PSM is not decreasing the number of Loss Events. What does a CEO need to know to stop Engineers and Operators blowing up the Plant?

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Operators and Engineers blew up a Crude Oil Heater safely without injuring anyone. Is this the ultimate outcome of PSM? Since PSM was implemented the number of Injuries in Petrochemical Plants has greatly reduced but the number and value of Loss Events has not. What do we have to do to improve Loss Prevention?

Key Words – PSM, Loss Events, Disasters, Loss Prevention, Safety, Refinery, Fire, Explosion, Normalisation of Deviance, Normalisation of Excellence

Summary

PSM is reducing the number of Deaths and Injuries in the Petrochemical Industry but insurance figures show that the number and value of Loss Events has not improved over the last twenty five years. All organisations that undertake hazardous tasks have Loss Events. As it appears that PSM is not having an effect on improving Loss Prevention, then I think a challenge for the Safety Community and in particular IChemE and the EI to take up, is to determine what will be effective in improving Loss Prevention and reducing the number of Loss Events.

I have been part of Loss Events, I have reviewed reports of other disasters and I have seen some recurring patterns. One observation is that no matter how many times you successfully launch a Space Shuttle, shutdown a Nuclear Reactor, pull out of an Exploration Well or light a Heater in an Oil Refinery the potential hazard remains the same each time but the expectation of the organisation is that having performed the procedure before, it will be easier to overcome the risks and reduce the hazards each time you do it. This has also been described as "Normalisation of Deviance" where successfully doing something hazardous many times deludes the organisation into thinking that the risk of disaster is reduced. When this leads to continuing with a hazardous task when the people who know and understand it are not present and there is also misleading information, then there is a double jeopardy situation that has happened in several actual disasters. PSM does ingrain safe working practices but it can lead to an attitude that if you tick the box and follow the rules then that reduces the hazard and the risk. When the CEO and the Managers become overconfident about the ability of their organisation to manage hazardous tasks then that is when the Engineers and Operators unintentionally blow up the Plant.

What a CEO does need to know is that until we can prevent Loss Events they will continue to occur and it is the CEO's responsibility to ensure survival of the company by making sure that the organisation is prepared to mitigate and manage the consequences of disasters whether the Loss Event is due to a natural catastrophe or the actions of Engineers and Operators. To do this the CEO needs to understand the major hazards and risks, the consequences and to know the capabilities of the resources in the organisation that manage them.

Background

I have spent over forty years working in the Oil Refining Industry. I started in 1974 at Gulf Oil Refining Limited, Milford Haven as a Graduate Engineer in the Inspection Department. Earlier in 1974 there had been the disaster at Flixborough and I took a lot of interest in the findings of the Inquiry Report [1] that highlighted amongst other things Nitrate Cracking of Carbon Steel and Eutectic Melting of Stainless Steel in the presence of Zinc from galvanised wire. Most of my subsequent career has been managing various technical aspects of Loss Prevention including design and commissioning. In 2015, I was the CEO of an Oil Refining Complex in Pakistan when there was a fire and explosion in the firebox of a Crude Unit Heater. Nobody was injured but the Refining Unit was out of commission for over a year whilst a replacement Heater was built. In 2016 I presented a paper on the Heater Explosion [2] at the ARTC in Kuala Lumpur where I saw a presentation by AIG Insurance [3] that showed that the number and value of Losses in the Petrochemical Industry has not declined since 1990 even though Safety has improved and Injuries are far fewer. I re-examined the Heater Explosion, the details of which are in this paper, took another look at the Flixborough Report and at reports of other Losses to see if there were common causes. This is not an exhaustive study but two causes seem to be present together in many of the Loss Events. These are that there was wrong information from a normally reliable source and the absence of people at the time the event was developing who understood the hazards and could properly manage that incorrect data. More recently I saw the film Deepwater Horizon, a film about the Gulf of Mexico oil rig disaster in 2010. They too had incorrect data from a zero pressure test on the "Kill Line" and the absence of the OIM whilst the test was being carried out and the decisions were being made as he was busy at a Safety Award meeting.

I have found from my own experience that solving a problem where part of the data is incorrect is extremely difficult. Even in non-critical daily events if we have a wrong piece of data from a normally reliable source it causes incorrect decisions. We devise cross checking mechanisms such as meetings to filter out wrong information. In the Process Plant we also use cross checks and compare experiences to manage incorrect information and most of the time we solve our problems without incident. Examples of incorrect information from a reliable source that leads to a Loss can be a valve indicating on the DCS as "Open" but is actually closed as at Texaco in 1994 or a valve indicating "Closed" when it is open as at Three Mile Island in 1979. It can be the incorrect result of an Explosive Atmosphere Gas Test as at Byco Oil Pakistan in 2015 or a negative result on the "Kill Line zero pressure test" on Deepewater Horizon. In each of these cases the wrong information results in decisions that lead to the disaster because although the organisations had people who could have managed a safe decision even though the information was wrong, they were not there at that time. Texaco happened on a Sunday after lightning strikes had caused massive disruption to the Refinery Complex. Three Mile Island happened at night. Byco happened after the planned start-up schedule was changed so a Shift with less than adequate skills had to do the start-up whilst Senior

Managers were occupied by a different event on another part of the Refinery Complex. Chernobyl happened in 1986 on a Friday night after the planned Reactor Shutdown and Test Run was delayed by external factors. Flixborough exploded on a Saturday when the start-up was delayed due to a lack of Nitrogen. Deepwater Horizon happened just after a Shift Change and whilst the OIM was otherwise occupied in a Safety Meeting.

In the cases of the Loss Events that I have looked at it appears there is often a double jeopardy where the people who can manage having wrong information are not there when needed because of changes in plans or due to other events. When we design a Safety Relief System we identify events that have the maximum relief load. We size the Flare for the largest combined single case. We do not design for double jeopardy. We seem to have adopted the same principle of not designing for double jeopardy in many of the systems we have in the Process Industry including manning. In our organizations we select and train people who solve problems and make correct decisions, even with incorrect data, to ensure safe normal operation and for all planned operations. PSM reinforces this approach. We also have a few people who can safely manage commissioning, changes in plans, unplanned events, and crisis situations safely. Part of planning and scheduling in our industry is to arrange for potentially hazardous activities to be executed when the appropriate people and resources are present. My personal practice is never to start commissioning a Plant on a Friday afternoon. However schedules do change and events do happen. Chernobyl was delayed shutting down by the Grid Controller. Challenger took the first launch opportunity after bad weather. Byco had a Crude Ship delayed then an incident on another Plant. Organisations need to realise that in previous cases they managed hazardous procedures successfully because they applied adequate resources, the hazards and risks have not reduced or become easier due to doing the procedure successfully before.

Process Safety Management (PSM) is the culmination of experiences and thought processes put together by the Process Industries to manage and improve Safety. IChemE and EI have done excellent work and are at the forefront of the study and implementation of PSM. Byco were implementing PSM. They did not have it all working but accepted the principles and were building on their existing Safety and Quality programmes. I accept that the principal aim of PSM is the avoidance of Injury but I would like those experts who are developing and improving PSM to determine ways to reduce the number of Loss Events in our Industry. IChemE publish the Loss Prevention Bulletin. I would like to know why has Loss Prevention not improved but Safety has?

Whilst looking into Deepwater Horizon, I read an article by James B. Meigs [4] where he draws parallels with the Challenger disaster in 1986 and quotes a book by a Sociology Professor Diane Vaughan [5] called “The Challenger Launch Decision” in which she describes how an organisation such as NASA that successfully manages technical hazards on a day by day basis becomes tolerant of deviance. The sealing rings on the first and subsequent shuttles leaked a little but the launches were successful. The deviance became an acceptable risk. I believe this is a key insight of organisational behaviour and that CEOs need to know about it and to counter it to avoid loss events. The more often an organisation successfully overcomes a hazard and it becomes an acceptable risk the more confident it becomes in its abilities even though there are faults and deviances. Each record breaking deepwater well that Transocean and BP drilled at the forefront of technology gave them the confidence to go further until they failed. All the Senior Technical people at NASA knew the seals leaked but collectively they accepted it as an acceptable risk. All the Senior Exploration people at BP knew they were leading at the forefront of risk in drilling in deep water and that difficulties had set back their schedule and increased their costs but they were confident that they could manage the risk because they had done it before. As CEO of Byco I knew that starting up a Heater is a hazardous task and I knew that we had safely started up this Heater many times before. I was not alarmed when the start-up schedule was changed by the delayed discharge of a Crude Oil Ship because there was a proper revised plan from the Planners that was technically safe and had that plan been implemented there would not have been a disaster. That plan was not implemented because Engineers without adequate understanding of the systems and hazards started activities whilst key Senior Managers were not at the start-up as they were dealing with an incident on another plant.

Byco Incident

I have the dubious honour of having my team blow up an Oil Refinery completely safely. Nobody was hurt. Is it a goal of Safety Professionals today to have Safe Incidents? In the eyes of the Insurance Company the Loss at Byco was caused by Operator Error and events that were covered by the policy. Am I the culmination of PSM? Is it OK to blow up your facility as long as it is insured and nobody is hurt? I don’t think so.

Byco Overview

For over eight years I worked with Byco Oil Pakistan Limited who operate an Oil Refinery outside Karachi. I was part of the Project to relocate the Process Units of the old Gulf Oil Refinery from Milford Haven and rebuild and restart them in Pakistan on a site that already had a smaller Refinery operating that was relocated from the USA. This is recycling on a grand scale. In 2015 I was the CEO of Byco’s Refining Company and we had been operating the two Refineries in a stop start mode to meet the Marketing demands. After over twenty start-ups of the larger Crude Unit there was a fire and explosion in the firebox of the Heater that destroyed the Heater. The Insurers indicated in their report that Byco was essentially a well run Refinery and the primary cause of the Incident was Operator Error. Byco has a good safety record with over eight years and twenty million manhours without an LTA. Nobody was significantly injured during the Incident and the Emergency Response was well rehearsed, prompt and effective. The Insurance Company accepted the claim to replace the damaged Heater.

The recollections and opinions expressed in this paper are my own personal ones.

Background

Byco established its first Oil Refinery Unit in Pakistan in 2004-6 in the Province of Balochistan approximately 40 km from Karachi. This was an 18 MBPD Hydroskimmer relocated from the USA. In 2007/8 Byco revamped the Refinery to add DCS control and increase the capacity to 36 MBPD. I coordinated the Commissioning and Start-up of the Revamped Refinery. Byco has a business model that takes a used Oil Refinery in good condition that is no longer wanted in their original country and relocates it to Pakistan, refurbishes it and brings it back into service. This model works well. In 2006 Byco purchased the process units of the Gulf Oil Refinery in the UK. The equipment was in good condition with fewer than 10 out of over 400 electric motors needing to be rewound as part of their refurbishment. We commissioned the first units of this 120 MBPD Hydrokimming Refinery in 2012-13. Having one Refinery running assisted in recruiting and training Operators and Engineers for the Second Refinery Complex. To manage the Commissioning and Start-up of the new Refinery Byco employed an experienced Refinery Manager, a number of Senior Managers with Refinery and Process industry experience, about 60 Graduate Engineer trainees and a similar number of young Operator Trainees.

CEO

Byco was set up as an entrepreneurial organisation with the owner taking a leading role as Chairman and CEO during the Commissioning stages with Presidents of the Refining and Marketing Divisions. This was then revised for improved governance and separate CEOs were established for the Refining and Marketing Companies reporting to the Boards. The CEO of a Refinery provides:

- Leadership, to set the direction and goals,
- Responsibility, to have the final decision on all non-board matters;
- Resources, to balance human, financial and risk resources;
- Culture, to set the tone and values for Managers; Performance, to drive the team to deliver;
- Interface with all external stakeholders, officials, corporate and customers.
- The CEO keeps the organisation moving forward in response to the challenges of the business.

I am from a Refinery Technical and Operations background. Safety and Loss Prevention were my key performance objectives. PSM was established and Change Management was firmly in place. The Refinery Integrity Department was competent and adequately resourced and supported.

Senior Managers

For the Commissioning of the Second Refinery Byco recruited experienced Senior Managers to give the Organisation strength. Some of those Managers came from Refineries in Pakistan that had very little automation, no DCS systems, natural draft Heaters and little in the way of PSM systems. These experienced people had their own way of doing things, one of which was to start-up the Refinery manually using the block valves to throttle flows and then handing over to the Control Valves when the operation was steady. Byco's official procedures did not include this practice but during Commissioning it was evaluated by the Executives as safe and so tolerated during the initial test start-ups. After start-up in 2014 Byco reviewed its organisation and replaced the Refinery Manager and several older Engineers and Operators who were not experienced in, nor supportive of PSM systems with younger Managers who had a more modern outlook on Refinery Management and were enthusiastic about PSM. In the month prior to the Incident Byco had again re-shuffled the Senior Refinery Management Team with the former General Manager Technical taking over Operations. He is a well qualified and experienced Engineer and Technical Manager and he had experienced Operations Managers reporting to him for Process, Utilities and Logistics.

All the Senior Managers are qualified Engineers. They have limited man-management skills as there has been little training in Management and Leadership at Byco or at any of the other Refineries in Pakistan.

Middle Managers

It is difficult in Pakistan to retain or recruit good Middle Managers in the age range of 30-45 as the good Engineers with a few years experience leave Pakistan to work abroad, mostly the Middle East. Byco recruited some Middle Managers from other Refineries in Pakistan for commissioning and developed some from the staff at the small Refinery. It is possible to recruit experienced Engineers who are 50+ coming back from the Middle East but they have little Middle Managerial experience. So there is a skill gap for effective First Line Managers and their Managers. When a company like Byco has limited availability of good people to fill the Middle Manager levels it has to take the best resources it can get from the limited choice of people available. Recruiting foreign Engineers to Pakistan is not feasible at the level of Middle Manager. I was the only non-Pakistani working with Byco and I was at a very senior level. I don't think this problem of getting good Middle Managers is unique to Byco and settling for adequate but not good Managers can be made to work and result in a Safe Refinery under normal circumstances.

The Crude Unit Manager at the time of the Incident was an experienced qualified Chemical Engineer who had been with Byco for more than ten years and had been with another Pakistan Refinery before that. He was trained as a PSM Trainer for Operations people at the Refinery. He was selected to this partly to enhance his commitment to Quality Systems and PSM. He moved from the First Refinery to the Second Refinery after the Second Refinery had been commissioned. In my opinion

he was adequate as a Manager but lacked leadership skills. Byco provided him limited Man Management and Leadership training.

Shift Incharges are experienced Graduate Chemical Engineers with at least ten years experience working in Operations. Some have stayed in Pakistan and others have been abroad and returned.

Shift Engineers are Graduate Chemical Engineers with at least four years experience.

Technical Service Engineers and Managers are typically selected from the pool of Operations Engineers.

Graduate Engineers

In Pakistan a student choosing Chemical Engineering typically chooses to do it with the expectation that once they have had five or six years experience they will be able to move out of Pakistan to a well paid job in the Middle East. After a few years they can earn enough to buy a house back in Pakistan and get married. This creates a constant turnover of young Graduate Engineers of around 25% per year. Byco chose to use Graduates, train them and get as much useful work from them before they leave. The pay levels in Pakistan cannot compare with the Gulf States. The batch of Graduates recruited in 2009-10 who commissioned the Second Refinery in 2012-13 were well trained and very effective but that batch had mostly left by 2015. They were replaced by fresh Graduates.

Operators

In Pakistan the tradition is to employ non-academic Technicians as Operators for Oil Refineries at a near minimum pay rate. These are taken on as trainees at the age of 18-19 with basic skills in English and Science and do at least two years on the job training with some classroom support. The intention is to train them on the outside units and then on the panel. Between 2010 when Byco started recruiting for the Second Refinery start-up and 2015 none of the Operators recruited had been trained to operate the panel. The panel was operated by Graduates. A basic requirement to operate the panel is to be able to read and implement the procedures and operating guidelines. Few of the Operators that Byco recruited had that level of English skill. Once an Operator was trained outside he could get jobs elsewhere in Pakistan in the Oil Fields and Processing Industries at a reasonable salary so there was a high turnover of Operators as well as Engineers. To address the issue of high turnover of Graduates as Panel Operators and to ensure that Operators had the skills required to be a Panel Operator Byco had modified the Organisation Chart to show half of Operators as Trainee Panel Operators and half as traditional Outside Operators. The new recruitment to meet this requirement had not been implemented at the time of the Incident

Operation

During 2014-15 Byco operated the Second Refinery on a batch basis, typically running for ten days a month. The on-off operation was not due to technical reasons but due to limitations in Marketing and Cash Flow. This was not Byco's intended mode of Operation, but when the Second Refinery started up the Pakistan State Owned Marketing Company took and did not pay for the product volumes that they had contracted for. This was not sustainable so Byco had to develop other marketing outlets to keep the Refinery running and run it at lower throughputs till the market share increased. The Refinery Operations Group became skilled in this type of intermittent operation and organised themselves accordingly utilising the manpower resources available to best advantage. Operations Group at the Second Refinery organised into three shifts rather than four to best utilise the people and skills available. This was possible when the Refinery was operating for only part of the month. The shift did 12 hours days then were off the next day, then came in the following night, then off the next day and night and back in on days. Rest days were taken when the units were not running.

Organisation

Against this background, Byco Executive Management had to put together an Organisation Chart that would work with the resources that were available and had identified the additional resources that were needed and was trying to find ways to recruit them. A lot of executive time and effort was put into devising a working Organisation Chart and specifying the Job Descriptions for the positions created. Safety was always the priority and the first two requirements on the Job Description of the Refinery Manager and the Operations General Manager are:

1. Don't let them kill themselves or each other
2. Don't let them blow it up

These were absolute conditions of their jobs. When the Refinery failed on the second requirement it was not just the Managers who lost their jobs but over two hundred other staff were laid off until the Refinery Unit was rebuilt and ready to be re-commissioned.

Events Leading to the Incident

The First Refinery was operating smoothly at 30MBPD. There was a Crude Ship due to discharge on Saturday. On Friday the Refinery Plan was issued stating that on Monday after the discharge, when the Crude Oil was settled and ready, the Second Refinery Crude Unit, Naphtha Treating Unit and Isomerization Unit were to come on-line at 60 MBPD and for the Crude Unit of the First Refinery to come off-line. All plans and arrangements were made on Friday and the Shifts notified that there would be a start-up on Monday. Ahead of the CDU start-up the Naphtha Hydrotreater at the Second Refinery was brought on-line using stored feed. All of this was normal and could be easily managed by the experienced Refinery Staff.

On Saturday the discharge of Crude Oil was delayed. A new Refinery Plan was issued on Monday morning delaying the start-up of the Second CDU till Tuesday evening. This worked well for Operations as the Shift selected to do the start-up on Monday were back in again on Tuesday night. Then there was another event, early Tuesday morning a leak occurred on a Cooling Water line on the Reformer Unit of the First Refinery. As a precaution the rate on the Reformer and the First Refinery CDU was reduced but they were kept running.

On Tuesday morning the site Managers reviewed the water leak and re-evaluated the plan to start-up the Second Refinery CDU. As a precaution the Operations Process Manager instructed the Operations CDU Manager at the Second Refinery to prepare to start-up the CDU. The intention was to be ready whilst the leak situation was evaluated and priorities and decisions were being sorted out. The Shift reported to the CDU Manager that it was not at the strength needed for a start-up as they had been re-scheduled on Monday for the Unit being shutdown. The Operations Manager for the CDU started to find and arrange additional suitable trained people from the General Shift (Day) group in case the start-up was brought forward. Whilst the Operations CDU Manager was organising day staff to supplement the Shift, the Shift Engineer went to prepare the Crude Charge Pump and the Outside Operators started to prepare the Heater. The CDU Panel Operator was a Graduate Engineer who had not done a CDU start-up before from the Panel. The Panel Operators on the other Units were busy with the Naphtha Hydrotreater start-up. The Outside Operators on the CDU Heater were well experienced in starting the Heater having done it several times and they took the lead. They were instructed by the Shift Engineer to prepare for start-up and they took this to mean that they were to establish pilots in the CDU Heater. Lighting the pilots was not an explicit instruction from the Operations CDU Manager but it was not an unreasonable assumption of what was required. The Operators went through what they considered was a preparation and Air Purge of the Heater. They arranged for a Safety Officer to carry out a Flammable Gas test around the Heater and sample the atmosphere inside the Heater. They reported back to the Control Room that the gas test was clear and they received to go ahead to light pilots. When they lit the first pilot there was a fire and explosion in the firebox that destroyed the Heater.

Heater Design

The Heater was a 1969 design Foster Wheeler, horizontal tube, twin cabin Heater with a common Convection Section and a Balanced Draft Deka Air Pre-heater. The Radiant Section had been re-tubed as part of the renovation of the unit in Pakistan. It had 12 floor mounted dual fuel Oil/Gas Burners in each cabin. Each burner had a permanent pilot that was the primary safety device. The Pilot Gas was on a separate circuit to the main Fuel Gas each having independent Emergency Isolation Valves. The pilots were designed and tested to stay alight even if the burner went out even whilst there was a full air flow. Lighting the pilot was achieved by an Operator inserting a lance with a gas flame through an opening at the pilot then turning on the Pilot Gas to the Pilot Burner. The Start-up Procedure was to purge the Firebox with Air by opening the Dampers on the Forced Draft Fans, Induced Draft Fans and the Stack Damper and if there was insufficient natural draft then to start up one or more of the Fans. After purging, the atmosphere inside the Firebox was to be tested for Explosive Gas and if clear, then the first Pilot was lit followed by each of the others. All Pilots were to be lit before lighting any Main Burners.

Operator Actions

The Shift Engineer was the First-Line Manager for preparing the Heater for Start-up. He was an experienced Engineer from one of the other Refineries in Pakistan and had trained on and was familiar with operating Natural Draft Heaters. He had joined Byco after the original commissioning of the Heater. When instructed by the Crude Unit Manager to prepare the unit for Start-up he asked for additional support but didn't wait for the additional support to arrive before he directed the Panel Man to purge the Firebox by opening the Stack Damper and to open the Emergency Shutdown Valve on the Fuel Gas to the Pilots Burners and Main Burners. There was plenty of natural draft as the Heater vents into a 300ft Stack and the NHT Heater was already firing and venting into the same stack. The Shift Engineer and Panel Man do not appear to have realised that on a Balanced Draft Heater that to get a purge the Damper on the Air Inlet has to be open as well as the Stack Damper as the log showed the Inlet Damper remained closed. Also they do not appear to have been aware of the separate Fuel Gas Systems to the Pilots and Burners as the Shift Engineer helped the Panel Man override the trip for Low Feed Flow on the Main Fuel Gas Emergency Valve before lighting the Pilots. When the Emergency Valve on the Main Fuel Gas was opened the DCS recorded a flow of Fuel Gas into the Heater. This was not noticed by the Panel Man. Nor was the reading on the DCS that the Oxygen content of the Gas leaving the Heater to the Stack started to drop.

The conclusion after the event was that opening the EV on the Main Burner Fuel Gas line allowed Fuel Gas into the Heater through isolation gate valves on the Burner that were supposed to be tight shut but may have been passing, that the Air Purge was inadequate to remove the Fuel Gas and that when the Gas Test was made the negative pressure in the Firebox resulted in Air being drawn around the sampling tube giving a false indication. The Shift Engineer and Panel Man did not have adequate experience and understanding to prepare this Heater for Start-up. They were not prepared for the Start-up and they should have waited until additional trained support was there either from the Day Shift or from the incoming Shift who had prepared for this Start-up. The Senior Managers who would normally have ensured all preparations had been verified before lighting the Heater were engaged on an incident on the First Refinery.

There were two Outside Operators working to prepare the Heater for Start-up. Both were trained on the Heater one had been present during more than twelve start-ups. They were supported by two casual fitters and the Safety Officer who carried out the Gas Test. They were aware that they need an Air flow to light the Pilot but that it is difficult to light the Pilot if there is too much Air flow through the Burner. After they had done the Gas Test and the result was negative, they requested that the Inlet Air Damper was partially opened and the Stack Damper was partially closed. They then waited to get authority to light the Pilots. When they got authorization from the Shift Engineer they lit the Gas Lance and presented it to the first Pilot. The flame of the lance was sucked into the opening alongside the pilot and soon after there was a blow back fire and an

explosion. The Operators were stunned but the direction of the explosion was away from where they were standing and they both walked away unhurt.

The conclusion after the event was that the Outside Operators thought that everything was in good order when they went to light the first Pilot. They were completely surprised when the Firebox exploded. They did not intend to blow up the Heater.

Gas Testing

Gas Testing in Byco is performed by trained members of the Emergency Response Team who are part of the Safety Department. The test equipment is modern and kept in good order. There are clear Work Instructions for the calibration, use and maintenance of the equipment and these are audited, updated and followed as part of PSM. Prior to lighting the Pilot Burners the Operating Procedure requires that the atmosphere inside the Firebox is tested. In addition, Operations practice is that before an Operator creates an open flame such as to light the Pilot Ignitor they require an area gas test. The person doing the gas test is guided by the Outside Operator about where to test as they do not have process knowledge. Gas Testing is part of the Refinery Hot Work Permit Procedure and is a fundamental safety check. The Hot Work Permit is signed by the Head of Operations and the Head of Safety and there is a lot of confidence placed by Refinery Management in this test.

In this case the gas testing failed to detect the explosive gas mixture that was in the Firebox. The Gas Testing equipment was re-tested after the incident and was in full working order. The person doing the gas test was experienced in using the equipment. Getting access to this Firebox to check the atmosphere is not straightforward as the viewing holes on the first platform have glass covers that cannot be removed. There are additional viewing holes without glass at a level above the first platform, Flue Gas sampling connections on the Induced Draft Fan and access to each burner through the Pilot Lighting facility. From interviews after the event it appears the Outside Operators directed the Gas Tester to test the atmosphere around the Heater and through the Pilot Lighting facility of the Pilot they were preparing to light and not at the other points. The Gas Testing equipment has a flexible tube for sampling. The tube is not long enough to get into the Firebox through the Pilot Lighting facility.

The conclusion after the event is that the Outside Operators did not direct the testing to get a proper sample of the atmosphere inside the Firebox.

Procedures

The written Procedures for Start-up of the Heater were prepared by Byco's Commissioning Team in 2012-13 and were based on the Procedures from Milford Haven. The Procedures were part of an ISO 9001 system and PSM and had been reviewed but not updated since Commissioning. They did not include detailed Work Practices. The Procedures were not pulled out by this Shift for this Start-up and were not referred to directly by this Shift. The Shift that had been planned to do the Start-up had been through the Procedure in preparation for Start-up but this Shift had not. The Procedures are written in English in a formalised style. Many of the Outside Operators do not have the English skills to read and understand the Procedures. They rely on the Engineers reading and explaining it to them. A copy of the Procedure is supposed to be made before the Start-up and be kept on the Panel so that it is annotated with times and events. This did not happen on this occasion but there were records from previous Start-ups showing it to be usual practice.

Manager Meetings

At the time of the Incident there were three management meetings just finished or still in progress. The Operations Morning Meetings at the First Refinery, the Operations Morning Meeting at the Second Refinery and the Marketing Coordination Meeting at the Head Office linked by video to the Refinery.

The Managers at the First Refinery were concerned with the cooling water leak and ways to manage and repair it. The General Manager Safety and Technical, the Senior Manager Process Operations, the Senior Manager Logistics, the Senior Manger Production Planning and the First Refinery Plant Managers were at this meeting. The conclusion of the meeting was that there was no immediate Safety Risk due to the leak and that the planned Start-up of the Second Refinery could proceed as planned. Logistics and Planning did come up with a way to manage the Crude Oil Tanks so that the First Refinery could switch to a small Tank and carry on running and the Second Refinery could be lined up to the large Tank of Crude Oil that the First Refinery was processing so that it could Start-up whenever it was ready. This was agreed by the General Managers and implemented by Logistics and both Refineries were advised of the Tank switch.

The morning meeting of the Managers at the Second Refinery was concerned with the Start-up that was in progress of the NHT and Isom Unit and preparations to Start-up the Crude Unit. The General Manager Operations, General Manager Maintenance, and the Plant Managers were at this meeting.

The Refinery CEO was at the Head Office in a coordination meeting with the Marketing and Distribution Companies and was linked by video conferencing to both the Refinery Plants. There was no-one from the First Refinery on the link at the time of the Incident and the General Manager Operations had minutes before come on to the link after leaving the Morning Meeting of the Second Refinery. The GM briefed the CEO that the situation at the First Refinery was under control and that preparations were being made to bring the Second Refinery on-line as planned in the afternoon and evening including switching tanks. The Crude Unit Operations Manager appeared briefly to say he was arranging additional support from the Day Shift to prepare the Unit for Start-up. During this brief video meeting there was an explosion at the Heater.

Everybody rushed to the scene of the Incident.

Post Incident Actions

The Refinery Emergency Response Team immediately mobilised both Fire Engines and called support from the adjacent Power Station and Local Authority. Some Crude Oil tubes in the Heater ruptured during the explosion. The Crude Unit was under Fuel Gas Pressure ready for Start-up and this Gas flowed back from the Crude Column into the Heater causing flames in excess of 100ft high. Fire Monitors kept the adjacent equipment cooled whilst the fire burnt out. All of the Fire Fighting and Emergency equipment performed well keeping the Loss contained to the Heater and directly adjacent area.

The Refinery CEO immediately assigned the Site Administration Coordinator who was previously a Refinery Manager and the Senior Manager Integrity and Inspection to head up the first post incident investigation. They collected the immediately available information and gave a first report that day and a formal report within two days. The information indicated that the Incident was not Sabotage, Equipment Failure or an Act of God but was due to Human Error. The Shift were not adequately prepared for the Start-up and they had made mistakes in getting the unit ready for start-up. On that day the Shift were short of their Shift Incharge and regular Crude Unit Panel Man because they had been advised they would not be required to start-up or to run the Unit on that day. The Refinery Managers should not have allowed lighting of the pilots until there was adequate manning in place, but the satisfactory report of the Gas Test although incorrect gave them confidence to proceed. A larger Formal Inquiry was then set up, run by three Direct Reports to the Chairman. They suspended those directly involved, issued show-cause notices to those to be interviewed and assessed who was responsible for the Loss.

I set up a Root Cause Analysis to assist in determine the underlying causes of the Incident. This showed that the PSM and Quality type controls that were being used effectively for Safety related Procedures were not being used effectively and were less than adequate for normal Operating Procedures and that training and testing in the Operating Procedures was inadequate. It showed that the communication between Managers and the Shift was less than adequate.

The Insurance Assessors set up an Investigative Panel and interviewed those involved and evaluated the Incident and the Loss. The Insurers determined that the claim was covered by the terms of the Insurance and the primary cause was Operator Error.

Consequences

As a result of the Loss, the Business had to re-adjust and rely on the First Refinery and direct product imports to meet the demands of Marketing. The time to rebuild was over one year so I recommended to the board to lay off all Refinery and other personnel not required for the survival of the Business. Over two hundred people were laid off. Some will be re-hired when the Business is ready to run again.

Conclusions for the Byco Incident

In my opinion the reasons this Incident happened, in order of significance are:

1. The reported clear result of Gas Testing was incorrect information from a normally reliable source. The Managers, Engineers and Operators at the Refinery believed that if the Gas Test on the Firebox was good then it was safe to light the Pilot Burners regardless of the thoroughness of the Air Purging. They relied on incorrect information that resulted in the explosion. Managing information when some of it is false is always difficult. When the information is as fundamental as the Gas Test, then I am not aware of any way for the Managers to know this is false. However the Senior Managers from experience would not have allowed lighting of the Pilots until proper manning was established. The additional experienced support would have re-checked the purging cycle.

2. Manning for a Start-up was less than adequate due to changes in the Production Schedule followed by an incident elsewhere. This Incident would not have happened if the Production Schedule for the Start-up had not been changed. The Shift that was planned for the Start-up was ready and prepared and fully capable of managing it properly and without incident. The Shift that attempted the Start-up had been told they would not be doing the Start-up. They could have managed it properly if they had been advised ahead of time that they were to do the Start-up as the Shift Incharge and the regular Panel Operator would not have been given the day off that day leaving the Shift under manned.

3. Less than adequate Supervision and Management present for a Start-up. The Shift went ahead with preparations for Start-up without adequate manning, knowledge and support. Had they waited for experienced Engineers and Operators from the General Shift to replace the absent Shift Manager and Crude Unit Panel Operator then this Incident is unlikely to have happened. Had the CDU Manager waited for the Senior Manager to return they would not have gone to light the Pilots before support staff were in place,

4. Absence of Operator Work Instructions. The Outside Operators on this Crude Unit did not have Work Instructions covering basic activities including sampling, using the Pilot Lighting facility and carrying out isolation verification before start-up. All Work Instructions on this Crude Unit were conveyed to Operators via on-the-job training. Had there been Operator Work Instructions on Sampling for Explosive Gas in the Firebox and this had been part of Operator Training then this Incident is unlikely to have happened.

5. Less than adequate Management skills of the Crude Unit Manager. He knew that the Crude Unit Shift Manager and Panel Operator were absent. He did not communicate clearly what he required the Shift Engineer to do in their absence and he did not stop the Shift from proceeding without adequate support. When he heard that the Gas Test on the Heater was clear he gave the go ahead to light the Heater with no further checks even though he was still arranging additional support. He did not instruct the Shift Engineer to refer to and to follow the Heater Start-up

Operating Procedures. He did not adequately inform his Senior Manager of what was going on. Had the Crude Unit Manager been less keen to get the job done and better at managing the people doing the job then this Incident may not have happened.

6. Distractions due to multiple events. The Cooling Water Incident on the First Refinery took away the attention of the Senior Manager Operations Process and the General Manager Technical and Safety from the Start-up of the Second Refinery. It also drew the attention of the CEO and made the decision to get the Second Refinery ready for Start-up appear to be a sensible one to take even though it was not scheduled.

Texaco Refinery Incident in 1994

In July 1994, I was sitting at home near Milford Haven having Sunday Lunch with my family when the ground shook followed closely by two huge bangs. Across the Haven, ten kilometres away at Pembroke Refinery, there had been a huge explosion. I am familiar with the FCC Complex at Pembroke as I had been part of the Design and Commissioning team for it in 1979-83. The explosion was followed by a massive fire. Gulf Oil were part owners of the FCC at Pembroke so I was assigned to assist in making the remaining Plant safe. I conducted, in a fast and efficient manner, Safety Reviews on all the proposals made by Technical, Operations and Maintenance to drain down, isolate, make temporary connections to and repair the equipment that had not been destroyed.

There is an official report by the HSE [6] that describes the incident. The HSE highlight that a severe weather condition on Sunday morning caused disruption on the Refinery and the Crude Unit was shut down. The FCC kept running. A valve on the bottom of the FCC De-Butaniser was showing open on the DCS Panel but was actually closed. This resulted in the De-Butaniser filling and the liquid going to the Flare from the relief valves on the De-Butaniser Overhead System. This filled the Flare Drum located at the Battery Limit. The High Level Alarm and High High Level Alarms were not noted by the Panel Operators in the mass of other Alarms that were going off. The automatic pump-out system to the Slop Tank was closed in and not functioning due to a dispute between the Tank Manager and the FCC Manager about Sour Liquids in the Flare System. Sour Liquids from the Wet Gas Compressor Inter-stage Knock-Out were routinely routed to Flare as the pump continuously failed. The Refinery installed a small pump at the Flare Drum to return this Sour Liquid to the Process Units. The Operators and Engineers struggled for hours to get rid of the liquid building up in the Plant but they did not recognise that the valve that was showing open on the DCS was a false indication. Engineers and Managers who had come to the Plant on Sunday to deal with the Lightning Incident were busy on other Units,

A high level in the Interstage of the Wet Gas Compressor caused it to trip and a large amount of Gas went into the Flare System and lifted liquid in the Flare Drum into the Outlet Piping that was not designed for two phase flow. The outlet line failed and approximately 20 Tonnes of gas and liquid sprayed towards the Heaters on the Alkylation Unit where they ignited and there was a blast reported as equivalent to approximately 4 tonnes of High Explosive [6].

The FCC was closed for over six months whilst repairs were made.

There were no fatalities and only 26 minor injuries reported. This was an early case of PSM type systems working to save people but not to stop Loss Events.

As in the case at Byco, information from a system that Operators, Engineers and Managers relied on completely during normal running was false and they did not recognise this even though it was the most obvious cause of their multiple problems. As in Byco the Engineers and Managers were distracted from the problem that caused the Loss Event by other events. As in Byco the desire to keep the Unit running (or get it started) was what the Plant Manager tried to do.

Chernobyl

The October 2016 issue of IChemE of Loss Prevention Bulletin has a well written account of the Chernobyl Disater by Fiona Macleod [7] which describes how, on top of many other reasons, a principal cause of the Chernobyl Disaster was a change in the Reactor shutdown schedule due to external reasons moving it from the Day Shift to the Night Shift. When the Operator attempted to lower the control rods into the reactor, the leading Graphite Section got stuck and instead of stopping the reaction with the Boron, the Graphite Section of the Control Rods displaced water and actually increased the reaction rate leading to an explosion. This effect was known from other similar reactors but had not been communicated to Chernobyl. Fiona states that in her opinion had the planned Test Run, as flawed as it was, been done on schedule by the Day Shift with Engineers in support the disaster would probably not have happened.

As in Byco the change in the Operating Plan due to non technical reasons resulted in a Shift that was not planned to do the non-routine hazardous operation being left to do it with less than adequate support. A test run of the Cooling Pumps attempted during the shutdown further complicated and confused the issue

The result was a massive disaster with huge consequences for Nuclear Power throughout the world.

Conclusions

The job of a CEO is to lead the organisation. With the board they have to set the directions and goals. They interface with external stakeholders including officials, customers and corporate entities. They are responsible for the final decision on all non-board matters and for balancing the human, financial and all other resources including risk. The CEO sets the cultural tone and values for Executives and Managers. The CEO drives the organisation forward in response to the challenges of the business and gets the team to deliver.

Safety has improved significantly in the Petrochemical Process Industries but Loss Prevention has not. PSM is working to reduce deaths and injuries but is not working to reduce the number and value of loss events. Implementing PSM requires a commitment from Executives to lead the Safety effort throughout the organisation. This is happening in the realm of safety equipment and procedures but as was seen on the film Deepsea Horizon although the Fire Extinguishers were probably all tested and logged, the phone, computers and other seemingly minor, non-safety items were not being fixed promptly and people were accepting these annoying deviations even on the drilling rig that had recently completed the deepest and possibly most hazardous drilling ever. When an organisation tolerates small annoying deficiencies and deviations I think it indicates a culture that has accepted "Normalisation of Deviance" and is on its way to a disaster.

What does a CEO need to know to stop Engineers and Operators blowing up the Plant

1. The first and foremost thing that a CEO and all Executives need to know is that your Plant is going to have a Loss Event and your Engineers and Operators are most likely to cause it. The clear evidence from the Insurance Industry shows that accidents and natural catastrophes leading to Loss Events are continuing to happen at the same level that they have happened in the past. Exxon, Dupont, BP, BASF, NASA and all the top organisations that deal with hazardous processes have Loss Events. We can try and reduce the number of Loss Events but we have to accept that accidents happen. We have to be prepared for these Events and we have to mitigate the consequences of theses Events. After Flixborough the Politicians in the UK realised that a disaster was a threat to them if it made the International news. An event does that if it the consequences are massive such as killing school children, injuring people in a hospital, or polluting a river or sea. The Politicians took steps to separate schools and hospitals from Chemical Plants. A CEO needs to know which Loss Events are going to be a threat to the survival of the company and act to mitigate the threat. To do this the CEO has to understand the major hazards and risks at all the Plants in the company and the measures the organisation uses to manage them. It is the job of the CEO to ensure the company and organisation is prepared and ready to deal with the consequences of accidents and Loss Events.

2. A CEO can and should get the organisation to reduce the consequences of a Loss Event. Good leadership and a culture of good management, including PSM and other programmes to promote Excellence and a culture of Safety, may not eliminate accidents but it is essential for the health of the company and will reduce the incidence of the Engineers and Operators killing themselves and each other.

3. A CEO needs to know that a hazardous task that has been done successfully many times before does not become less hazardous the more times it is done. However, human nature is to become more relaxed about these events the more times they are successfully completed. The first time a Heater is lit there is a full Commissioning team to manage it. The fourth time the Plant Managers and all the Engineers are there. The twentieth time it is lit the hazards are similar but as at Byco the Engineers and Managers may have become confident that the Operators can manage the hazards without them or they may not have the direct experience themselves. The CEO needs to know that every time the organisation executes a hazardous task, they will have in place Engineers and Operators with the knowledge, skills and resources to mange the risks successfully. All companies have junior people to prepare cheques for payment but they only allow trained and trusted people to sign them to reduce the risks to the company. How much more so should the company apply such safeguards to hazardous tasks?

4. A CEO needs to know that risks increase when plans change. This may be an application of the old saying "Order, counter-order, disorder" or as at Chernobyl a Grid Controller delaying a power station shutdown. The increase in risk due to changes in the plan have been part of a number of Loss Events including Byco where the competent decision makers were not present as the Event developed and those who were there, although they were quite convinced that they were safe and that they were doing their jobs properly, made errors as they did not have the knowledge and understanding of the systems and risks to carry out the hazardous task successfully. A CEO needs to know that the Managers will ensure that when the schedule of a hazardous task changes that it will not go ahead unless the Engineers and Operators with the knowledge, skills and resources are present to manage the risks successfully. Engineers and Operators do not want to blow up your Plant. I think that all Engineers and Operators have a self preservation instinct and generally want to do their best for the company. They carry out the actions determined by the decision makers.

5. CEOs need to recognize if "Normalisation of Deviance" is part of the culture of their organisation. If it is, then they have to address this and drive the organisation towards a culture that does not accept deviance as normal. It is human nature to bend and avoid rules, we have all probably broken the speed limit when driving. Even having good rules and following up with PSM does not avoid deviance. To reduce the acceptance of deviance, the organisation has to be one that fixes the phones, computers, instruments and everything else that is a deviation, promptly and efficiently. I have seen this described as "Normalisation of Excellence"[8].

6. A CEO needs to know that his organisation can manage incorrect information, minimise its occurrence and avoid it in hazardous tasks. If a Control Room clock is showing the wrong time, or an instrument is faulty, it is not for the CEO or the PSM Manager to fix it but they have to ensure that the organisation does not tolerate these things as a deviance.

7. A CEO needs to know if the Managers, Engineers and Operators are complacent towards risk management. PSM introduces a lot of form filling and cross checking that may lead Engineers to believe risk management is the responsibility of HSE. In my opinion it is not. HSE do not blow up the Plant, Engineers and Operators do. The CEO needs to pull the organisation towards reducing risks and hazards rather than getting good at managing them

or covering them up. I believe that technical solutions to reduce the hazards are more important to the organisation than procedural solutions to reduce the risk.

8. A CEO drives the company forward. Safely doing nothing is not part of the job description.

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