
INITIAL CONSIDERATIONS

1.1 INTRODUCTION

Problem solving is found throughout all activities of daily life. Problem solving tends to take place in two mind modes. There is the intuitive or instinctive reactionary mode, which has also been called “gut feel.” Then there is the methodical reasoning approach, which is usually based on theoretical considerations and calculations.

Both of these approaches have a place in real world problem-solving activities. The intuitive reactionary person will respond much faster to a problem. The response is usually based on experience. That is, he has seen the same thing before or something very similar and remembers what the problem solution was. However, if what is occurring is a new problem or is somewhat different, his approach may lead to an incorrect problem solution. The methodical reasoning person will not be able to react to problems quickly, but will usually obtain the correct problem solution for complicated problems much faster than the intuitive reactionary person, who must develop and perhaps discard several “gut feel” solutions.

Here is an example of how two people with these different mind-sets can react. On a golf course, the cry of “Fore” will elicit different responses. The person responding based on intuition or instinct will immediately crouch and cover his head. This will reduce the probability that the errant golf ball hits a sensitive body part. The person responding based on methodical reasoning will begin to assess where the cry came from and where the ball might be coming

from, and then reach a conclusion as to where it might land. Obviously, in this case, reacting based on intuition or instinct is a far superior mode of operating. There are many more examples from the sports world where reacting in an intuitive fashion yields far superior results than reacting in a methodical reasoning manner. However, essentially all of these examples will be experience-based. People who are reacting successfully in an intuitive mode know what to do because they have experienced the same or very similar situations.

Similar things happen in industrial problem solving. Experienced people such as engineers or operators react instinctively because they have experienced similar events. These operators or engineers do an excellent job of handling emergency situations or making decisions during a startup. As a rule, the person who tends to respond based on methodical reasoning and calculations can rarely react fast enough to be of assistance in an emergency or if quick action is required in a startup situation. The exception to this rule is the engineer who has designed the plant and has gone through calculations to understand what will happen in an emergency or startup. In effect, he has gained the experience through calculations as opposed to actual experience.

The experience necessary to conduct problem solving in the real world does not always exist. In addition, while the need for quick response when solving industrial problems is real, there is not always an emergency or crisis that requires immediate action. Thus the methodical reasoning approach is often the desirable mode of operating. The three components of this methodical reasoning approach are:

1. A systematic, step-by-step procedure. This includes the three essential problem-solving skills (Daily Monitoring System, Disciplined Problem-Solving Approach, and Determining Optimum Technical Depth).
2. A good understanding of how the equipment involved works.
3. A good understanding of the specific technology involved.

Before discussing problem solving in industrial facilities, two examples from everyday life are discussed. It often aids learning to discuss things that are outside the scope of the original thrust of the teaching. The two examples from everyday life discussed below will be helpful in understanding the difference between intuitive problem solving and that based on methodical reasoning.

1.2 AN ELECTRICAL PROBLEM

While trimming bushes with an electric hedge trimmer, a laborer accidentally cut the extension cord being used to power the trimmer. He had been using an electrical outlet in a pump house located approximately 70 ft from the main house. The only other use for 110 volt electricity in the pump house was for a small clock associated with the water softener. The laborer found another extension cord and replaced the severed cord. However, when he plugged it

in and tried to turn on the hedge trimmer, it did not have any power. He then had to report the incident to the homeowner. The homeowner checked the panel-mounted circuit breakers. None of them appeared to be tripped. To be sure, he turned off the appropriate circuit breaker and reset it. However, power was still not restored to the outlet in the pump house. To make sure that the replacement extension cord was not the problem, the homeowner plugged another appliance into the electrical outlet in the pump house. It did not work either. The homeowner then concluded that the electric outlet had been “blown out” when the cord was cut. He replaced the electric outlet. However, this still did not provide power to the equipment. When the homeowner rechecked the circuit breaker, he noticed that a ground fault interrupter (GFI) in a bathroom in the main house was tripped. Resetting this GFI solved the problem. Ground fault interrupters are designed to protect from electrical shock by interrupting a household circuit when there is a difference in the currents in the “hot” and neutral wires. Such a difference indicates that an abnormal diversion of current from the “hot” wire is occurring. Such a current might be flowing in the ground wire, such as a leakage current from a motor or from capacitors. More importantly, that current diversion may be occurring because a person has come into contact with the “hot” wire and is being shocked.

While the homeowner believed that in this particular house every GFI protected a single outlet, it is not unheard-of to protect more than a single outlet with a GFI. It seemed surprising that the GFI in a bathroom also protected an outlet in the pump house 70 ft away. The homeowner then recalled that at some point in the past, he had noticed that the small clock in the pump house was about 2 hours slow. This clock was always very reliable. In retrospect, he remembered that at about the same time that the clock lost 2 hours, this particular GFI in the bathroom had tripped during a lightning storm and had not been reset for a few hours. Thus it became obvious that the accidental cutting of the extension cord had caused the GFI to trip rather than tripping the circuit breaker or “blowing out” the electrical outlet. The failure to correctly identify the problem cost the homeowner a small amount of money for the electrical plug and a significant amount of time to go to town to purchase the plug and then install it.

Note that the homeowner’s intuitive conclusions were all valid possibilities. That is, the circuit breaker could well have tripped, the replacement extension cord could have had an electrical break in it, or the electrical outlet could have failed when the original extension cord was cut. His problem solving just did not go into enough detail to solve the problem quickly. Several lessons can be learned from this example. While it seemed to be a simple problem that could be easily solved based on the homeowner’s experience, the intuitive approach did not work. A more systematic approach based on methodical reasoning might have improved results as follows:

- Consideration would have been given to the possibility that GFIs can protect more than one electrical outlet. The distance between the GFI

and the electrical outlet would not be a consideration. The homeowner did not fully understand the technology.

- A voltmeter would have been used to check that power was available coming to the electrical plug. If power was not available coming to the outlet, the “blown plug” hypothesis would be invalid. A systematic approach was not used.
- In addition, a systematic approach would have raised the question of whether the clock losing 2 hours could be related to the lack of power at the electrical plug.

1.3 A COFFEEMAKER PROBLEM

A man experienced problems with a coffeemaker when it overflowed about half of the time when he made either a flavored or decaffeinated coffee. The coffee and coffee grounds would overflow the top of the basket container and spill all over the counter. The coffee maker performed flawlessly when regular coffee was used. A sketch of the coffee maker is shown in Figure 1-1. When the coffeemaker is started, water is heated and the resulting steam provides a lifting mechanism to carry the mixture of water, steam, and entrained air into the basket where the ground coffee is located. The hot water flows through the coffee and into the carafe. The coffeemaker is fitted with a cutoff valve that causes the flow out of the basket to stop if anyone pulled the carafe out while coffee is still being made.

The man, a graduate engineer, attempted to determine what was wrong. He examined the problem by first convincing himself that he was following

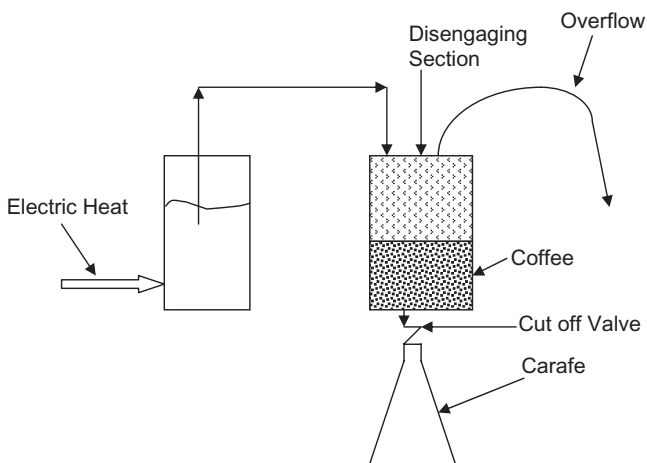


Figure 1-1 Coffeemaker schematic.

directions when it came to making the coffee. He then carefully examined the equipment, especially the cutoff valve. He concluded that somehow the cutoff valve was restricting the liquid flow whenever decaffeinated or flavored coffee was being made. That is, the incoming flow of hot water and steam was greater than the flow out of the valve. This would cause the level in the container to build up and run over. The problem solution seemed relatively simple. He removed the valve and made a sign that read, "Do not remove carafe until coffee is finished brewing." He felt a surge of pride in not only solving the problem, but that he prevented a future problem by providing instructions to prevent someone from pulling out the carafe. The next time that one of the suspect coffees was made, the container did not overflow. He then announced that the problem was solved.

Unfortunately, the glow of successful problem solving did not last long. The next time that flavored coffee was made, the problem recurred; that is, the coffee and grounds flowed over the top of the basket container. The engineer then began a more detailed investigation of the problem, including understanding the technology for making flavored and decaffeinated coffee. He discovered that when decaffeinated coffee was produced at the coffee supplier, a surface active material was utilized. This surface active material was mixed with the coffee to extract the caffeine. Materials that are surface active have the capability to thoroughly contact the coffee solid so that caffeine is removed from not only the surface, but the deep pores. The surface active material also reduces the surface tension of water, which creates a system that can easily foam.

The engineer then extrapolated from this knowledge and theorized that when flavored coffee was made, a surface active material was used to evenly distribute the flavor to the coffee. Once that he understood the difference in the coffee making processes, he theorized that residual amounts of the surface active material being left on the coffee reduced the surface tension of the hot water and coffee and caused it to foam up in the container and out over the sides onto the counter.

Since the amount of residual surface active material would vary slightly from batch to batch, it was theorized that only the batches of either flavored or decaffeinated coffee that contained greater than a critical level would cause an overflow. After studying this theory, the engineer decided that the problem solution would be to obtain a coffeemaker that had a basket container with a different design. The problematic coffeemaker had a small cylindrical basket. A new coffeemaker with a large conical design basket was purchased. The comparison of the two baskets is shown in Figure 1-2. It was theorized that the large conical design would provide a reduced upward velocity of the foaming material and this would allow release of the vapor trapped in the foam. The purchase of this coffeemaker eliminated the problem completely.

Several lessons can be learned from this problem-solving exercise. The intuitive hunch that coffee was not flowing through the valve as fast as hot

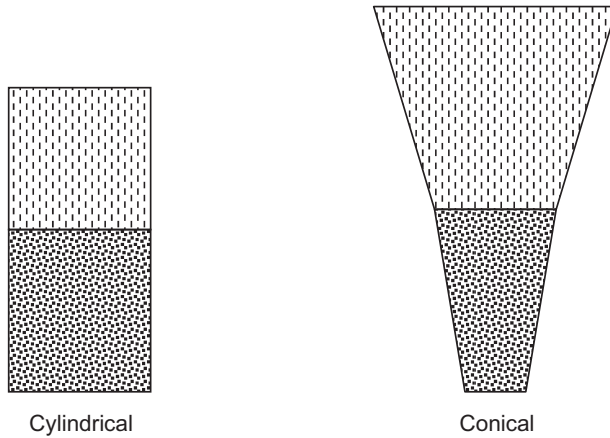


Figure 1-2 Basket comparisons.

water was coming into the basket made logical sense. However, no logical explanation was provided for why this only happened with flavored or decaffeinated coffee. Any theory that includes the phrase “for some reason” is suspect and is an indication of an incomplete problem analysis. A portion of an incomplete problem analysis is almost always logical. However, it is imperative that the entire analysis be logical. Another error was that in formulating the hypothesis, the engineer assumed that only liquid water and solid coffee existed in the container. He overlooked the fact that steam vapors and entrained air were always carried into the container with the hot water. The presence of steam and air would provide a mechanism for creating a frothy mixture. The example also illustrates the need for the following:

- A systematic approach, as will be described later in this book, would have eliminated the incomplete hypothesis that suggested the outlet valve was a restriction on only certain grades of coffee.
- A sound understanding of how the equipment works: If the engineer had understood how the coffee maker worked, he would not have assumed that only a liquid was present along with the coffee in the container. He would have recognized that both steam and air were carried over into the container along with the hot water.
- A sound understanding of the technology involved: The fact that decaffeinated and flavored coffee performed differently than did regular coffee should have been an indication to the engineer that he needed to examine the difference in the coffee-making technology.

These relatively simple examples of how successful problem solving requires a more detailed analysis than simple logic and/or intuition are meant to set

the stage for the next chapter, which deals with limitations to industrial problem solving. While industrial problems are almost always more complicated than those described in this section, they require the same problem-solving approaches.

1.4 CLASSIFICATION OF INDUSTRIAL PROBLEMS

It will be of value to classify problems into four categories. This will help determine what kind of effort is required to solve the problem. These categories are as follows:

1. *Problems that can be solved based strictly on experience and/or instinct.* These are the problems that are typically solved during a startup and/or upset condition. In these situations, there is minimal time for analysis. Experience and instinct are the only way to solve problems in the time available. As you would imagine, the best problem solvers in this situation are those with experience with the particular problem being encountered.
2. *Equipment problems that can be solved by application of “first principles.”* The definition of “first principles” is knowledge that has been summarized as a series of mathematical relationships or expressions. An example of this might be a compressor that is not performing as desired. A study of the head curve (a relationship between flow and pressure head expressed in feet) might reveal that the gas flow and/or molecular weight of the gas have changed so that the anticipated pressures can no longer be achieved.
3. *Process technology problems that can be solved by application of “first principles.”* These are process technology problems that can be solved because there are known relationships available. These relationships are often provided in licensing packages or operating instructions. For example, a reactor productivity problem related to impurities in the feed could be solved by using a simplified productivity model. The “base line” for this productivity model will be based on a licensing package or experimental results. The deviation from the base line would be based on laboratory results and a dynamic model. The simple dynamic model would provide a relationship between time and reactor productivity. These models based on the process technology could be used to show that the loss of productivity correlates with “spikes” in a feed contaminant.
4. *Process technology problems that cannot be solved by “first principles.”* These might be problems which do not have any reliable solution theory or for which no reliable theory can be developed that relates to the cause of the problem. In other words, theoretically correct “first principles” do not exist. These are usually very complicated problems involving highly

qualitative and subjective variables such as reactor fouling or product attributes such as color, haze, turbidity, or roughness. These subjective variables are often controlled by several independent variables, some of which are well hidden. Some of these controlling variables may be present below the level of analytical detectability. The analysis of such problems is beyond the scope of this book. Fortunately, this classification amounts to only a very small percentage of industrial problems.

The majority of problems in the process industry fall into category 2 or 3. These are the types of problems that the techniques discussed in this book were developed to solve. With an experienced workforce, some of the problems in category 2 or 3 can be solved based on previous history or intuition. However, this experienced workforce is rapidly becoming history. In western countries, the experience level is decreasing as the “baby boomers” reach retirement age. In developing countries, the workforce is just beginning to build experience. Thus there will be an increasing emphasis on using quantitative methods of problem solving. In addition, cost pressures are driving organizations to reduce the number of graduate engineers in operating plants and to use process operators, specialists, or mechanics as the primary problem solvers.

The problem solver will find it helpful to consider which of the above categories best describes a new problem he is trying to solve. This will aid him in determining what kind of effort is required to solve the problem.