What they should have known
Human Factors Competencies in Plant Environments

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In this presentation the participating human factors in two incidents from the process industry will be explained and discussed. Thus appropriate human factors competences for the different hierarchy levels of a typical chemical plant in Germany will be developed.

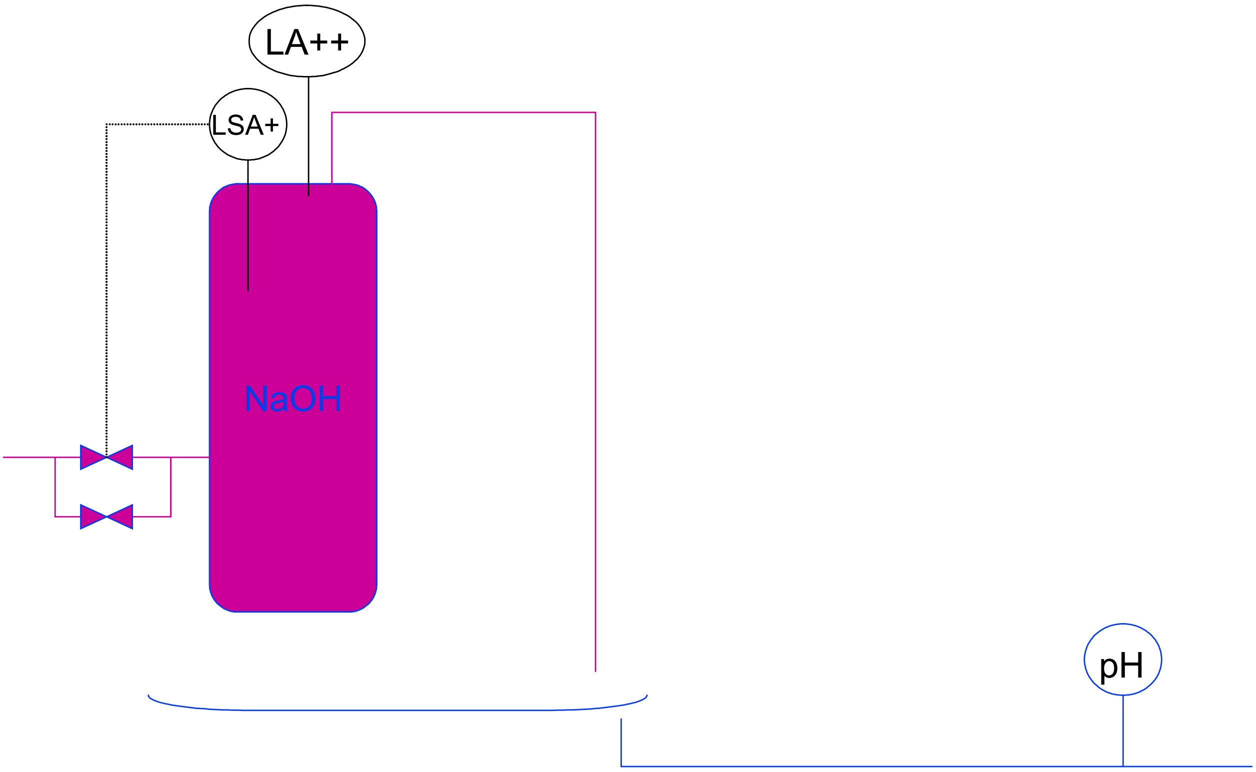
Incident one revolves about a spill of caustic soda into a river. The involvement of different levels inside and outside of the company will be discussed. The management of the chemical plant will be split up in the different hierarchy levels to show the potential for accident avoidance by human factors trained and competent personal.

Incident two shows an incident caused by computer related faults and how skilled operators could avoid the imminent accident due to their situational awareness and instant problem solving ability. Human factors worked here as safety resources. Due to lacking human factors competences in the management of the chemical plant no further learning could be derived from the avoided accident.

A one sided human factors training is not sufficient. Human factors have to be introduced top down with support from top management. During the training a feedback loop has to be established bottom up yielding a continuous improvement process for all hierarchy levels. Especially in the chemical industry government agencies have to be involved periodically so they can participate from the learning process.

Case Study 1

In a continuous operating chemical unit producing phosphor derivates a spill of caustic soda 33% occurred into a river running through the chemical plant. The chemical plant consists of more than 100 chemical and pharmaceutical units plus research and infrastructure facilities. The respective chemical unit is a relatively small unit belonging to an inorganic business unit of a chemical division.



On the day of the incident a shift worker had to fill a storage tank for 33% caustic soda. The tank was filled from an internal pipeline of the site. To fill the tank he used an automatic filling valve connected to a high level alarm of the tank acting as closing device. The filling process used to take a very long time due to the low flow capacity of the valve. To shorten the time an additional bypass was opened by the shift worker. Thus the filling time could be reduced to less then half an hour. The regular checking tour shift workers performed at the beginning of each shift started and ended at the storage tank. Therefore some shift workers opened the bypass valve at the beginning of the tour and closed it at the end. It was officially forbidden to use the bypass valve except for maintenance or in case of problems with the automatic valve.

On the day of the incident the shift worker had to interrupt his checking tour to help a co-worker with a congestion of a component of the unit. This took more time than expected. In the mean time the storage tank filled up and the high level alert closed the filling valve as designed. But the storage tank was now filled further trough the bypass. A second high level alert sounded in the control stand. No one was present there, so the tank filled further and the caustic soda finally spilled through the ventilation pipe into the tank pit. There it gathered in the drainage sump and flew further into the rain water channel. On the chemical site the rainwater channels led directly to the river running trough the site. The drainage was tough controlled by a pH monitor that caused an alarm that rang through the complete unit alerting all shift workers. It took another 20 Minutes to locate the open bypass valve because the checklist obligatory for a response of the pH alarm mentioned the storage tank as last point.

At first glance the only contribution factor to the incident is the deliberately opened bypass valve, a typical human failure of a single worker. But at a closer look it becomes obvious that all hierarchy levels plus the regulation regulating authority take part in the accident:

- The regulating authority demanded a separation of the drainage of the tank pit for the caustic soda storage tank from the sewage to the biological treatment plant. This was due to the fact that in this area a caustic pH was prevailing, so a spill of caustic soda would have caused a chemical reaction in the sewage line. So the pit was drained into the rainwater sewage. The only demand was the monitoring of the pH in the sewage.
- The plant did not have a capture tank at the discharge of the rain water sewage.
- The production management knew that the manager of the chemical unit lacked communication skills with the shift personal. But the retirement was due in half a year, so no further steps were taken.
- The unit manager was a very experienced chemist who had a special expertise for phosphorous chloride plants. He had travelled almost the whole world starting up such plants. He had spent several years in India and Brazil and had a low opinion on shift personal. He had established a thorough set of check lists and operating procedures and demanded a 100% commitment to them, refusing discussions about them.
- The unit personal tried to avoid contact with the unit manager as much as possible since they used to be criticised almost any time on contact. The unit day shift foreman was the only accepted sparring partner for the unit manager. Thus the low flow capacity of the filling valve for the store tank was discussed with the foreman. But he saw no chance in realizing the proposal due to the costs of the replacement.
- The unit personal had thus established the unorthodox filling procedure; well aware that is was not allowed. But since the walk around started and ended at the storage tank it was considered a fail safe procedure.
- The unit manager had made the use of the checklist in case of a major alarm absolute obligatory. Therefore the unit personal followed the procedure closely and used their complete mental resources to work the checklist as efficient as possible. Therefore the deliberately left open bypass valve was forgotten by the shift worker performing the checking tour. Since the probability of a leaking storage tank was very low, it was the last point on the checklist.

The spill and emission in a public river caused a shut down of the unit by the regulating authority. Only three days later, after several additional safety procedures had been established and further technical measures taken the plant was allowed to operate again.

How could this incident have been prevented by more knowledge in human factors?

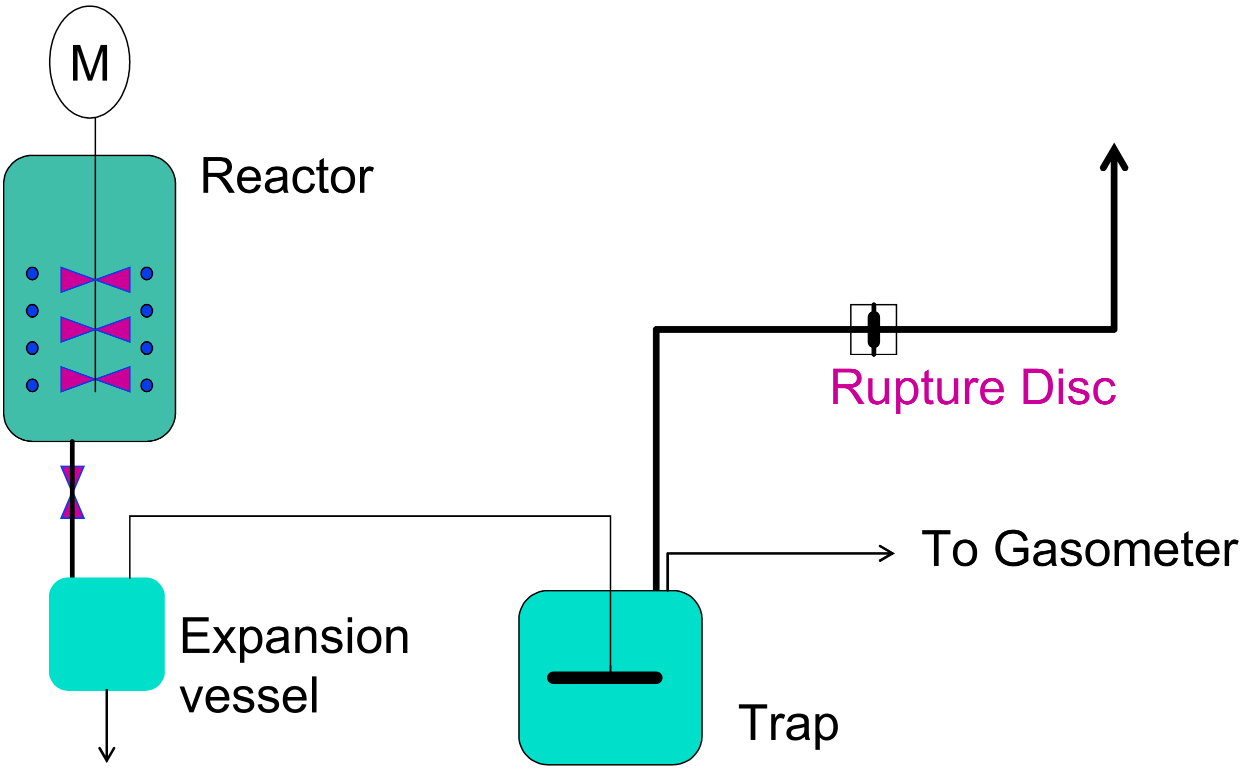
- The plant management would have considered that a solution of a latent problem can not be delayed. Relying on the built in redundancies in the safety system does imply that they are kept upright all the time.
  - The rain water system should have a cut off
  - The unit manager should have been replaced
- The plant manager would have seen his workers as acting and thinking characters and not as contributors to failures. Even the well meant checklists for major alarms should not prevent the situational awareness.
- The dayshift foreman would have established a routine to ensure safety standards and so would have detected the problem with the filling valve. He would have discussed the problematic valve with the unit manager. Eventually he would have

sought support from the unit assistant or unit engineer. Furthermore he would have installed a safeguard to prevent the use of the bypass valve.

- The dayshift foreman would have trained the use of checklists especially stressing the special situation of thinking and acting under pressure.
- The shift foreman would have discussed the cumbersome filling procedure with his shift workers but stressed the importance of the safety procedure not to use the bypass valve. He would have locked the bypass to prevent the opening. He would have communicated the latent problem to the shift foreman and unit manager.
- The shift worker would have considered "Murphy's Law" and filled the tank without using the bypass.

Case Study 2

In a chemical plant producing emulsions in 30 m³ reaction vessels an incident happened during the polymerisation process.



The polymerisation process is performed in water. The major components consist of vinyl acetate and ethylene. Thus high pressure up to 90 bars is necessary to perform the reaction. The polymerisation takes about 6 hours at temperatures between 70 an 90°C. The reactors are automated and monitored by an extensive control system. During the polymerisation a bottom valve was abruptly opened by the process control system. In the control room three shift workers were monitoring six reactors. An opening bottom valve of a pressurized reactor leads to numerous alarms in the reactor periphery and the outlet including the emergency expansion unit. In this so called alarm shower the monitoring shift worker was able to locate the origin of the problem, and close the valve manually with the process control system. He did this in such a short time, that a busting of the rupture disc in the emergency expansion pipe could be prevented. A busted disc would have caused a foaming spill of the complete reactor content over the roof of the production building. Not reacted vinyl acetate would have been emitted in the surrounding and a warning of the neighbourhood would have been necessary. It should also be mentioned that the problem occurred during a Sunday night shift at about two o Clock in the morning.

The cause for the abnormal opening of the bottom valve was programming errors in the control system. During a modernisation of the system another manufacturer was selected. To save costs crucial parts of the monitoring system were kept and interfaces programmed. The new control system comprised two CPUs for safety reasons. During a breakdown of one CPU a faulty source code in the program caused a step in the recipe control. Though the control system had been tested thoroughly this programming error had not been detected.

It took the process control experts half a day to find the origin of the malfunction the night before. The source code was corrected and the unit manager demanded a thorough check of all remaining interfaces between the modules of the process control system. Since an actual emission was prevented the problem was treated internally in the production unit. The respective shift worker got the notice, that the problem had been found and eliminated.

This incident shows that humans are the actual safety factor in our plants. The question is, do they know it? In this case the good reaction of the shift worker was seen as normal, “That is his job”. Often the “experienced worker” can be found in descriptions of safety systems as last resource.

Therefore it is important to ensure that this last resource can act as safety factor. He has to know it, and he has to be supported by management and technology.

How could a gainful reaction to this incident have looked like?

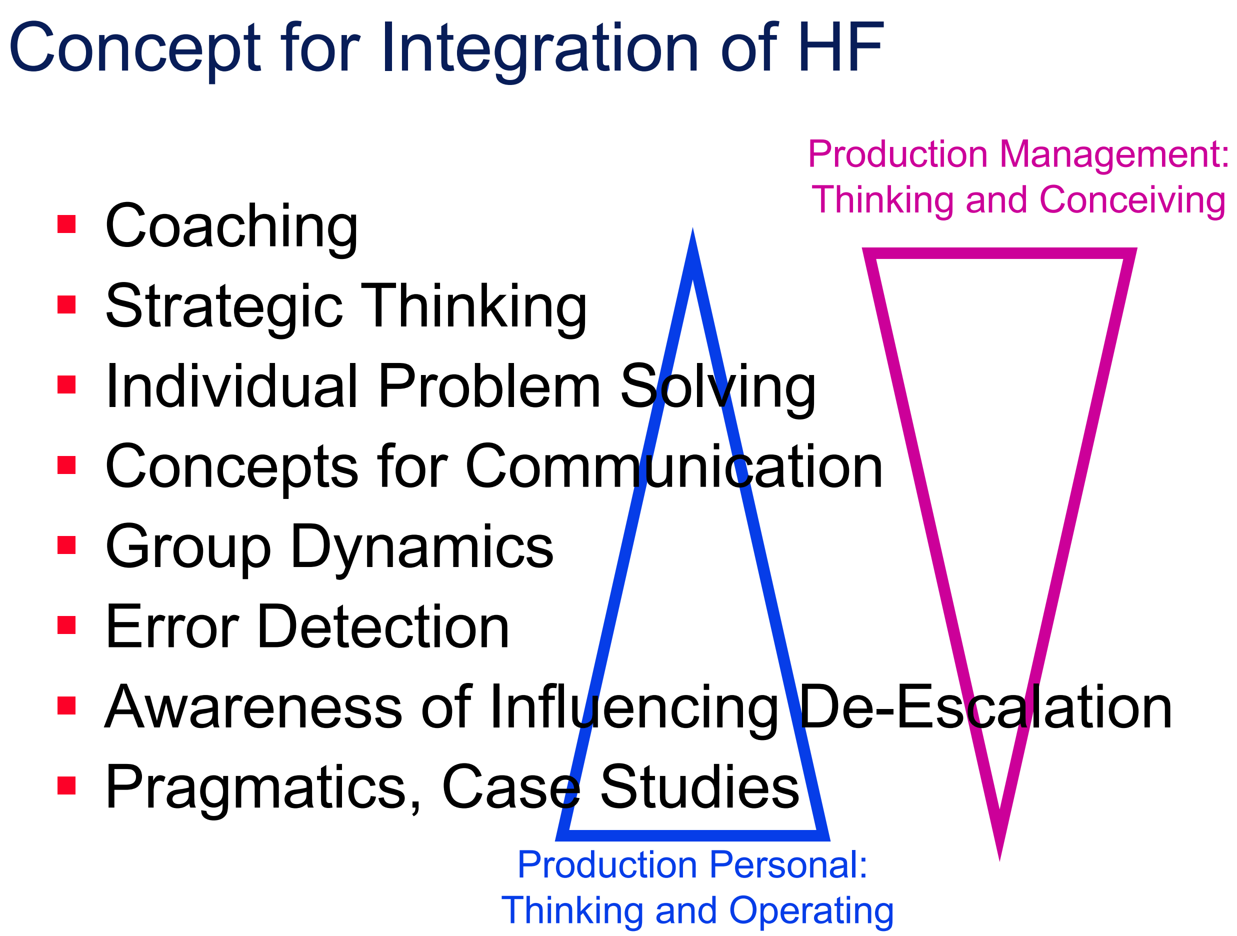
- The unit manager should have reported the excellent reaction of the shift worker internally and to the management. A learning lesson for other shifts and units could have been developed.
- The corporate management should have acknowledged the shift worker officially, i.e. via an internal publication. At the same time it could have announced that standards for interfaces in process control units would be revised and enforced.
- The incident should have been discussed in all shifts by the daytime foreman to show the capabilities of man in a complex technological surrounding for problem solving in unforeseen situations.
- Interfaces between older and newer process control systems have to be tested completely. Standards for requirements should have been derived from the learning of the incident and applied in all units.
- Process control engineers should have been confronted with the incident to learn how to involve human factors into safety systems. The problematic alarm shower could have been investigated and measures to ensure the competent actions of the monitoring workers derived.

What would the effect of this reaction have been?

- Revealed latent problems are handled promptly and are not covered up.
- Human capabilities are not ignored or seen as normal
- Human limitations can then be discussed and trained
- Communication on latent problems is opened up
- A constructive error culture can be established as integral part of the safety culture

Conclusion

The case studies show, that a thorough competence on human factors is necessary to ensure the human capabilities in complex working environments and especially in safety systems. The focus on special fields has to be adjusted to the hierarchy level and the field of responsibility. Management levels have minor compact on the actual operating of the unit. Thus only basic knowledge on active mistakes, escalation mechanisms and group dynamics are necessary. On the other hand strategic thinking and problem solving in complex situations is a major issue. Upper hierarchies have to learn how to communicate and coach the thematic into the operating units. Operating staff from the actual shift worker to the daytime foreman have to have a profound knowledge on active mistakes and the human capabilities and limitations in tackling escalation in complex working environment. They have to learn i.e. to handle errors in a team effort to bundle resources. This learning should be achieved as close to the working environment as possible so case studies in workshops seem to be a good way.



The training issues have to be adjusted and tuned so that the communication bottom up and top down on human factors ensures that human factors can be the superior safety factor.

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