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# New Risk Assessment for Innovation Management


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**Abstract:** Risk management and with this risk analysis and risk evaluation are mandatory for today's companies, not only because it is requested by laws and regulations but also to ensure the future existence of a company. Although methods are used to fulfil this task many failures in innovation processes occur after product launch or lead to long testing cycles representing the products life cycle. This paper presents a method that is able to generate potential failures not by asking what might go wrong, but by inverting the problem to how can we make it go wrong and finding a solution for preventing that failure from there. With its system based modelling and its systematic approach to failure generation an almost comprehensive set of failures and failure scenarios can be provided.

**Keywords:** Risk analysis; Risk Evaluation; Anticipatory Failure Determination; AFD; Failure Prediction; Theory of Inventive Problem Solving; TRIZ.

## 1 Introduction

Risk Assessment is part of the Risk Management of a company. Risk Management is an important issue for companies all around the world, especially if they deal with innovative products or services that are offered to customers. Some countries have regulations and laws in place that force companies to take care about technical risks as well as financial risks, and the risk of loss[1]. International standards (such ISO 31000: Risk management) give a frame work for implementing such a system.

The single stages of a risk management and the methods for the risk management are shown in Fig. 1. These methods can be used as well for strategic as for operational risk management tasks. Reasons for executing the risk management process within the innovation cycle are:

- New products
- Main changes on product (or parts of the product)
- New materials
- New technologies
- New or changed field of use
- Changed procedures

There are a lot of methods for setting the context of the risk management in innovation. On the operation side there is the Cross-Impact-Analysis that gives one a more general view on how decisions might influence each other and sets the context for the risk management. Not set here are the details that cause failures in the innovation process (for more details of Cross Impact Analysis see (Roper, Cunningham, Porter, et al., 2011; chap. 6.4).

If we take a closer look at the innovation of products, process and services the methods for Risk Identification, Risk Analysis, and Risk Evaluation (the steps of Analysis and Evaluation are often executed in parallel) are now considered for this paper. In this area there are only a few methods available, if the focus is set to the innovation of technical systems:

- FMEA: Failure Mode and Effects Analysis
- HAZOP: Hazard and Operability Study
- FTA: Fault Tree Analysis
- Cause and Effect Diagram

Amongst these methods the Failure Mode and Effects Analysis (FMEA) is the most established tool for risk analysis and failure prevention in engineering. The fact, that FMEA emerged as a standard in this area, is particular the result of the implementation by QS-9000 within the automotive industry (McDermott, Mikulak, and Beauregard, 2008). FMEA is hugely useful to identify possible, but in some degree expected, failures, e.g. the non-performance of a function or the minor deviation from an expected data (Hippel, 2006)

[1] In Germany for example the “Corporate Sector Supervision and Transparency Act” explicitly demands from management to implement a warning system for risk (Gabler, 2012). Another type of regulation is the Sarbanes-Oxley-Act that set new or enhanced standards for all U.S. public company boards, management and public accounting firms (Soxlaw, 2002).

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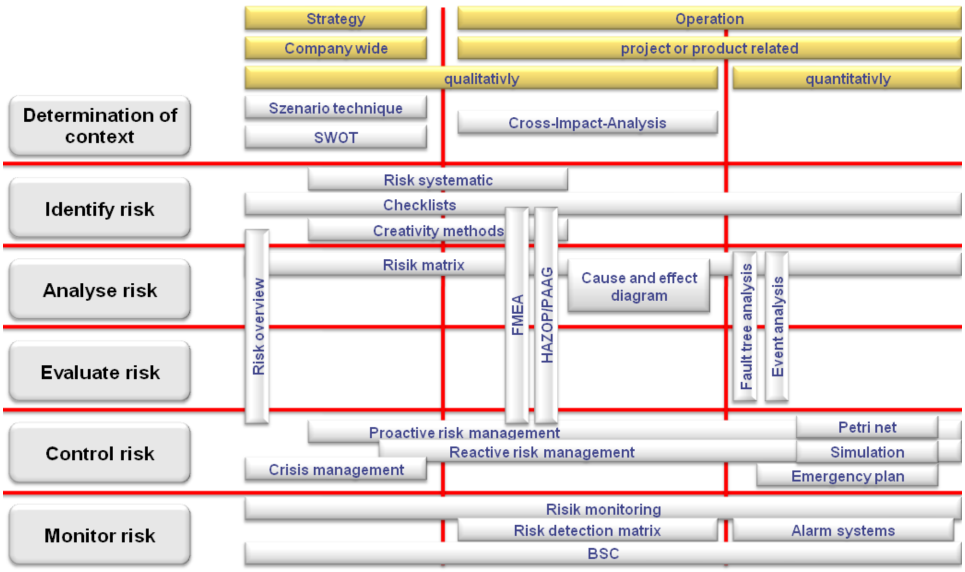


Figure 1 Methods for risk management and their position in the risk management process according to (Woll, 2007)

Sooner or later every company has to experience that the number of occurred defects is still too high. The impacts can either be quite innocent or of particular importance for companies, employees, regions or the whole mankind. Failures, not expected in the slightest, are particularly fatal. They happen, when the cause of trouble cannot be derived directly from the product or process structure. Moreover, the combination of several errors can cause more serious impacts, than each error itself. In most risk management methods the failures are derived by:

- Negating the intended function
- Brainstorming about possible failures
- Look for failures that have already happened

Anyway, locating possible and future failures is by no means automatism, but rather a procedure, that requires, besides a systematic approach, lots of creativity and inventive talent. According to *Frenklach* it requires not only asking the characteristically FMEA-questions “why” and “what”, but furthermore asking the question “how” several times (Frenklach, 1998).

Anticipatory Failure Determination (AFD) encourages these questions. AFD is a TRIZ-based procedure. TRIZ (the Russian acronym for Theory of Inventive Problem Solving) is a set of methods developed by Genrich S. Altshuller for supporting creativity in the inventing and problem solving process (Altshuller, 1984). To invent failures, by inverting the problem, enables us to use other TRIZ tools for revealing hidden failure mechanisms and for predicting unexpected future failures. Using TRIZ tools allows us to achieve innovative preventive measures respectively preventive system designs. Examples from different fields of application prove the success of this procedure (Frenklach, 1998) (Proseanic, Tananko, and Visnepolschi, 2000), (Proseanic, and Visnepolschi, 2000), (Ruhe, 2003), (Zlotin et al, 2000). Hereafter this preventive aspect will be defined as AFD Failure Prediction (AFP).

Based on Altshullers insight that TRIZ offers powerful approaches for different scopes including research and development (Altshuller, 1984), the evolution of AFD is affected by the work of other well known names e.g. Zlotin and Zusman creating AFD method in the early eighties introducing the inversion and operators as key elements (Kaplan, Visnepolschi, Zlotin, and Zusman, 1999) or V. Mitrofanov who worked on problems regarding waste elimination in manufacturing using the principle of intensification. The evolution of the AFD is shown in detail in the book “How to deal with failures (The smart way)” (Visnepolschi, 2008).

The implementation of the main AFP idea can be done by using different TRIZ tools and different levels of standardization. Promising lines of action and potential software support exist and are published (Kaplan, Visnepolschi, Zlotin, and Zusman, 1999), (Ungvari, S., 1999), (Visnepolschi, 2008). But as a matter of fact, Anticipatory Failure Determination in general is still one of the TRIZ tools that is not used very frequently (Livotov, 2004).

## 2 Anticipatory Failure Determination Prediction

Since there is no AFP-standard this work will refer to the detailed process description of S. Visnepolschi (one of the authors of this work). This process includes the following eight steps (Visnepolschi, 2008):

### *2.1 Obtaining information (Step1)*

In this first step the expectations for the AFP project have to be defined. Usually there is the need for a “practically safe” system – a system that will not collapse, injure anyone or cause some trouble for the responsible persons or institutions (Visnepolschi, and Proseanic, 2003). After this definition a set of well-proven questions supports the gathering and/or creation of necessary information. These questions help to explore the system of interest, its structure, its functioning, undesired effects, its environment and the history of the system.

### *2.2 Developing a System Diagram (Step 2)*

The System Diagram visualizes cause-and-effect connections in the functioning of the system. The favoured notation is based on the problem formulation notation (Ideation, 2005), (Terninko, Zusman, and Zlotin, 1998). So the system diagram for the AFP should include the useful and harmful functions (or operations). In this case an important event or a meaningful state of the system may also be considered as a “function”. The functions are the knots of the diagram that are connected somehow by cause-effect links. The diagram also indicates the primary useful function of the system. The graphical representation of the system assures, especially for complex systems that nothing is

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forgotten and the risk analysis team gets more insight to the system itself. An example is given in Fig. 2.

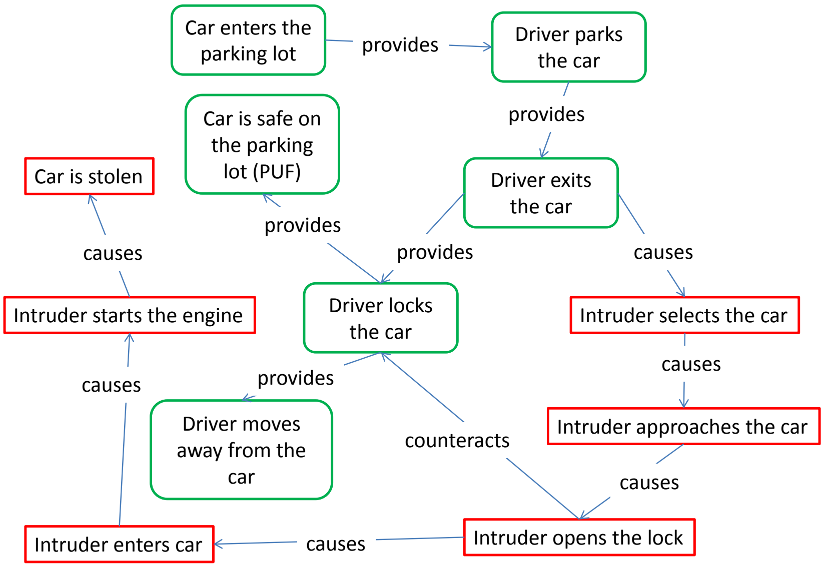


Figure 2 Example System Diagram (Visnepolschi, 2008).

## 2.3 *Identifying Focal Points (Step 3)*

Focal Points are the zones or weak points of the system that may cause the biggest weakness of the system or the greatest danger. So using the system diagram the focal points are represented by useful functions that lead to big weakness and harmful functions that cause great danger. Typically focal points in the system diagram have a high number of incoming and outgoing links and are strongly connected with the systems functioning (Fig. 3). The approach to concentrate on Focal Points emphasizes the intention to identify the unexpected and especial critical failures. For each identified focal point the next step is executed.

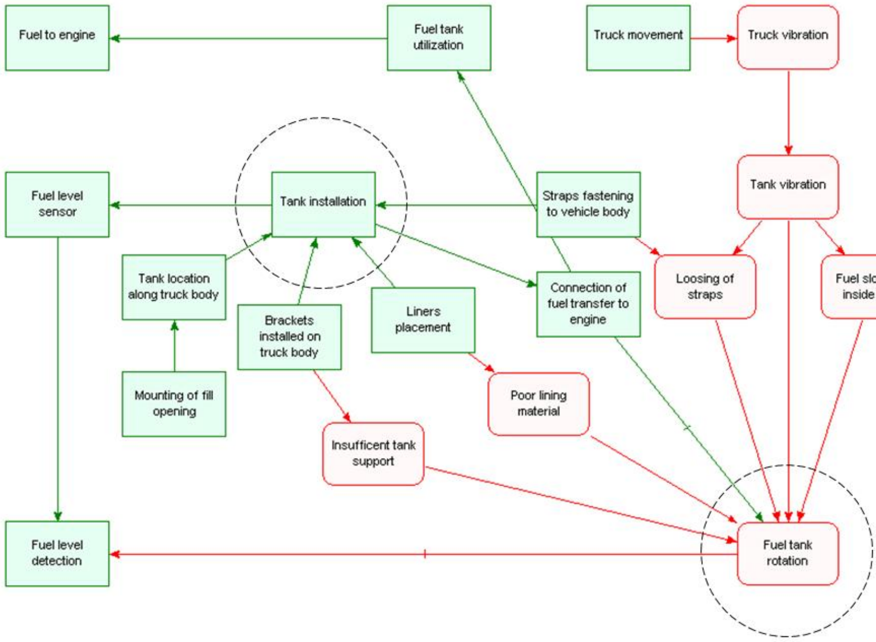


Figure 3 Examples for focal points (circled elements).

## *2.4 Generating Failure Hypotheses (Step 4)*

The generation of failure hypotheses is divided in two stages: the development of “AFP Directions” and the application of Checklists and Operators.

A systematic way to develop the AFP Directions is given by the consequent utilization of the SEOR-model regarding the Focal Points. The AFP Directions are abstract commands that are challenging readers to develop failure hypothesis (e.g.: Find ways to strengthen harmful impact on the Focal Point!). Fig. 4 shows the SEOR-configurations to formulate the AFP Directions.

An example for the SEOR-Model can be described as follows: to destroy (melt) an Object (a plastic pad) the harmful Source (a heating device) should be placed close the Object. Conversely: to protect the plastic pad (opposite effect), it should be moved away from the harmful Source (the heating device).

Answering the commands of the AFP Directions leads to a first list of failure hypotheses. With this systematic approach even more failure hypotheses can be found as just with intuition.

The Checklists and Operators can now be used to enforce this effect dramatically. This well structured lists (e. g. typically hazardous materials, typically hazardous processes, typically hazardous individuals ...) and Operators (concrete but not specific thought-provoking impulses, derived from different TRIZ-tools and experience in AFD) let the list of failure hypotheses expand even more.

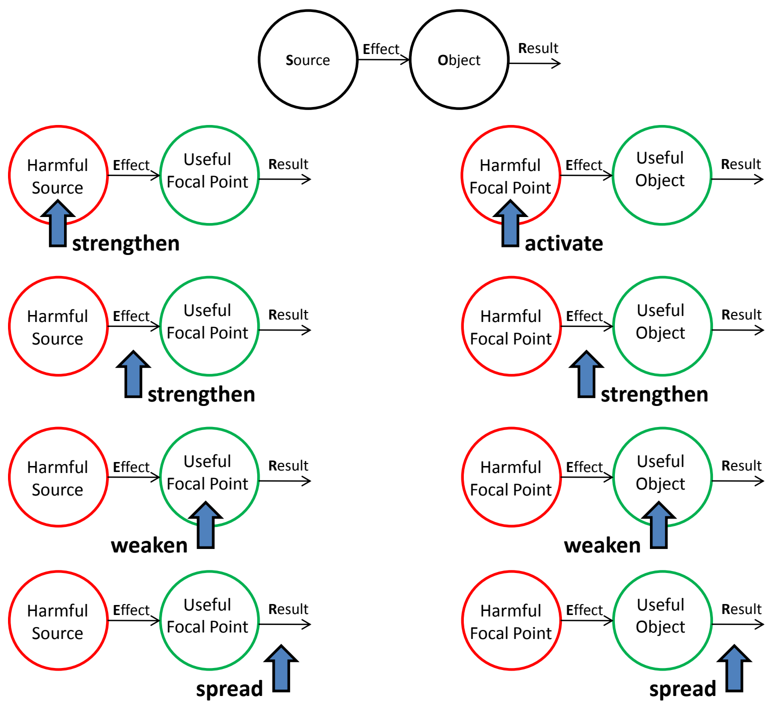


Figure 4 SEOR configurations (Visnepolschi, 2008)

SEOR formulations for the truck tank modelled in Fig. 3 are (partial list):

1. Utilizing the resources of [the] (Tank installation) to deteriorate other systems.
2. Consider utilizing the resources of [the] (Straps fastening to vehicle body) to deteriorate [the] (Tank installation).
3. Consider utilizing the resources of [the] (Tank installation) to deteriorate [the] (Straps fastening to vehicle body).
4. Consider utilizing the resources of [the] (Fuel level sensor) to deteriorate [the] (Tank installation).
5. Consider utilizing the resources of [the] (Tank installation) to deteriorate [the] (Fuel level sensor).
6. Consider utilizing the resources of [the] (Fuel to engine) to deteriorate [the] (Tank installation).
7. Consider utilizing the resources of [the] (Tank installation) to deteriorate [the] (Fuel to engine).
8. Consider utilizing the resources …

### *2.5 Generating Failure Scenarios (Step 5)*

This step continues the search for failures in two ways: Inventing most dangerous failures and combining resources of multiple failures.

Inventing the most dangerous failures is a procedure supported through particular checklists. It encompasses the attempts to intensify already found possible failures and to explore possibilities to hide the failures. The combination of multiple failures helps creating failure scenarios with intensified impact on the system.

### *2.6 Assessing Risks (Step 6)*

The process of evaluating the risks in AFP is based on the definition of hazard and likelihood. But these two factors may be used in a different way (Visnepolschi, 2008): Regarding the hazard failure hypotheses and scenarios have just to be judged whether they are causing injury to human beings, danger to the systems functioning or pollution to environment or not.

Regarding the likelihood estimation is very hard for potential critical errors that are invented by thinking about the most dangerous failures and the combination of different errors. Instead of guessing the likelihood of failure exposure the likelihood can be evaluated by the evaluation of the availability of the existing resources that are necessary to provide the failure.

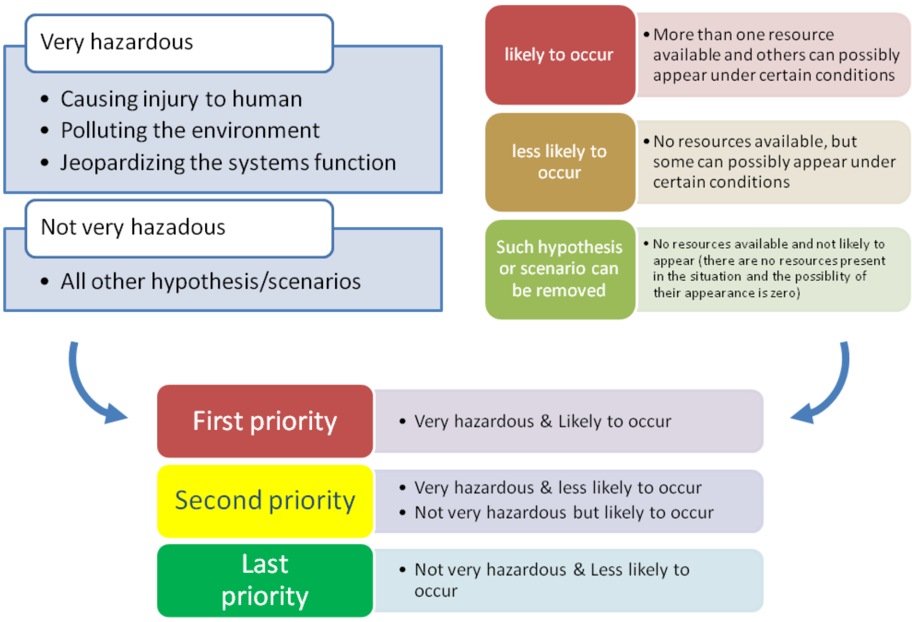


Figure 5 Risk assessments depending on impact and likelihood of availability of necessary resources.

As a result of this consideration failure scenarios and hypotheses can be defined as very important, if they are very hazardous and the resources to provide the failure are available (at the moment or under specific but possible conditions). Failures not very hazardous but likely to occur or failures very hazardous less likely to occur are designated as “second priority”. The lowest priority group includes the failure scenarios and hypotheses that are not very hazardous and less likely to occur (Fig. 5).

### *2.7 Preventing Probable Failures (Step 7)*

The prevention of the failures should be started by developing a system diagram (see step 2) for each failure hypothesis or scenario that is to consider. These diagrams are the starting point to find the solutions to prevent the failures. The diagrams show failure mechanism chains and contradictions. Just analyzing these diagrams can produce reliable solutions. With the help of checklists, operators or some other TRIZ-tools more effective solutions can be developed.

### *2.8 Evaluating Results (Step 8)*

The evaluation of the results shows if the solution really can be implemented preventing the failure completely. To prove that the solutions should be examined in detail – like in the procedure described so far, now the solutions have also to be checked with a simplified Express-AFP procedure.

## 3 Example

To give an example of the AFD a problem of a Northern American chemical company is explained.

At one chemical facility in Northern America a minor gas leak happened through a scrubber. The gas itself was not dangerous, however, smelt unpleasantly. Because of the school that was located nearby, the leak caused negative reaction in the neighbourhood. AFD specialists were invited to the facility.

To shortcut the example a simplified Failure Analysis process will be used, containing the following steps:

1. Identify the Ideal State: No release of hazardous gas ever occurs from the process
2. Invert the Ideal State: We want to release hazardous gas from the facility
3. Exaggerate the Inverted Ideal State: We want the leaking gas to cause an explosion of the gasholder
4. How would we accomplish this? What resources are required?

Based on the approach the AFD-specialists considered the worst case scenario – explosion of the gasholder containing over 100 tons of pressurized liquid gas. The chemical facility personnel were very reluctant to deal with what they perceived as a fantasy.

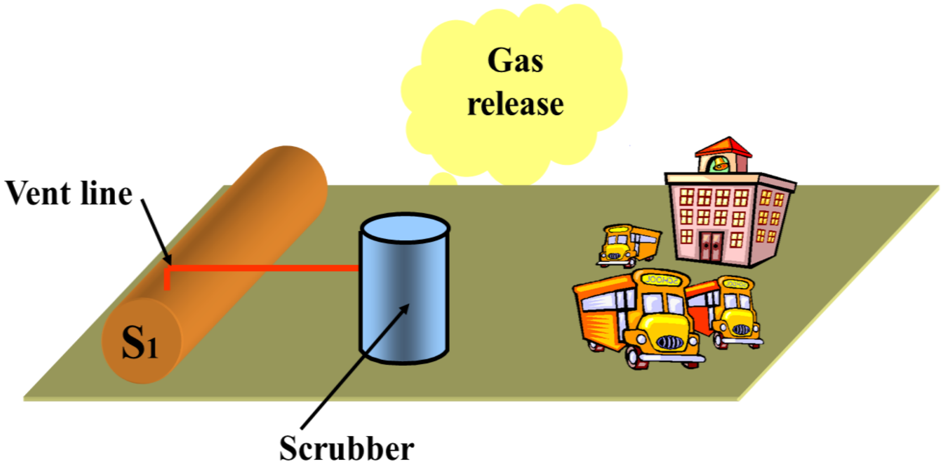


Figure 6 Setting of initial situation

More detail evaluation of the facility showed the following:

- The real technological process involved not one but two gasholders with two different gases, both under high pressure.
- The second gas was highly poisonous and extremely flammable.
- Both gases entered the reactor under pressure, producing a chemical reaction of explosive type accompanied with release of substantial amount of heat.

The AFD specialists formulated a Failure Prediction type of problem as follows:

> *Find a way to bring two gases in contact out of reactor initiating an explosion capable to destroy one or both gasholders.*

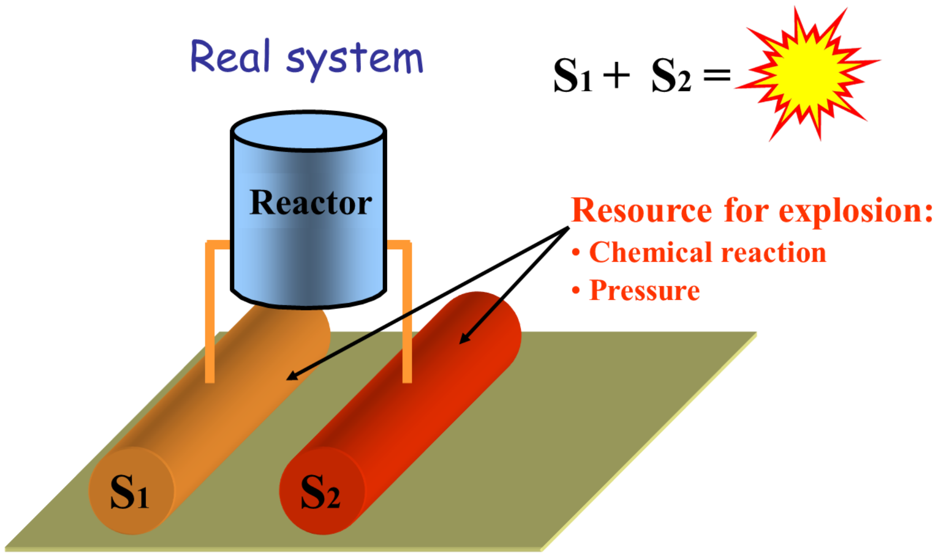


Figure 7 Real system with necessary resources

First, the facility personnel insisted that such explosion could not take place. However, analysis of available resources unveiled the following:

- Both gasholders were connected with the above mentioned scrubber through the same ventilation line
- Ventilation line had two valves – manual and automated (controlled by computer)
- If one of the valves was closed gases could mix in one of the gasholders (the one with lower pressure) causing a **powerful explosion**
- Each of the valves could be closed any time as a result of human mistake or computer glitch

Basically, this facility had been functioning for 10 years and all that time a dangerous risk was always latently hidden there. To avoid this dangerous situation the solution was implemented very quickly. To make sure, that both valves are always open, is to disable them: the manual valve by welding a rod to the valve wheel that hinders the movement of the valve wheel and the automatic valve by disconnecting the wires.

> *The most interesting was the question – why such dangerous valves had been installed in the system in the first place?*

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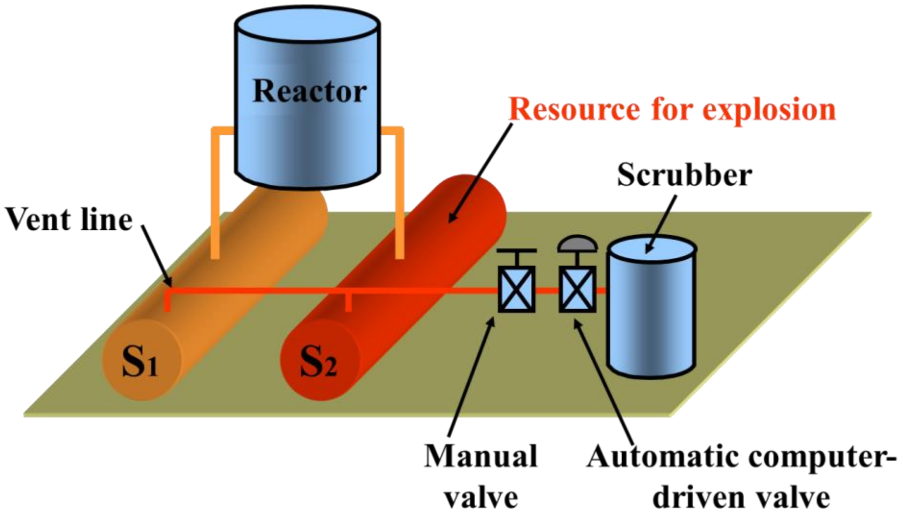


Figure 8 How to make the most dangerous situation happen

The answer was rather simple – they were needed during the system installation to allow testing and tuning the scrubber separately, without impacting other portions of the system. The situation is quite typical for many industrial environments and innovation processes. After installation works had been completed, it happened to be rather expensive to remove the valves. And due to typical human inertia (nothing really happened so far!) no one recognized the valves as dangerous, in spite of regular safety checks using standard safety technique like HAZOP.

Altogether, over 21 various scenarios of possible failure scenarios (fortunately, less dangerous, however, still painful) have been developed.

## 4 Conclusion

Innovation processes need to indentify risks at all stages. Finding important potential failures during the innovation process should not be based on serendipity, but on systematic approaches. Beyond traditional tools and methods AFD Prediction is a system-based structured method for unveiling hidden and dangerous failures. Following the process of AFD Prediction one can achieve a comprehensive set of potential failures and, furthermore, generate and evaluate failure scenarios from combinations of single failures that might be more dangerous than the single failure itself (like the combination of earthquake, tsunami, and loss of electrical power in Fukushima power plant).

Although the examples given here are more of technical nature one can imagine that it is not too difficult to use this method in fields of business, project, and strategic planning:

- How would I MAKE SURE that my merger and collaboration was doomed to failure? (Hipple, 2006):

- How would I MAKE SURE that my employees never understood my corporate mission (Wouldn't that make an interesting discussion? Do I do what I say all the time with everyone?) (Hipple, 2006)
- How would I MAKE SURE that my personnel evaluation and payroll system irritated ALL my employees so that they were ALL out looking for work? (Hipple, 2006)
- How can I MAKE SURE that I do not reach the project goals?

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