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Service Information for Product Quality

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ABSTRACT

Engineering products roughly go through 4 stages of lifecycle, namely design, production, use, and disposal. Design for manufacturing succeeded in tearing down the wall between design and manufacturing so designers now have tools to avoid machines that are not manufacturable or too hard to assemble. Designer also have such tools as FMEA or FTA so they can foresee costly troubles while the products are in the market and work in design solutions to prevent them. Nevertheless, accidents and malfunctions happen, and some are even catastrophic bringing down the company with them.

Major corporations often have subsidiaries or sister companies that specialize in service after products are placed in the market. This structure has a negative effect of creating a wall in the product lifecycle between the production and use stages. When troubles with products occur, service companies tend to seek solutions within their own organization without going back to the design stage. This approach may prove less costly, however, quick and easy fixes may lead to disastrous conclusions. These are cases when people in the service stage worked too hard to provide solutions within their own field.

Our society is full of immature systems that rely on human consciousness and attention for preventing accidents. They work most of the time but imperfect nature of human can cause accidents when all the factors line up in the worst scenario.

This paper first contrasts two failures cases in the food industry and explains why we have to go back to the original design and work in mechanical solutions instead of relying on people's efforts in preventing the same mistakes. It then reviews some catastrophic accident cases in Japan to discuss why they happened and what we need to do to avoid them.

Industry structures often require hard work in the use stage by service people. We need effective ways of feeding back failure information to the design stage so that designers can improve their FMEA closer to the real situation and work in mechanical solutions if necessary. Relieving service people from hard work is a key in preventing failure.

1. INTRODUCTION

In 2002, the authors took major roles in establishing "Association for the Study of Failure." The association offers people a place to openly discuss failures including accidents so that others can learn from the events and avoid repeating the same mistakes.

We currently have over 1,000 members and 38 corporate members registered with the association. Through our efforts and work by others (1, 2, and 3) the society is gradually chancing to openly discuss mistakes made, their causes, and plans to avoid them in the future.

As more cases are openly discussed, we have come to realize a problem in the way people try to counteract troubles once they emerge in the field. This paper discusses the problem and highlights an inherent obstacle in the way the industry is structured that causes these troubles.

We first discuss the four stages of product lifecycle and then contrast two similar failure events in the food industry (Case 1). Although apart from steel and plastics manufacturing, they show why we need solutions that disable failures from happening rather than relying on people's attentiveness in failure prevention. The paper then discusses four industrial failure cases that turned out deadly, some catastrophic. All cases point to the trouble we have in the current practice of product lifecycle. At the end we discuss our findings and pointers for our research efforts to enhance product quality.

2. FAILURES IN PRODUCT LIFECYCLE AND HOW TO COUNTERACT

Product lifecycle has various definitions. This paper takes the four-stage definition (Fig. 1), namely, design, manufacture, use, and disposal. Other definitions may look closely at the design stage (4), production stage (5), or the use stage while the product is in the market .

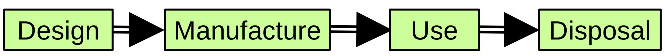


Fig. 1 Four Stages of Product Lifecycle

Almost all so called failures, or maybe the word accidents is a better fit here, take place in the "Use" stage. Their causes may lie in the design or manufacturing stages. We now look at a failure case in the food industry to emphasize why we need solutions that disable failure from repeating instead of relying on people's consciousness to avoid them.

Case 1: Senba Kicho vs. Akafuku

In October to November of 2007, the media broadcasted that one of the most highly respected high-grade traditional style Japanese restaurants, Senba-Kitcho was altering expiration date labels on their dessert products sold at stores and also place of origin of meet so they can sell outdated desserts and prepared food at much higher prices.

Management of the family-owned business first tried to blame the wrongdoing on their employees and distributors, however, the news led to police investigation and on December 10, the management turned in a reform report to the Ministry of Agriculture, Forestry and Fisheries and held a press conference to admit their involvement. During the press conference, they announced that the top management would retire, they would study and abide by the law and implement ways to prevent repeating the mistakes, however, their sales started to plunge.

On January 16 of the following year, Senba-Kitcho requested application of corporate reorganization act and Sachiko Yuki, the mother of the then president, was assigned president. During the December press conference, the management merely kept begging for forgiveness saying they would straighten out their acts and seriously reform their management. While none of the promised reorganization was visible, in May of 2008, the media found out about their over 10 years of practice reusing dishes that had already been served before and the company was forced into bankruptcy.

In October of 2007, Akafuku, a well-known traditional style Japanese cake manufacturer was under investigation by the health department. An informant had notified the department about Akafuku's practice of freezing returned cakes and labeling them as if they were made on the date they were defrosted for shipping again. The health department also revealed they were reusing the rice ball and bean paste from returned cakes for other products.

The local government took an administrative act to suspend their license. Similar to the case of Senba-Kitcho, Akafuku, a family-owned business, announced retirement of all top management except the president. Akafuku also filed a reform report with the authorities.

While their business was suspended, however, Akafuku took the following measures.

- Destroyed the freezing equipment
- Started placing date stamps on the cake boxes in addition to the wrapping paper.

Note: Akafuku cake, once taken out of its box changes its shape and cannot be put back in the box without trace, thus, stamping the box is equivalent to directly stamping the cakes.

In January of the following year, the suspension was lifted and Akafuku restarted its business on February 6, 2008. Fig. 2 shows the busy main store of Akafuku in the city of Ise 11 months after its restart.

The two scandals hit the media at about the same time. They were both family owned businesses that deceived the consumer by intentionally mislabeling their food products. After their misconduct made the national TV news, the family members retired except the president.

While the scandals and their management reforms were almost identical, Senba-Kitcho had to disappear, whereas Akafuku made a comeback and their product again is popular among the consumers. The distinct difference between the two is their solutions. Senba-Kitcho asked people to believe in their oath of reformation, in contrast to Akafuku that actually destroyed their freezing facilities and started labeling their product in a way impossible to repeat the same wrong-doing.

The case may be symbolic, however, we need to learn that for preventing failure from repeating, we should not rely on people's attentiveness, mind, or promises. We have to implement mechanisms that disable the mistakes from happening.

Fig. 2　Main Store of Akafuku after Its Revival (Dec. 7. 08, photo by K.Iino)

3. SOME FATAL ACCIDENT CASES

We will now turn our attention to industrial failure cases. Through these cases, we show that the industry have organizations or groups that specialize in service to look after products in the use stage. These service organizations tend to separate themselves from engineers in the design stage.

Case 2: JR West Fukuchiyama Line Derailing (6)

On April 25, 2005, a 7-car express passenger train of Fu-kuchiyama-line exceeded its speed limit on a curve, derailed, and crashed into an apartment building. 106 passengers were killed and 506 others were injured (Fig. 3).

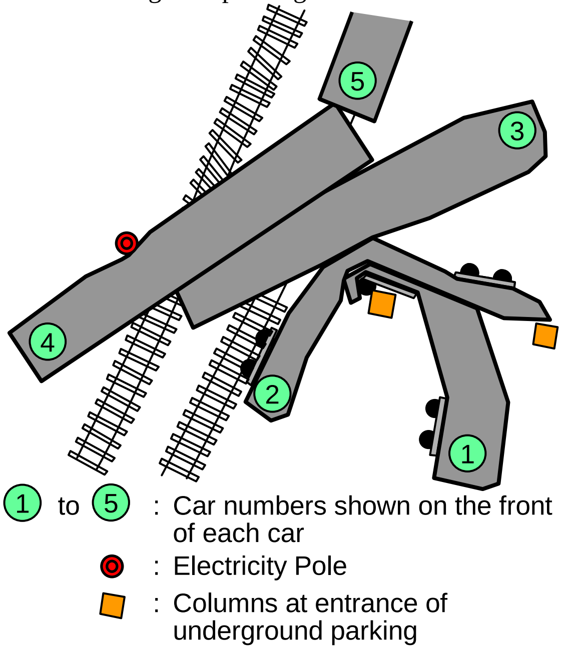


Fig. 3 Crash of the first 4 cars in Fukuchiyama accident

While the media attacked the busy train schedule and pressure during disciplinary training after making mistakes, if an ATS was installed in the curve the accident would have been prevented. ATS stands for Automatic Train Stop (Fig. 4) that consists of a fixed device on the track and its counter part mounted on the train. When the system detects dangerous car movement including overspeed, getting too close to the preceding train, or running a red light, it forces the train to stop. Earlier systems only worked with the lights, whereas, more recent ones handle complex control algorithms.

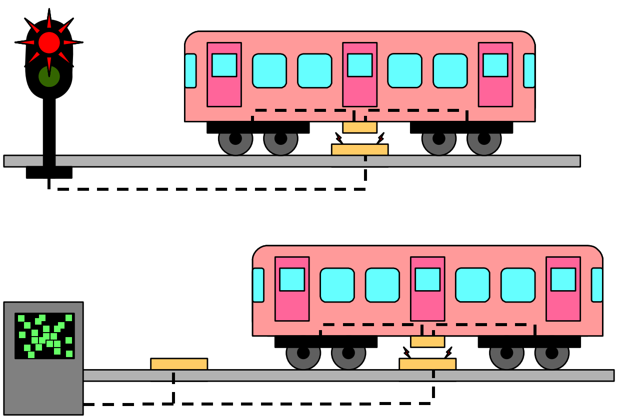


Fig. 4 ATS systems on railway tracks

This solution is a change in design, now implemented on the curve where the accident happened, and it has eliminated the chance of the same accident from repeating.

The driver of train added 1 to the fatality count. We must note that within his job scope, the driver had no way of installing or even suggesting placing an ATS on the curve. The only preventive care he, as well as all the other drivers, could perform was try not to overspeed on this deadly curve.

Case 3: Japan Airline 747 Crash

On August 12, 1985, a JL flight 123, Boeing 747 on its way from Tokyo to Osaka, lost control and crashed into a mountain, killing 520 passengers and crew.

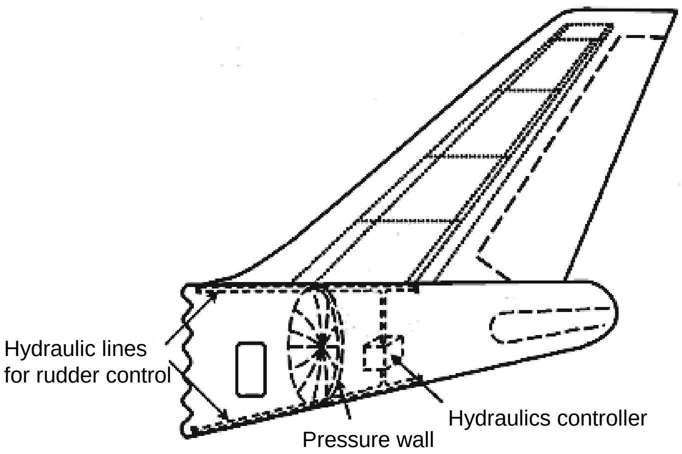


Fig. 5 Aft bulkhead of 747

Later a record of a 1978 minor accident led to the discovery of the cause. Seven years earlier, the plane had scratched its tail upon landing damaging the pressure wall. Fig. 5 shows the pressure wall installed on a 747 between the cabin and the aft pressure bulkhead. It is a hemispherical plate that keeps the cabin pressure at a level comfortable to the passengers in the high sky.

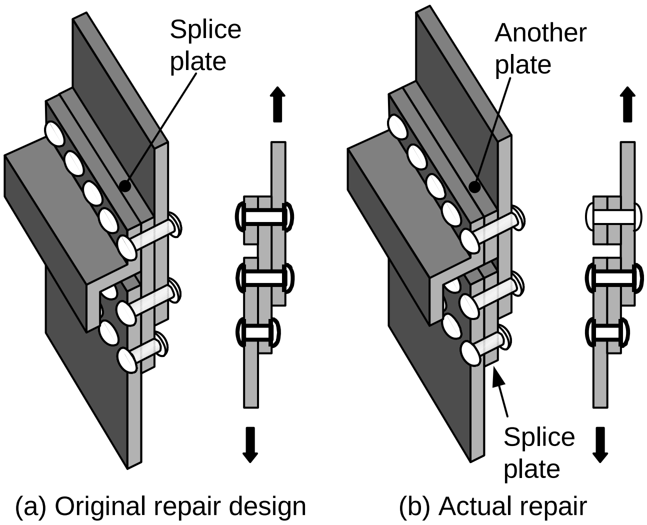


Fig. 6 Pressure wall repair on JL123

The upper and lower halves of the pressure wall are connected with rivets through a splice plate (Fig. 6). Boeing engineers repaired the pressure wall. During the repair, however, finding that the splice place they had prepared was not wide enough, the service engineers decided to split the splice plate design into two pieces installing the prepared plate on the lower half and another plate on the upper.

The three rows of rivets were designed so that each half of the pressure wall was held with two rows, and the splice plate with three. The altered repair, as seen in Fig. 6, clearly shows that the upper half of the pressure wall was connected to the splice plate/lower half assembly with a single row of rivets.

The failed pressure wall was recovered from the accident scene and is now on display at the Japan Airlines Safety Promotion Center in Tokyo (Fig. 7).

In this case, the safety engineers probably was concerned only with how the repair appeared and did not understand how they changed the structural strength of the assembly.

Fig. 7   Actual pressure wall from JL123 accident

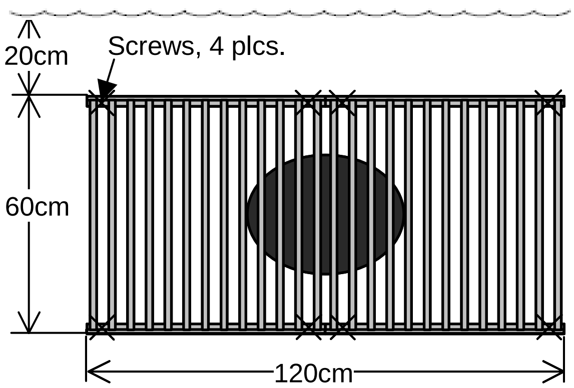
Case 4: Flowing Pool Accident (7)

On July 31, 2006, a six-year-old girl was sucked into the inlet pipe of a swimming pool pump and killed. The pump generated water flow in the 120 meters long circulating pool.

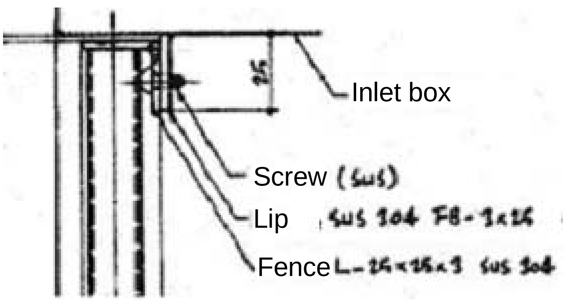
The accident happened shortly after the guard fence over the inlet hole was found lying on the pool floor. Later, the investigation found the original contractor had subcontracted the pool management work to another contractor without informing the city, who owned it. Lifeguards that lacked qualification were watching the pool area, and moreover, they were understaffed. A lifeguard received the guard fence from an anonymous swimmer and without knowing what it was, went to his supervisor who then went back to the office to find wire to replace the fence plate back to cover the inlet hole. The accident happened when the lifeguards were warning swimmers from the poolside not to get close to the pump inlet opening.

The media attacked the staff on duty and the practice of using wire instead of screws. The pool management company said they started to use wires instead of screws because they could not mate the screw holes on the guard fence with the threaded holes on the pool side.

Fig. 8 shows the design. Two 60cm x 60cm stainless steel fences are fixed over the inlet hole each by 4 screws at the corners.



(a): Two 60cmx60cm fence plates cover the inlet hole



(b): Screw fixture section from actual drawing

Fig. 8   Pump inlet hole guard fence design

For having 4 screws on such a large piece of metal, the installers must have opened the holes by holding the fence against the 60cm x 120cm rectangular hole and using a handheld drill. There were 3 such inlet openings each with two fence plates; the total number of square fences was 6. Each fence plate can be rotated 180 degrees and the total number of possible combinations to install the 6 plates was 42. Among the 42 combinations, there was only 1 where all the screw holes and threads match perfectly as with the original configuration.

Just before opening the pool each season, it was natural that the screw holes did not match after taking the plates off to thoroughly scrub the pool and when they were replaced back on. This caused the maintenance company to fix the fences over the pump inlet holes with wire.

The close-up view of a screw in Fig. 8(b) shows stainless steel lips being only 3mm thick. The screws were not called in the original drawing but they must have been either M5 or M6 each with thread pitch of 0.8mm and the later, 1.0mm, thus, there were only 3 threads on the poolside lip that engaged each screw. Water constantly flowed through the fences and naturally the fences were subject to flow induced vibration.

This design will cause the screws to loosen and drop at some point during the long summer season. Mechanical designers have a long history of battle against loosening screws from vibration. In that sense, wire, if it were thick enough to prevent kids from playing with them and taking them off, was probably more reliable than screws.

The crew that cleaned the pool before use, without complaining to the designer, did what they thought was most appropriate. They tied wires to hold the fences over the pump inlet holes, however, they lacked proper knowledge of what will happen to the wire was not thick enough.

<u>Case 5: Paloma Instant Water Boiler</u>

In 2006, following a police investigation, the Ministry of Economy, Trade and Industry uncovered 28 cases of carbon monoxide poisoning causing 21 deaths and 19 injuries over the period of 1985 to 2005. These cases were caused by wrong alteration of the control circuit by the servicemen of Paloma gas operated instant water boilers.

The alteration was popular among the servicemen to counter the case of gas shutting off during use. The method hot-wired the gas shut-off valve circuit that closed the solenoid valve when either i) the pilot burner was not on, ii) the main burner was too hot, or iii) the exhaust duct was overheated. Fig. 9 shows the structure of the gas operated water boiler. Besides the 3 sensors shown in Fig. 10, there were 2 others sensors for water flow and exhaust gas temperature for exhaust fan control.

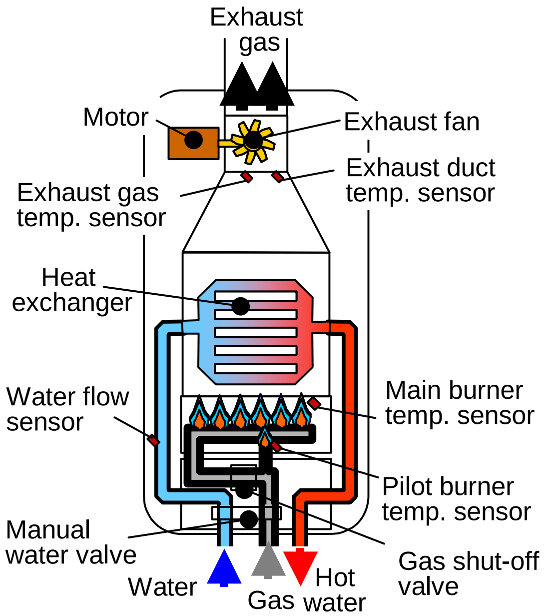


Fig. 9 Structure of the gas operated water boiler

The media, as soon as they found out about the wrong alteration, they attacked Paloma and their attitude of blaming the maintenance company.

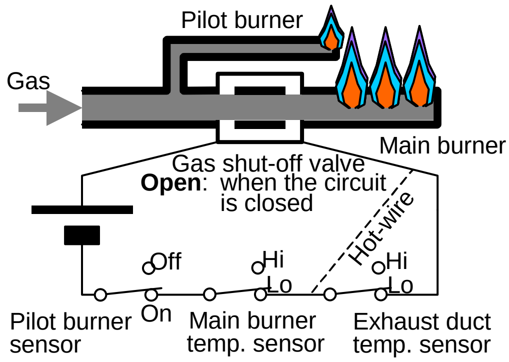


Fig. 10 Gas shut-off valve control circuit

Fig. 10 shows the circuit of the gas shutoff valve and how the wrong alteration was made. The electric potential to drive the circuit in the figure is shown as a battery but in fact, it was supplied from the thermocouple at the pilot burner. The first sensor to detect the pilot burner served the purpose of supplying power to the control circuit. This probably was a convenient design for boiler models designed without exhaust fans because the boiler would operate even when there was no electricity to it. The design, however, turned deadly for models with exhaust fans because the boiler would operate even when the exhaust fan was not rotating for lack of power or other reasons.

In this case, the service people only wanted to satisfy their customers without the large cost of controller replacement. They probably told the customers to keep good ventilation while using the boilers. Such information decays over time, and people do change their places of living. A new occupant of a house equipped with the wrongly altered gas boiler had no warning of keeping good ventilation while using the boiler.

4. WALL BETWEEN DESIGN AND USE

Designers work hard trying to foresee all possible problems with their design and counter them while products are still on paper on their desks. Nowadays, they lie inside their computers as CAD models.

The designers are equipped with plenty of tools like dfM (9), dfA, and so on, now collectively called dfX (Fig. 11). they have been successful in tearing down the wall that used to exist between the design and manufacturing stages.

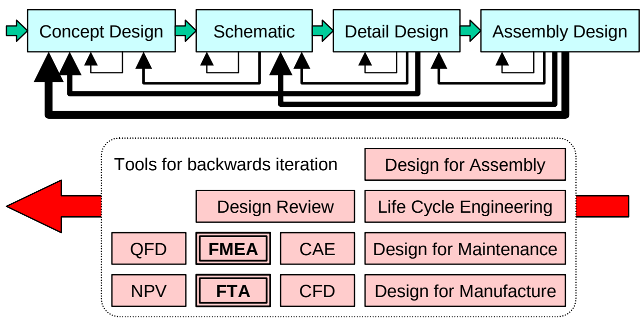


Fig. 11 Design iterations and their tools

Among our tools, we also have such tools like FMEA or FTA for predicting malfunctions or accidents with our designs. Designers make every effort to foresee "what can go wrong" with the design and if the negative impact is too large, we will change our design so that such failure would not happen.

Accidents, despite our efforts, still happen and it means that FMEA or FTA by the designer was not perfect.

As we saw in cases 2 through 5, the industry is typically structured so that service people, or operators of products try to fix problems within their own territory. What is even worse is service companies often are subsidiaries or totally different entities from the manufacturers. The harder the service people work to fix troubles in the field, there is less chances for the manufacturer to know about fundamental flaws in the design. And with service people in the field without the engineering expertise can make product alterations that can cause terrible accidents, although their intensions were good customer service.

We have been successful in and are continually working on removing the hidden wall between manufacturing and design. There exists an even larger wall between design and use. If we succeed in collapsing this wall, there will be a much smaller number of accidents caused by design flaws.

5. PRODUCT SERVICE DATABASE

Accidents caused by flaws in design still happen and sometimes the information is not properly fed back to the designer. On the other hand, service people work hard trying to eliminate problems that users of products are faced with. Sometimes such efforts can lead to disasters for making changes that affect the original function of the design.

Service people never intend such poor service in the first place, however, not having the engineering knowledge can be fatal.

To prevent such poor service caused by not having proper knowledge, we propose to build an information system so that services that make fundamental changes in structure, control, or software are forced to go through authorization before the fixes are implemented. Such practices are present with, e.g., nuclear industry, however, mostly paper-based.

When we think of service people in the field, probably the better tool to use is the cellular phone instead of the PC. We plan to build prototypes of the system for the next step in our research.

6. CONCLUSION

Design tools have made large progress and are still working in removing the wall between the design and manufacturing stages. Designs have less problems when passed on to the manufacturing stage.

Accidents take place in the use stage and they are signs of incomplete FMEA by the designer. There is another wall in the four-stage product lifecycle between the design and use stages and the structure of service organizations will make the wall even thicker and taller.

We showed some fatal accident cases as results of service people making their own efforts without going back to or feeding the information to the design stage.

We propose building an information system that forces the service people to gain authorization in case fundamental changes in products or services are planned. Such information system has to be easy to use.

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