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LIMITATIONS TO PLANT PROBLEM SOLVING

2.1 INTRODUCTION

While later chapters will consider the structured approach to problem solving, any book dealing with plant problem solving will touch on the question, "Is problem solving really part of my job description?" The paradigm of this book is twofold.

- It is based on the concept that all people working in industrial plants have problem solving as part of their job description whether it is written or not.
- To a great extent, the modern process industry has placed operators and process specialists into roles of solving problems. For this problem solving to be done efficiently, they must use some engineering knowledge and calculations. Thus this book discusses "engineering problem solving," meaning problem solving that can be done by engineers or operators using engineering calculations.

The first step in developing an effective problem-solving approach is to have the correct mind-set. Some operators and specialists believe that their job is only to turn valves or make "educated guesses." At the other end of the spectrum some engineers raise the question, "Is problem solving really engineering?" Often, engineers may conclude that problem solving is not truly engineering because of the following:

Problem Solving for Process Operators and Specialists, First Edition. Joseph M. Bonem.

- Engineering is defined in such narrow terms that only “design work” appears to be engineering.
- Intuition and “gut feel” have replaced thorough analysis as a preferred tool for problem solving.
- Considerations of “optimum technical depth” are not well understood.

If one defines engineering, as dictionaries do, as “The science of making practical application of knowledge in any field,” we must conclude that problem solving is truly engineering. In addition, this definition of engineering also fits an operator with engineering training who is working not just to turn valves, but to solve problems.

It is also important to understand why a course in engineering problem solving is of value. In an example of a typical industrial problem, a customer is unhappy with the appearance of the plastic pellets being received from his supplier. Specifically, the pellets have visual discontinuities similar in appearance to gas bubbles. The customer describes these as “voids.” If a particle has more than a single void, it is described as a “multi-void particle.” A simplified statement of the problem is shown in Figure 2-1. As shown in the figure, the process in which the pellets are manufactured consists of two parts, polymerization and extrusion. In the polymerization section, propylene is polymerized to polypropylene particles (700 microns in diameter) using a catalyst. In the extrusion area, these particles are melted, extruded, and formed into cylinders approximately 1/16 by 1/8 in. A strong correlation was developed between the pellet appearance (fraction of pellets with multi-voids)

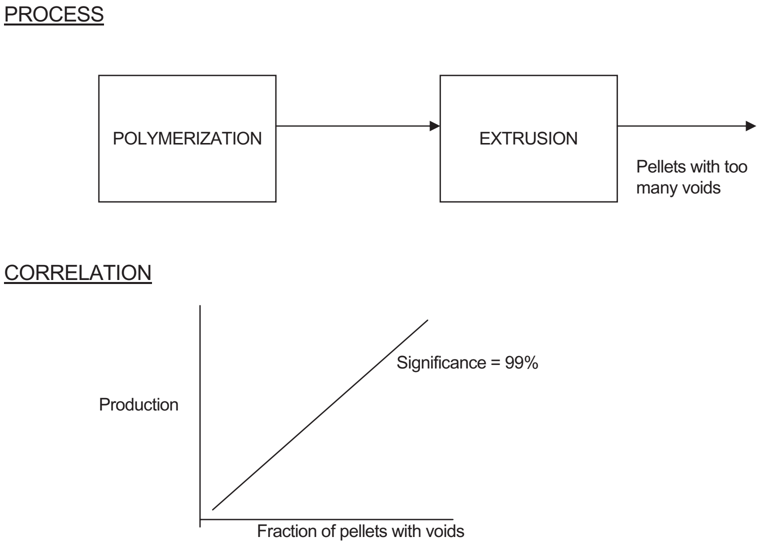


Figure 2-1 An example of improper problem solving.

and the polymerization production rate. The problem solver recommended that the production rate be reduced to solve the "multi-void" problem. This solution to the problem (reducing production rate) is, at best, only a short-range solution. This solution cannot be considered a lasting solution because of the following:

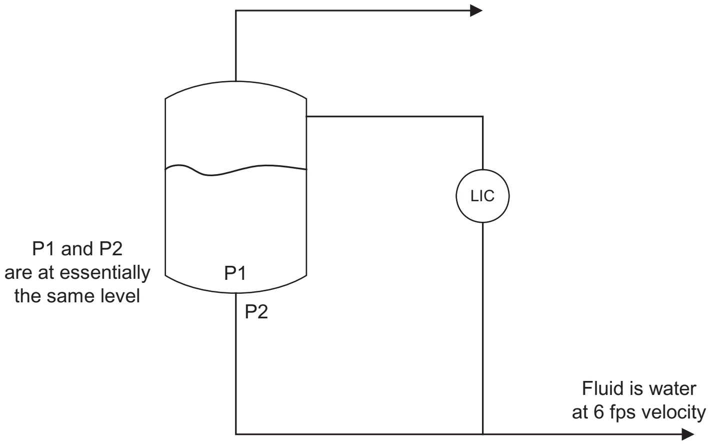
- The basic cause of the voids was not considered.
- The solution required a severe economic penalty (it might have solved one problem, but it created another one). In most process industries, the limited profits are made at production rates above 75 or 80% of capacity.
- Since the basic cause of the voids was not discovered, the problem will likely recur even at the reduced production rates.

2.2 LIMITATIONS TO PROBLEM SOLVING

The previous example is typical of much of the improper problem solving that occurs in many industries in today's hectic, fast-paced society. It also illustrates why a course in engineering problem solving is of value. There are ten primary limitations to problem solving in today's process plants. They are described as follows.

1. Modern-day processing plants are large and complex. For example, a relatively simple process such as propylene purification has evolved from fractionation followed by a drying process to remove water to a process incorporating "heat pump fractionation" and more complicated conversion steps to remove impurities to the part per billion (ppb) level. In addition, plant sizes have increased significantly. Thus, there is even more emphasis on solving problems quickly and correctly.
2. The problem is usually more complicated than first described. Typical initial problem descriptions might consist of such statements as, "It won't work as designed," or, "It won't work unless you modify it to …" If either of these problem descriptions is accepted exactly as stated, the problem solver is doomed to failure. In order to practice true engineering problem solving, the problem solver must use a disciplined approach that involves writing out an accurate description of the problem that does not include a problem solution. This is necessary to avoid ignoring data and jumping to conclusions.
3. Conflicting data will always be present, and can take many forms. Some examples are that the verbal descriptions eyewitnesses give can disagree; laboratory data may be in disagreement with physical factors, instrumentation, or even other laboratory data; and/or instrumentation/computer data may be in conflict with other sources of data.

4. Modern day plants have a great deal of variable interaction. This results in difficulty in isolating the real problem affecting either independent variables or strong correlations between dependent variables. While a strong correlation between dependent variables may be of interest, it rarely results in the solution to problems. An independent variable can be changed or set by an operator or by operating directives. Dependent variables are those that are changed by the reaction of the process. In the plastic pellet example given earlier, the independent variable is the production rate and the dependent variable is the fraction of particles with voids.
5. Besides a high degree of variable interaction, there is also a high degree of interaction between various engineering disciplines. Thus, what appears to be an obvious mechanical engineering problem often has its true roots in chemistry and/or chemical engineering. The converse is also true. This confusing scenario often leaves the process operator caught in the middle, not knowing which course of action to pursue.
6. System dynamics involve long holdup times. In the modern day process, there is usually an incentive to push the process to higher efficiency or higher purity. This usually leads to longer residence times in equipment. Problem solving with long residence time equipment requires the use of a dynamic model. Unfortunately, when faced with the need for a dynamic model, the problem solver will often take one of two unsatisfactory approaches. He will give up on the basics and say, “It’s too complicated.” Since the dynamic model is truly required to solve the problem, the problem solver must now take an approach that can be characterized as “guess work.” The other extreme is that he will begin the development of an elaborate, technically correct model that will probably not be finished in time to be of any assistance. Both of these approaches overlook the fact that there are ways to build simple, technically correct dynamic models. These simple models will contain assumptions, however, these assumptions will still provide a model with sufficient accuracy to solve industrial problems.
7. Engineering principles are often inadequately applied by operators as well as engineers. In today’s industrial environment, pressures to perform at a minimum cost and manpower commitment often encourage “shooting from the hip” as a problem-solving technique. This may be completely appropriate in some limited situations. However, the purpose of this book is to address the chronic problem that is only wounded by the “shoot from the hip” technique. The modern chemical engineering curriculum, while providing an excellent theoretical foundation, often fails to adequately stress the application of fundamentals. For example, Bernoulli’s theorem can be used to explain inaccurate values given by the poorly designed level instrument shown in Figure 2-2. This design may have its origins in an engineering contractor or an



Connecting the level instrument in the process line as shown will result in the measured level reading being 0.5 ft lower than actual.

This is based on Bernoulli's theorem

$$dP/D + dV^2/2g + dZ = 0$$

where

dP = difference in pressure
D = density of liquid
dV^2 = difference in liquid velocities squared
g = gravitational constant
dZ = difference in liquid height h

At base level the pressure at the level instrument will be less than the same pressure in the drum as follows:

$$(P_2 - P_1)/62.4 + (36 - 0)/64.4 = 0,$$
$$P_1 - P_2 = 34.9 \text{ lbs/ft}^2.$$

This is equivalent to 0.5 ft in measurement of level. This ignores the friction loss in the line and nozzle.

Figure 2-2 Example of improper level instrumentation.

operator who had to improvise to get a level instrument installed in an operating plant. Either way, it must be recognized that the design will not provide accurate level readings.

8. There is often failure to use a methodical approach. While this limitation is closely allied with the previous one, it points out a need to structure even the best application of engineering principles. This structuring step is necessary to allow one to define which of the engineering principles are most appropriate. The failure to use a methodical approach could lead one to hypothesize erroneously that a fractionating tower had a plugged tray and that that was the cause of a high-pressure drop. In fact, the problem might well be associated with a change in internal vapor and liquid loading, buildup of an impurity that boils between the light key and heavy key, foaming caused by a trace impurity, or improper assumptions regarding the tower's loading point.
9. The whole picture is often not seen. The problem solver who fails to use a methodical approach is vulnerable to arriving at the wrong answer

because he fails to see the whole problem. There are often verbal clues which can hint that the problem solver is failing to see the whole picture. Some of these clues are comments such as, "That's a mechanical problem," or, "The laboratory is wrong again." While these statements may be valid, they are often indications that the problem solver is excluding essential pieces of data. It should be noted that someone using the methodical approach is less vulnerable, but still subject, to this limitation.

10. There is often an over-dependence on history. While a historical database is a mandatory prerequisite for successful problem solving, the database should be used to define deviations rather than a repository of answers. The statement, "The last time that this happened, it was due to …" must always be tested by data analysis.

As described earlier, Figure 2-1 shows a typical industrial problem. Several of the limitations discussed above are apparent. The problem was certainly complex in that it could be caused by conditions in either the polymerization or the extrusion processes. There appears to be both a lack of a methodical approach and an inadequate application of engineering principles. In addition, while only a limited amount of data is present in Figure 2-1, the problem solution appears to be only historically based. There is no evidence that a hypothesis was developed and tested with a plant test. Was the problem solver seeing the entire picture? For example, was the independent variable polymerization production rate or extrusion rate? Was the independent variable production rate or residence time (the inverse of production rate)? Perhaps the confusion of the problem solver is illustrated by the figure, which shows the voids on the *x*-axis normally reserved for the independent variable.