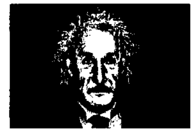
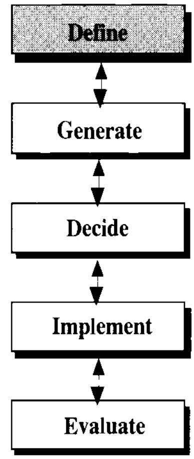
3 *PROBLEM DEFINITION*



The mere formulation of a problem is far more often essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science.

- Albert Einstein



Often, the most difficult aspect of problem solving is understanding and *defining the real problem (sometimes also referred to as the underlying or root problem).* In Chapter 1, we presented a number of true examples of incorrectly defined problem statements that demonstrate how competent, conscientious people can define the wrong problem and waste considerable time looking in the wrong direction for a solution. In this chapter we address the first part of the heuristic, *problem definition.* A study that we conducted of experienced problem solvers in industry revealed some common threads that run through their problem definition techniques. We have classified these common threads into a number of steps that can help you understand and define the real problem.

3.1 THE FIRST FOUR STEPS

The first four steps used by experienced problem solvers to understand and define the real problem are given in Table 3-1. You will observe that the first four steps focus on gathering information.

TABLE 3-1: What Experienced Problem Solvers Say

1. Collect and analyze information and data.
2. Talk with people familiar with the problem.
3. If at all possible, view the problem first hand.
4. Confirm all findings.

Step 1. *Collect and analyze information and data.*

"Start with an open mind."

"Don't jump to conclusions."

"Look at the big picture."

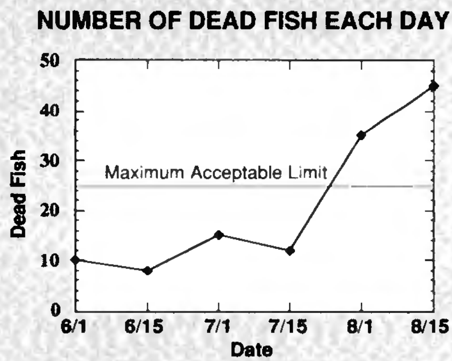
"Review the obvious."

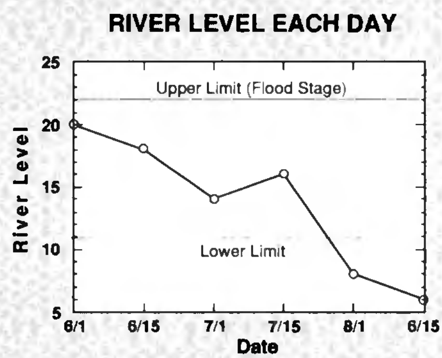
Learn as much as you can about the problem. Write down or list everything you can think of to describe the problem. Until the problem is well defined, anything might be important. Determine what information is missing and what information is extraneous. The information should be properly organized, analyzed and presented. It will then serve as the basis for subsequent decision making. Make a simple sketch or drawing of the situation. Drawings, sketches, graphs of data, etc. can all be excellent communication tools when used correctly. Analyze the data to show trends, errors, and other meaningful information. Display numerical or quantitative

data graphically rather than in tabular form. Tables can be difficult to interpret and sometimes misleading. Graphing, on the other hand, is an excellent way to organize and analyze large amounts of data. Methods for plotting data to reveal trends are given in Appendix 2. The Case of the Dead Fish provides an interesting example of the use of graphical data to solve problems.

The Case of the Dead Fish

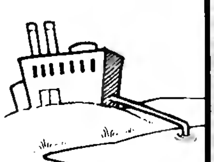
Research and information gathering are great tools in problem solving. We consider the case of a chemical plant that discharges waste into a stream that flows into a relatively wide river. Biologists monitored the river as an ecosystem and reported the following data of the number of dead fish in the river and the river level:





Graphs of the type shown above are called time plots and control charts. A time plot shows trends over a period of time (e.g., the level of a river over several days or weeks). A control chart is a time plot that also shows the acceptable limits of the quantity being displayed. For example, in the control chart of the river level, the upper and lower acceptable water levels would also be shown. If one of the acceptable limits is exceeded, this occurrence may yield some information about the timing of the problem and possible causes of it. We can then examine time plots of other pertinent quantities and look for additional clues about the problem,

From the graphs we see that the acceptable level of dead fish was exceeded on August 1 and 15. We look for anything that might have occurred on or between July 15th and August 1. We discover that on July 29 there was a large amount of chemical waste discharged into the river. Discharges of this size had not caused any problems in the past. Upon checking other factors, we see that there has been little rain and that the water level in the river, measured on August 1, had fallen so low it might not have been able to dilute the plant's chemical waste. Consequently, the low water level, coupled with the high volume of waste, could be suggested as a possible cause for the unusually large number of dead fish. However, to verify this, we would have to carry the analysis further. Specifically, we shall soon use one or more of the problem definition techniques discussed later in this chapter.



Step 2. ***Talk with people familiar with the problem.***

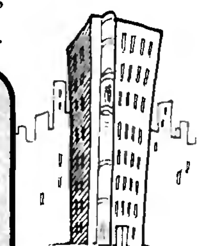
Find out who knows about the problem. Ask penetrating questions by

- Looking past the obvious
- Challenging the basic premise
- Asking for clarification when you do not understand something

Ask *Insightful* Questions

Our experience shows that seemingly naive questions (often perceived as "dumb" questions) can produce profound results by challenging established thinking patterns. This act of *challenging* must be an ongoing process.

You should also talk to other people about the problem. Verbalizing the problem to someone else helps clarify in your own mind just what it is you are trying to do. Try to find out who the experts in the field are and talk to them. Nonexperts are also a rich source of creative solutions, as evidenced by the following example.



Seeking Advice

Joel Weldon, in his tape "Jet Pilots Don't Use Rearview Mirrors," described a problem encountered by a major hotel a number of years ago. Since the hotel had become very popular, the elevators were very busy, and frequently caused backups in the lobby area. The manager and assistant manager were lamenting the problem in the lobby one day and were brainstorming about how to increase the elevator capacity. Adding additional elevator shafts would require removal of a number of rooms and a significant loss of income. The doorman, overhearing their conversation, casually mentioned that it was too bad they couldn't just add an elevator on the outside of the building, so as not to disturb things inside. A great idea! It occurred to the doorman because he was outside the building much of the time, and that was his frame of reference. Notice, however, that the doorman's creativity alone was not enough to solve the problem. Knowledge of design techniques was necessary to implement his original idea. A new outside elevator was born, and the rest is history. External elevators have since become quite popular in major hotels. Information, good ideas, and different perspectives on the problem can come from all levels of the organization. (*Chemtech.*, 13, 9, p. 517, 1983)

When equipment malfunctions, it is a *must* to talk to the operators because they know the "personality" of the equipment better than anyone.

Most organizations have employees who have "been around a long time" and have a great deal of experience, as illustrated in the following example.

Go Talk to George

Remember the leaking flowmeter discussed in Chapter 1? The solution that the company adopted was to replace the flowmeter at regular intervals. Let's consider a similar situation in which, immediately upon replacement, the flowmeter began to leak. List in order four people you would talk to.

- the person who installed the meter
- the technician who monitors the flowmeter
- the manufacturer's representative who sold you the flowmeter
- George

Who's George? Every organization has a *George*. George is that individual who has years of experience to draw upon and also has street smarts. George is an excellent problem solver who always seems to approach the problem from a different viewpoint– one that hasn't been thought of by anyone else. Be sure to tap this rich source of knowledge, when you are faced with a problem. Individuals such as George can often provide a unique perspective on the situation.

> 'You can see a lot just by looking."
> –Yogi Berra

Step 3. ***View the problem first hand.***

While it is important to talk to people as a way to understand the problem, you should not rely solely on their interpretations of the situation and problem. If at all possible, go inspect the problem yourself.

Viewing the Problem Firsthand

In the mid 1970s a company in the United Kingdom completed a plant to produce a plastic product (PVC). The main piece of equipment was a large reactor with a cooling jacket through which water passed to keep the reactor cool. When the plant was started up, the plastic was dark, nonuniform, and way off design specifications. The engineers in charge reviewed their design. They reworked and refined their model and calculations. They analyzed the procedure from every point of view on paper. They had the raw material fed to the reactor analyzed. However, they all came up with the same results– that the product should definitely meet the design specifications. Unfortunately, nobody examined the reactor firsthand. Finally after many days, one of the engineers decided to look into the reactor. He found that a valve had been carelessly switched to the wrong position, thereby diverting cooling water away from the reactor so that virtually no cooling took place. As a result the reactor overheated, producing a poor quality product. Once the valves were adjusted properly, a high quality plastic was produced.

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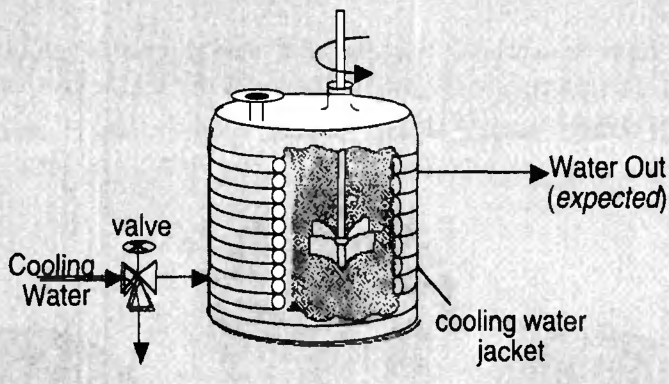
Viewing the Problem Firsthand –continued



Step 4. ***Confirm all key findings.***

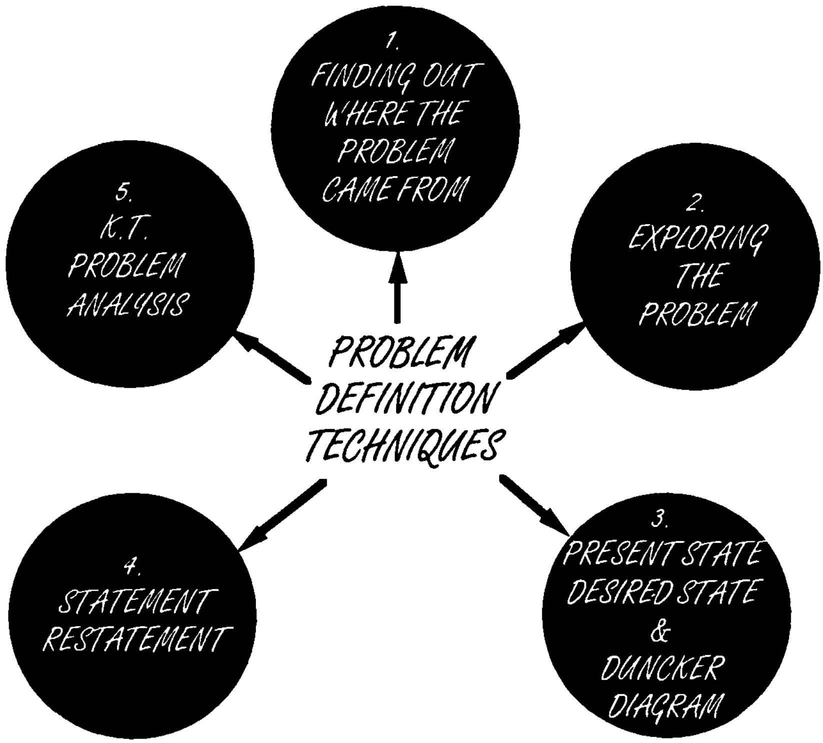
Verify that the information that you collected is correct. Cross check and cross reference data, facts, and figures. Search for biases or misrepresentation of facts. Confirm all important pieces of information and spot check others. Distinguish between fact and opinion. Challenge assumptions and assertions.

Confirm All Allegations

The authors of this book were involved in a consulting project for a pulp and paper company we will call Boxright. Several years ago, Boxright had installed a new process for recovering and recycling their "cooking" chemicals used in the papermaking process. Two years after the installation, the process had yet to operate correctly. Tempers flared and accusations flew back and forth between Boxright and Courtland Construction, the supplier of the recycling equipment. Courtland claimed the problem was that Boxright did not know how to operate the process correctly, while the company contended that the equipment was improperly designed. Boxright finally decided to sue Courtland for breach of equipment performance. Much data and information were presented by both sides to support their arguments. Courtland presented data and information from an article in the engineering literature that they claimed *proved* Boxright was not operating the process correctly. At this point it looked like Courtland had cooked our goose by presenting such data. However, before conceding the case we needed to confirm this claim. We analyzed this key information in detail, and to our glee found in the last few pages of the article it was stated that the data would not be expected to apply to industrial-size equipment or processes. When this information was presented, the lawsuit was settled in favor of the pulp and paper company, Boxright.

3.2 DEFINING THE REAL PROBLEM

The four steps just discussed are all related to gathering information about the problem. This information lays the groundwork that will help us use the problem definition techniques discussed in this chapter.



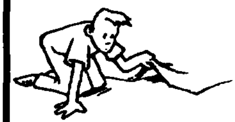
These techniques are used to help understand the problem so that we may define the real problem as opposed to the perceived problem. The K.T. Problem Analysis will be discussed in Chapter 5 as part of the Kepner-Tregoe Approach.[1]

3.2A Finding Out Where the Problem Came From

Many times you will be given a problem by someone else rather than discovering it yourself. Under these circumstances, it is very important that you make sure that the problem you were given reflects the true situation. This technique focuses on finding out who initiated the problem and ascertaining the validity of the reasoning used to arrive at the problem statement.

Find out where the problem statement came from.

- Where did the problem originate?
- Who posed the problem statement in the first place, your supervisor, his/her supervisor, a colleague in your project group, or someone else?
- Can that person explain the reasoning as to how they arrived at that particular problem statement?
- Are the reasoning and assumptions valid?
- Has that person considered the situation from a number of different viewpoints before arriving at the final problem statement?
- Have you used *the first four steps* to gather information about the problem?



Try to detect any errors in logic as you trace the problem back to its origins. Distinguish opinion from fact and conclusions from evidence. **Never** assume that the problem statement you were given is correctly worded or has been thoroughly investigated.

Trace the problem back to its origin.

Always check to be sure that the problem statement directs the solution to the true cause and does not seek merely to treat the symptoms. For example, it would certainly be better to find the cause of the off-taste in the hamburgers at a fast food chain rather than treating the symptoms by adding more spices to cover the off-taste. Make certain that time and energy are not wasted merely dealing with the symptoms.

Remember *The Case of the Dead Fish* in the river on p.30? The dead fish example is a case where giving directions to treat the symptoms rather than discovering the real cause of the problem could have lead to a costly, unnecessary solution.

Finding Out Where the Problem Came From

The Case of the Dead Fish

The Situation: Stan Wilson is an engineer with six years of experience with his company. The instructions given by Stan's supervisor to solve the perceived problem: *"Design a new waste treatment plant to reduce the toxic waste from the chemical plant."* Stan and his team are requested to design treatment facilities to reduce the toxic chemical concentrations by a factor of 10. A quick back-of-the-envelope calculation shows that the plant could cost well over a *million* dollars. Stan is puzzled because the concentrations of toxic chemicals have always been significantly below governmental regulations and company health specifications.

Who posed the problem?

Stan approaches his supervisor to learn more about the reasons for the order. The supervisor informs Stan that it was not his decision, but upper management's.

Can reasons for arriving at the problem statement be explained?

The supervisor tells Stan it has something to do with the summer drought and a number of recent articles in the local newspaper about the unusually high number of dead fish that have turned up in the river in the last few weeks. He said that it was his understanding that the drought has brought the river to an extremely low level and that the discharge was no longer sufficiently dilute to be safe to the fish and other aquatic life. Consequently, to deflect the negative press and avoid possible lawsuits, the company has announced the planning of a new waste treatment facility.

Keep digging to learn the motivation (who, why) for issuing the instructions to solve the perceived problem.

Are the assumptions and reasoning valid?

Thus, Stan realizes that the decision to design and build a waste treatment plant is based on *an unusually large number of dead fish in the river, and **not** necessarily on the presence of high concentrations of toxic chemicals.* The company had decided to try to treat the symptoms (many dead fish) by removing toxic chemicals, thus solving the perceived problem, but not necessarily the true problem (how to prevent the fish from dying).

Has sufficient data/information been collected?

In the Explore Phase, we'll see how Stan initiated his own investigation into the case of the dead fish and eventually found the true cause of the problem.

Finding Out Where the Problem Came From

Sweet and Sour

The Situation: (which has nothing to do with Chinese food): Natural gas (methane), which contains significant levels of hydrogen sulfide, is called a *sour gas*, while natural gas that does not contain hydrogen sulfide is called a *sweet gas*. Sour gas is particularly troublesome because it is extremely corrosive to the pipes and equipment used to transport it. Tom Anderson was the sour gas piping expert at a major oil company that was drilling an off-shore well in a gas field in the North Sea. Regions near the well being drilled were known to produce sour gas. Tom received a call from the head office. The instructions given to solve the perceived problem: *"Fly to Copenhagen to begin the design and installation of a piping system that would transport sour gas from the new well to the platform facility."*

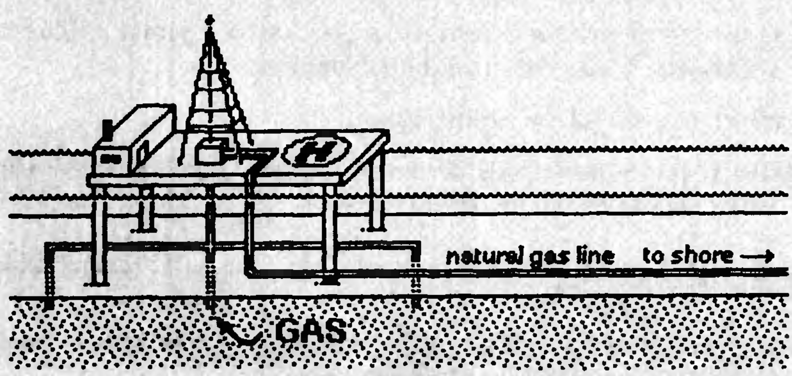
Challenge Assumptions and Reasoning

Laboratory tests were believed to have been carried out on gas samples from this well and it was assumed that the head office had reviewed these tests. An expensive piping system that would be resistant to corrosion by sour gas was designed and installed. When the gas well was brought on-line, it was found that the gas was sweet gas which did not require the corrosion resistant piping system that had cost several million dollars extra.

Who was responsible for this blunder? Could this waste have been eliminated if Tom had found out where the problem had come from? Did the problem come from the lab or from the head office? What would have been the course of action regarding the type of piping installed,

1. **If** Tom, who was the piping expert, had asked the head office to explain why they wanted to install piping resistant to sour gas for *this* well, or,
2. **If** Tom had challenged their reasoning by asking what evidence they had that *this* well produced sour gas, or
3. **If** Tom had gathered more information by tracking down the laboratory results to learn how much sour gas was in the natural gas?

If Tom had traced back the original source of the product to find out **where the problem came from,** this waste could have been eliminated.



A good rule of thumb is to treat the symptoms *only* if it is impossible or impractical to solve the real problem. For example, in the case of the leaking flowmeter discussed in Chapter 1, it was impractical to solve the real problem of finding an inexpensive corrosion resistant material. As a result, the symptoms were treated by periodically replacing the flowmeter.

3.2B Exploring the Problem

This technique works well both for situations of analyzing incorrectly defined problems assigned to you and for formulating problem statements for new problems you uncover yourself. Once presented with a problem, we want to explore all aspects of the problem and its surroundings. This technique, which has its origins in the McMaster Five-Point Strategy given in Appendix 1, is a procedure that guides us to understand and define the real problem. Gathering information is also the key to the success of the exploration, and *the first four steps* (p. 29) are very helpful in this process.

TABLE 3-2: Exploring the Problem[2]

1. **Identify All Available Information.**
2. **Recall or Learn Pertinent Theories and Fundamentals.**
3. **Collect Missing Information.**
4. **Solve a Simplified Version of the Problem to Obtain a "Ballpark" Answer.**
5. **Hypothesize and Visualize What Could Be Wrong with the Current Situation.**
6. **Brainstorm to Guess the Answer.**
7. **Recall Past or Related Problems and Experiences.**
8. **Describe or Sketch the Solution in a Qualitative Manner or Sketch Out a Pathway That Will Lead to the Solution.**
9. **Collect More Data and Information.**
10. **After Using Some or All of the Activities Above, Write a Concise Statement Defining the Real Problem.**

"Exploring the Problem" can also be used to build upon the results of the previous technique "Finding Out Where the Problem Came From."

Exploring the Problem

The Case of the Dead Fish

Stan decides to initiate his own investigation into the dead fish problem over the weekend.

1. **Identify Available Information**: There is a toxic discharge from the plant, the river level is low, and there are a large number of dead fish in the river.

2. **Learn Fundamentals**: Stan calls a friend in the biology department at the local university and asks her about the problem of what could be causing the fish to die. She tells Stan that the extremely low water levels lead to significantly warmer water temperatures, and hence lower levels of dissolved oxygen in the water. These conditions make the fish susceptible to disease.

3. **Missing Information**: Secondly, she says that a fungus has been found in two nearby lakes that could be responsible for the death of the fish. Upon checking the recent daily temperatures, Stan learns that the day before the fish began dying was one of the hottest of the decade. Stan starts making phone calls to people upstream and downstream from the plant and learns that dead fish are appearing at the same unusually high rate everywhere, not just downstream of the plant.

5. **Hypothesis**: The fish were dying all over the area as a result of the fungus, and not from the plant discharge.

9. **More Information**: Upon examination of the dead fish, it was discovered that the fungus was indeed the cause of death, and that toxic chemicals played no role in the problem. Stan was glad that he had found out where the problem had come from and had explored the situation rather than blindly proceeding to design the treatment plant.

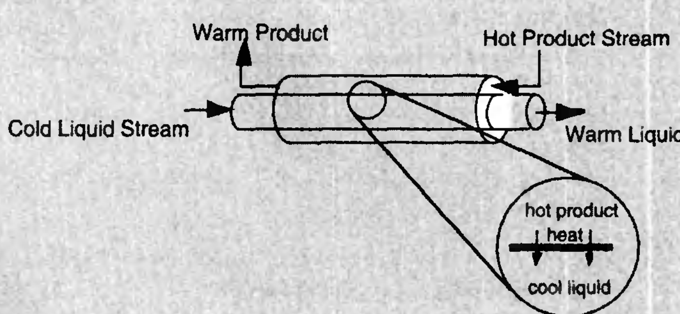
10. **Define the Real Problem**: Identify ways to cure the infected fish and prevent healthy fish from being infected.

We note from the above example that it is not always necessary to address all ten steps in Table 3-2 to fully explore the problem. However, as seen in the next example, each of the steps has a purpose and contributes to revealing the true problem.

De-bottlenecking a Process

Even though the following example is taken from an actual case history, don't worry if you don't know much about heat exchangers; just follow the reasoning. It is too good an example to pass up. The situation: A valuable product was being sold as fast as it could be manufactured in a chemical plant. Management tried to increase production but was unable to do so. Analysis of each step in the production line showed that the bottleneck was the refrigeration unit. This unit was a simple heat exchanger in which the hot liquid stream was cooled by passing it through a pipe which contacted a cold liquid stream. Heat flowed from the hot stream through the pipe wall into the cold stream. Unfortunately the refrigeration unit (i.e., heat exchanger) was not cooling the hot liquid stream to a sufficiently low temperature for it to be treated effectively in the next processing step. The instructions given to solve the perceived problem: "*Design and install a larger refrigeration unit.*" The design of a larger refrigeration unit was started.

Refrigerator
(Heat Exchanger)



Explore Phase

1. **Identify inputs/outputs:** Cold liquid stream not cooling hot product stream.
2. **Recall related theories and fundamentals:** The rate of cooling between the two streams is related to the temperature difference between the two streams, their flow rates, and the materials and condition of the unit.
3. **Collect missing information:** What is the size of the current refrigeration unit? What are the entering and exiting temperatures of the liquid streams?
4. **Carry out an order of magnitude calculation:** AH HA! The new unit need be no larger than the old one.
5. **Hypothesize and visualize what could be wrong with the current system:** Inefficient operation of current system? Could something be increasing the resistance to heat transfer (i.e., insulating)?
6. **Guess the result:** Could scale (minerals deposited from the liquid) have built up on the inside of the unit acting as an insulating blanket?

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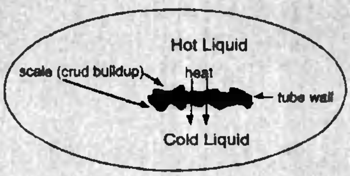
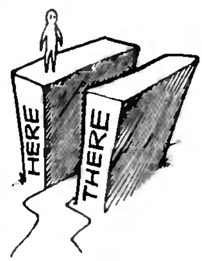
De-bottlenecking a Process –continued



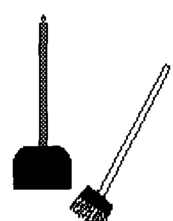
The buildup of scale on the pipe walls of the exchanger reduces the amount of heat that will transfer from the hot fluid to the cold fluid which severely degrades the ability of the exchanger to perform its intended task. The thicker the scale, the greater the resistance to heat transfer and the poorer the performance of the unit.

7. **Recall past problems, theories, or related experiences:** Scale greatly reduces the efficiency of the unit.
8. **Sketch solution or solution pathway**: Examine the unit for evidence of scale or fouling that may be reducing the heat transfer efficiency.
9. **Collect more data:** An examination of the heat exchanger showed it was indeed badly fouled.
10. **Define the real problem:** The scale on the pipe wall must be removed in order to cool the product stream effectively.



3.2C Using the Present State/Desired State Technique

How many times have you heard the statement "You can't get there from here?" The *Present State/Desired State* technique helps us verbalize where we are and where we want to go, so that an appropriate path can be found and we can indeed get there from here. The Present State/Desired State technique also helps us learn whether the solution goals (Desired State) are consistent with our needs (Present State).[3] When writing the Desired State statement, avoid using ambiguous and vague words or phrases like "best," "minimal," "cheapest," "within a reasonable time," "most efficient," etc. because these words mean different things to different people. Be quantitative where possible. For example, "The children's playground needs to be completed by July 1, 1994 at a cost under $100,000" *as opposed to* "The playground should be completed in a reasonable time at minimal cost." It is important that the Present State statement match the Desired State statement. In order for the Present State and Desired State to match, every concern in the Present State should be addressed in the Desired State. In addition, the Desired State should not contain solutions to problems that are not in the Present State. Sometimes a match exists, but it really doesn't get to the heart of the problem or allow many solution alternatives. Reworking the Present State and Desired State statements until they match is a technique that increases the probability of arriving at the true problem statement. Let us consider the following example of the Present State/Desired State Technique.



Cleaning up the Problem Statement

Hitting 'Em Where They Aren't

The Situation: During WWII, a number of aircraft were shot down while engaging in bombing missions over Germany. Many of the planes that made it back safely to base were riddled with bullet and projectile holes. The damaged areas were similar on each plane.

The instructions given to solve the perceived problem: *"Reinforce these damaged areas with thicker armor plating."*

Present State	Desired State
Many bullets/projectiles penetrating aircraft.	Fewer planes being shot down.

Discussion: This is not a match because there are planes that are surviving that still have bullet holes. There is not a *one-to-one mapping* of all the needs of the present state being addressed and resolved in the desired state.

Present State	Desired State
Many bullets/projectiles penetrating aircraft.	Fewer bullet holes.

Discussion: These states are matched, but the distinction between the present state and the desired state is not clear enough. It may take only a single bullet hitting a critical area to down a plane.

Present State	Desired State
Many bullets/projectiles penetrating aircraft in critical and noncritical areas.	Fewer bullets/projectiles penetrating critical areas.

Discussion: These two statements now match and the distinction between them is sharp, opening up a variety of solution avenues such as reinforcing critical areas, moving critical components (e.g., steering mechanism) to more protected locations, providing redundant critical components, etc.

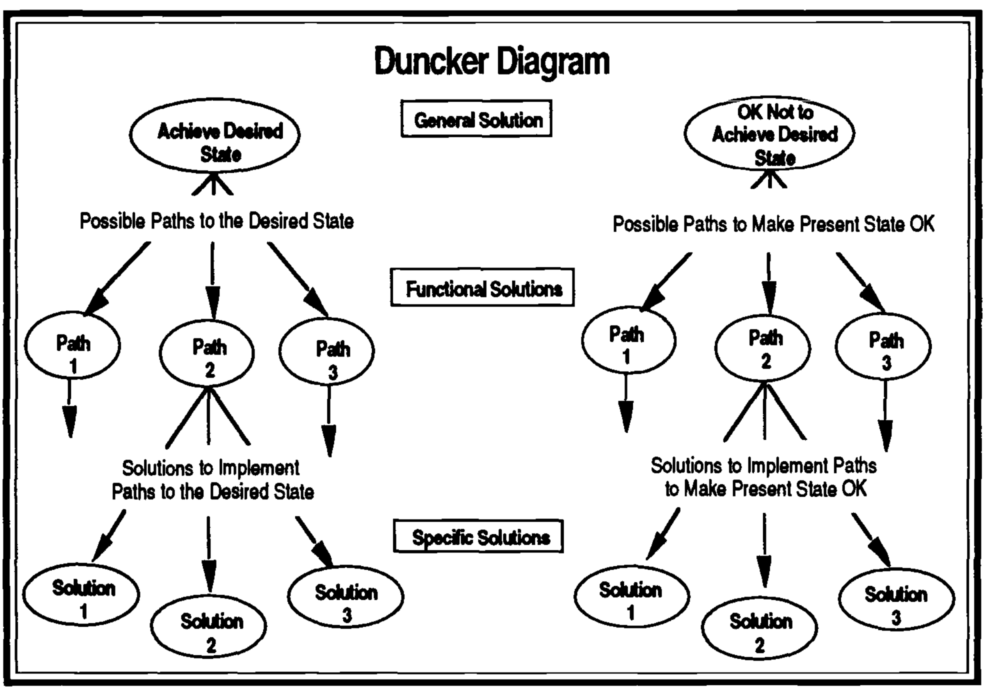
Note: The original instructions given to solve the perceived problem would have failed. Reinforcing the areas where returning planes had been shot would have been futile. Clearly these were noncritical areas; otherwise these planes would have been casualties as well.

3.2D The Duncker Diagram

The Duncker Diagram helps obtain solutions that satisfy the criteria set up by the Present State/Desired State statements.[3] The unique feature of the Duncker Diagram is that it points out ways to solve the problem by making it OK *not* to reach the desired solution. Duncker Diagram solutions can be classified as General Solutions, Functional Solutions, and Specific Solutions (see Figure 3-1).

There are two types of General Solutions: 1) Solutions on the left side of the diagram that move from the present state to the desired state (i.e., we have to do something) and 2) solutions on the right side that show how to modify the desired state until it corresponds with the present state (make it OK ***not*** to do that *same* something). For example, suppose your *present state* was your current job and the *desired state* is a new job. The left hand side of the diagram would show the steps to reach the desired state of obtaining a new job (e.g., update resume, interview trips). The right side of the diagram show the steps that would make it OK to stay in your current job (e.g., greater participation in the decision making, salary increase). In addition, there could be a compromise solution in which both the Present State and Desired State are moved toward each other until there is a correspondence.

Functional Solutions are possible paths to the desired state (or modified desired state) that do not take into account the feasibility of the solution. We could solve the problem *only if...* we had more time, more personnel, ... we won the lottery.... After arriving at each functional solution, one has to suggest feasible *Specific Solutions* to implement the functional solutions. For example in the job change situation, a functional solution on the right side of the diagram might be feeling more appreciated and a specific solution to feeling appreciated could be a salary increase or bonus, more verbal praise on a job well done, or a letter of commendation in your company personnel file. Representing the problem on a Duncker Diagram is a creative activity, and as such, there is no right way or wrong way to do it. There are only more and less useful ways to represent the problem. Typically, the most difficult activity is choosing the appropriate desired state. This skill improves with practice.



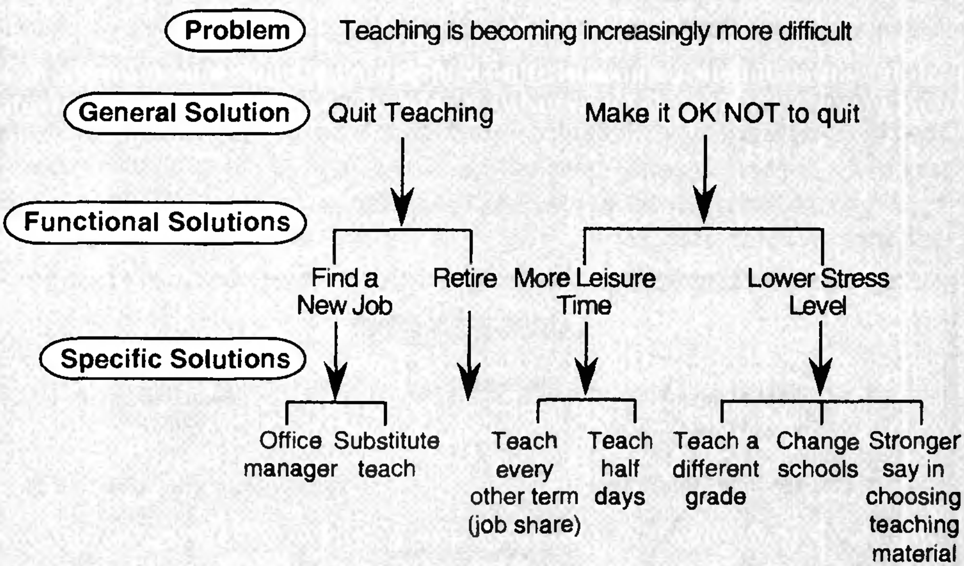
Functional Solutions: What to do.

Specific Solutions: How to do it.

Figure 3-1. The Duncker Diagram

Kindergarten Cop†

Linda Chen, who has been teaching elementary school for 25 years, has just finished a six-month leave of absence and is scheduled to return to teaching in February. She is dreading returning to teaching because the last few years have been extremely stressful and difficult, and she feels burned out teaching kindergarten. Students seem harder to control, Linda doesn't like the materials she is required to use in the classroom, and the parents don't seem to take much interest in their children's education. She also enjoyed the time she had to herself during her six-month leave and strongly feels she must continue to have more time to herself as she nears retirement which will be in five years if she is to receive full benefits. Consequently, Linda's *present state* is returning to teaching, and her *desired state* is not to return to teaching. Prepare a Duncker Diagram to analyze this situation.



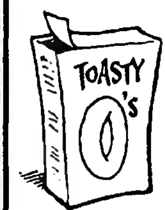
Recap: Upon analyzing her situation using a Duncker Diagram, Linda discovered the real problem was the high stress level brought on by the unruly classes she had the year before her six-month leave. Consequently, with the aid of a Duncker Diagram, she arrived at the conclusion that the *real* problem was she should find ways to lower her stress level at her workplace.

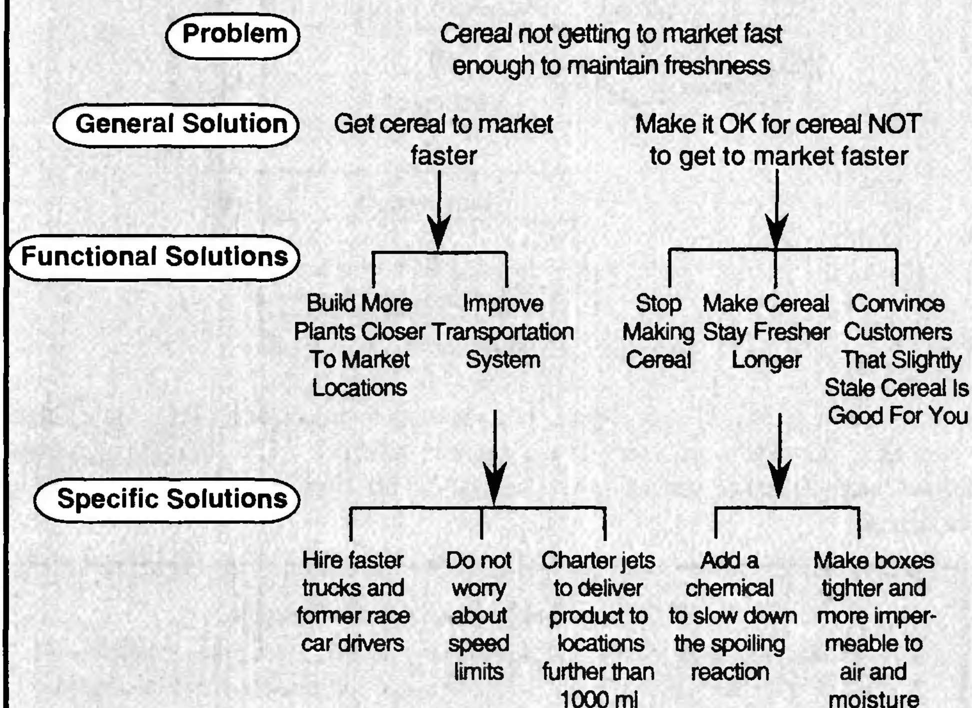
†Based on an actual case history.

Let us consider the application of the Duncker Diagram to the following To Market, To Market example.

To Market, To Market

The Situation: Toasty O's was one of the hottest selling cereals when it first came on the market. However, after several months, sales dropped. The consumer survey department was able to identify that customer dissatisfaction was expressed in terms of a stale taste. The instructions given to solve the perceived problem: *"Streamline the production process to get the cereal on the store shelves faster, thus ensuring a fresher product."* However, there wasn't much slack time that could be removed from the process to accomplish the goal. Of the steps required to get the product on the shelves (production, packaging, storage, and shipping), production was one of the fastest. Thus, plans for building plants closer to the major markets were considered, as were plans for adding more trucks in order to get the cereal to market faster. The addition of new plants and trucks was going to require a major capital investment to solve the problem.



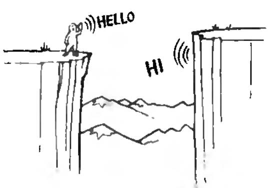


The **real problem** was that the cereal was not staying fresh long enough, not that it wasn't getting to market fast enough. Keeping the cereal fresher longer was achieved by improved packaging and the use of additives to slow the rate of staling.

3.2E Using the Statement-Restatement Technique

> *A problem well-stated is a problem half solved.*
> -Charles F. Kettering

This technique is similar to the Present State/Desired State technique in that it requires us to rephrase the problem statement. The *Statement-Restatement* technique was developed by Parnes,[4] a researcher in problem solving and creativity. Here, one looks at the fuzzy or unclear problem situation and writes a statement regarding a challenge to be addressed. The problem is then restated in different forms a number of times. Each time the problem is restated, one tries to generalize it further in order to arrive at the broadest form of the problem statement (see Figure 3-2).



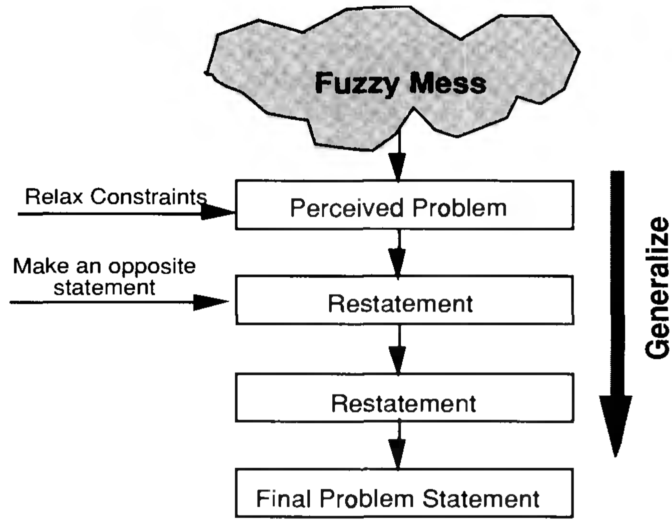


Figure 3-2. Stating the Real Problem

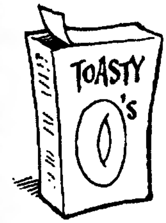
In restating the problem it is important to inject new ideas, rather than changing only the word order in the restated sentence. The following problem restatement *triggers* should prove helpful in arriving at a definitive problem statement.

TABLE 3-3: Problem Statement Triggers

1. Vary the stress pattern—try placing emphasis on different words and phrases.
2. Choose a term that has an explicit definition and substitute the explicit definition in each place that the term appears.
3. Make an opposite statement, change positives to negatives, and vice versa.
4. Change "every" to "some," "always" to "sometimes," "sometimes" to "never," and vice versa.
5. Replace "persuasive words" in the problem statement such as "obviously," "clearly," and "certainly" with the argument it is supposed to be replacing.
6. Express words in the form of an equation or picture, and vice versa.

Using the Triggers

Original Problem Statement: Cereal not getting to market fast enough to maintain freshness



Trigger 1
- Cereal not getting to market fast enough to maintain freshness. (Do other products we have get there faster?)
- Cereal not getting to market fast enough to maintain freshness. (Can we make the distance/time shorter?)
- Cereal not getting to market fast enough to maintain freshness. (Can we distribute from a centralized location?)
- Cereal not getting to market fast enough to maintain freshness. (How can we keep cereal fresher, longer?)

Trigger 2
- Breakfast food that comes in a box is not getting to the place where it is sold fast enough to keep it from getting stale. (Makes us think about the box and staleness. . . what changes might we make to the box to prevent staleness?)

Trigger 3
- How can we find a way to get the cereal to market so slowly that it will never be fresh? (Makes us think about how long we have to maintain freshness and what controls it?)

Trigger 4
- Cereal is not getting to market fast enough to always maintain freshness. (This change opens new avenues of thought. Why isn't our cereal always fresh?)

Trigger 5
- The problem statement implies that we obviously want to get the cereal to market faster to maintain freshness. Thus, if we could speed up delivery freshness would be maintained. Maybe not! Maybe the store holds it too long. Maybe it's stale before it gets to the store. (This trigger helps us challenge implicit assumptions made in the problem statement.)

Trigger 6
- Freshness is inversely proportional to the time since the cereal was baked, i.e.,

$$(\text{Freshness}) = \frac{k}{(\text{Time Since Baked})}$$

Makes us think of other ways to attack the freshness problem. For example, what does the proportionality constant, k, depend upon?

The storage conditions, packaging, type of cereal, etc. are logical variables to examine. How can we change the value of k?

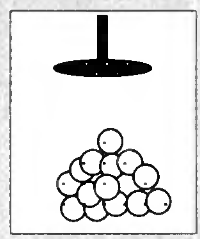
The total time may be shortened by reducing the time at the factory, the delivery time, or the time to sell the cereal (i.e., shelf time). So, again, this trigger provides us with several alternative approaches to examine to solve the problem: Reduce the time or change (increase) k.

As an illustration of the use of these triggers, consider *trigger 3* above. Instead of asking "How can my company make the biggest profit?" ask "How can my company lose the most money?" In finding the key activities or pieces of equipment which, when operated inefficiently, will give the biggest loss, we will have found those pieces that need to be carefully monitored and controlled. This trigger helps us find the *sensitivity* of the system and to focus on those variables that dominate.

It is often helpful to *relax constraints* on the problem, modify the criteria, and idealize the problem when writing the restatement sentence (see trigger 4). Also, does the problem statement change when different time scales are imposed (i.e., are the long-term implications different from the short-term implications)? As one continues to restate and perhaps combine previous restatements, one should also focus on tightening up the problem statement, eliminating ambiguous words, and moving away from a fuzzy, loose, ill-defined statement.

Making an Opposite Statement

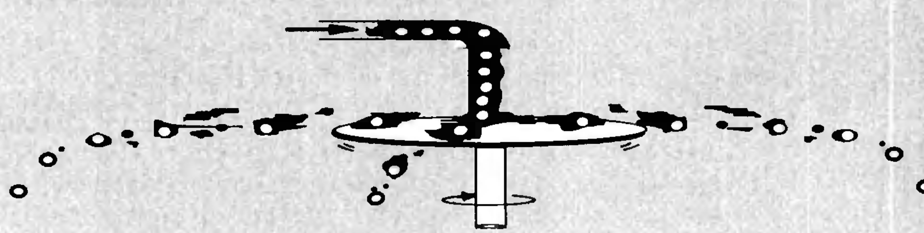
The Situation: To many people, taking aspirin tablets is a foul-tasting experience. A few years ago, a number of companies making aspirin decided to do something about it. The instructions given by the manager to his staff to solve the perceived problem were: *"Find a way to put a pleasant-tasting coating on aspirin tablets."* Spraying the coating on the tablets had been tried, with very little success. The resulting coating was very nonuniform and this led to an unacceptable product. Let's apply the triggers to this problem.



Trigger 1 Emphasize different parts of statement
1. **Put** coating **on** tablet.

Trigger 3 Make an opposite statement
2. **Take** coating **off** tablet.

This idea led to one of the newer techniques for coating pills. The pills are immersed in a liquid which is passed onto a spinning disk. The centrifugal force on the fluid and the pills causes the two to separate, leaving a nice, even coating around the pill.

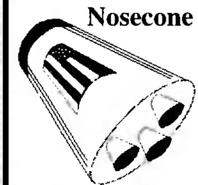


An example from reliable, although undocumented, sources that elucidates the need to find the real problem is one related to the early research on the reentry of space capsules to the earth's atmosphere. It was evident that available materials would not withstand the temperatures from frictional heating by the atmosphere. Consequently, a directive went out to find a material able to withstand the temperatures encountered on reentry. Application of the Statement-Restatement technique to this problem is shown in the following gray box.

The real problem here was to protect the astronauts (restatement 3) rather than find a material that would withstand high temperatures. Once the real problem was found, an appropriate solution to the capsule reentry problem soon followed.

Wanted: Exotic Materials, or...?

The Situation: In the 1960s scientists recognized that there was no available material that would survive the high temperatures generated on the capsule's surface during reentry to the earth's atmosphere. Consequently, a government directive went out to *"find a material able to withstand the temperatures encountered on reentry."* By the early 1970s no one had produced a suitable material that satisfied the directive, yet we had sent astronauts to the moon and back. How had this achievement been possible? The **real problem** was to protect the astronauts upon reentry, rather than to find a material that would withstand such high temperatures. Once the real problem was determined, a solution soon followed. One of the scientists working on the project asked a related question: How do meteors eventually reach the earth's surface without disintegrating completely? Upon investigation of this problem, he found that although the surface of the meteor vaporized while passing through the atmosphere, the inside of the meteor was not damaged. This analogy led to the idea of using materials on the outside of the capsule that would vaporize when exposed to the high temperatures encountered during reentry. Consequently, the heat generated by friction with the earth's atmosphere during reentry would be dissipated by the vaporization of a material that coated the outside of the space capsule. By sacrificing this material, the temperatures of the capsule's underlying structural material remained at a tolerable level to protect the astronauts. Once the real problem was uncovered, the scientists solved the problem by using analogies and transferring ideas from one situation to another.



Statement-Restatement

The statement-restatement technique might have been used as follows:

Statement 1: Find a material that will withstand the high surface temperature of the capsule resulting from frictional heating upon reentry into the earth's atmosphere.

Restatement 1: Find a way to slow the reentry into the earth's atmosphere or to redesign the capsule so that the capsule surface temperature will be lower.

Restatement 2: Find a way to cool the capsule or absorb the frictional energy during reentry so that the surface temperature will be lower.

Restatement 3 Find a way to protect the astronauts on their reentry into the earth's atmosphere.

Restatement 4: Find a disposable material that could surround the capsule and could be sacrificed to absorb the frictional heating.

3.2F Evaluating the Problem Definition

Now that we have used one or more of the preceding techniques to define the problem, we need to check to make sure we are going in the right direction. Consequently, we need to evaluate the problem definition before proceeding further. The following checklist could help us in this evaluation.

If you break the problem apart . . . be sure to put it back together.

- Have all the pieces of the problem been identified?
- Have all the constraints been identified?
- What is missing from the problem definition?
- What is extraneous to the problem definition?
- Have you challenged the assumptions and information you were given to formulate the problem?
- Have you distinguished fact from opinion?

3.3 THE NEXT FOUR STEPS

We now extend the first steps experienced problem solvers recommend and continue Table 3-1 in Table 3-4.

TABLE 3-4: What Experienced Problem Solvers Say

The First Four Steps of Experienced Problem Solvers

1. Collect and analyze information and data.
2. Talk with people familiar with the problem.
3. If at all possible, view the problem firsthand.
4. Confirm all findings.

The Next Four Steps

5. Determine if the problem should be solved.
6. Continue to gather information and search the literature.
7. Form simple hypotheses and quickly test them.
8. Brainstorm potential causes and solution alternatives.

Step 5. ***Determine if the problem should be solved.***

Establish criteria to Judge the Solution.

Having defined the real problem, we now need to develop criteria by which to judge the solution to the real problem. One of the first questions experienced engineers ask is: Should the problem be solved? Figure 3-3 shows how to proceed to answer this question. The first step is to determine if a solution to an identical or similar problem is available. A literature search may determine if a solution exists.

How do experienced problem solvers go about deciding if the problem is worth solving? Perhaps it is just mildly irritating and consequently may be ignored altogether. (For instance, suppose the garage door at your plant's warehouse facility is too narrow for easy access by some of the delivery vehicles. They can pass through, but the clearance is very tight. This is an annoying problem, but if the fix is quite costly, you could probably "live with it.") Questions you should ask early in the process are: What are the resources available to solve the problem? How many people can you allocate to the problem, and for how long a time? How soon do you need a solution? Today? Tomorrow? Next year? These are key questions to keep in mind as you take your first steps along the way to a problem solution. The quality of your solution is often, but not always, related to the time and money you have to *generate it and carry it through*. In some instances it may be necessary to extend deadlines in order to obtain a quality solution.

It may not be possible to completely address the cost issue until we are further along in the solution process. The cost will depend on whether or not the solution will be a permanent one or if it will be a temporary or patchwork solution. Sometimes *two* solutions are required: One to treat short-term symptoms to keep the process operating and one to solve the real problem for the long term. Be aware of these two mindsets in the problem-solving process. In some cases the **No's** in the figure on deciding if the problem should be solved can be changed to **Yes's** by *selling* the project to management. This change can be achieved by showing that the problem is an important one and is relevant to the operation of the company.

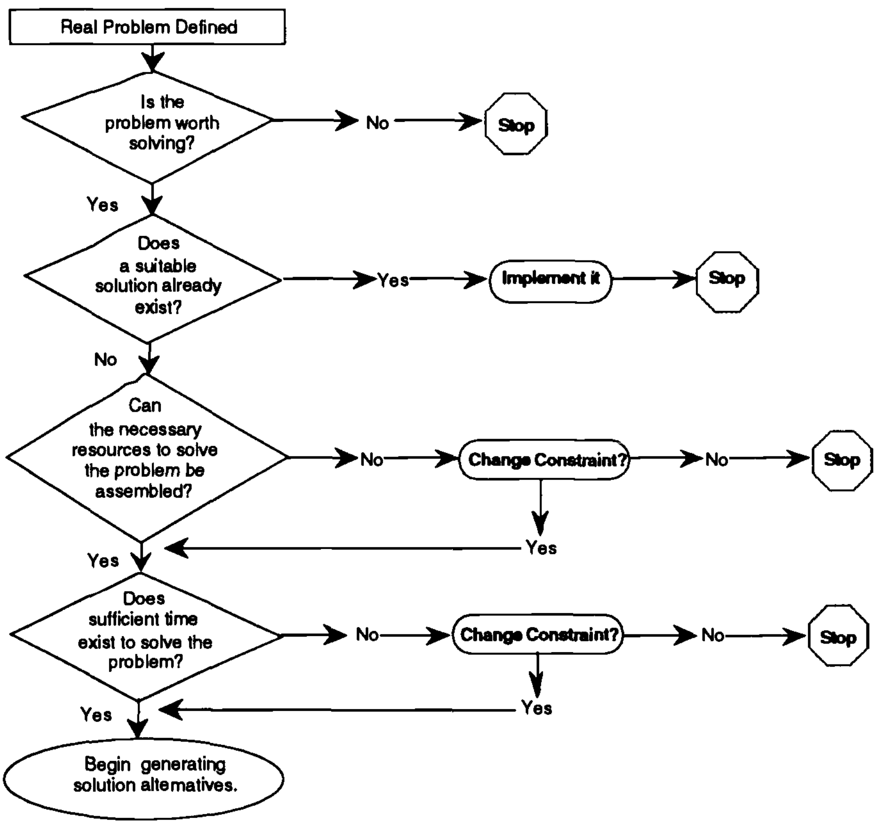
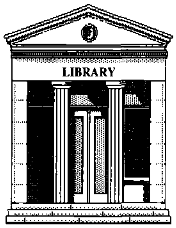


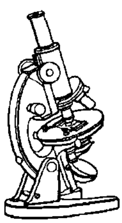
Figure 3-3. Deciding If the Problem Should Be Solved



Step 6. ***Continue to gather information and search the literature.***

Gather as much information as possible by reading texts and literature related to the problem to learn the underlying fundamental principles and peripheral concepts. Literature searches are particularly helpful. Perhaps a closely related problem has already been solved. George Quarderer of Dow Chemical Company appropriately describes the idea of reinventing the wheel by his statement, *"Four to six weeks in the laboratory can save you an hour in the library."* The message is clear: Doing a bit of research into the background of the problem may save you hours of time and effort.

Search out colleagues who may have useful information and pertinent ideas. Have them play "**What if... ?**" with you; that is, "What if you did this?" or "What if I applied this concept?" Also have them play the devil's advocate and deliberately challenge your ideas. This technique stimulates creative interactions.



Step 7. ***Form simple hypotheses and quickly test them.***

Returning to the Dead Fish example, an experienced problem solver could hypothesize that there was something else present in the water that was killing the fish. This hypothesis could be tested in the laboratory by analyzing samples of river water or by performing post-mortem examinations on the dead fish. These tests may have uncovered the presence of the fungus, thereby quickly defining the problem.

Step 8. ***Brainstorm potential causes and solution alternatives.***

This last "first step" brings us to the close of the first phase of the creative problem-solving process and is really the first step of the second phase of the process: Generating Solutions to Problems. Techniques to generate solutions will be discussed in the next chapter.

Which Techniques to Choose

We do not expect the reader to apply every technique to every situation. In fact, when 400 problem solvers were surveyed as to which two techniques presented in this chapter were the most useful, *the choices were virtually equally divided among those presented in this chapter.* In other words, different techniques work better for different individuals and different situations, and it is a personal choice. The main point is to be organized as well as creative in your approach to problem definition.

SUMMARY

In this chapter we have discussed the necessity for defining the real problem. We have presented the eight steps that experienced problem solvers first use to attack problems. They are

- Collect and analyze information and data.
- Talk with people familiar with the problem.
- If at all possible, view the problem firsthand.
- Confirm all findings.
- Determine if the problem should be solved.
- Continue to gather information and search the literature.
- Form simple hypotheses and quickly test them.
- Brainstorm potential causes and solution alternatives.

Five problem definition techniques were presented to help you zero in on the true problem definition. They are

- *Find Out Where the Problem Came From*
  - Use the first four steps to gather information.
  - Learn who defined the problem initially.
  - Challenge reasoning and assumptions made to arrive at the problem statement given to you.
- *Explore the Problem*
  - Recall or learn the fundamental principles related to the problem.
  - Carry out an order-of-magnitude calculation.
  - Hypothesize what could be wrong.
  - Guess the result.
- *Present State/Desired State*
  - Write a statement of where you are and a statement of what you want to achieve and make sure they match.
- *Duncker Diagram*
  - Devise a pathway that makes it OK not to solve the problem posed to you.
- *Statement-Restatement*
  - Use the six triggers to restate the problem in a number of different ways.

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1. Kepner, C.H., and B. B. Tregoe, *The New Rational Manager*, Princeton Research Press, Princeton, NJ, 1981.
2. Woods, D.R., *A Strategy for Problem Solving*, 3rd ed., Department of Chemical Engineering, McMaster University, Hamilton, Ontario, 1985; *Chem. Eng. Educ.*, p. 132, Summer 1979; *AIChE Symposium Series*, 79 (228), 1983.
3. Higgins, J.S., et al., "Identifying and Solving Problems in Engineering Design," *Studies in Higher Education*, 14, No. 2, p. 169, 1989.
4. Parnes, S.J., *Creative Behavior Workbook*, Scribner, New York, 1967.

FURTHER READING

Copulsky, William, "Vision → Innovation," *Chemtech*, 19, p. 279, May 1989. Interesting anecdotes on problem definition and vision related to a number of popular products.

DeBono, Edward, "*Serious Creativity*," Harper Business, a division of Harper Collins Publishers, New York, 1993. Summary of 20 years of creativity researched by deBono. Many useful additional problem definition techniques are presented.

EXERCISES

1. Make a list of the most important things you learned from this chapter. Identify at least three techniques that you believe will change the ways you think about defining and solving problems. Which problem definition techniques do you find most useful? Prepare a matrix table listing all the problem definition techniques discussed in this chapter. Identify those attributes that some of the techniques have in common and also those attributes that are unique to a given technique.

	Attribute 1	Attribute 2	Attribute 3
Technique A	X		X
Technique B		X	X
Technique C	X	X	

2. Write a sentence describing a problem you have. Apply the triggers in the *Statement-Restatement Technique* to your problem.

   Perceived Problem Statement ______________________________

   ____

   ____

   Restatement 1 ______________________________

   ____

   ____

   ____

Restatement 2 ____

____

____

____

Final Problem Statement ____

____

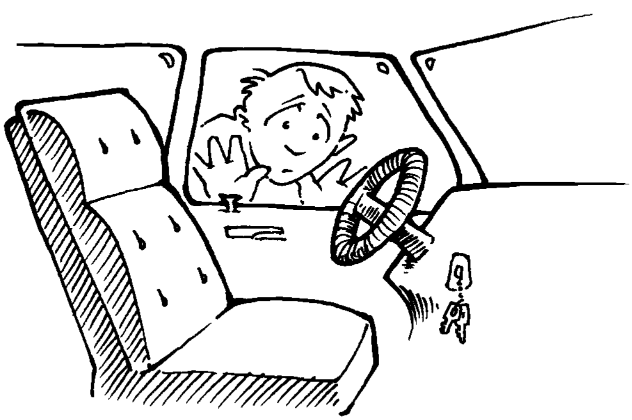
____

____

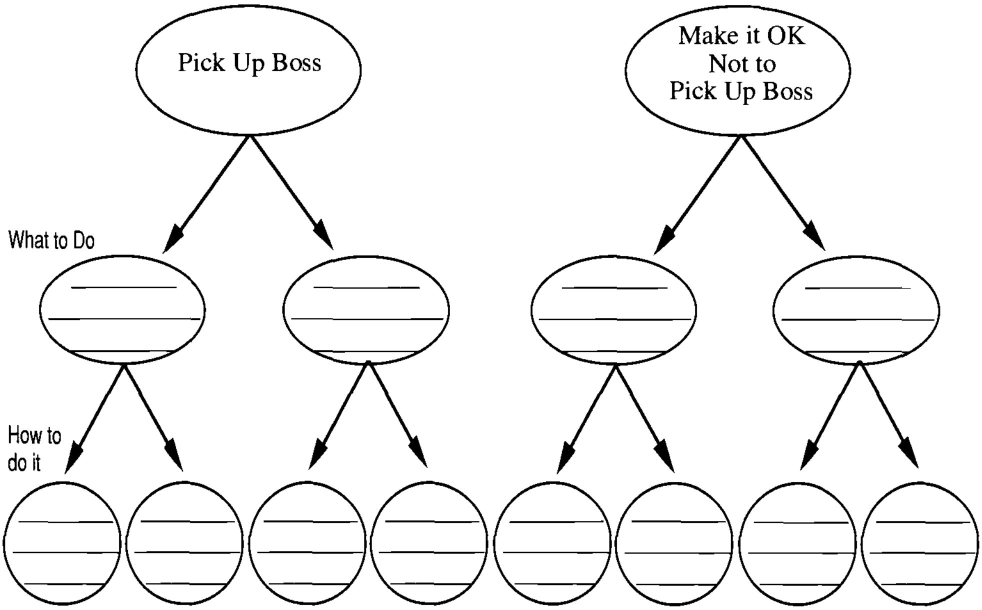
Next apply the Duncker Diagram to this same problem. (Use the Duncker Diagram work sheet on page 59.)

3. Carry out a *Present State/Desired State* analysis on "I want a summer internship but no one is hiring" and then prepare a Duncker Diagram to solve the problem.

4. You have had a very hectic morning, so you leave work a little early to relax a bit before you meet your supervisor, who is flying into a nearby airport. You have not seen your supervisor from the home office for about a year now. He has written to you saying that he wants to meet with you personally to discuss the last project. Through no fault of yours, everything went wrong: The oil embargo delayed shipment of all the key parts, your project manager met with a skiing accident, and your secretary enclosed the key files in a parcel that was sent, by mistake, to Japan via sea mail. Your supervisor thinks that you have been so careless on this project that you would lock yourself out of your own car.



As you are driving through the pleasant countryside on this chilly late fall afternoon, you realize that you will be an hour early. You spot a rather secluded roadside park about 200 m away. A quiet stream bubbles through the park, containing trees in all their autumn colors. Such an ideal place to just get out and relax. You pull off into the park, absentmindedly get out and lock the car, and stroll by the stream. When you return, you find the keys are locked in the car. The road to the airport is not the usual route; there are cars about every 10 to 15 minutes. The airport is 9 km away; the nearest house (with a telephone) is 1 km away. The plane is due to arrive in 20 minutes. Your car, which is not a convertible, is such that you cannot get under the hood or into the trunk from the outside. All the windows are up and secured. Apply the Duncker Diagram and one other problem-solving technique to help decide what to do. (D.R. Woods, McMaster University)

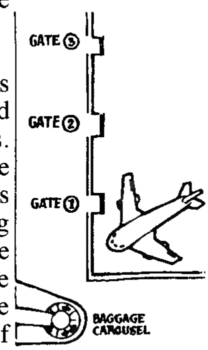


5. You are driving from Cambridge to London on the M11 motorway (expressway). You are scheduled to give a very important slide presentation at 1 PM. The drive normally takes 1 hr and 30 minutes but this morning you left at 10:30 AM to insure you had sufficient time. Suddenly your car stalls on the motorway halfway between Cambridge and London. What do you do? Apply two or more problem definition techniques to help answer this problem. (From J. Higgins and S. Richardson, Imperial College, London)

6. A propellant used in an air bag system is the chemical sodium azide. It is mixed with an oxidizing agent and pressed into pellets which are hermetically sealed into a steel or aluminum can. Upon impact, ignition of the pelletized sodium azide generates nitrogen gas that inflates the air bag. Unfortunately, if it contacts acids or heavy metal (e.g., lead, copper, mercury and their alloys), it forms toxic and sensitive explosives. Consequently, at the end of an automobile's life, a serious problem surfaces when an automobile with an undetonated airbag is sent to the junk yard for compacting and shredding, whereby it could contact heavy metals. The potential for an explosion during processing represents a serious danger for those operating the scrap recycling plant. Apply two or three problem definition techniques to this situation. (*Chemtech,* 23, p. 54, 1993)

7. Pillsbury, a leader in the manufacture of high-quality baking products, had its origins in the manufacture of flour for the baking industry. However, at the time Charles Pillsbury purchased his first mill in Minneapolis, the wheat from Minnesota was considered to be substandard when compared to the wheat used in the St. Louis mills, then the hub of the milling industry. Part of the problem was that winter wheat, commonly used in high-grade flour, could not be grown in Minnesota because of the long and cold winters. Consequently, the Minnesota mills were forced to use spring wheat which had a harder shell. At the time, the most commonly used milling machines used a "low grinding" process to separate the wheat from the chaff. The low grinding process refers to using stone wheels. A stone wheel rests directly on the bottom wheel, with the wheat to be

ground placed between them. With harder wheats, a large amount of heat was generated, discoloring and degrading the product quality. Thus, the flour produced from the Minnesota mills was discolored, inferior, and had less nutritional value and a shorter shelf life. The directions given could have been "Order more river barges to ship winter wheat up the Mississippi from St. Louis to Minneapolis." Apply two or more problem definition techniques to the situation. (Adapted from "When in Rome" by Jane Ammeson, *Northwestern Airlines World Traveler*, 25, No. 3, p. 20, 1993.)



8. *Late Baggage*. An airline at the Houston Airport tried to please the passengers by always docking the plane at a gate within a one to two minute walk to the airport entrance and baggage claim and by having all the bags at baggage claim within eight to ten minutes. However, many complaints were received by the airline about the time it took to get the bags to the claim area. The airline researched the situation and found that there was virtually no way they could unload the bags to the transport trucks, drive to the unloading zone, and unload the bags any faster. However, the airline didn't change the baggage unloading procedure, but did change another component of the arrival process and the complaints disappeared. The airline did not use mirrors to solve the problem as was the case for the slow elevators. (a) What was the real problem? (b) Suggest a number of things that you think the airline might have done to eliminate the complaints. Apply two or more problem-solving techniques. (*The Washington Post,* p. A3, Dec. 14, 1992)

9. In 1991, 64% of all commercial radio stations in the country lost money. In order for a radio station to remain solvent it must have significant revenue from advertisers. Advertisers, in turn, target the market they consider desirable (i.e., income, spending, interest), and for the past several years this target has been the age group from 25 to 54. Along with the revenue loss, the number of radio stations playing the *Top 40* songs (i.e., the 40 most popular songs of that week) has decreased by a factor of 2 in the past three years, as did the audience for the *Top 40* songs. Many stations tried playing a blend of current hits with hits of 10 and 20 years ago; however, this blend irritated the younger listeners and also did not seem to solve the economic problem. Apply two or more problem definition techniques to this situation. (Adapted from *The International Herald Tribune*, p. 7, March 24, 1993.)

10. ***The situation:*** Sara is a freshman away at college preparing for her first final exams. She is homesick, stressed out, and would like to go home for the weekend to visit her parents, but her car is not working.

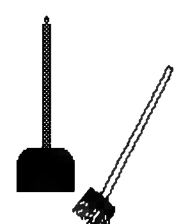
Present State	**Desired State**
Sara's car is not working.	At home with her parents.

Discussion: These states do not match and this mismatch confuses the problem. Which problem should she be attacking? The malfunctioning car? The visit?

First Revision.

Present State	**Desired State**

Continue in this manner until the states match.



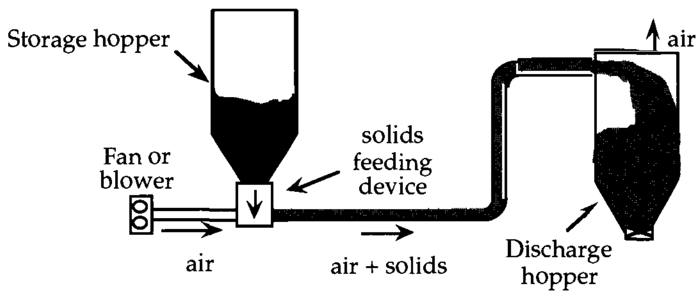
Cleaning up the Problem Statement

11. ***The situation:*** FireKing is a small manufacturer of rich looking fireproof filing cabinets and wanted to increase its market share of 3%. While the designs were elegant, the cabinets were also the heaviest ones on the market and in people's minds, this meant the highest quality. However, higher weight meant higher shipping and transportation costs which made them very expensive. FireKing asked the following question, "How can we make our product lighter so as to have a competitive price?" However, some executives

believed a lighter product might hurt the image of quality. Apply one or more problem definition techniques to this situation. (David Turczyn)

12. ***The situation:*** A new method for killing roaches was developed by Bug-B-Gone Company which was more effective than any of the other leading products. In fact, no spraying was necessary because the active ingredient was in a container that is placed on the floor or in corners and the roach problem would disappear. This method has the advantage that product does all the work. The user does not need to search out and spray the live roaches. The product was test marketed to housewives in some southern states. Everyone who saw the effectiveness test results agreed the new product was superior in killing roaches. However despite a massive ad campaign, the standard roach sprays were still far outselling the new product. Apply one or more problem definition techniques to this situation. (David Turczyn)

13. ***The situation:*** A pneumatic conveyor is a device that transports powdered solids using air in the same manner that money is transported from your car at a bank's drive-through window. In the figure below, the solids are "sucked" out of the storage hopper and conveyed by air into the discharge hopper.
The instructions given to solve the perceived problem: *"Find an easier way to clean a pneumatic conveying system when it plugs and interrupts operation."*



First Revision.

Present State

Conveying system plugs, interrupting operation.

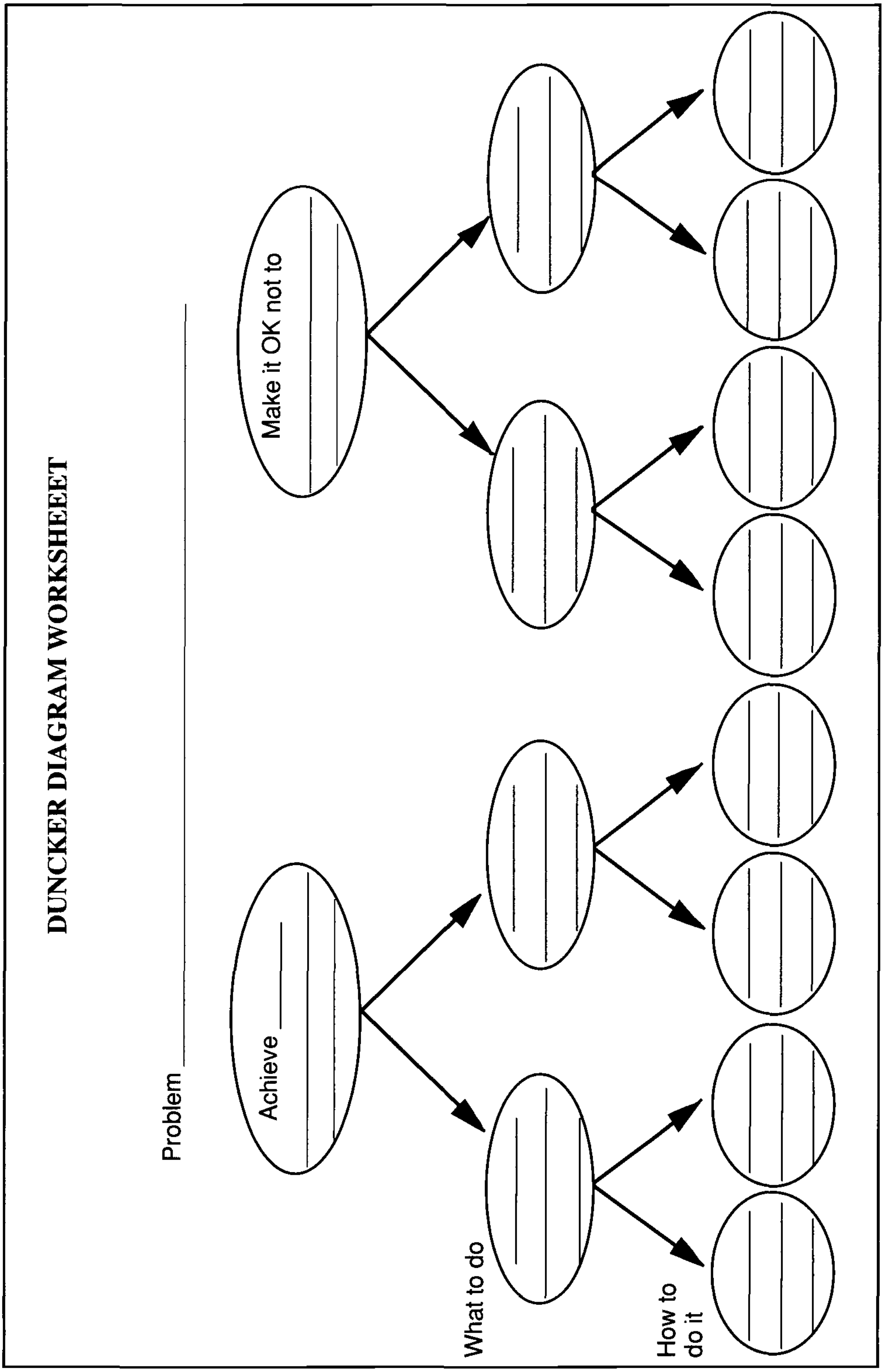
Desired State

The system is easily and rapidly cleaned.

Continue in this manner until the states match.

14. ***The situation:*** A major American soap company carried out a massive advertising campaign to expand its market into Poland. The T.V. commercials featured a beautiful woman using the company's soap during her morning shower. Thousands of sample cakes were distributed door to door throughout the country. Despite these massive promotional efforts, the campaign was entirely unsuccessful. Polish television had been used primarily for communist party politics, and commericals were relatively rare. What is aired is usually party line politics. Apply one or more problem definition techniques to this situation. (Christina Nusbaum)

15. ***The situation:*** Employees are allowed to take merchandise out of the department store on approval. The original procedure required the employee to write an approval slip stating the merchandise taken. However, some employees were abusing the system by taking the clothing and destroying the slip, thereby leaving no record of the removed merchandise. Apply one or more problem definition techniques to this situation. (Maggie Michael)


DUNCKER DIAGRAM WORKSHEET
Problem
Achieve
Make it OK not to
What to do
How to do it