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Kolmetz Handbook Of Process Equipment Design

TROUBLESHOOTING OF PROCESS EQUIPMENT AND SYSTEMS

(ENGINEERING DESIGN GUIDELINES)

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INTRODUCTION

Scope

Process Equipment Malfunctions offers the chance to develop proven techniques for finding and fixing process plant problems and contains details on failure identification. One of the most important traits that process operators, maintenance personnel, and engineers can have is the ability to diagnose equipment and process upsets and respond accordingly quickly and accurately.

Troubleshooting is a step-by-step procedure whose purpose is to identify a problem quickly and easily in a system or process. Troubleshooting is an art, but a good portion is a learned skill, which is enhanced by experience and operator capability. A good operator will work at developing troubleshooting skills and abilities. A good troubleshooter is worth his or her weight in gold to a company.

While operational troubleshooting and equipment troubleshooting share some similar thought processes, one of the major differences between troubleshooting failed equipment and process operational troubleshooting is the time frame. The first challenge is to come up with an actionable time frame for solving the problem with the information available to the operator.

A failed pump or pump skid can be an expensive and inconvenient event. When systems or pumps go down, time is often of the essence. It’s tempting to hastily replace parts and push buttons with the hope that operators get lucky and something will make the equipment work again. However, there’s a better way to troubleshoot.

In troubleshooting process problems and upsets, the operator has a tough job, because modern process plants typically are large, have high throughputs, and process hazardous materials. They have many interconnections and potentially are integrated into larger facility processes. The experience, training, and capability of the operator are key to having a successful troubleshooting experience. The operator must also have a clear situation awareness of the developing problem.

General Design Considerations

A trouble shooting problem is one where something occurs that is unexpected and out-of-the-ordinary. Troubleshooting is not an exact science. It begins with sound process and equipment knowledge, attention to detail, and good listening skills. From there, however, there is no blueprint or flowchart to success. Every problem is different, although specific techniques are applicable to several different types of situations. Experience can play a vital role, but only if used correctly.

The reasons for troubleshooting are

- Something not functioning properly
- Don't know what's wrong
- Equipment down or product out of specifications
- Isolate problems between the equipment and the process

The one universal truth of troubleshooting is that it cannot be done successfully from behind a desk. Even when the solution is arrived at by calculation, the information needed to manipulate the numbers is obtained through field work. Personal communication with operators, direct observation of field and control-system data, and even watching operators pull samples can provide vital information for solving a problem.

The Purpose of Troubleshooting:

- Maintain Safety of Personnel and Plant Equipment
- Identify the problem
- Minimize down time
- Improve plant efficiency
- Improve product quality

Some immediate corrective action may be needed to such an extent that it is perceived. The action may be:

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

Troubleshooting begins with solid engineering fundamentals. Finding the actual problem requires a sound understanding of the process and the specific unit in question. This includes the relevant theoretical background, and details of the process flowrates, instrumentation and control schemes, and the equipment and piping, as well as data from sampling and lab analyses. Know where temperature and pressure indicators and sample points are located.

Certain skills can be helpful in troubleshooting:

- Logical or methodical approach
- Ability to learn from past experiences
- Curiosity
- Patience
- Self-motivated
- Knowledge of information location
- Use of computer-based information
- Drawings
- Spare parts

Troubleshooting Skills Dependent On

- Level of expertise
- Familiarity with instrumentation or equipment
- What test equipment you have & familiarity with it
- Company's philosophy
- Access to information resources
- What parts you have available (for repair)
- What time frame you have

Several components are useful in developing Trouble Shooting Skill:

1. becoming comfortable talking aloud about your thought processes,
2. identifying a strategy and monitoring the stages used,
3. doing a pretest of user awareness and skills,
4. identifying on preferred style of making decisions,
5. reflecting on interpersonal and the human dimensions of trouble shooting and recalling "experience" knowledge about the equipment and processes

Characteristics of a Trouble Shooting Situation

1. Have some stated or beginning evidence that may suggest a stated problem. e.g. that the fuel gas pressure is too low
2. Have severe constraints: time and existing facilities. The process may yield hazardous conditions unless the trouble is corrected quickly. Thus, if not astute, the trouble shooting problem becomes a safety problem. For other problems, you may 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.
3. Usually the operator has never encountered this problem before. It is a real mental workout. Operator cannot just apply what he did last time. Experience helps, but operator must synthesize the past experience to yield a new, unique solution.
4. 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.

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.

How Improve Trouble Shooting Skill? Several components are useful in developing the skill:

1. Becoming comfortable talking aloud about thought processes, develop the confidence that can talk aloud about the processes use to solve problems. Should use an organized approach or a strategy.
2. Identifying a strategy and monitoring the stages you use; such a strategy will help to monitor our thinking and activities.
3. Doing a pretest of awareness and skills, to help develop the confidence and be proud of the progress, before do the workshop activities, please estimate awareness and skill with the topic "trouble shooting" now.
4. Identifying on preferred style of making decisions. 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
5. Reflecting on interpersonal and the human dimensions of trouble shooting. Some of the human characteristics that are important include pride and willingness to risk admitting a mistake,

6. Stress and distress, the amount of stress one has experienced affects our performance. 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
7. The environment and interpersonal skills in listening and responding. Effective communication is vital for trouble shooting

Recalling "experience" knowledge about the equipment and processes. 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

Types of Errors Made and the Probability of Occurrence

1. 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.

2. 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.

3. 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.

There is no substitute for spending time in the field learning about a process unit. Knowing where the key pieces of equipment are located. Follow the piping for major streams. Sometimes, things that do not seem out of the ordinary on paper will stand out in the field.

Use a systems-oriented approach to troubleshooting, rather than a unit-operations focus. This approach begins with the problem symptoms (*e.g.*, high-pressure drop in a column) and evaluates potential causes to determine the root cause. If the focus is too narrow, then there is a risk of a fix that masks the symptom and ignores the problem.

Practice good listening skills. Not only does this allow for efficient information collection, but it also helps you to establish credibility. Never immediately challenge a diagnosis provided by another individual.

Understand the observations that were made that led to the diagnosis. He or she might be right and even if not so, the observations may prove valuable. Never underestimate the importance of the information you can get from operators. They are generally very good at describing the symptoms. Often, their knowledge goes unused because their analysis of the symptom is inaccurate and, therefore, is discarded. Learn how to ask the right questions to get to the description of the symptoms.

Occasionally, troubleshooting just happens and a solution pops up. The right piece of information clicks, and the root cause is apparent. Most of the time, it is not that simple. There is either no readily apparent cause or many to choose from. When this happens, it necessary to troubleshoot by the process of elimination. Develop a hypothesis of a possible cause based on the available data. Then design an experiment to eliminate or confirm that hypothesis. Conduct the experiment and evaluate the results. If the experiment disproves the hypothesis, then eliminate it and move on. Don’t get hung up on a preferred theory. If the data show that a hypothesis is not correct, come up with a new one. This may be difficult because of one’s emotional ties to the idea. However, chasing a theory after the data reject it wastes valuable time.

Whatever troubleshooting method is used, a logical approach should be taken to identify and repair a problem

i. Verify that something is wrong
- Ask the operator
- Observe for yourself
- Is the process being operated under normal conditions and productions rates
- Begin with and test with the assumption that the instrumentation and controls are not the problem
- Familiarize yourself with the loop
- Make sure you understand how the controls are supposed to function when operating properly
- Make sure you understand the associated equipment and how it can influence the operation of the suspect equipment

ii. Identify and locate the problem
- Confirm whether the instrumentation and control or something else is causing the problem
    a. Make the easiest checks first
    b. Can the desired control be achieved with the control loop in manual?
    c. Could the measuring instrument be correct and showing that something has changed in the process?
    d. Isolate the problem to the instrumentation and controls or to something else (process, equipment, etc.)
    e. Inform Production of the steps that you are taking that could cause an upset, alarm, etc.

f. Work to isolate the source of the problem using one of 3 methods
   - History
   - Input/output: Series, Divide and Conquer

- Develop a plan for how to proceed to locate and confirm cause

iii. Fix the problem

- Once you feel the problem has been isolated, develop a plan to repair the problem
- Inform Production of your repair plan
- Repair or recommend the repair of the problem
- Follow production area safety procedures and manufacturer specifications and procedures during repair
- Communicate closely with Production

iv. Verify the problem is fixed

- Confirm that all repaired and associated parts of the system operate correctly, including: Measurements, Control, Alarms, Interlocks
- Confirm that the Operator is satisfied with the performance of the repaired system and understands how it is to operate under all conditions

v. Follow-up to prevent future problems

- Document in history file
- Suggest changes, if needed
- Upgrade PM program
- Submit changes to update all documentation (As built)

Current documentation is as important a troubleshooting tool as any test equipment or other tools

- Process & Instrument Diagrams – P&ID
- Instrument loop diagram
- Instrument maintenance records
- Instrument specifications and manuals
- Electrical – motor control schematics
- Interlock and alarm information
- System drawing
- Operational logs/procedures and data

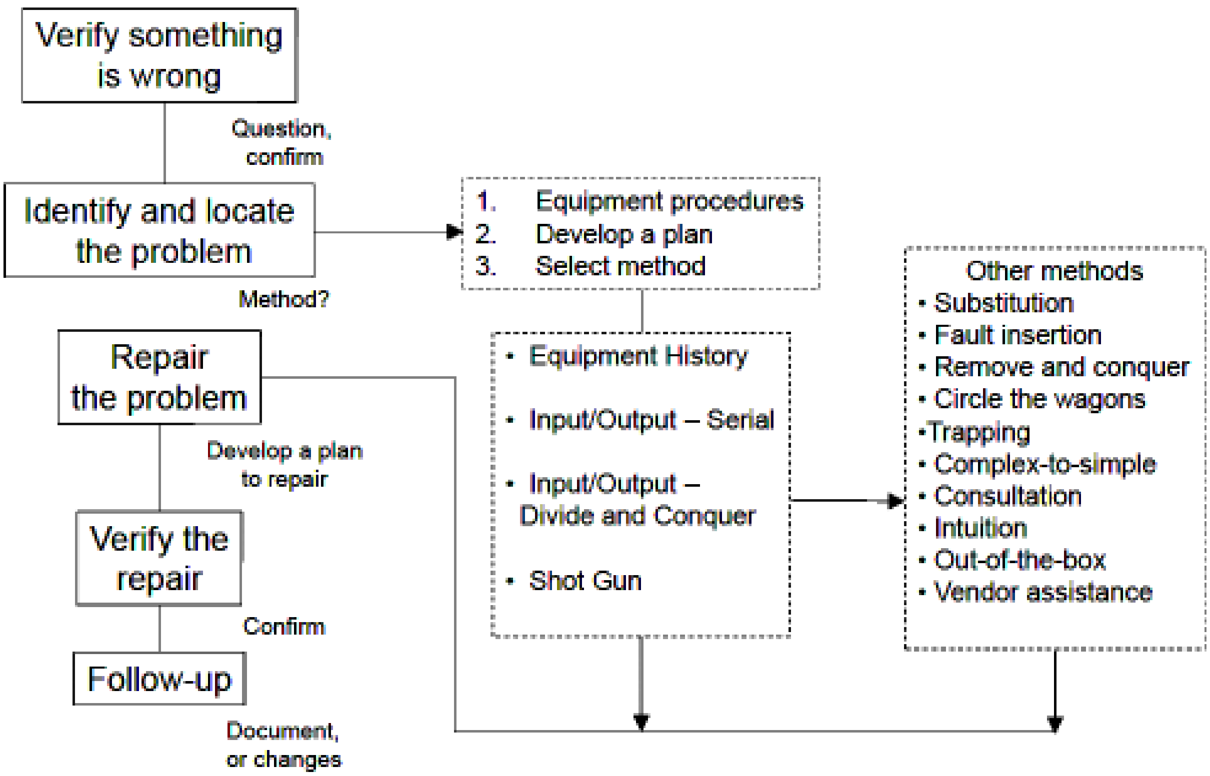

Figure 1. Troubleshooting Framework Review

DEFINITIONS

Absorption-refrigeration – One refrigeration process that uses heat-transfer (thermal) driving force to utilize the refrigerant.

Accumulator - a storage vessel for liquid refrigerant; also known as surge drum.

Approach temperature - The delta T in heat exchangers between the inlet and outlet on the cold or hot end of the exchanger.

Bearing – Is a device to permit constrained relative motion between two parts, typically rotation or linear movement. Compressors employ at least half a dozen types of journal bearings. Essentially all of these designs consist of partial arc pads having a circular geometry.

Blades - Rotating airfoils for both compressors and turbines unless modified by an adjective.

Blowdown - The flow of boiler feed water or cooling tower water drained to the sewer to control the accumulation of hardness deposits.

Bubble point: the temperature at which the vapor pressure of the liquid refrigerant equals the absolute external pressure of the liquid-vapor interface.

Bypass - any system of pipes or conduits for redirecting the flow of a liquid. Also can be defined as A pipe or channel used to conduct gas or liquid around another pipe or a fixture

Capacity - Is the water handling capability of a pump commonly expressed as either gallon per minute (gal/min) or cubic meter per minute (m^3/min).

Capacity, refrigerating system: the cooling effect produced by the total enthalpy change between the refrigerant entering the evaporator and the refrigerant leaving the evaporator.

Cavitation - Is the result of vapor bubbles imploding. That are the consequence of forces acting upon the liquid. It usually occurs when a liquid is subjected to rapid changes of pressure that cause the formation of cavities where the pressure is relatively low.

Check valve - Also called a "nonreturn valve." Prevents fluids from flowing backwards through a pipe.

Compressor – A device that compressing the fluid to raise its pressure.

Compressor Efficiency - This is the ratio of theoretical horsepower to the brake horsepower.

Condenser: a heat exchanger in which the refrigerant, compressed to a suitable pressure, is condensed by rejection of heat to a cooling medium.

Cooling medium: any substance whose temperature is such that it is used, with or without change of state, to lower the temperature of refrigerant either during condensing or subcooling.

Coupling- A device for connecting the pump shaft to the driver shaft consisting of the pump shaft hub and driver shaft hub, usually bolted together.

Critical speed - For a centrifugal compressor, the RPM at which the compressor will vibrate in a self-destructive manner. This speed is noted on the compressor's nameplate.

Cyclic Refrigeration – A cycle that take place in the refrigerant as it alternately absorbs and rejects heat as it circulates through refrigerator.

Delta P - The pressure difference between two points, usually measured across the same piece of equipment or process line

Discharge Port —Point where the discharge hose or pipe is connected to the pump.

Downstream - Flow goes from upstream equipment to downstream equipment, except when there is a flow reversal.

Draft - The negative pressure (vacuum) at a given point inside the heater, usually expressed in inches of water.

Dynamic Discharge Head- The static discharge head plus the friction in the discharge line also referred to as Total Discharge Head.

Dynamic Suction Head - The static suction lift plus the friction in the suction line also referred to as Total Suction Head.

Endurance limit – Is the stress below which the shaft will withstand an infinite number of stress reversals without failure. Since one stress reversal occurs for each revolution of the shaft, this means that ideally the shaft will never fail if the maximum bending stress in the shaft is less than the endurance limit of the shaft material.

Evaporator – A device used to turn the liquid into gaseous form. Heat exchanger used to absorb heat energy.

Expansion valve – A device that used to control an expansion of liquid refrigerant. Controls the flow of refrigerant and allows for phase change from a liquid to vapor.

Fire Box - A term used to describe the structure which surrounds the radiant coils and into which the burners protrude.

Fired Heater Efficiency - The ratio of heat absorbed to heat fired, on a lower heating value basis.

Flooding - In distillation, when tray efficiency is degraded, whether due to downcomer backup or entrainment, as vapor and liquid rates increase.

Flue Gas - A mixture of gaseous products resulting from combustion of the fuel.

Forced Draft - Use of a fan to supply combustion air to the burners and to overcome the pressure drop through the burners.

Fouling - The building up of a film of dirt, ash, soot or coke on heat transfer surfaces, resulting in increased resistance to heat flow.

Gauge Pressure - The pressure determined by most instruments and gauges, usually expressed in psig. Barometric pressure must be considered to obtain true or absolute pressure (psig).

Heat Duty - The total heat absorbed by the process fluid, usually expressed in MBtu/hr

Heat transfer coefficient - Heat transfer efficiency expressed in Btus per hour per unit of heat transfer surface area, per unit of the log mean temperature difference.

Horsepower, Brake - Horsepower delivered to the output shaft of

Hydraulic horsepower - is the horsepower required for pumping liquid at operating conditions without loss of pump efficiency

Impellers - a rotor used to increase (or decrease in case of turbines) the pressure and flow of a fluid. A rotating component of a centrifugal pump, usually made of iron, steel, bronze, brass, aluminum or plastic, which transfers energy from the motor that drives the pump to the fluid being pumped by accelerating the fluid outwards from the center of rotation.

Induced Draft - Use of a fan to provide the additional draft required over that supplied by the stack, to draw the flue gas through the convection section, and any downstream heat recovery equipment.

Lower Heating Value (LHV) - The theoretical heat of combustion of a fuel, when no credit is taken for the heat of condensation of water in the flue gas.

Measurement- The act or process of determining the dimensions, capacity, or amount of something.

Pump displacement - A measure of centrifugal pump vibration, which may damage the seal.

Pressure Head - Pressure Head must be considered when a pumping system either begins or terminates in a tank which is under some pressure other than atmospheric. The pressure in such a tank must first be converted to feet of liquid.

Process compression stage - Is defined as the compression step between two adjacent pressure levels in a process system. It may consist of one or more compressor stages.

Refrigerant – A substance that used as a medium to cool the process in refrigeration system. the fluid used for heat transfer in a refrigeration system, which absorbs heat at a low temperature and low pressure and rejects heat at a higher temperature and a higher pressure.

Refrigeration – A process in which work is done to move heat from one circumstance to the other environment. the heat transfer of heat from a lower temperature region to a higher temperature one. A device called a refrigerator or heat pump accomplishes refrigeration.

Reservoir - large tank used for collecting and storing water, esp for community water supplies or irrigation

Specific gravity - Is a relative measure of weight density. Normally pressure has not significant effect for the weight density of liquid, temperature is only condition must be considered in designating the basis for specific gr

Steady-state - volume rates of flow, pressures and pump speeds do not change with time) condition all the time, since starting up and stopping the pump alone will change the duty conditions.

Surge - The erratic and dangerous unstable flow of gas through a centrifugal compressor, usually due to low gas flow rates, low gas density, or high discharge pressure.

Troubleshooting - a form of problem solving, often applied to repair failed products or processes on a machine or a system. It is a logical, systematic search for the source of a problem in order to solve it, and make the product or process operational again.

Total Head - Pressure required in feet (meter) of head that the pump must produce. The head at the discharge pump flange minus the head at suction flange.

Upstream - The upstream stage of the production process involves searching for and extracting raw materials.

Volumetric efficiency - The ratio of real flow rate to theoretical flow rate (pump displacement)

Viscosity- Defined as the shear stress per unit area at any point in a confined fluid divided by the velocity gradient in the direction perpendicular to the direction of flow, if the ratio is constant with time at a given temperature and pressure for any species, the fluid is called a Newtonian fluid.

Volute — A stationary housing inside the pump housing in which the impeller rotates. It is used to separate air and water.

REFERENCES

1. Norman. P Lieberman (1991). Trouble Shooting Process Operation. Penn Well Publishing Company. USA

2. Dana Laird, Brian Albert, Cary Steiner, Douglas Little (2002). Take a Hands-On Approach to Refinery Troubleshooting. www.cepmagazine.org

3. Emerson Automation Solutions. (2020). The Engineer's Guide to DP Flow Measurement.

4. Seven Step Troubleshooting. www.myodesie.com

5. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, Fluid Flow Piping Hydraulics Fluid Flow Line Sizing and Material Selection Engineering Design Guideline, 2018

6. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, Compressor Selection, Sizing and Troubleshooting, Engineering Design Guideline, 2014

7. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, Pumps Selection, Sizing and Troubleshooting, Engineering Design Guideline, 2014

8. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, Furnace Selection, Sizing and Troubleshooting, Engineering Design Guideline, 2014

9. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, General Instrumentation Selection, Sizing and Troubleshooting, Engineering Design Guideline, 2014

10. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, Refrigeration Selection, Sizing and Troubleshooting, Engineering Design Guideline, 2014