyshire* on or about 9 September 19080 in position approximately 25de.g.rees30' North, 130de.g.rees30' East with the loss of 44 lives, 1986.

3. Faulkner, D., An independent assessment of the sinking of the *M.V. Derbyshire*, SNAME Transactions, Vol. 106, 1998, pp 59-103.

4. M.V. Derbyshire, Report of Court No. 8075, Formal Investigation, Department of Transport, 1989, ISBN-0-11-550896-1

5. Bishop, R.E.D, Price, W.G. and Temarel, P., A theory for the loss of the M.V. Derbyshire, Trans. RINA, Vol. 133.

6. Grigson, C.W.B., On the contention that bulkers and tankers are too weak for storms, Trans. RINA, Part B, Vol. 140.

7. Lord Dixon, House of Lords, 3 December 1987, Hansard, 3 Dec 1997 : Column 1456.

Curry R., “Merchant Ship Losses 1934-1993, An Overview”, Trans RINA vol 138, 1996.

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Transverse Sector Reports

Procedural Constraints and Opportunities for Investigations – Prof David Newland FREng

1. Synopsis

1.1. Conflicts of interest arise when finding the cause of an accident and learning lessons are confused with seeking to punish those responsible.

1.2. For most industries (except for aircraft, ships and, very recently, railways), the HSE (and/or the police) take primacy both for investigating accidents and for initiating prosecutions. Following established practice for investigating aircraft accidents, it has been suggested that independent standing bodies should investigate the cause of all major accidents.

1.3. The function of accident investigation would then be separated from consideration of wrong-doing and punishment. Definite conclusions about the cause of a major accident and the lessons to be learned from it are likely to be reached much sooner than has been the case in several recent high profile inquiries.

1.4. This alternative process in which investigating cause comes before determining punishment may disadvantage those likely to be prosecuted as a result of a major accident. In order to protect those potentially at fault, it is essential that knowledge gained by all accident investigators, including statutory bodies, should be freely and openly available to experts advising defendants in legal proceedings arising from accidents.

1.5. Balancing a potential "scene of crime" investigation with the requirements of an accident-investigating body requires new protocols for the removal, preservation and long-term storage of forensic materials. Establishing the admissibility or otherwise of evidence collected in an accident inquiry in any subsequent legal proceedings may prove a very difficult complication.

1.6. It has been suggested that the identity of witnesses in an initial inquiry to determine the cause of an accident should be kept secret. However this presents formidable problems.

1.7. Once a technical inquiry has reached a conclusion it may be extremely difficult, if not impossible, for individuals to challenge these findings because of the huge resources required to do so. Nevertheless to rest a prosecution on the outcome of an engineering inquiry and secure a conviction without adequate provision for that inquiry's conclusion to be challenged breaches the rules of natural justice.

1.8. The modern trend to assign blame when accidents happen may make insurance to cover legal defence costs as important for engineers as it is for doctors. Whether corporate or individual, potentially huge costs are involved.

2. Conflicts of interest

2.1. A public inquiry was set up within days of the chemical plant explosion at Flixborough in 1974. Conduct of the inquiry was handled by the Treasury Solicitor who appointed a leading consulting company to gather evidence. As a result, formal hearings began within months. The Court of Inquiry's report was published within a year of the accident (the accident was on 1 June 1974 and the Inquiry's Report was signed on 11 April 1975). Its conclusions had a far-reaching effect both for the industry and for the HSE which was then in the formative stage of its early development. But there were no prosecutions either of individuals or of the companies involved at Flixborough although glaring inadequacies of operational procedures became apparent.

2.2. Now, 30 years later, such individual and corporate failures will invariably lead to prosecution or at least the threat of prosecution. As a consequence, the interests of those potentially threatened by prosecution must be protected. The mechanism of doing that as investigations of accidents and near-misses proceeds has not yet been agreed.

3. Who should investigate

3.1. An important initial step is to decide who should investigate a major incident. In the case of Flixborough, the lead consultants had a substantial number of people they could apply to the task, and they quickly supplemented these with other specialists recruited from industry and the universities. This established an informed, independent and inter-disciplinary body of people with the necessary expertise. Also the parties to the Inquiry had their own experts and they all had open access to the results of site investigations and other evidence.

3.2. That *ad hoc* approach worked well in the circumstances of the time, but would be unlikely to happen again. Unless there are exceptional circumstances, the HSE would now take primacy in accident investigations (except for aircraft, ships and, very recently, railways). It has been suggested that the possibility of using standing bodies of technical investigators like AAIB, MIAB and RIAB merits examination as an alternative means of investigating accidents in other industries. The initial experience of the RIAB (including how it works with the BTP) will be a helpful guide in what is at present uncharted territory outside the aviation and marine fields. The main point at issue is how accident investigators and police interact and how the interests of the parties concerned can be properly protected.

4. Need for transparency

4.1. A disadvantage of any standing body is that it may build up a corpus of unpublished technical accident data relating to its own industry so that other experts for interested parties in consequential court cases will be disadvantaged by not being so well-informed. The sharing of technical information, whether gathered from specific accident studies, or gleaned from the experiences of others elsewhere in the world, needs to be a mandatory duty for any government-appointed accident investigating body.

5. Who should prosecute

5.1. At present HSE has responsibility for ensuring that the Health and Safety at Work Act is observed and for initiating prosecutions when it is not observed, but for air, marine and, now, railway accidents the position is more confused. British Transport Police have held primacy in some recent railway accident investigations. Peter Watson has noted that this “can damage the output of the technical inquiry and have other conflicting consequences.” Also Jeff Jupp has commented that “Evidence given to AAIB inspectors will not subsequently be used in a criminal prosecution.” I am not clear how that works. For manslaughter allegations, ultimate authority rests with the Director of Public Prosecutions but the role of the police is paramount, and balancing a potential “scene of crime” examination with the requirements of an accident-investigating body requires new protocols to be established for the removal, preservation and long-term storage of forensic material. Establishing the admissibility or otherwise of evidence collected in an accident inquiry in any subsequent legal proceedings may prove a very difficult complication.

6. Defending prosecutions

6.1. There remains the need to work out how individuals (and companies) caught up in events that lead to the threat of their prosecution should have their interests properly protected. It has been suggested that the identity of witnesses in initial inquiries carried out by statutory bodies should be kept secret. However this presents formidable problems. There have been examples of air accidents which have been attributed by initial inquiries to pilot error, which have led to disciplinary action against the pilots concerned, but which have subsequently been vigorously contested by the pilots and their representatives (who may not have participated in the initial inquiry). A disadvantage is that once an initial technical inquiry has reached a conclusion it may be extremely difficult if not impossible for individuals to challenge these findings because of the huge resources required to do so.

6.2. Nevertheless engineers know that there are often alternative explanations for technical failures and that all experts are fallible. To rest a prosecution on the outcome of an engineering inquiry and secure a conviction without adequate provision for that inquiry's conclusion to be challenged would seem to breach the rules of natural justice.

7. Legal costs

7.1. This raises the question of the cost of inquiries and of mounting a defence against charges that may follow from the conclusion of such an inquiry. The possibility of mandatory insurance to cover legal defence costs may become as important for engineers as it is for doctors. Potentially huge costs are involved and the bankruptcy of companies and individuals is by no means impossible.

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Legal Framework – Prof John Uff FREng

1. Introduction

1.1. The individual sector papers demonstrate the wide variety of legal rules and the different legislative paths which different industries have followed to arrive at the present point. There are some significant common features spanning a number of sectors, particularly through the Health and Safety at Work Act 1974 and its Regulations. European Law, which has the potential to create unifying structures appears to have had little effect up to the present. It will increasingly influence developments in industries that span the European community, particularly railways. Other fields, notably shipping and aviation, cannot sensibly be limited to Europe and operate on the basis of international conventions. These particular industries have in fact shown the way to overcome some of the deep-seated problems arising from the interaction of different interests and jurisdictions in the conduct of investigations.

2. Different Fora

2.1. Within the UK, it is to be noted at the outset that an accident involving either injury to persons or damage to property will inevitably give rise to a multiplicity of actual or potential legally-based procedures and fora which will frequently come into conflict as they pursue their separate objectives. A brief summary of the more significant individual procedures is as follows:

2.1.1. Coroners' Court

2.1.1.1. The Coroner for each district (who is usually dual qualified in medicine and law) is required to hold an inquest into the death of any persons which appear to have been violent or unnatural or of unknown cause[1]. Coroners' Courts are of ancient and uncertain origin, but they have acquired a new relevancy as a court of record where evidence concerning the death will be heard in public. The Coroner will usually open an inquest shortly after the accident and then adjourn the proceedings pending other forms of inquiry. Inquests have been used in a number of high profile cases as a vehicle for seeking to expose evidence not otherwise available through other proceedings. The process is subject to judicial review and, in a number of cases, applications have been made to the High Court for orders compelling Coroners to re-open inquests expressly for the purpose of allowing further investigation into evidence, usually on behalf of aggrieved relatives. This process can continue almost without limit and affords considerable opportunities to re-open old cases.[2]

2.1.2. Civil Court Proceedings

2.1.2.1. Persons injured or suffering other physical loss as a result of accidents are generally free to bring civil actions against those responsible. Liability may be denied by the Defendants but in the case of members of the public the only serious contest is likely to be as between different Defendants who may each blame others. A recent well-publicised example was the Civil Proceedings brought following the Potters Bar rail accident where the maintenance contractor disputed its liability. All companies likely to be involved as Defendants will maintain appropriate liability insurance and, in the case of the Rail Industry, the prime operators are required to maintain cover through the same insurer so that no such dispute should normally arise.

2.1.2.2. In the case of employees or other work persons who may suffer injury or loss, legal action against employers may sometimes be seriously contested on the ground that the injured person was himself or herself responsible. In general terms, however, statutory insurance requirements mean that injured persons rarely go uncompensated. The factor which may prolong civil litigation will usually be the ascertainment of quantum of damages, but this may again be defused by the courts' ability to order interim payments. In practice, parties will suffer little detriment if the progress and final resolution of civil proceedings is delayed. Evidence presented in Civil Proceedings must be collected by or on behalf of the parties to the litigation through their own legal advisors.

2.1.3. Criminal Proceedings

2.1.3.1. Any loss of life caused by circumstances involving culpability on the part of companies or individuals responsible for a process or operation gives rise to the possibility of criminal proceedings, either under the Health and Safety at Work Act 1974[3] or, in the case of more serious conduct, by way of a charge of manslaughter or the proposed alternative statutory offence of corporate killing. Once a criminal investigation has commenced, the investigation process itself will be largely controlled by the police[4] who have the duty to collect evidence to be placed before the Director of Public Prosecutions, who must decide whether charges are to be brought.

2.1.4. Internal Inquiries and Investigations

2.1.4.1. Most industries provide for one or more forms of inquiry or investigation conducted by appointed persons who will normally be experts in the issues requiring investigation. The essence of these inquiries is that they should be conducted as soon as practicable and one of their objectives is to find and secure real evidence i.e. the damaged equipment, plant or vehicle. These inquiries operate under a variety of legal umbrellas. In the case of rail and air accidents in particular, they are likely to require support from emergency services and the police to carry out their work. In the latter case this creates a real potential for conflict of interests where the police are also engaged in collecting evidence for potential Criminal charges. Inquiries are not concerned with apportioning blame but with establishing what went wrong in order to pass on as soon as practicable any lessons which may affect other players in the industry. Some controversy has arisen in the past as to the identity of persons appointed to conduct such inquiries or investigations. It is now generally accepted that all such persons must be independent of any company or body involved in the accident or incident.

2.1.5. Public Inquiries

2.1.5.1. There have been a number of increasingly high-profile public inquiries conducted over the last two decades into accidents involving multiple fatalities in which there has been sufficient public interest and concern to justify the cost. These have concerned major railway accidents as well as a major fire incident (the Kings Cross Inquiry) and a shipping accident (the Marchioness sinking). In addition, the re-opened formal investigation into the sinking of the Derbyshire was conducted in the High Court in the same manner as a public inquiry.

2.1.5.2. Public inquiries are conducted according to specific Terms of Reference by inspectors or panels appointed, usually with the approval of the Secretary of State. As in the case of internal inquiries their objective is to determine facts and causes (not liability) and to make recommendations for the future conduct of the industry in question. They serve to afford appropriate publicity to the events under consideration and usually involve a much wider range of representation and views than would be the case in any other form of proceedings. They are, however, invariably protracted and expensive, the inquiry process itself being largely funded from public sources.

3. Cross Industry Issues

3.1. The individual industry papers contain a number of common features which touch on legal issues and procedures. These can conveniently be dealt with under the following headings.

3.1.1. Post-Accident Procedures

3.1.1.1. As noted, there is a serious potential for conflict between technical accident investigators (comprising the initial stage of an internal inquiry) and potential prosecuting authorities comprising the police and/or (in the UK) HSE Investigators. Each has an interest in securing and preserving real evidence but this may be done through entirely separate investigation processes. The police will usually be capable of enforcing their own procedures, at least in the short-term, and this has on a number of occasions resulted in experts being excluded from a crash site and important evidence being initially overlooked or even lost. Examples are given in the Rail Accident Investigation Report (Peter Watson). A detailed account of the generally unhelpful intervention of the British Transport Police is given in the report of the public inquiry into the Southall rail crash in 1997 (report published 2000). In the aviation field, crash investigators are said to have more clout as a result of the Convention on International Civil Aviation (the Chicago Convention). But the sector report (Jeff Jupp) relates similar problems which occurred in Paris following the Concorde crash, where investigators were hampered by the French authorities, apparently in breach of the Chicago Convention. In the UK, apart from aviation, such problems are generally dealt with by non-binding protocols between the police and the investigating bodies. At the Southall rail accident site, the protocol was found to be seriously wanting. It was revised and was said to operate much more efficiently at the Ladbroke Grove crash site.

3.1.2. Decision to prosecute and its effects

3.1.2.1. The root cause of the friction between investigators and the police is the need for the latter to collect evidence in support of possible prosecution proceedings. Where such proceedings are considered to be a serious possibility an accident will be declared a “Scene of Crime” and cordoned off by the police, leading to the type of conflict already mentioned. As long as there remains an intention to bring criminal proceedings (the final decision will be taken only upon advice based on the evidence collected) the police will seek to withhold relevant evidence from publication so that the prospective accused are not prejudiced. The protocols mentioned above provide for the release of safety-sensitive information to the relevant operating authorities, but there remains a serious problem in obtaining evidence necessary to support a public inquiry.

3.1.2.2. In addition to the problem of collecting evidence, it will not usually be possible for a public inquiry to proceed while criminal charges are outstanding. As quoted in the aviation report, a memorandum was issued by the Lord Chancellor recognising that in a case of serious criminality, prosecution proceedings should take precedence over the public interest in the holding of an inquiry. This issue has been the subject of much public debate including opinions expressed by the Parliamentary Transport Committee. It remains the case, however, that criminal proceedings must normally take precedence. This was the case following the Southall rail crash, where the public inquiry was held up for two years on account of criminal proceedings which ultimately proved largely abortive. Conversely, following the Ladbroke Grove accident, the public reaction was such that a decision was made to proceed with the public inquiry. It was recognised that this would make criminal proceedings (other than technical charges brought under the Health and Safety at Work Act) incapable of being maintained. This still gives rise to serious expressions of public concern that those who were thought to be responsible have not been brought to book.

3.1.3. Adequacy of Internal Inquiries

3.1.3.1. All or most industries have their own procedures for internal or "non-public" inquiries, conducted by appointed experts who are available to act at short notice. These procedures are highly developed in the marine and aviation fields, who benefit from bodies established under international conventions: in the case of marine accidents, the Marine Accident Investigation Branch (MAIB) established under the Merchant Shipping Act 1995 and its Regulations; and in the case of aviation, the Air Accident Investigation Branch (AAIB) established under the Chicago Convention. While, as already noted, they can potentially suffer through competition with other investigating authorities, the AAIB and the MAIB are generally successful in securing and preserving real evidence relevant to the crash investigation. The importance of this is well illustrated in the Aviation Report (Jeff Jupp).

3.1.3.2. The extent to which internal inquiries in other fields and industries are satisfactory varies. The internal investigating procedures in the Rail Industry at the time of the Southall crash (1997) were unsatisfactory in that there was no requirement for an independent Tribunal. The Tribunal in fact appointed decided not to investigate an issues (whether the ATP system was working) which later became a matter of some importance in the public inquiry. Procedures have been progressively improved and, as a result of Lord Cullen's second report in the Ladbroke Grove inquiry, there has now been established a Rail Accident Investigation Branch (RAIB), modelled on the marine and aviation precedents. One of the intentions is to provide for public access to inquiries set up under the new regime in order to obviate a least part of the argument for holding a public inquiry. The RAIB was established under the Railways and Transport Act 2003 and has not yet been tested in earnest.

3.1.3.3. One of the disadvantages of internal inquiries is the potential for suppression of publicity and in particular that reports may never be published. This was the case following a major nuclear incident at Windscale in October 1957. Despite the gravity of the incident, inquiry reports were never published.

3.1.4. Inquiry Procedures

3.1.4.1. Internal inquiries and indeed public inquiries up until recent times have been conducted using "inquisitorial" procedures by which the Inspector or investigating panel itself makes inquiries, identifies evidence and seeks to uncover the truth. Witnesses called to give verbal evidence will be examined by the panel members who will also search out and examine relevant documents. This is in sharp contrast to both Civil and Criminal Court procedures which are generally "adversarial" in nature. The Tribunal (which will include a lay jury in criminal proceedings) acts as a passive assessor of the evidence presented on behalf of the parties or the prosecuting authority and the issues are argued out by advocates for the parties.

3.1.4.2. Regrettably the adversarial approach has expanded in recent years into the field of public inquiries. All of those conducted in the last decade or more (including the Kings Cross inquiry) have been conducted on an adversarial basis with the parties represented by barristers and solicitors. This situation is indeed perpetuated by the regulations dealing with public inquiries (Health and Safety Inquiries (Procedure) Regulations 1975) which require a procedure more akin to Court proceedings than an inquiry. These Regulations make express provision for any person who was injured or suffered damage as a result of an accident, or his personal representatives, to be entitled to appear at the inquiry, usually with the assistance of publicly funded legal representation. This is, in large part, responsible for the huge escalation in the length and cost of public inquiries. The setting up of the RAIB may be seen as a reaction against this trend aimed at permitting a more rapid investigation procedure to which the public may be given some access, but without the right to play a prominent part in it as seen in successive public inquiries.

3.1.5. Public Inquiries and other procedures

3.1.5.1. The usefulness of public inquiries is not to be doubted. The inquiry into the Piper Alpha disaster in 1988 led to the introduction of an entirely new approach to safety based on the Safety Case System as now applied to the Oil and Gas Industry. In 1992 the same principles were applied to the forthcoming privatisation of the Heavy Rail network, leading to the Safety Case System currently in operation. Until about 2000 there was a firmly established convention that public inquiries should be held into accidents involving multiple fatalities (usually in excess of four). This convention was, without any public announcement, departed from following the major rail incident at Hatfield in which a derailment followed disintegration of the railhead. The cause was soon diagnosed as gauge corner cracking (GCC), a phenomenon which was already well-known but whose significance was said not then to be fully appreciated. As is well known, the consequences of the Hatfield crash were immense. Railtrack, then the infrastructure operator, had no detailed asset register and no means of knowing the extent of the previously unheeded danger. The immediate result was the widespread imposition of Emergency Speed Restrictions and general disruption of services, accompanied by large-scale track repairs and replacements all at huge cost.

3.1.5.2. The repercussions of the Hatfield accident included the winding up of Railtrack and its replacement by Network Rail and other consequences which are still operative. Yet no public inquiry was ordered and a full account of the circumstances of the accident is still awaited. Hatfield was followed by other fatal accidents at Great Heck (train derailed by land-rover on line) and Potters Bar (derailment following points failure) each of which would normally have given rise to public inquiry. There has been no officially announced policy change. Whether the next major rail accident leads to a public inquiry remains to be seen.

3.1.5.3. Instead of a public inquiry into the Hatfield derailment, the decision was announced in 2003 to bring manslaughter charges against six individuals and two companies involved in the accident. The case will be heard at the Old Bailey, probably in 2005, although at the time of writing there is before the Court a strike-out application on the ground that the Accused can no longer receive a fair trial by reason of the inordinate delay since the accident (October 2000). Other high profile criminal proceedings have been brought in relation to the sinking of the Herald of Free Enterprise and, as described in the Nuclear Industry report (Sir Robert Hill), in relation to the accident at the Wylfa Nuclear Power station in July 1993. It is commented that there was "long delay" before the case eventually came before the Court in September 1995. This might be contrasted with the four years which it has so far taken the prosecuting authorities to bring the Hatfield case to Court.

3.1.5.4. The comment to be made in relation to all these cases is that it is highly questionable whether the Criminal Courts are an appropriate vehicle for placing such serious incidents before the public. The nature of the criminal process is that part only of the available evidence will be presented and the process of inquiry will be limited to seeking to establish criminality on the part of the specific defendants, rather than enquiring more generally into what went wrong and as to its consequences. Furthermore, the delay involved (whether two years or five years) inevitably means that the industry in question has moved on and the procedures in use at the time of the accident are unlikely to be of much relevance to any future incidents. The Crown Prosecution Service has a poor record in establishing convictions for manslaughter arising out of major accidents. It is doubtful whether the public would regard the conviction of any of the accused as throwing more light on the original incident than would an acquittal.

4. Conclusion

4.1. The Law and the legal profession play a significant and at times dominant role in some aspects of the aftermath of major accidents. Their contribution in terms of public inquiries has been notable in establishing serious shortcomings and promoting the adoption of more appropriate procedures, as in the case of Piper Alpha. Public inquiries, however, run the serious risk of becoming hijacked by special interest groups, a development which is encouraged by the applicable Regulations. If public inquiries have become unacceptable in their present form on account of their length and cost, a solution would be to devise better procedures for such enquiries. Criminal prosecutions are not an adequate substitute for the public airing of such matters.

4.2. There is no generally applicable legal framework governing the aftermath of major accidents and incidents. Action through the European Community remains at a relatively low level. Consequently, different industries are governed by different regimes, although the Health and Safety at Work Act 1974 provides many common features which apply in the absence of specific provision. Air and marine investigation procedures are governed by particular measures deriving from international conventions and these have generally proved successful in promoting the rapid and efficient investigation of accidents. This model has now been adopted for the Heavy Rail system but still awaits its first major test.

Notes

1. See generally Halsburys Laws of England vol 9(2) para 852.

2. See e.g. R v Inner West London Coroner ex p Dallaglio [1994] 4 AER 139 regarding re-opening of the Marchioness Inquiry.

3. Section 3(1) imposes a duty, so far as reasonably practicable, not to expose persons to risks to their health or safety.

4. In the case of a railway accident, the British Transport Police.

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Human Factors– Prof Helen Muir

1. Synopsis

1.1. The term 'Human Factors' is widely and variously used. It may be used to denote an area of academic study, to reflect some issues affecting people's performance at work, or to identify possible contributions to the causes of an accidents or incidents. One of the difficulties is that the term does mean different things to different groups of people. A widely used definition suggests that "human factors concerns the interaction between people – their characteristics and abilities, organisation and management – and technology" (Dekker 1998). In the context of accident investigation, the term 'Human Factors' can be used to encompass all of those considerations which affect an individual's ability to perform the task.

1.2. Figures for the contribution of human factors to accidents and incidents do vary but there is general agreement that in as many as 70% of accidents, human factors issues will have been involved. Some estimates put this figure as high as 80 or 90%. It has been suggested that as technology advances, reliability increases, and the proportion of mechanical failures falls, then the proportion of accidents in which human factors are implicated can only increase. Interestingly this does not necessarily appear to be the case. Even during the Second World War, two out of three Spitfires which crashed were reported to have been due to a 'human error'. This led the Government of the time in 1939 to fund the Psychology Laboratory at Cambridge University to conduct research into the human acquisition and maintenance of skills. The 'Cambridge Cockpit' which was developed for this purpose was the first attempt to develop a simulator for the study of human performance. In aviation, as in many other industries, it was widely believed that as technology advanced and more of the tasks which had been under the manual control of the pilot were subsumed by the avionic systems, not only would the accident rate fall, but the human factor would become of less importance. Undoubtedly, automation did change the nature of the task for the pilot and the accident rate did fall. However, the percentage of accidents involving human factors did not significantly change. It did however lead to a change in the nature of the human factor causes and contributors to accidents.

1.3. When considering accident causation it is important to differentiate between the factors which contribute to accidents and the factors which cause them directly. Causal factors are typically failures of critical pieces of equipment or actual human errors. By contrast, contributory factors include aspects of the task itself, or the conditions in which the task is carried out, which promote human failures. Thus, removing a causal factor would have prevented the accident, whereas removing a contributory factor from the accident chain would have reduced the probability of the accident occurring. (Active safety management is aimed at reducing the occurrence of contributory factors.) An error can be defined as a human action that exceeds some limit of acceptability or tolerance. Much has been written on the subject of human error but for the purpose of preventing or understanding accidents, it can be useful to differentiate between unintentional errors (slips, lapses) such as may occur through lack of attention or memory failure, and intentional errors (mistakes, violations) such as intentionally not complying with a procedure (Reason 1990). The problem for investigators is that, particularly in a highly automated environment, many human factors tend to contribute to accidents and incidents, rather than causing them directly. Thus "the relationship between human performance and an accident or incident is usually probabilistic and not direct" (Thomas 2003). This can create difficulties for those who may be more used to dealing with mechanical failures, where failure modes may be more predictable. However, the importance of the human factors part of the accident investigation process is that in addition to providing information on “what” has happened, it can also provide valuable information on “why” the accident happened.

1.4. When considering human factors and accident investigation it is also important to be aware of the distinction between primary and secondary safety. Primary safety, also known as active safety, refers to the things which can be done to prevent the occurrence of an accident e.g. good ergonomic design and operator training. Secondary safety, also known as passive safety, refers to steps which can be taken to minimise the consequence of an accident e.g. crashworthiness and passenger evacuation procedures. Whenever an accident or incident is being investigated, both primary and secondary safety factors will require consideration as these factors may not only be relevant as a cause or contributor to the accident but will also influence the human behaviours which occur during and following the event.

2. The Investigation of Accidents and Incidents

2.1. The primary purpose for investigating any accident or incident must be to obtain learning and, where appropriate, instigate change. Although individuals do make mistakes, these must always be considered within the context of the system in which the individual is working. That is not to say that humans do not make errors, sometimes without any apparently predisposing factors in the system. Also it is clear that on some occasions, individuals or groups will deliberately violate rules and procedures (Reason 1989). Such situations obviously require action. However, individuals exist within a system and overlooking the possibility of system-based antecedents in error occurrence is to overlook the opportunity to take more far reaching preventative measures (Baker 1999). In fact, only blaming the individual will not lead to a change to the system and do nothing to prevent future occurrences. For example, an accident occurred when a pilot was inadvertently partially sucked out of a windscreen of a BAC 1-11 as a consequence of an engineer inadvertently fitting incorrect windscreen retaining bolts during maintenance. Rather than merely blaming the engineer, as a result of the in-depth human factors part of the accident investigation, significant changes in the procedures and practices for aircraft maintenance were instigated (AAIB 1990).

2.2. Within each industry, criteria have been established for the classification of the severity of accidents and as a consequence the extent of the investigation required. In many industries the criterion for an accident which warrants a full-scale investigation involves the occurrence of a number of fatalities or major physical damage. However, there is an inherent danger in making the consequences of an accident the sole criterion for the comprehensiveness of the investigation. The reason for this is that chance frequently plays a part in the consequences of an accident. Take, for example, a heavy piece of metal falling off an aircraft, train or the side of a building. Depending on the location of the vehicle at the time, there could be no one near to be hit, there could be two or three people injured or there could be many fatalities (Perrow 1999). A criterion for the type of investigation undertaken should therefore also be the process by which the accident has occurred and its potential for consequences, rather than only the actual consequences which have occurred.

2.3. In addition to the investigation of accidents, there is much which can be also learnt from the investigation of incidents. The frequency of accidents to incidents has been likened to an iceberg (Van der Schaaf 1991) since there are many more incidents than accidents. However, because in any industry there are relatively few accidents and because there are opportunities to learn from both, it is important that information from incidents is also obtained. For example, from the investigation of incidents it is possible to determine whether any particular event is a repeatedly occurring problem or a ‘one off'. This will have implications fro the conclusions drawn and subsequent decisions taken. From the investigation of similar incidents a greater understanding of the particular situation can be gained together with any trends. Incidents may be defined as near misses and behavioural action involving errors with subsequent recovery. Thus many incidents can have the same potential consequences as accidents. Also, it is recognised that the behaviour of individuals or groups will not necessarily differ between an accident and an incident, although the consequences may be significantly different. In fact it has been asserted that "an incident investigation can often produce better accident prevention results than can an accident investigation" (ICAO Circular 240-AN/144 1993). The challenge in any industry is how much time should be spent investigating incidents as opposed to accidents and how and by whom should they be conducted.

3. Human Behaviour and Accident Investigations

3.1. In order to understand the potential contribution of human factors to the accident investigation process, some awareness of the major influences on human behaviour in accidents can be helpful.

3.1.1. Human Performance

3.1.1.1. The process by which humans take in information from the external world and make decisions about what is occurring and what actions to take is complex. Human performance in any situation will be influenced by what an individual expects to happen, what has happened to them in similar situations in the past and their assessment of the consequences for themselves and important others e.g. family, colleagues. Thus how a human behaves in an accident, either as the operator of the system e.g. driver, pilot, or as a member of the public e.g. passenger, will be influenced by what they expect, their previous experience and their estimate of consequences. In the rail accident which occurred when a driver failed to stop at a red signal (SPAD) at Ladbroke Grove, the driver had driven the route less than twenty times (limited experience) and that the signal had been yellow on all previous occasions meant that in the difficult visual sunlight conditions of that morning he relied too heavily on his expectations that the future would resemble the past (Cullen 2001). Emotional factors such as fear and stress, together with workload, fatigue and time pressure can also be important influences on human performance and decision making. The purpose of training is not only to develop competent skills but also to rapidly build up experience.

3.1.2. Human Behaviour After An Accident

3.1.2.1. After involvement in an event such as a accident, an individual will think about it in an attempt to remember as much as they can. The event itself may be replayed in the mind as a vivid "flash bulb" memory. This will be highly emotive and therefore liable to distortion. If an individual has an incomplete picture of the whole experience, or cannot understand what has happened, the mind forces them to make a hypothesis of what could have occurred, to attempt to complete the picture or to make sense of their experiences. Furthermore, over time, what has initially been a tentative hypothesis becomes more certain. This process is not necessarily helped by the fact that we tend to look for evidence to support our hypotheses and not seek evidence which may refute them. Our ability to recall memory for an event is also influenced by an individual's expertise and experience of the issues relevant to the event. The whole process will also be influenced by what an individual subsequently learns, either by talking to others or from the media. Research has indicated that as the length of time increases, the accuracy of subsequent recall declines (Loftus, Greene and Doyle 1989). This is why it is of paramount importance that the process of interviewing those involved in the accident, together with key witnesses, is undertaken at the earliest possible opportunity and before they have a chance to talk to each other or to obtain information from the media.

3.1.3. The Influence of Attitudes and Culture

3.1.3.1. Following involvement in an accident, the cultural background and attitudes of an individual can all influence the information given to investigators. Today's world is not a blame free culture. In fact, one of the difficulties associated with accident investigation is that if those investigating the accident are perceived to have the intention of apportioning blame, the information which they are potentially able to obtain may be impeded (Baker 1999). Individuals do not normally "intentionally" make mistakes, nevertheless during the investigation process everyone who can be potentially regarded as culpable can feel under threat (from driver to members of management). Members of the public, either passengers or witnesses, may not be familiar with the vehicle(s) and therefore may have difficulties describing verbally what they have seen. Diagrams or models of the vehicle(s) can assist more accurate recall. Many factors can, perhaps not even consciously, influence their account of their decisions and experiences. For instance, some of those who have survived the accident will be wanting to establish culpability and will be immediately seeking compensation and this can have an influence on their account of their experiences and observations. Following most major transport accidents, the passengers are usually interviewed by the police. In the public mind the role of the police is to 'solve the crime' thus this may unintentionally influence what is reported to them. The religious and cultural differences may also influence this process, especially when fatalities are involved.

4. The Collection of Evidence

4.1. Following any accident information must be obtained from all those associated with the accident or incident under investigation. This will include the operators of the system (driver, pilot, etc.), other associated co-workers (e.g. cabin crew), other staff involved within the control of the system (e.g. signaller, air traffic controllers), where relevant, members of the public travelling as passengers and members of the organisation or the public who were eye witnesses to the accident. Since accidents happen within a system, it may also be relevant to interview members of the management team of the organisation involved.

4.2. In addition to examination of the physical evidence, interviews with all of those involved enables not only the event but the whole context in which the accident took place to be better understood. Because of the complexity of human behaviour, the process of conducting these interviews requires professional human factors specialist expertise.

4.3. It has historically been proposed that "most accidents and incidents are investigated by investigators who are trained as "generalists" and that human factors investigators need not be "physicians, psychologists, sociologists or ergonomists" (ICAO Circular 240-AN/144). However, it is increasingly being recognised that this attitude can limit the quality of the human factors contribution to the investigation. It is undoubtedly the case that it would never be suggested that the engineering or instrumentation aspects of an investigation should be conducted by a generalist. In the UK the aviation military has recognised the importance of a human factors professional always being an integral part of the accident or incident investigation team for several decades, as has been the case in air traffic control (Baker 1999).

4.4. Many of the issues arising from an investigation involve the application of the science of psychology, which includes not only ergonomics and equipment design, but attention, perception, decision making, problem solving, group processes. Thus, just as other specialist investigators need training in their science, human factors investigators need professional training in the science of psychology before joining an investigating team and obtaining training in the investigation task. In fact the British Psychological Society (BPS) currently states that chartered occupational psychologists are “the only professional group to have a minimum of six years training specifically on how people behave individually or in organisations”.

4.5. Across many of the safety critical industries and within the Health and Safety Executive there is recognised to be a shortage of suitable trained psychologists. One of the reasons for this is that there are currently no specific post-graduate courses or career structure which will enable them to become a chartered psychologist (equivalent to a chartered engineer). In the fields of clinical, occupational and forensics, relevant post-graduate psychology courses currently exist (accredited by the BPS) and students can apply for chartership from the BPS once they have achieved a post-graduate degree together with the appropriate supervised practice. A potential benefit to society could be the provision of an equivalent clearly defined career structure, involving post-graduate education and supervised practice in Safety and Accident Investigation, leading to registration as a chartered psychologist. This would enable the safety critical industries to attract high quality graduates who might otherwise pursue a career in an alternate field of application where the process of becoming a chartered psychologist was available.

5. Information from Members of the Public

5.1. When an accident involves large numbers of members of the public, for example in a major aviation or rail accident, it may not be practicable for the human factors specialists, or indeed even the “generalists” in the investigation team to interview everyone. In some industries this task is usually undertaken by the police. However, if the primary goal of the investigation is to obtain learning, consideration could be given to the recruitment and placing ‘on call’ of a team of trained and experienced professional interviewers. Such teams would be able to interview the personnel and passengers within a rapid time-frame and, given suitable training, would not necessarily have to be industry specific. In today’s world, the passengers on any

5.2. Aircraft or even train can come from anywhere, thus their dispersal may make it impossible to trace or speak to them if contact details are not obtained at the time and rapidly followed up. It is also important to consider the potential inclusion within the team, of interviewers able to speak other languages and who are from a range of ethnic and religious groups. From these interviews, passengers who are found to have had experiences of particular importance to the investigation e.g. assisting with the rescue operation or significant difficulty escaping, could be given a second interview by the professional human factors specialist in the investigation team.

5.3. In order to improve the quality and reliability of the passenger human factors data, the information should ideally be collected in a structured manner and recorded on incident/accident databases for future use. This could also be linked to the general accident database for the industry concerned. In order to obtain structured and consistent information from the interviews, the interviewers could be trained to conduct the interviews using a human factors tool. This will improve the consistency of the method of collecting the data by the different interviewers. A number of such tools are available. For example, the Critical Event Reporting Tool (CERT) (Wiegmann & Thaden) which was developed for improving the type of information gained from aircraft accidents and incidents, or the Behavioural Sequence Interview Technique (BSIT) (Keating & Loftus 1984) developed for use when interviewing people after they have been in a fire. Indeed, Cullen (2001) suggested "consideration should be given to reducing the investigation of accidents or incidents at industry level to a single method".

6. Theoretical Frameworks for Investigating Accidents

6.1. Many theoretical perspectives and frameworks have been proposed to assist the understanding of the multifaceted nature of accidents. They include The Human Factors Analysis and Classification System (HFACS) which was developed for the United States military and is a tool for investigating human error based on Reason's (1990) model of latent and active failures (Shappell & Wiegmann 1993). The Cognitive Reliability and Analysis Method (CREAM) is a classification system which is based on a theory which allows for the analysis and prediction of errors (Hollnagel 1998). The Techniques for Retrospective Analysis of Cognitive Errors (TRACEr) was developed for use in Air Traffic Management (Shorrock and Kirwan 1999). The Integrated Safety Investigation Methodology (ISIM) is the accident investigation methodology used by the Transportation Safety Board in Canada. The Canadian Board uses this methodology within the marine, rail, aviation and pipeline industries for accident investigation. The UK Marine Accident Investigation Branch (MAIB 2000) uses a human factors classification for accident investigation which operates in parallel with an accident database (MAIB 2000). The classification scheme includes "external bodies liaison" (policy and legislation), "company and organisation", "crew factors", "equipment", "working environment" and "individual". The Casualty Analysis Methodology for Maritime Operations (CASMET) has recently been developed for the purpose of providing integrated human factors and accident investigations within Europe. This instrument is intended to focus on "fact-finding" rather than guilt-finding (Caridis 1999). A useful review of these systems used in parts of the transport industries can be found in Thomas (2003).

7. Databases for Information Storage

7.1. Databases are necessary because a single accident or incident is unlikely to provide information on every possible causal or contributory factor. It may be difficult on the basis of one accident to say whether there is, for example, a safety culture problem, but this may be possible following a series of incidents as more evidence may have been obtained. From this it may be possible to make the case for introducing changes. Alternatively where further information into the problem, or possible solutions is required, it may be possible to recommend initiating some research.

7.2. Databases are therefore an important resource for both public and private organisations for the monitoring of accidents and incidents, in order to make changes aimed at improving safety and for defining areas of research. Holding information in electronic databases not only means that the data can be reviewed for integrity and to fill gaps but also that statistical treatment of the data enables the frequencies of contributory factors and trends to be determined. In the UK across the various industries there are numerous different databases. Although in an ideal world there would be a general classification system which could be used for all accident and incident data, in practice it would be unlikely to hold all of the required information. Due to the sensitive nature of the information in some of these databases, access is frequently restricted to authorised users.

7.3. Within any industry the analysis of all accidents and incidents should ideally be undertaken within an agreed theoretical framework which includes the human factors issues. This will enable statistical analyses to be regularly performed in order to monitor the contribution of causal and contributory issues for both primary and secondary safety. The goal must be not only retrospective analysis but also to use the information derived from the database in a proactive manner. For instance, if from the data from a human factors perspective, instances of sub-optimal design of a piece of equipment can be identified, changes can be recommended which will enable future improved designs to be introduced.

7.4. Some of the major accident and incident databases have been developed in the UK. The Civil Aviation Authority's Mandatory Occurrences Reporting Programme (MORPs) now has a vast quantity of data, although at the moment the information has not been subjected to any form of human factors statistical analysis. The Confidential Human Factors Incident Reporting Programme (CHIRP) for the aviation industry was also initiated in the 1970's. This was originally designed to receive reports from pilots but more recently it has been extended to include reports from cabin crew and maintenance engineers. Since 2003 it has been further extended to include maritime accidents. The Air Accidents Statistics and Knowledge database (AASK), developed at the University of Greenwich, is unique in that it contains information which relates to secondary safety i.e. passengers' human factors. The Maritime Incident Database System (MIDS) is used to recall all incidents and accidents reported to the Maritime Accident Investigation Branch. In the rail industry the Signals Passed at Danger (SPAD) database is now extensive and their confidential reporting programme (CIRAS) has built up a substantial database. Other databases exist within the construction, nuclear, chemical and allied industries.

7.5. However, it is evident that even within the different industries from the range of databases available, different information is stored in different formats for different purposes and organisations. For example, the aviation industry has traditionally collected data on incident and accident causes without necessarily imposing a theoretical structure on it. This means that the analysis of causal and contributory factors cannot be undertaken directly. By contrast in the maritime industry, the data is collected for their database throughout the investigation process and the framework which is used requires structured consideration of the human factors issues.

7.6. It should be noted that data from mandatory occurrences or confidential reporting programmes can all be subject to potential biases. When filing a mandatory report the reporter will inevitably present the incident in the most favourable manner for themselves. Equally, confidential reporting programmes inevitably suffer from the fact that reports can be from a self-selected percentage of the workforce who have either chosen not to use the official company channels or who have been dissatisfied with the response obtained when using the official channel.

8. Conclusion

8.1. From a human factors perspective it is clearly beneficial for each industry to have a robust process for investigating accidents and incidents whose main purpose is to establish the facts and the associated causes and contributors and who are seen to be not seeking blame. For the maximum opportunity for learning from these events the multi-disciplinary investigation team should include professional occupational psychologists. The information collected from all of the parties involved in the accident or incident should include the use of a theoretically based structured interview method. This will enable comprehensive and reliable databases to be built up on the human causes and contributors, from which recommendations for safety improvements can be determined.

References

AAIB (1990) Air Accident Investigation Branch. Report on the accident to BAC One-Eleven, G-BJRT over Didcot Oxfordshire on 10 June 1990. Department of Transport, HMSO, London.

Baker, S (1999) "Aviation Incident and Accident Investigation" in (Ed) D J Garland Handbook of Aviation Human Factors, Lawrence Earlbaum Associates, London.

Caridis, P (1999) CASMET: Casualty analysis methodology for maritime operations. National Technical University of Athens, Report Number C01.FR.003, October 1999.

Cullen, The Rt Hon Lord (2001) The Ladbroke Grove Rail Inquiry Part II. HSE Books; HMSO.

Dekker (1998)

Hollnagel, E (1998) Cognitive Reliability and Error Analysis Method. Elsevier; Oxford.

International Civil Aviation Organisation (1993) Investigation of human factors incidents and accidents (ICAO circular 240-AN/144, Human Factors Digest No.10) Montreal, Canada.

Keating, J P & Loftus, E F (1984) Post Fire Interviews: Development and Field Validation of the Behavioural Sequence Interview Technique. Centre for Fire Research, US Department of Commerce; Gaithersburg.

Loftus, E F, Greene, E L and Doyle, J M (1989) "The psychology of eyewitness testimony." In D C Raskin (Ed) Psychological methods in criminal investigation and evidence. Springer; New York.

MAIB (2000) Categories of accident factors. Draft 2, March 2000. Marine Accident Investigation Branch, Department for Transport.

MAIB (2002) Marine Incident Database System User Guide. Version 1.5, September 2002. Marine Accident Investigation Branch, Department for Transport.

Perrow, C (1999) Normal Accidents. Princeton University Press; NJ, USA.

Reason, J (1990) Human Error. Cambridge University Press; New York.

Shappell, S A & Wiegmann, D A (1997) A human error approach to accident investigation: The taxonomy of unsafe operations. International Journal of Aviation Psychology, 7(4), 269-291.

Shorrock, S T & Kirwan, B (1999) The development of TRACEr: A technique for the retrospective analysis of cognitive errors in ATM. In Harris, D (Ed) Engineering Psychology and Cognitive Ergonomics. Ashgate; Aldershot.

Thomas, L J & Rhind, D J A (2003) "Human factors tools, methodologies and practices in accident investigation: implications and recommendations for a database for the rail industry". Cranfield University Report for The Engineering Link. Available in Cokayne, S P (2004) "Data to be collected in investigations of railway accidents", The Engineering Link report reference 09/T122/ENGE/003/TRT. Published by the Rail Safety & Standards Board Limited, available from www.rssb.co.uk

Van der Schaaf, Lucas D A & Hale A R (1991) Near Miss Reporting as a Safety Tool. Butterworth – Heinemann Ltd.

Wiegmann, D A & von Thaden, T (submitted) Using schematic aids to improve recall in incident reporting: The critical event reporting tool (CERT). Submitted to Human Factors and Aerospace Safety.

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