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Early warning signals noticed, but management doesn’t act adequately or not at all: a brief analysis and direction of possible improvement

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ABSTRACT

History has taught us that quite disastrous events with much human loss, injuries and asset damage could have been prevented or at least mitigated, if top management had recognized early warning signals in some form as urgent and had decided to take timely preventative measures. It turns out to be a rather common phenomenon in various sectors of life and some process industry examples are presented. The problem is further analyzed from a leadership point of view, from organizational structure and culture aspect, and what modern technology developments can help to improve the situation. Research in the latter directions is encouraged.

1. Introduction

At the beginning of the COVID-19 pandemic in various countries the complaint was heard that the president, or prime minister had been lax in taking measures to curb and control the hazard. In leading countries, such as the U.S., specialists and people with experience seeing what happened in Wuhan, China, warned the executive in vain (Haberman, 2020). This is not unique at all. How many times in history a military organization that has been set up with the mission to collect signals and perform intelligence, have warned top commanders of an imminent surprise attack, where that same management failed to act adequately on the warnings received, for example the attack on Pearl Harbor (Wohlstetter, 1962) and the paramilitary terrorist attack on the WTC buildings (The 9/11 Commission Report, Executive Summary, 2004).

And what about major process plant accidents? There are many examples where precursors, previous incidents, incidents at other plants in the sector, or indications and early warning signals of the unexpected have been ignored. This happened apparently with lack of insight how terrible a disaster can develop and with an attitude of ‘there are higher priorities’, the risk is negligible, and ‘it will not happen to me’. A few examples:

- Zinc distillation tower explosion: Two times an explosion occurred of a zinc distillation tower in a zinc refinery at Noyelles-Godault in the north of France in 1993 and early 1994 (Pasman and Grollier Baron, 2002; French Ministry of the Environment, 2008). Besides injuries, the first explosion took the lives of 10 people; in the second there was one fatality. After both explosions, committees investigated the cause, but since the examining magistrate wanted a deeper investigation your author became involved. Despite the totally different material involved, the case has parallels with the 2005 BP Texas City ISOM plant explosion (CSB, 2007). It concerned a newly built 50-tray distillation tower of the so-called New Jersey type for the purification of zinc at about 900 °C. Although the tower needed to be renewed every 18 months, the system had functioned well for many years. However, at the time of the first accident instrumentation was not only limited but partly non-functional; the operators had no way to know the column hold-up, and had no written procedure (writing was a work-in-progress). Days before the explosion during start-up a power black-out happened and because after this event the column did not start distilling operators increased the heating, while the feeding of raw material continued. On the work floor anxiety arose because of strange noises, column vibrations and leaks. It was reported but management took no action. The anomalies lasted for days and increased in intensity.

Suddenly, just when operators, supervisor, technicians and a production manager assembled around the column discussing what to do, the column burst and a huge cloud of hot zinc aerosol was violently released and exploded. (Finely dispersed hot zinc ignites and explodes just like aluminum dust). Different committees investigated the cause but did not find the physical root cause. One committee credited it to a gas explosion in the column furnace. This was because operators had noticed the heating decreased and tried to increase heating by admitting more fuel gas and an additional air supply. In hindsight, reason of reduced heating, though, was clogging of the air inlet by zinc oxide from...
liquid zinc jets from the column into the furnace. Also, the cracking and partial collapse of bottom trays was seen as a cause. After the second explosion, in which the heating-up of the column purposefully was slowed down to avoid damage to trays, an international committee examined the case and came closer to the cause. However, after an invitation to further investigate, the authors of (Pasman and Grollier Baron, 2002), members of the EFCE Loss Prevention Working Party, concluded based on observations and experiments that due to the open sump at the bottom, the column acted as a chimney with air flowing upwards. This air flow causes zinc dripping down the trays to oxidize and while zinc oxide density is much lower than of molten zinc it stays at the surface. However, the bubbling of air through molten zinc solidifies the molten zinc into a paste and clogs the column. Since the feed stream continued, the pressure in the lower part of the column increased, producing cracks and leaks. Had in the first incident the power black-out not occurred, air would have had less chance to form zinc oxide in the column and distilling would have started earlier. Many more details on the process leading to explosion can be found in the US CSB report (CSB, 2015) on a similar explosion a few years later at a zinc refinery plant in Monaca, PA, USA.

In the industry sector at the time, eleven units of the New Jersey type zinc distillation existed at various locations in the world. The columns appeared to have been subject to smaller explosions and also more violent ones before 1993. A very destructive incident in Italy had been reported in a meeting at the French company’s headquarters in Paris a few months before the first French accident. In the French plant the safety section, though, was fully on personal/occupational safety and was subordinate to human resources. With the knowledge about the Italian plant explosion nothing has been done, not even during the days the noises and vibrations occurred and the operators anxiously com-

- Fukushima Daiichi nuclear power plant disaster: There are quite a few reports on the disaster of the Fukushima seaside nuclear power plant; an early report is that of IAEA, 2011. In 2011 due to a subsea earthquake, a huge tsunami wave washed over the protective dam at the coast line 45 min later and flooded the plant area. The six reactors had survived the earthquake but had shut down automatically and also the turbines. However, due to damage by the earthquake shocks to an offsite transformer station, power supply to the plant ceased. Diesel generators took over to start pumps to keep the reactors cool, but despite the area being 10 m above sea level the water destroyed and penetrated buildings and inundated the basement where the majority of diesel generators was located. By short-circuiting these generators broke down and did the spare batteries. The absence of electricity caused the escalation of events, the hydrogen explosion at one of the reactors and the core melt-downs at a number of the reactors.

Was such a tsunami unforeseen and was TEPCO management not warned? In fact, in the past tsunamis in the area water was propellied even higher as indicated by small stone monuments with an engraved warning not to build at a level below such stone (Pasman, 2015, p. 210). The Japanese investigative committee report to the Parliament, the Diet (The National Diet of Japan, 2012), is very clear. Both the company management and the nuclear regulatory authority (NISA) knew since 2006 that a tsunami could cause a total power failure, however nothing was done.

- A more recent example is that of the management of aircraft manufacturing company Boeing. There have been multiple signals before the two disastrous crashes of the new Boeing 737 MAX aircraft in October 2018 and March 2019, that the planes suffered deficiencies that endangered their safety. The best-known evidence was the e-mail exchange between a test pilot and an employee in November 2016 (Forkner, 2016), revealing the problems with the new Maneuvering Characteristics Augmentation System (MCAS). This system served as a compensation in the flying characteristics of the aircraft caused by other changes to the former 737 design. There is also the story in (Baker and Gates, 2019) about an engineer who had complained about fire safety, which was endorsed by others, but who later was fired. Management was focused on production speed under pressure of the competition with Airbus (Gelis and Kitroeff, 2019) and top management was not warned fully in time. Safety was not given sufficient priority; whistleblowers had filed complaints with the Federal Aviation Agency without reaction. In the 3 h lasting October 2019 Congressional hearing (CH, 2019), in which many details were discussed, it also was made clear that the insufficient oversight by the Federal Aviation Agency as regulator, inspector of safety, and supervising certification contributed to problem. This phenomenon is not new either. The same contributed to the Macondo disaster in the Gulf of Mexico in 2010 with the lack of oversight by the Minerals Management Service (MMS) (Chief Counsel’s Report, 2011; Chap 6). Shortly after the disaster MMS was reorganized. In fact, it was disbanded and its functions assigned to two specialized organizations.

- And the latest example is the August 2020 disastrous ammonium nitrate (AN) detonation event in Beirut, where preliminary reports mention that over the period of six years these 2750 tons of AN were stored at the harbor site. On a number of occasions warnings were given to higher management about the destructive potential of this amount of AN. These warnings were ignored.

Of course, there may be even more examples in which management took adequate measures to prevent a potentially severe event, sometimes even accepting a painful contractual or financial consequence due to the delay caused by implementing the measures. Records of these successful interventions are scarce as only accident histories draw attention. Two examples from oil and gas production of what would have gone wrong when management not had taken signals seriously are given, though, by Behie (2020, pp.2–3). In the next few sections various organizational aspects that can determine what happens when a signal is received, will be briefly described.

2. Types of leadership

Naturally, for the problem we examine in this paper, it is the leader of the organization, who has to take action to set the priority and express urgency in the event of a significant threat. No one else can muster the full support of the whole organization. So, the decision making and the role of the leader in this context is crucial. While the main roles of senior leadership are to give guidance and take decisions, the leader also must give direction as to what needs to be done. To be successful the leader shall therefore be knowledgeable and have insight in the implications if action will not be taken.

However, for a signal to reach the top management a few premises must be fulfilled. In the first place, at some office in the organization an early warning signal or indication should be received, detected within clutter, recognized as important and urgent. Because receiving the signal is usually at a low level in the organization, the signal must be forwarded upward through various management layers to the top. In this chain of action events much can go wrong and costly time can be lost. In many organizations, middle management can act as a filter to prevent “bad news” of potential upsets from reaching executive management and preventing timely action. According to the CEO of Boeing, he received the test pilot’s message of November 2016 that the MCAS caused problems in January 2019 after the first crash of the 737 MAX plane and just before the second.

But suppose the message reaches the top, how will the leader react, will he/she take action? Leadership embraces many aspects about which
Table 1  
Perrow (1999) examples with the aspect of management ignoring warning signals.

| Disaster location | Year | Warning signal to higher management ignored | Reference |
|-------------------|------|---------------------------------------------|-----------|
| Bhopal            | 1984 | Low morale; essential safety devices in maintenance; despite operator reported an anomaly at flushing operation supervisor ordered him to continue, causing water to enter MIC tank leading to the disaster. | Shrivastava (1987), Chapter 3 |
| Seveso            | 1976 | Low safety culture; bad design; serious management errors; not learning from previous incidents with serious consequences elsewhere; ignoring concerns from unexplained accidents in the sector. | Fabiano et al., 2017 |
| Three Mile Island | 1979 | Due to insufficient training operators had wrong mental image of process; shift supervisor ignored/wrongly interpreted signals providing warning; superintendent technical support appeared not familiar with this reactor. | Rogovis & Frampton (1980) |
| Chernobyl         | 1986 | Bad safety culture; in principle unstable design; insufficient insight in reactor complexities; procedures not followed; ad hoc change of plans; late response top management, at first trying to downplay consequences. | Insaq-7, 1992 |

In view of the problem discussed in this paper it is useful to draw attention to all these points but in particular to the concept of resilience as it encompasses most of the factors in play in decision making. Weick and Sutcliffe (2007) define this as “Resilience is a combination of keeping errors small and of improvising workarounds that allow the system to keep functioning”. Jain et al. (2017, 2020) elaborating the concept of resilience for a socio-technical system, such as a process plant, emphasized the elements of early signal warning besides design of error tolerant equipment, plasticity of mind, and recoverability, which starts with effective emergency response. Thorough risk assessment is a basic underlying requirement. Plasticity of mind means flexibility but not to such extent that it embraces ‘jumping to conclusions’, hence resistive flexibility. From a socio-technical system point of view, including the technology element with all its (somehow human caused) failure possibilities, the concept goes further than the paradigm of resilience engineering oriented on people’s attitude and culture as initiated by Hollnagel et al. (2006). Results so far of the concept are summarized by Pasman et al. (2020), Weick and Sutcliffe (2007) also underlined the importance of training and the availability of skilled and knowledgeable employees.

Training work floor and middle management is generally accepted as a basic necessity, but in order to take the right decision quickly in case a threat signal comes in, top management, such as CEO’s, should be given adequate training to recognize hazardous situations. In the UK there has been an attempt to do that systematically around 2013 when Judith Hackitt (2013) was Chair of the Health and Safety Executive and President of IChemE, but the efforts were ineffective given the heavy time pressure on top management. However, a company as Dow with its Leadership in Action initiative (Dow, 2020) provides training to potential leaders to prepare for the many aspects, they, as leader in their later career will be confronted with; also, plant managers at the start of their job are being trained and given insights into process risks.

Reality is very diverse and to know on the forefront all what can happen is not and include it in training is impossible. Risk assessments are fallible because of uncertainty (incomplete identification of scenarios, inaccurate data and models). For those reasons, the mentioned resilience elements should help to sustain business continuity.

Besides recognizing situations causing major risk, precursor and other convincing early signals should reach top management quickly. For this to happen effectively, overall organizational structure is important. In the French example of the zinc distillation incident discussed earlier, the safety section was part of the human resources

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Journal of Loss Prevention in the Process Industries 70 (2021) 104272
department. That arrangement was quite common in those days, because emphasis was on personal safety and personal protection equipment. Process safety causing major risk was taken for granted. Top management did not consider a process safety failure event causing a high impact-low probability (HILP) calamity, a risk to continuity of the enterprise. Even in a large oil company, such as BP until after the 2005 Texas City refinery and the 2010 Macondo oil drilling disaster with the demise of the Deepwater Horizon platform, local safety concerns didn’t reach top management. However, as Monteiro et al. (2020a, 2020b) further mentioned, following the 2010 event world-wide operating BP (British Petroleum) reorganized and established a Safety & Operational Risk function, reporting to the group chief executive (BP, 2010, p.15). According to the 2019 annual report this further developed and BP features now a risk management system “for managing and reporting risks from the group’s operations to management and to the board. The system seeks to avoid incidents and maximize business outcomes” (BP, 2019, pp.68–71). TEPCO management of the Fukushima Daiichi power plant went the same direction (TEPCO, 2013, pp.7–15). The new CEO of Boeing has confirmed that safety concerns would now be reported faster to top management. Alas, these changes come after those heavy losses occurred.

However, for the response to imminent threat, not only is organizational structure an important factor, but also the corporate culture. If for example there is a lack of solidarity and openness to share information or bureaucratic rules slowing information exchange down, it is a sure sign of an immature safety culture. It is well known fact that organizational culture is determined by the top, for example see Zohar and Hofmann (2012).

All of the above is not only valid for commercial organizations but certainly also applicable in case of public administration/municipal and higher governmental organizations (Henstra, 2010).

4. Operational risk management/dashboard

Quite a few years ago Knegtering and Pasman (2013) hinted on the possibility to continuously monitor risk level of a plant. Meanwhile, thanks to increased computing power, dynamic risk assessment (Patrini and Khan, 2016; Khan and Amyotte, 2020) has become a known tool. Computing power and automation are the drivers behind the trend toward digitalization of the process industry enabling the use of big data and analytics, such as neural networks, machine learning techniques and Bayesian networks. This enables pattern recognition, advanced statistics and revealing cause-effect structures. These techniques make it also possible to detect a weak signal amidst clutter in continuously measured data streams. It also combines data from various sources: the process, the business, maintenance, laboratory, work permits, visitors etc. Lee et al. (2019) explained how ISO 15926 standardizing CAD formats makes it possible for computers to read flow sheets and P&IDs of an entire plant and construct a digital twin. For process safety this will have a beneficial effect, because it will enable improved semi-automated hazard identification, and more accurate risk assessment, while operators can train on simulators and learn how to better respond to various upset situations to keep a process in safe state. At the same time, it holds the promise of optimizing process conditions, and hence, economics.

The sketched developments will lead to the possibility to build a relatively reliable risk ‘dashboard’ with information what risk, where and recommended action. Such development will help top management to make true what an HRO stands for.

Of course, failure of taking decision at the top in case of a warning signal that a disruptive event throws its shadow forward, is by far not the only way something can go wrong. Behie (2020) gives examples how decisions taken at lower levels of the hierarchy led to disaster, how these decisions can be analyzed in decision matrices, and lists so-called decision types termed “buckets” to prevent. These decision types are rooted in the process safety management system. A plea is made for risk-based decision making (RBDM), hence performing a risk assessment when a decision of the bucket type shall be made.

5. Future perspective and conclusion

History has clearly shown how inaction of top management to take adequate measures despite clear indications of an approaching threat, can lead to accidents and disastrous outcomes. Choo (2008) in his analysis of the problem summarizes it with its causes as shown in Fig. 1, and also presents suggestions for prevention, in which HRO plays a major role. Weick and Sutcliffe (2007) claim that an HRO distinguishes itself most from the ordinary in responding to an early warning signal.

Indications or early warning signals may be internal to the organization by an increased risk level or occurrence of precursors, and externally generated through a range of considerations, such as cyber-attack, other criminality/fraud or terrorism, extreme weather, earthquake, or other sudden changes in conditions. In the end a major upset will affect business; process break-down of some sort will also lead to financial risk, logistic changes and other stresses. With the present state of information technology (IT) and the advent of many types of sensors, processors, and computers in the organization to automate processes and help manage complexity, uncertainty and confusion with the effect of improving the situation. In fact, as the BP, 2019 Annual report mentions the company group risk team analyzes the entire group’s risk profile, hence business and associated risks which includes technical process risks. This team undoubtedly will also benefit from big data and analytics. As we have seen, an adaptation of the organizational structure would be required in many cases in order to gain a better appreciation of process safety in addition to the many other priorities of top management team. More research should be encouraged to find practical solutions to the challenges raised in this article.

Author statement

Hans Pasman selected and discussed the material, has done the writing, and submitted the paper.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The suggestions made by Dr. Stewart W. Behie, interim director MKOPSC are gratefully acknowledged. I also acknowledge the positive comments of anonymous reviewers that improved the paper substantially.
