Developing Trouble Shooting Skill [206]

Donald R. Woods
McMaster University
Hamilton ON Canada
Nov 1990, revised 1991

Engineers face a wide variety of problems to be solved each day. A trouble shooting (TS) problem is one where something occurs that is unexpected and out-of-the-ordinary, to such an extent that it is perceived that some immediate corrective action may be needed. The action may be:

- -to flee,
- -to forget the situation; it will eventually correct itself,
- -to initiate emergency shut-down procedures,
- -to put the situation into "hold" as you methodically diagnose the fault, identify the cause, decide on corrective action and ensure that everything is done to try to prevent a reoccurrence.

Case 1: "The pipe on the exit line from our ammonia storage tank burst between the vessel and the valve. An uncontrolled jet of -33ºC ammonia is streaming out onto the ground. What do you do?"

Case 2: "During the startup of the ammonia synthesis reactors, the inlet and outlet valves to the startup heater were opened. The pressure in the synthesis loop was equalized. The valves to the high pressure stage of the synthesis gas compressor were opened and the firing on the start-up heater was increased. However, we experienced difficulty getting the fuel gas pressure greater than 75 kPa; indeed a rumbling noise is heard if we try to increase the pressure. The process gas temperature was only 65 ºC. What do you do?"

34.1 Characteristics of a Trouble Shooting Situation

For trouble shooting situations,

a. we have some stated or beginning evidence that may suggest a stated problem. eg. that the fuel gas pressure is too low.

the stated or beginning evidence may not adequately describe the real cause of the problem or the real problem- eg in Case 2: the suction pressure of the synthesis gas compressor was lower than normal, the alarms on the cold bypass "low flow" meter has been disarmed and the "real" problem was that there was insufficient process gas flow through the heater.

b. we have severe constraints: time and existing facilities. The process may yield hazardous conditions unless the trouble is corrected quickly. Thus, if we are not astute, the trouble shooting problem becomes a safety problem. For other problems, we lose money for every minute that the process is malfunctioning. Thus, time puts a great strain on us. Next, the process is fabricated in a given way. The valves, lines and instruments are in fixed locations. We may want to measure or sample but no easy way is available. Because of the constraints we may choose an interim and a long term solution.

c. usually we have never encountered this problem before. It is a real mental workout. We cannot just apply what we did last time. Experience helps, but we have to synthesize the past experience to yield a new, unique solution.

d. sometimes the problems are "people problems". The alarm may have been turned off, the orifice plate may have been put in backwards, someone may have left his lunch in the line during the construction.

34.2 Some Possible Tactics or Strategies to Use

For general TS problems --where life and emergency shutdown is inappropriate-- we have two different tactics we can use:

Focus on the changes that have occurred in the past and isolate the one that seems to have triggered a fault OR/AND

create hypotheses based on fundamentals and systematically check these out. (For a startup situation, only the latter tactic seems to be useful.)

For the change-type, the plant used to operate OK. Now, because of some change, the process no longer operates satisfactorily. If we can find out what changed, then we can correct it. A strategy we might use for this type of problem is the Kepner-Tregoe strategy (Kepner Tregoe (1956)(1981)).

On the other hand, perhaps no noticeable, observable change occurred. No one ordered the raw materials from a new supplier. No one repaired a pump. No one changed the temperature setting on the heater. Instead, inside the equipment a hunk of corroded metal fell into the liquid; or a truss weakened and gave way inside the vessel. The catalyst bed collapsed. We cannot easily identify the change because there is nothing to "see" from the outside. Instead, we rely on creating hypotheses. Thus, two different but complementary tactics can be used. These are compared in Table 34-1.

The Medical Practitioner model: Another pertinent approach is to model our medical colleagues. They try to diagnose the fault following a four stage process:

1. History: gather information about the history of the situation, what is the complaint, when

did it occur, historical "family" evidence. Analogously, ask operators, maintenance personnel and engineers about background.

2. Perform a usual battery of simple monitoring tests (check weight, height, blood pressure, heart beat, lungs, reflexes) or analogously check pressures, temperatures, flowrates piping layout and configuration for the easy to read, and available instrumentation, and put the instrumentation on manual. Do pressure profiles, heat and mass balances.

3. Sample and order special tests related to a hypothesis or group of hypotheses (ECG, blood work, X-rays) or analogously liquid samples, insert other gauges, calibrate.

4. Bring in consultants, do a detailed simulation, bring in consultants.

Usually, in applying any tactic we will apply it three times. Once to identify the fault. Twice to select a corrective action and third, to take action to try to prevent this from happening again.

34.3 Preparing to Improve Your Trouble Shooting Skill

Six components are useful in developing your skill: becoming comfortable talking aloud about your thought processes, identifying a strategy and monitoring the stages you use, doing a pretest of your awareness and skills, identifying on your preferred style of making decisions, reflecting on interpersonal and the human dimensions of trouble shooting and recalling "experience" knowledge about the equipment and processes.

34.3-1 Becoming Comfortable Talking Aloud and Using an Organized Strategy

Our first activity is to develop our confidence that we can talk aloud about the processes we use to solve problems. This was developed through MPS Unit **1**. We should use an organized approach or a strategy. Such a strategy will help us to monitor our thinking and activities. MPS Unit **4** considered this skill.

34.3-2 Pretest

It is very difficult to realize how much we change in our thinking, our problem solving ability and research skills from the workshop activities that you are going to do. To help you develop your confidence and be proud of the progress you make, before you do the workshop activities, please estimate your awareness and skill with the topic "trouble shooting" now .

Activity 34-1:

Awareness: "When I trouble shoot, I am very aware of the mental processes I use, the steps I follow and can describe these extremely well, completely and coherently to another."

How well does this describe you?

Yes, this describes me.	A little	No, this does not describe me.

1 2 3 4 5 6 7

Knowledge: We also know that a crucial component to successful trouble shooting is that the trouble shooter has a rich set of knowledge and experience about the subject. In this workshop, the subject is chemical process equipment: more specifically it is centrifugal pumps, shell & tube heat exchangers, steam traps, control systems and distillation columns. Rate your fundamental and experience knowledge as it relates to these.

None	A little	Extensive

1 2 3 4 5 6 7

Skill: Now, think about this next statement. How well does it describe you?

"I am very skilled at trouble shooting (and especially at trouble shooting this type of equipment)".

How well does this describe You?

Yes, this describes me.	A little	No, this does not describe me.

1 2 3 4 5 6 7

****

34.3-3 Personal Preference

Each of us has a preferred style of making decisions. Some prefer to be active, to make choices even though they might be wrong. Others, want to gather data and really understand the situation before action is taken. The **P-J** dimension of the Jungian typology, or Myers Briggs Type Indicator (MBTI) may provide you with insight as to your preferences. Complete and score Fig 34-1.

34.3-4 People and the Environment

In any problem, people are involved. You as trouble-shooter are the major person we might focus on. Yet there are others: the operators, the maintenance team, other team members, the designers, your supervisors and your colleagues. Some of the human characteristics that are important include pride and willingness to risk admitting a mistake, stress and distress, the environment and interpersonal skills in listening and responding.

a) Pride and Willingness to Admit Errors

Each person has his/her own pride and self esteem to keep intact. We do not want to admit:

-that we are wrong;
-that we made a mistake;
-that we are guilty of wrong doing.

People want to behave so that they "look good" in the eyes of those who matter... their spouse, their colleagues, their supervisors, themselves.

Our personal willingness to risk affects our willingness to admit errors. More about risk is given in MPS Unit **57.**

The environment also affects our willingness. If making a mistake is considered the worst possible thing to do; then no one will admit to making a mistake. If mistakes are accepted, understood and no serious repercussions occur, then people will be more ready to admit their mistakes.

b) Distress and Stress

Personally we encounter stress as a cumulation of events from home, work and play. Fig 34-2 illustrates the type of stress from this source that members of a startup team for a new process had experienced.

Activity 34-2:

Use the stress inventory form given in Table 34-2 to estimate the stress that you have experienced over the last year.

The amount of stress one has experienced affects our performance. Fig 34-3 suggests that if there is not much stress or there is too much stress in our life, we are prone to make mistakes. The numerical values have not been included in this graph because these vary from person to person. For more on stress and stress management see MPS Unit **5**.

The individual experiences stress from a variety of sources. The work environment also provides daily stress: through the amount and type of interruptions, the noise and cleanliness of the environment and the complexity of the tasks being done.

c) Listening and Responding

Effective communication is vital for trouble shooting. We need to actively listen, to ask key questions, to develop trust so that the other person will "level" with us. We do this through body language, through developing skills at tracking and following and learning how to respond to difficult behaviours.

Consider first the "What" of the message. Most messages have facts, opinions and opinionated facts. One of the greatest challenges in trouble shooting is to discover the facts. Often people will focus on what they think is wrong or what action they think should be done... instead of giving the facts. Some examples to illustrate facts about people and facts about facts are illustrated in Table 34-3.

Activity 34-3:

Distinguish between facts, opinions and opinionated facts in the scenario described in Table 34-4. Then, consider the statements given in Table 34-5 about the situation in Table 34-4. Which of the statements in Table 34-5 are facts?
Summarize what you discovered in Table 34-6 (Worksheet 3400)

Activity 34-4:

For the trouble shooting situation in Table 34-7, verbally describe to a listener just the facts. Then change roles and repeat for a new scenario. Summarize your findings in Table 34-6.

What is the importance of "facts about people". Examples are illustrated in Table 34-3 where we have direct quotes; for example, John said "....". Are we not just interested in the facts about the process? This is an interesting question. In trouble shooting, we are usually looking at the data about the **process** but we must gather some of that information from people. We need to know "who says what" and "what precisely did they say". We need this so that we do not appear to misquote our colleagues. If our colleagues get vexed with us because they think we misrepresented them, they will be reluctant to help us again. Consider the following example.

> The operator, Charlie, tells you "we may have potential trouble on the centrifugal compressor because I have detected some slight vibration". Phil thanks Charlie. Upon reaching the

operations room Phil said that Charlie thinks the compressor has a lot of vibration. [Note that Phil does not use a direct quote and that Phil has altered what Charlie actually said.] Dick, upon hearing this, immediately starts to shut down and isolate that section of the plant.

Charlie is surprised by Dick's action and asks Dick "Why did you shut down the plant?" Dick reacts by saying "You should know! You are the one who said there was a lot of vibration on the compressor." Charlie says "I didn't say that".

Thus, it is crucial that we identify the facts about people and the facts about the process.

We may be able to give the facts. However, some of us communicate an attitude that "I know better." This pattern of "know it all" tends to occur if we prefer a "collaborative" or a "forcing" way of responding to conflict as illustrated in Fig 34-4.

Activity 34-5:

Use the questionnaire in Table 34-8 to **suggest** your preferred style of responding to conflict. How we respond depends on the situation. However, this might help us to see any preferred styles. Add the numerical values to the different sections of Fig 34-4. The "know-it-all" tends to be an extension of the "collaborative" style.

How might this apply to trouble shooting? Sometimes, people deliberately fail to follow someone else's instructions because "they know better". A designer selects his/her own design procedure instead of the company's standards because "I did a thesis on this topic."

A Plant operator opens the bypass valve on the steam trap or overrides a control system because "those silly systems don't work! I know best."

In these examples, the person "knows it all". Our task is to ensure that we understand the person's opinion. However, skill in dealing with difficult behaviour can be developed as illustrated in MPS Unit **46.**

d) Feedback about the Environment

The Environment can have a dramatic affect on our ability to trouble shoot.

Activity 34-6:

Use Table 34-9 as a trigger to think about your particular environment and the potential impact it might have on your effectiveness. Summarize your ideas in Table 34-6, Worksheet 3400.

e) Types of Errors Made and the Probability of Occurrence.

What types of mistakes are made? Table 34-10 summarizes some of these that affect process design and operations. In general, these are in sensing, interpreting, and action taken.

Powers and Lapp (1983) and Kletz (1986) summarize efforts to quantify the probability of different types of operator error to occur. For tasks involving sensing-interpreting-acting,

if the person is well trained, and motivated and with no stress then,

> -he/she will make about **1** error in **1000** trials if feedback is given to the person after they have made the action;
>
> -he/she will make about **1** error in **100** trials when there is no feedback to the person for the action taken.

if the person is under distress- not because of high stress levels cumulating throughout the year-- but because of the situation, then

> -he/she will make about **1** error in **10** trials . This might happen in a busy operating center where other alarms are sounding, the telephone is ringing and people are asking for information about a part of the process.
>
> -he/she will make about **1** error in **2** trials if, for example, many complex actions are needed and the implications of making an error are frightening.

The distress comes from poor training, confusion because of poor training, conflicting data; from the need for fast action; or from a large penalty if a mistake is made, or from extensive confusing and contradictory types of demands.

Activity 34-7:

Consider ten of the cases in Kletz's text "What went Wrong?". From his description of the case, classify the cause as to equipment malfunction, human design mistake, human maintenance mistake, human operator mistake or other.

If an operator makes a mistake, the type of mistake is likely to be:

90 %	**no action** taken (when some kind of action was needed),
5 %	took corrective action but moved the correct and appropriate variable in the **wrong direction**. Thus, he/she knew that the temperature should be changed but increased it instead of decreased it.
5%	took corrective action on the **wrong variable**. Thus, he/she should have changed the

temperature but, instead, changed the composition to the reactor.

Table 34-11 lists the probability of error for a mixture of operator, maintenance and design activities.

f) Summary

Whether the task is trouble shooting, startup or safety analysis;
whether the people involved are you or others or both;
whether the task is sensing, interpreting or doing something--the human component is a crucial part of the task.

34.3-5 General Knowledge and Experience about Process Equipment.

Gans et al (1983) suggests that big failures usually have simple causes, such as a compressor that will not start. On the other hand, small failures (or deviations from the norm) often are caused by complex causes, such as the product does not quite meet specifications because of a buildup of contaminants.

The general most likely causes for failure differ depending upon whether this is the

startup of a new process or

startup after a shutdown and maintenance or

fault that develops for an on-going, operating process.

a) Common Faults for First Time Startup.

The faults encountered are:

75%	Mechanical/electrical failures	leaks, broken agitators, plugged lines, frozen lines, air leaks in seals.
20%	Faulty design or poor fabrication	unexpected corrosion, overloaded motors, excessive pressure drop in heat exchangers, flooded towers.
5%	Faulty/inadequate initial data	often chosen to be the scapegoat by inexperienced trouble shooters.

b) Startup after Maintenance

Ask questions about what specifically was changed, repaired, modified.

c) Trouble for On-going Processes

For ambient temperature operations, about **80%** of the problems experienced are fluid dynamical.

For high temperature operations, about **70%** of the problems experienced are materials failure.

34.3-6 Specific Experience Knowledge about Process Equipment

Before we zero in on giving you feedback about your trouble shooting skills we should reflect on our experience knowledge that relates symptoms, causes, probabilities, fundamentals and remediation for different process equipment. Here we consider pumps, shell and tube heat exchangers, process control, steam traps and distillation columns.

a) Centrifugal Pumps

The fundamental principles are that the performance of pumps can be described by a performance curve showing the output pressure as a function of the output flowrate. If the pressure is expressed as "head" of liquid, then the same curve describes the performance regardless of the liquid being pumped. Although the head curve is independent of liquid density, the power requirement is not and depends on the density. Pumps operate along their head capacity curve. The performance is dependent upon the system providing enough Net Positive Suction Head so that the liquid does not boil inside the pump. The pump is selected so that the head-capacity match the system requirements at the "design conditions".

Table 34-12 lists common faults for pumping systems and asks that, for each fault, you reflect on what would be observed, smelt, or heard for each fault. In other words, summarize the "cause-effect" relationships for centrifugal pumps.

Table 34-13 summarizes and prioritizes some of these.

b) Valves, Controllers and Instruments

A control loop or system usually consists of a measuring element, a controller and a control element. Typical measuring elements include:

-thermometers, thermocouples or pyrometers;
-a pressure gauge or transducer,
-a flowmeter such as an orifice plate, venturi, rotameter or mass flowmeter.
-a level indicator,
-pH, surface tension or density measurement,
-strain gauge,
chemical analyzer.

Typical control elements include:

-a valve that controls flowrate,
-electrical power to a heater or a motor.

Controllers vary by type and signal (electrical signals or air/pneumatic signals). Furthermore, such components as valve positioners may be included to ensure that large valve stems move to the expected position.

Signals are transmitted from the measuring element to the controller and thence to the control element.

Some possible cause effect relationships are summarized in Table 34-14.

Steam traps are self contained control systems to remove condensate and perhaps air from the system. When we want steam to condense, we normally would put it into a closed tube. If we just sent steam through an open tube, although some of the steam might condense, some would pass through the tube uncondensed. This is inefficient. However, when the steam condenses, the resulting condensate builds up and floods the tube so that the steam no longer can condense directly on the tube wall. We want to prevent the buildup of condensate. One option would be to put in a level controller near the end of the tube and use the signal from the level to actuate a valve. This is illustrated in Fig 34-5.

However, it is easier to develop a steam trap as a self-contained control system. Three basic designs of steam traps are:

1. mechanical design that exploits the difference in density between steam and condensate.

2. thermodynamic design that exploits the kinetic energy difference and the Bernoulli principle.

3. thermostatic design that exploits the subtle temperature difference between slightly cooled condensate and uncondensed steam.

Some traps are designed to remove air from the system.

Sketches of the different devices are given in Fig 34-6. Table 34-15 lists the characteristics of the different types of traps while Table 34-16 summarizes potential causes of trouble from steam traps.

<u>Strategies and Actions:</u>

Some general suggestions are

1. Check the controller settings: are all the set points correct? if the product is off-specifications because of cycling, switch the controller to **manual** setting . The cycling should stop.

2. Check for false signals. Is the instrument reading correctly? Use a consistency check.

3. Check for a fault in the control loop.

For a control valve:

1. Check that a signal is getting to the valve. For a pneumatic system, check that the air pressure to the valve diaphragm equals the output pressure at the controller.

2. Check that all block valves around the control valve are open and that the valve on the bypass is closed.

3. Check that the position of the valve stem corresponds with the signal. (Note whether the valve is valve to close or valve to open.)

4. If there seems to be no flow, open the bypass valve to see what happens.

5. Check the pressure gauges on the valve positioner. The positioner should have three gauges. Normally the supply pressure would be 140 kPa gauge (20 psig) unless a 2:1 ratio is employed on the positioner; then the supply pressure would be 240 kPa (35 psig). The input gauge or control air signal should be equal to the output air (or valve) gauge or else half that pressure if a 2:1 ratio is used. If not, the fault might be a sticky valve or a faulty positioner.

6. If the valve is pumping rapidly up and down, the trouble may be from a faulty positioner.

For flow measuring devices, ensure that flashing and vaporization of liquid is not occurring in the instrument.

<u>c) Shell and Tube Heat Exchangers</u>

Sketches of some of the configurations are given in Fig 34-7. Table 34-17 lists some of the cause of faults.

<u>Strategies and Actions.</u>

Some suggestions about furnaces and refrigeration units are given in Table 34-18.

d) Distillation Columns

Fig 34-8 illustrates a column configuration. Table 34-19 lists common causes. Of the causes, the more frequently encountered causes are:

Mechanical mistakes:

-leaky and misplaced baffles in condenser bonnets, decanters or column sumps.

-vibration of trays at critical vapour velocities or of condenser tubing; these lead to tray and tube failure.

-plates not held down properly.

-inadequate support bearing area.

-plates not level,

-unable to drain trays during shutdown,

-incorrect downcomer clearance.

inadequate allowance for thermal expansion.

Hydraulics:

-incorrectly installed liquid distributor plates,
-insufficient NPSH,
vortexing in the suction lines,
-siphoning in the down pipes,
-inadequate venting of inerts from condensers and reboilers,
-plugging of startup screens,
-overheating and flashing in the pumps because of excessive throttling from downstream control valves,
-inadequate pressure equalization causing surging,
-gas pockets in liquid lines,
-plate downcomers not sealed.

Mistakes in Installation:

-reflux drum outlet plugged with insulation used during fabrication to keep the spatter from welding from going into the drum,
-stuff left in lines.

Strategies and Actions:

Drew (1983) outlines, in Table 34-20, some suggestions about how to handle these problems.

34.4 Characteristics of Successful Trouble Shooters

Extensive research has been done on successful and unsuccessful problem solvers. First, the In the context of diagnostic or trouble shooting situations, these are summarized in Table 34-21. These relate to:

> how well we monitor and check the mental process we use, how systematically we tackle the problem and how we process and interpret the data.
>
> Do we identify subproblems and yet keep the situation in perspective? Are fundamentals used? Is the reasoning accurate and complete? Are numerous hypotheses generated and do the ideas show flexibility? Is there bias in the decision-making? Are priorities identified?

These characteristics and attributes form the basis for a checklist feedback form that will be used in this workshop. This is summarized in Table 34-22.

34.5 Activities to Develop Skill

Table 34-22 can be used to provide feedback about performance as a trouble shooter. One way to use the form is to form triads as illustrated in Fig 34-9. One person plays the role of the trouble shooter. One is the "expert system" that responds with written data only about how the system responds to the tests requested by the trouble shooter. The observer uses the form in Table 34-22 to provide feedback to the trouble shooter. Here are the details about each role.

34.5-1 Observer for Trouble Shooting.

As the Trouble Shooter is tackling the problem, your task is to assess how well the problem solving components are handled. This is challenging because the skills are difficult to identify-- let alone observe and assess. The evaluation sheet is made to help you look at the mental process used by the trouble shooter. Try to focus more on the "types of questions asked", and " how can I create a hypothesis and test it?" and not on "what information do I need?" or on "what action should I take?". Look at the organizational pattern used; listen for the monitoring of the process.
Consider, "does he/she confuse activities unknowingly?"

Let the Expert System focus on "how well the trouble shooter wrote out the questions and tasks to be done".

34.5-2 the Expert System:

Before class, read over the background. Understand the process extremely well. Think about how "the fault" will affect all of the process variables. Try to anticipate the kinds of questions that the Trouble Shooter might ask; or experiments that he/she might ask to be performed. What would the fault do to the system under those conditions? Give results of experiments. Do not give explanations. Give correct information but do not be generous. If, for example, the fault occurs periodically, and you are asked to give the lab analysis for one sample taken: assume Murphy's law applies and give them the

result when the system was operating normally.
Insist that they write out all requests; write down the results opposite. Do **not** talk..... just acknowledge that they are working on it by saying "Ahemmm, mmmmm,"

Insist on their instructions, or requests be written precisely.
If they write " Inspect the instrument" then respond "It's OK". If they ask what you did, then say "I went out and looked at it." Be tough. Do not offer more information than they asked for.

<u>34.5-3 the Trouble Shooter.</u>

You have a challenging role to play:

-you are to talk aloud so that the Observer can track what you are doing. Think about the process you will be using: are you searching for change or for hypotheses; whether you are clarifying the situation or testing an idea. You may feel frustrated because the Expert System is going to supply <u>written</u> responses to your requests; the Expert System will not discuss things with you. He/she may say "Hmmm" or "mmmmmm" to you occasionally so that you do not feel too much like talking to a wall but basically the Expert System is there to provide instant system <u>written</u> response to your requests.

-you are to display all the good problem solving skills we have developed. Do this by verbally monitoring your progress, being active with pencil and paper to keep track of the route you are following,

-you are to write out your requests for information from the Expert System. These should be written out precisely. A sample form is given in Table 34-23.

<u>34.6 Summary</u>

Different strategies were given on how to solve trouble shooting problems. Some of the challenges of obtaining and interpreting the data--or the evidence-- were outlined.

The characteristics of good trouble shooters were given, and a method of providing feedback to you about your trouble shooting approach was described.

<u>34.7 References</u>

Addison, H. (1966) "Centrifugal and Other Rotodynamic Pumps" Chapman- Hall Publishers.

Eckert, J.S. (1979) "Design of Packed Distillation Columns" Section 1.7 in "Handbook of Separation Techniques for Chemical Engineers"., P.A, Schweitzer, ed., McGraw Hill, New York. p 1-221 to 1-240.

Ellerbe, R.W. (1979) "Batch Distillation" Section 1.3 in "Handbook of Separation Techniques for

Chemical Engineers"., P.A, Schweitzer, ed., McGraw Hill, New York. p. 1-164 to 1-167.

Farminer, K.W. (198?) "Defoaming" in Encyclopedia of Chemical Technology and Design", J McKetta, ed, Marcel Dekker, NY

Gans, M. and Fitzgerald, F.A. (1966) "Plant Startup" Chpt 12 in "The Chemical Plant" R. Landau, ed. Reinhold Publishing Co. New York.

Gardner, K.A. (1974) "Anticipation of Operating Problems in the Design of Heat Transfer Equipment" in "Heat Exchangers: Design and Theory Sourcebook" N. Afgan and E.U. Schlunder, ed., Scripta Book Co., McGraw Hill, New York.

Godard, K.E. (1973) "Gas Plant Startup Problems" Hydrocarbon Process. Sept. p 151 to 155.

Griffith, S. and Keister, R.G. (1970) "This Butadiene Unit Exploded" Hydrocarbon Process, **49**, no. 9, p 323

Kister, H.Z. (1979) "When Tower Startup has Problems" Hydrocarbon Process Feb p 89 to 94.

Kletz, T. (1979) "Learn from these HPI fires" Hydrocarbon Processing" Jan p 243 to 250.

Kletz, T.A. (1986) "Hazop & Hazan" 2nd edition, The Institution of Chemical Engineers, London, UK

Kletz, T.A. (1985) "What Went Wrong? Case Histories of Process Plant Disasters" Gulf Publishing Co., Houston, TX.

Lapp, S.A. and Powers, G.J. (1977) "Computer Aided Synthesis of Fault-trees" IEEE Transactions on Reliability, April p 2 to 13.

Lefevre, L.J. (1986) "Ion Exchange: Problems and Troubleshooting" Chem Eng, July 7, p 73 to 75.

Lieberman, N.P. (1983) "Process Design for Reliable Operations" Gulf Publishing Co. Houston, TX.

Lieberman, N.P. (1985) "Trouble Shooting Process Operations" 2nd edition, PennWell Books, Tulsa OK .

McLaren, D.B. and Upchurch, J.C. (1970) "Guide to Trouble-free Distillation" Chem Eng **77**, No 12, June 1, p 139 to 152.

Penny, W.R. (1970) "Guide to Trouble-free Mixers", Chem Eng **77**, No 12, June 1, p 171 to 180.

Powers, G. J. and Lapp, S.A. (1983) "Fault Tree Analysis" Carnegie Mellon University Short Course, Pittsburgh.

Powers, G.J. and Lapp, S.A. (1981) "A Short Course on Risk and Reliability Assessment by Fault tree Analysis" Carnegie Mellon University.

Powers, G.J. and Lapp, S.A. (1976) "Computer-aided Fault Tree Synthesis" Chem Eng Prog April p 89 to 93.

Reason, J. and Mycielska, K. (1982) "Absent Minded? The Psychology of Mental Lapses and Everyday Errors" Prentice Hall, Englewood Cliffs, NJ

Reginald, S. and Gupta, J.P. (1986) "A Note on 1-2 Heat Exchanger Trouble Shooting" Int Comm Heat Mass Transfer, **13**, p 235 to 243.

Riance, X.P. (1983) "Learning- the Hard Way" Chem Eng Oct 3, p115 to 116.

Riance, X.P. (1987) "More Learning -the Hard Way: part 4, Chem Eng Jan 19, p 131 to 133.

Shah, G.C. (1978) "Trouble Shooting Distillation Columns" Chem Eng. July 31 p 70 to 78.

Swartz, A. (198?) "Evaporator Operation: Trouble shooting" in Encyclopedia of Chemical Technology and Design", J McKetta, ed, Marcel Dekker, NY

Talley, D.L. (1976) "Startup of a Sour Gas Plant" Hydrocarbon Process. April p 90 to 92.

Troyan, J.E. (1960) "Trouble Shooting New Processes" Chem Eng. Nov 14, p 223 to 226.

_________ (1961) "Trouble Shooting New Equipment" Chem. Eng. March 20, p 147 to 150.

__________ (1961) "More on Trouble Shooting New Equipment: Pumps, compressors and agitators" Chem. Eng. May 1, p 91 to 94.

Wetherhorn, D. (1970) "Guide to Trouble-free Evaporators" Chem Eng **77**., No. 12, June 1, p 187 to 192.

Table 34-21 PROCESS ISSUES: HOW WE TROUBLE SHOOT

Detracting Behaviours   Enriching Behaviours

MONITORING

No assessment of potential   Asks "What will this get me?"
gain from a question or action

No words like " Am I through?Asks "Am I finished with this Where is this leading me?"task?"
"This should tell me..."

Unclear as to whether asking Clearly states type of question fishing or shooting questions,asking, whether working on whether creating a hypothesis hypotheses or checking for or checking for a change.change or gathering information for clarification.

CHECKING

Assumes everything is OK Checks and double checks Does not check, assumes instruments, diagrams, hardware, instruments OK, assumes procedures.
operating procedures OK, and
equipment as on diagrams.

SYSTEMATIC

Jumps all around, confused,Identifies plan and no apparent plan, does not systematically follows it.
follow through on ideas in
lists, no use of tables or
charts to keep track of idea
flow.

SUBPROBLEMS AND PERSPECTIVE

Keeps whole problem and does Breaks overall task into not identify subproblems,situation clarification, no identification of a hypothesis testing and /or change strategy.identification; into emergency action, cause identification, fault correction and future problem prevention.

Confuses issues, factors,Identifies phases clearly and fault detection, solutions,works through systematically,

Solves a minor fault while keeps situation in perspective, the process explodes,does not get lost in a subproblem.

DATA COLLECTION AND ANALYSIS: WHAT AND HOW TO COLLECT AND INTERPRET EVIDENCE

Detracting Behaviours Enriching Behaviours

DATA RESOLUTION

Gathers data but does not Correctly identifies the know what it tells him/her usefulness of the data collected.

Believes all he/she sees and Explicitly states limitations of hears; unclear of errors in the instruments, measurements and information.systematically checks these.

No data gathered explicitly.Gathers data for problem Jumps in making corrective clarification and hypothesis action without stating testing/or change rather than possible hypothesis or jumping in with corrective action cause.without any data.

Gathers data expensively,Gathers data easily through Takes process apart for simple changes in operating everything. Overlooks simple procedure, puts controllers on ways of gathering info.manual.

Asks for samples, but assumes Is present when samples are that sample locations and taken, bottles labelled.
procedures are as usual.

Imprecise instructions,Gives precise instructions
"Check out the instrument"
"Open up the exchanger"

ACTIONS BASED ON FUNDAMENTALS

Based on intuition.Based on fundamentals.

Estimates behaviour based on fundamentals.

Does mass and energy balances with at least two independent measurements.

Does pressure profiles through units.

REASONING

Jumps to invalid conclusions Draws valid conclusions; tests both positive and negative: what is; what is not; if it does happen; if it does not.

Detracting Behaviours Enriching Behaviours

COMPLETENESS

Uses only part of information.Uses all resources
Doesn't check the design calculations, or data from startup or data from initial, clean fluid.

SYNTHESIS

Cannot put all the ideas Can put the ideas together into together into a reasonable a plausible explanation.
story.

HYPOTHESIS FLUENCY and FLEXIBILITY

Becomes fixed, thinks of only Keeps at least four working one hypothesis or selects one hypotheses; keeps options open at the start and then cannot as data are gathered. become unfixed.

Considers steady state only,Considers unsteady state as well.

Considers all situations as Selects hypothesis or change, being caused by some change; identifies but keeps options open does not create any hypothesis shifts to other view if other than this.warranted.

Makes everything complex.Keeps it simple, especially if it is a "big failure".

One view Maintains many viewpoints.

Critical of ideas.Defers judgement when appropriate.

DECISION MAKING

No priorities; all of equal Sets and uses priorities.
importance.

Biased, stacks the deck so Unbiased in making decisions.
that favourite fault will be
the one even when the
evidence refutes this.

No criteria stated explicitly,Sets criteria.
just decides.

Table 34-22 Observer's Feedback

TS name______________________ Case_____ Initials ES_____ Obs___

Rough work area:

PROCESS: HOW DATA/ ANALYSIS: WHAT

Monitoring_____________________ Data resolution_____________

Checking______________________ Fundamentals?_______________

Systematic_____________________ Reasoning__________________

Subs and perspective____________ Completeness_______________

_______________________________ ___________________________

DECISION MAKING:HOW SYNTHESIS: WHAT

Priorities___________________ Hypotheses____________________

Bias__________________________ Flexibility____________________

____

RATING AND FEEDBACK

Clarity of Communication

None | Some | Most | All

0______0_______0_______0_______0_______0_______0_______0

Process used:

None | Some | Most | All

0______0_______0_______0_______0_______0_______0_______0

Data collections and analysis:

None | Some | Most | All

0______0_______0_______0_______0_______0_______0_______0

Synthesis:

None | Some | Most | All

0______0_______0_______0_______0_______0_______0_______0

Decision-making:

None | Some | Most | All

0______0_______0_______0_______0_______0_______0_______0

Five Strengths: Two areas for improvement

________________________________ ____________________________

________________________________ ____________________________

____

____

____

Table 34-6: Summary of What you Discovered.

Table 34-3: Examples of Facts and Opinions

Example:	**Fact about people**	**Fact about process**
John said "The gauge reads 50 kPa."	Yes	Yes
John said "The pressure is 50 kPa."	Yes	No
John said that the pressure gauge reads 50 kPa.	No	Yes
John said the pressure gauge reading is too high.	No	Opinion via words "too"
John said that the pressure is too high.	No	Opinion
John said" The Pressure gauge reads 50 kPa, the gauge was calibrated yesterday, the sampling line is clear. If I increase the pressure slightly, the gauge reading increases slightly. I infer that the pressure is 50 kPa."	Yes	Yes
John said" The Pressure gauge reads 50 kPa, the gauge was calibrated yesterday, the sampling line is clear. If I increase the pressure slightly, the gauge reading increases slightly. I infer that the pressure is 50 kPa. I conclude that pressure is too high."	Yes	Yes + Opinion

Analyze the following passage and classify it into facts, opinion and opinionated fact

Here is an accurate account of what happened.

"The telephone rang! "Trouble out on the ethylbenzene unit," said Bill. Harry said that he would be right out as he slammed down the phone. As Harry approached the unit Bill came out to meet him and said, "I am sure that the heat transfer coefficient is insufficient in the reboiler to the product column; I'll show you what I mean."

Harry glanced at the rotatmeter and saw that the flow to the column was the usual amount of 30 L/s; the pressure gauge read 1 MPa and the bottoms temperature theremocouple was 140ºC. Rounding the column, he saw the liquid level in the bottoms level gauge rising at a rate of about 15 cm per minute. The liquid level disappeared out the top of the level gauge. After about 2 minutes the level reappeared in the level gauge and after minutes disappeared out the bottom of the sight gauge. "See," said the operator, "we have lost all the bottoms out of the column just like that!" "It's gone off to the storage tank," offered John. "No, it has gone through the reboiler and straight up the column. You can see that by the instabilities in the pressure gauges that occur just after the level disappears out the bottom of the level gauge," said Bill."

****

Based on the account, which of the following statements are True? False? or can't tell ?

1. Bill said that there was trouble out on the ethylbenzene unit.
2. Harry said, "I'll be out immediately."
3. The heat transfer is insufficient.
4. The trouble is in the reboiler.
5. The flow to the column is 30 L/s
6. The pressure was 1 MPa.
7. The bottoms temperature was 140 ºC
8. The level in the bottom of the column is building up and then suddenly dropping.
9. John said, " The bottoms have gone off to the storage tank."
10. When the level in the bottoms of the column drops the pressure gauges show instabilities.

Table 34-9 Feedback about your Environment

To what extent do you agree with the following descriptors of your environment where you usually "trouble shoot".

People are Willing to admit error: "The people that I work with are very unwilling to admit errors; they blame others, they pass the buck and, if necessary, would purposely mislead me rather than to admit error."

Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately Agree	Strongly Agree
1	2	3	4	5	6

Encourage risk taking: "Risking is rewarded. We are expected to take about 10 times a day. Risks should be wisely, not indiscriminately selected. But, nevertheless, we are not only encouraged but we are rewarded for risk taking."

Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately Agree	Strongly Agree
1	2	3	4	5	6

General Stress at work they are under: "The environment is very stressful. People have many deadlines and interruptions. The consequences of making mistakes is very high. The issues are complex. The environment changes and includes a lot of uncertainty."

Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately Agree	Strongly Agree
1	2	3	4	5	6

General Stress at work you are under: "The environment is not stressful. I do not have many deadlines or interruptions. The consequences of making mistakes is low. The issues are straight-forward. The environment is safe, stable and secure."

Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately Agree	Strongly Agree
1	2	3	4	5	6

People's Listening & Responding: "The people are open, communicate well, can clearly identify facts, will offer opinion when asked for, and are very competent but are not aggressive "know-it-alls".

Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately Agree	Strongly Agree
1	2	3	4	5	6
