DISTILLATION TROUBLESHOOTING MODULE
INSTRUCTOR LESSON PLAN

Overview

Distillation is a process used to physically separate components in a liquid mixture based on their boiling points. Low boiling point materials are vaporized and leave the top of a column where they are condensed then sent forward as product or to storage, higher boiling point materials remain in the column base and are removed from the bottom to either product storage or recycle into the system for further processing.

Distillation has a history of usage as far back as the first century. In the 13th century Taddeo Alderotti is credited with the creation of fractional distillation, a process used in many refineries and specialty chemical plant productions today. (E.J. Holmyard, 1957) Simple distillation is used when boiling points of the materials differed by greater than 25 degrees Celsius; fractional distillation is used when material boiling points are very close together.

The process of distillation can be accomplished in both batch and continuous operation depending on the materials being separated and whether the resulting products are considered intermediates or final products. Distillation of products may be achieved by running the column at less than atmospheric pressure (vacuum), atmospheric pressure, or pressure greater than atmospheric depending on the boiling points and other physical characteristics of the process materials. Distillation processes such as extractive and Azeotropic require the addition of another material separating agent which binds with, or entrains with, one of the materials being separated.

The distillation types most commonly used in petrochemical, refining, chemical plants and natural gas processing plants are:

- Industrial Distillation
- Simple Distillation
- Fractional Distillation
- Steam Distillation
- Vacuum Distillation
- Azeotropic Distillation

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Competency	Performance Standards
Troubleshoot problems with distillation	Performance will be satisfactory when: ☐ Learner recognizes the problem and captures the problem in written form. ☐ Learner evaluates HSE risks involved with continued operation. ☐ Learner recognizes when the HSE hazard/s warrants shutting down equipment. ☐ Learner collects and analyzes data associated with the problem. ☐ Learner rewords problem based on initial observations and reasoning. ☐ Learner identifies possible causes of the problem. ☐ Learner selects most probable cause of the problem, one that explains every observation. ☐ Learner proposes corrective action that is rational and eliminates true cause (when possible). ☐ Learner accurately and completely documents problem and corrective action(s). ☐ Process equipment is stabilized (if simulator-based problem). ☐ System is returned to within $\pm$ 5% of design parameters (if simulator-based problem).
	Conditions: Given a paper-based (P&ID) and problem, competence will be demonstrated by the completion of troubleshooting steps and subsequent documentation.

Learning Objectives

1. Recall the purpose, applications, and types of distillation.

2. Recall potential problems associated with distillation.

3. Describe immediate actions a process technician could take to solve distillation problems.

4. Explain the relationship between variables for a specific process under normal operating conditions.

5. Given normal and abnormal operating conditions for a specific process:

    - Recognize the problem.
    - Collect and analyze data associated with the problem.
    - Define the problem.
    - Identify possible causes and the most probable cause of the problem.
    - Evaluate the effect of investigating, compensating and corrective actions.
    - Select an appropriate corrective action.
    - Document the problem and corrective action.

Learning Activities

Time Frame	Learning Activity	Teaching Activity	Instructional Materials	Supplies and Equipment	Notes
	PREVIEW learning objectives and performance standards for this competency.		Learning Plan		
	READ information provided in the Introduction section.		Learning Plan		
	LISTEN to the lecture on the purpose and applications of distillation and associated problems (if provided).	Deliver a brief presentation on distillation and associated problems.		Lecture Equipment	Address first two learning objectives.
	REVIEW the process flow, product specifications, equipment specifications, normal operating conditions, and normal design conditions sections for the specified process.	Choose a specific problem/s for learners to solve. Lead discussion of process to assure learners understand all aspects.	Process Description		
	COMPLETE the Self-Check Questions worksheet.	Introduce activity. Review worksheet with learners after completion.	Self-Check Questions worksheet		Reinforce learning objectives 1, 2, and 4.
	BRAINSTORM immediate actions a process technician could take to solve distillation problems with a small group of your peers.	Divide learners into groups of 3 to 4. Introduce activity.			
	COMPARE your list of immediate actions for solving distillation problems to another group's work.	Write all actions on board or flipchart.			
	LISTEN to instructor expand on actions a process technician could take to solve distillation problems.	Lecture on actions not captured and expand on those listed.		Lecture Equipment	Address the third learning objective.

	SOLVE at least one paper-based distillation problem including the completion of the Abnormal Operating Conditions table and Troubleshooting Form.	Choose a specific problem/s for learners to solve. Guide learners as needed during the activity. Do a quick de-brief after activity.	Problem Packet		Information for three Scenarios has been provided for students. Address learning objective 5.
	OBSERVE a normal and/or abnormal condition on the simulator associated with a distillation (if simulator is available).	Set up simulation. Guide learners as needed during the activity.		Simulator	
	SOLVE at least one simulator-based distillation problem including the completion of the Troubleshooting Form (if simulator is available).	Create a problem/s for learners to solve. Program fault for simulator-based problem. Guide learners as needed during the activity. Do a quick de-brief after activity.	Troubleshooting Form	Simulator	Address learning objective 5.

Distillation Troubleshooting Module
Process Description

Introduction

Distillation columns are of various sizes and are made of different materials. There are many different types of distillation columns. Some columns have internal sieve trays, bubble cap trays, or valve trays, while others are filled with an assortment of different packing materials based on materials to be separated.

Distillation columns operate on the principal of different boiling points for different chemicals. Heat is introduced to the bottom of the column: materials with higher boiling points concentrate in the bottom of the column while materials with lower boiling points vaporize and migrate up to the top of the column. The bottom temperature of the column will be higher than the top. As the components with lower boiling ranges migrate up the column, the ones with the lowest boiling range will go out the top in vapor form, enter a heat exchanger, be condensed back to a liquid, and captured in the overhead reflux or product tank. Part of this material is pumped back to the column as reflux, which helps improve product purity to concentrate light ends and also helps cool the upper portion of the column, while the rest is pumped to storage as finished product or to the next step in the process train. The materials with high boiling points leave the column from the bottom on to next step in the process train.

Pressure influences the boiling range of process materials. As pressure increases the boiling temperature of the process liquid will rise. The boiling temperature of water increases as it is put under pressure. At 15 PSIG, water boils at 250 degrees F as compared to 212 degrees F at atmospheric pressure. (Keenan and Keyes, 1969)

Process technicians constantly monitor process variables associated with distillation columns. Technology has advanced and the use of a Distributed Control System (DCS), which can electronically monitor hundreds of process variables, gives a more accurate reading and can be displayed using schematics and other displays via a monitor. Temperatures, levels, pressures, and flows are normally recorded on a datasheet by the technician and the DCS is reviewed and monitored to look for problems with the process. Process technicians also need to be aware of others working in their area, as maintenance personnel, contractors, or other operators could accidently open or close valves, which could have an impact on their equipment.

Product flows from the top, bottom, and sometimes various other points of the column are analyzed to make sure the column is operating as designed. Process variables (pressure, temperature, and level) are adjusted to maintain product purity.

Distillation column C-301 is a 60-foot tall stainless steel distillation column with sieve trays and is used for aldehyde drying. The feed comes from an adjacent unit that separates the aldehyde from other compounds. After separation in the adjacent plant, the aldehyde and water mix is fed to C-301 to separate the aldehyde from the water. It operates at 10 PSI by using N_2 supplied into the reflux tank and controlled by a split range controller. At lower than 10 PSI pressure one control valve supplies N_2 into the tank; at higher than 10 PSI pressure a control valve opens to send vapor to the vent system.

This type of system is used throughout industry to hold columns, reactors, tanks, etc. at predetermined pressures. The problem with this type of pressure control system is that it cannot control pressure if a large amount of N_2 is introduced somewhere else in the system. The system usually has to be bypassed during startup operations due to the large pressure increase caused by initial vapor pressure surges at start-up during initial column boil up. After startup, the pressure controller can be put in service and works well under most conditions.

Process Flow – A wet aldehyde mixture is fed to the column.
Product Specifications – The wet aldehyde is dried in the column. The dry aldehyde is removed from the top of the column as the top take off flow, leaving the water in the bottom of the column. Water is removed from the column as the base overflow.
Equipment Specifications – C-301 is a stainless steel distillation column operating less than 10 pounds of nitrogen pressure. The column heat is supplied by 160 PSI steam via a vertically mounted shell and tube exchanger. Operating under pressure helps to control the aldehyde in the column because it has the lower boiling point. The added pressure raises the combined boiling point of the aldehyde and water.

Normal Operating Conditions

The schematic for normal operating conditions is shown in Figure 1.

The feed to the column is determined by management according to current production needs.
The column is heated with 160 PSI steam.
The overhead condenser uses cooling water as the cooling medium.
The column controls are as follows:

Base level controller LIC-301 controls the overflow control valve to hold the base level at 50%.

The reflux tank level controller LIC-302 controls the reflux flow to the column.

The top temperature controller TIC-301 controls the top takeoff flow.

The differential pressure controller PDC-304 controls the steam to the column.

TI-302 and TI-303 are temperature indicators on the middle and the base respectively.

PIC-305 controls column pressure. Set on Auto at 10 PSI. It is a split range controller. 0%–50% output (3 to 9 PSI) on the controller opens the vent control valve, 50%–100% output (9 to 15 PSI) opens the N_2 control valve, 50% on the controller closes both N_2 and vent control valves.

Normal Operating Conditions

Tag ID	Range	Normal Value	Eng. Units
LIC-301	0-100	52	%
LIC-302	0-100	48	%
TIC-301	50-150	65	DEG F
TI-302	50-150	78	DEG F
TI-303	50-150	88	DEG F
PI-302	0-100	10	PSI
PI-303	0-100	14.5	PSI
PDC-304	0-25	4.5	PDI
FI-303	0-100	48	GPM
FI-302	0-100	55	GPM
FI-301	0-50	12	GPM
FIC-304	0-100	60	GPM

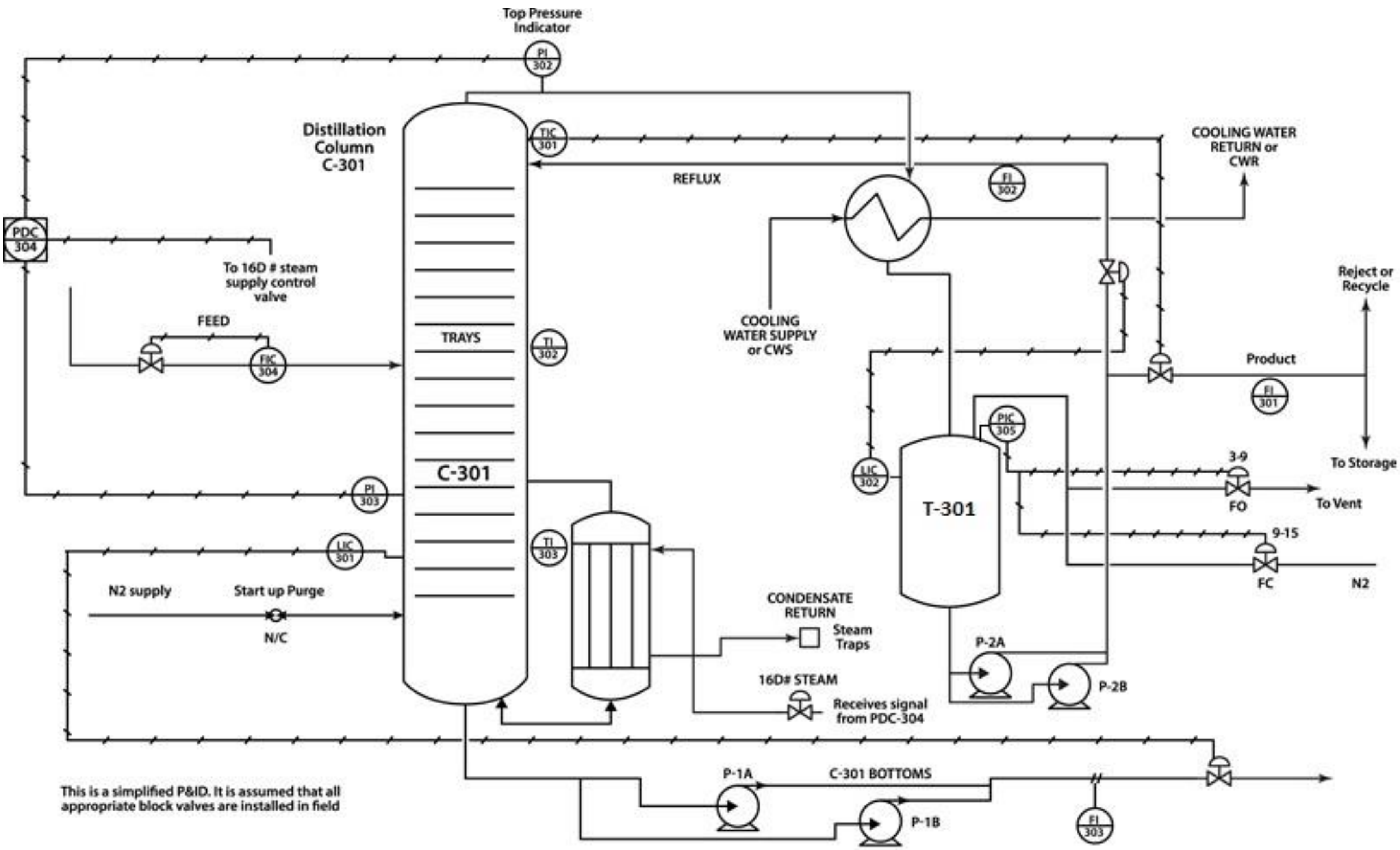

Figure 1. Distillation Column C-301 P&ID

DISTILLATION TROUBLESHOOTING MODULE
SELF-CHECK QUESTIONS

1. Distillation columns are operated with three different pressure profiles. What are they?

   Atmospheric Pressure
   Greater than atmospheric pressure (typically called pressurized columns)
   Less than atmospheric pressure (typically called vacuum columns)

2. What scientific principal is distillation based on?

   The difference in boiling points of different chemicals

3. As the low boiling material boils overhead, what is used to condense the vapor back to a liquid?

   The gaseous vapors go to a heat exchanger, which cools the vapors and condenses them back to a liquid.

4. What happens to the temperatures in a column if the pressure is increased?

   The temperatures will increase even though no additional heat is added to the column.

5. What condition can occur if too much steam is applied to the column?

   Column flooding can occur.

6. In the P&ID supplied in Figure 1, what instrument controls the base level on C-301?

   LIC-301 controls the overflow control valve to maintain the base level.

7. If you are trying to distill a chemical with a high boiling point, which type of distillation method would you probably use? Why?

   You would probably want to use vacuum distillation column because less heat would be required. You would be less likely to damage the material or cause chemical decomposition with less heat.

8. If your analysis started showing water in the top take off flow what would be the proper response?

   You would lower TIC-301 to lower the top temperature which would drop the water back down the column.

9. What steps would you take if your steam traps malfunctioned? (Assume that you do not have a **spare steam trap.)**

   You would open the steam trap bypass valve and match the steam pressure you had before you started having problems.

   If you do not have a bypass, you would route the condensate flow to the atmosphere until the steam trap could be repaired.

   Regular monitoring would be necessary while running with either the bypass opened or going to the air.

DISTILLATION TROUBLESHOOTING MODULE
SCENARIO #1 (PAPER-BASED)

Scenario Statement

<u>Process Technician</u> – John

<u>Lead Process Technician</u> – Tony

On July 6th John reports to work at 6:00 PM. Upon reading the log book, John learns the day shift operator has placed the steam controller on manual so that PDC-304 can be worked on by maintenance.

In the log book write-up John also notes the day-shift operator had written a permit for scaffold builders to erect scaffolding so instrument maintenance personnel can access PDC-304. After the first round of readings, John notes that readings looked to be in normal range.

At 9:15 PM, he receives an alarm on C-301 for column bottoms level. After checking with his lead operator Tony, they notice the column bottoms rate is elevated. Their first thought is the steam trap has malfunctioned. After investigating, the steam trap appears to be working correctly.

After checking the steam trap, the high bottom pressure and the high top pressure alarms sound. John and Tony notice that pressures are higher over the entire column, not just on the base, which could have indicated column flooding. Tony asked John to go back outside to check for anything else that could cause high column pressure.

Normal and Abnormal Operating Conditions

Tag ID	Normal	Eng. Units	Abnormal 1	Return to Normal
LIC-301	52	%	100	
LIC-302	48	%	2	
TIC-301	65	DEG F	55	
TI-302	78	DEG F	70	
TI-303	88	DEG F	82	
PI-302	10	PSI	20	
PI-303	14.5	PSI	24.5	
PDC-304	4.5	PDI	14.5	
FI-303	48	GPM	65	
FI-302	55	GPM	35	
FI-301	12	GPM	5	
FIC-304	60	GPM	60	

Troubleshoot the problem as follows.

Look at the P&ID drawing provided in Figure 1. Identify the probable cause(s) and explain. Be sure to read the issues John noted from the log book entries of the previous shift. Note what the different PVs are indicating. Which PVs have changed? Which ones have not changed? What is the likely cause of the increased pressure? What is the cause of the level, temperature, and flow changes?

Investigating Actions

Probable cause(s): *Column flooding, excessive feed, excessive steam flow, abnormal N_2 flow to the column*

Which PVs have changed? *Every PV except for the feed flow has changed.*

Which PVs have not changed? *The feed flow*

What is the likely cause of the increased pressure? *Excessive N_2 flow to the column*

What is the cause of the level, temperature, and flow changes? *Increasing the overall pressure would cause the temperatures to rise even though no additional heat was added to the column. Loss of boil-up on the column would cause the column level to increase, which would make the bottoms flow to increase to try to maintain the bottoms level. Again, loss of boil-up would cause the reflux tank level to be low and the reflux tank level controller would reduce the amount of reflux to try to maintain the reflux tank level. The increased top temperature would make the top take off controller cut back to try to maintain the top temperature in range. The feed flow would not change because it is unaffected by what is happening in the column. It could possibly go down a small amount because of higher pressure in the column but the flow controller should be able to compensate for that.*

At this time, John remembers from the previous shifts' log entry that scaffold builders were working in the area and realizes there was an N_2 supply valve to the column in the area that scaffolding was being erected. After investigating, the N_2 valve was found opened. He closes the valve at this time.

Troubleshoot the problem as follows.

Knowing that changes in pressure will change the boiling point, what actions should be taken at this time? Remember, it is always acceptable and encouraged to consult with someone with more experience if you have a situation you have not seen previously.

Compensating Actions

Knowing the problems that changing pressure could have on the column, John consults Tony, the lead process technician and explains what has been found. They take the following actions:

Put column flows on reject.

Divert column feed.

Slowly lower column pressure by opening PIC vent valve slowly.
NOTE: If the pressure had been dropped quickly, the low boilers would have boiled quickly, which could over filled the reflux tank causing a spill.

After the column conditions were back to normal, restart feeds and switch column flows back to the product tanks.

Normal and Abnormal Operating Conditions

Tag ID	Normal	Eng. Units	Abnormal 1	Return to Normal
LIC-301	52	%	100	50
LIC-302	48	%	2	49
TIC-301	65	DEG F	55	66
TI-302	78	DEG F	70	80
TI-303	88	DEG F	82	89
PI-302	10	PSI	20	10
PI-303	14.5	PSI	24.5	14.5
PDC-304	4.5	PDI	14.5	4.5
FI-303	48	GPM	65	48
FI-302	55	GPM	35	55
FI-301	12	GPM	5	12
FIC-304	60	GPM	60	60

Observations

Discuss with students the importance of pressure control on distillation columns. If the pressure on a distillation column is lowered quickly, the low boiling components will quickly boil which will overfill the reflux tank.

Discuss the relationship between pressures and boil up on column. Explain that the cause of the high base level in the column was that the column pressure was higher than normal which raised the boiling point on the components. Quickly lowering the pressure would have caused low boilers to flash over quickly. Use examples such as steam flashing, air conditioning compressors etc.

If PDC-304 had been in service, the steam would have increased as the pressure went up, which would have prevented some of the issues but may have caused other issues.

The cause of the incident was that the scaffold builders accidently opened the ¼ turn ball valve by bumping it with a scaffold board without realizing it.

This was a real scenario.

Remember that many contractors will work in your area and that accidents such as this happen from time to time. Always watch out for other workers in the area. If you start having trouble with a piece of equipment, always consider which contractors are working in your area and what they might have accidently done.

Corrective Action

Add car seal or lock to valve.

TROUBLESHOOTING FORM

1. **Recognize (and write) the problem.**
*(What **is** happening that should not be or what **is not** happening that should be?)*
High Column Pressure

2. **Stabilize the system.**
(Does it need fixing? Stabilize the unit. Can we keep the unit running? Do we need to shut it down?)
Yes it needs to be fixed. We can keep the unit running. Shut down not required

3. **Collect and analyze the data.**
(Look for changes, differences, readings that have not changed, etc. Write down all observations. After every observation, write down the reason why. Then answer why for each reason.
Ex. Observation why? because Reasoning why? because Reasoning why? because Reasoning...)

Y N ***a. High liquid level column***
why? Because: ***Loss of boil up on the column***
why? because
why? because

Y N ***b. Low level in the reflux tank***
why? Because: ***Less material being boiled because of high pressure***
why? because
why? because

Y N ***c. High steam pressure***
why? Because: ***Either high Nitrogen flow or***
why? Because: ***Excessive steam causing high vapor rates***
why? because

Y N d.
why? because
why? because
why? because

Y N e.
why? because
why? because
why? because

Y N f.
why? because
why? because
why? because

Y N g.
why? because
why? because
why? because

4. After initial observations and reasoning, **reword the problem** as specifically as possible.
Column losing boil up due to high pressure in the system

5. List **possible causes** of the problem.

Y **N** ***h. Column flooding***

Y N ***i. Column pressure controller malfunction***

Y N ***j. Column nitrogen supply open***

Y N k. ______

Y N l. ______

*****Would each possible cause explain the problem? Circle **Y** or **N** beside each possible cause.

6. List the **most probable cause** of the problem. *(Use your knowledge, experience and best judgment.)*

Column nitrogen supply accidently opened

******* Does this cause explain every observation? Circle **Y** or N beside every observation.

7. Determine alternative solutions and select solution.

m. What would be an **investigative** action you could take at this point? What would be the effect?

Inspect valve and make sure it is in proper position

n. What would be a **compensating** action you could take at this point? What would be the effect?

Close nitrogen valve

o. What would be a **corrective** action you could take at this point? What would be the effect?

Slowly lower column pressure to keep from overfilling reflux tank. Monitor until column levels, flows, temperatures, and pressure are in normal ranges.

Have the nitrogen valve either car-sealed closed or disconnected to prevent accidently opening valve again.

p. What will be the **effect** of the above actions? *(Would any of the actions cause other problems?)*

Column should return to normal operations.

8. Take the **corrective action** *(if empowered or within your responsibility).*

9. **Follow-up.** *(Was the problem eliminated? Was the "real" cause eliminated? What caused the real cause? You may need to start the problem-solving process again.)*

The problem was eliminated by disconnecting the permanent nitrogen line and using a flex hose to hook nitrogen to column when needed for purging.

10. **Document and share** with others.
(Document problem and actions taken in logbook or report; communicate with others.)

DISTILLATION TROUBLESHOOTING MODULE
SCENARIO #2 (PAPER-BASED)

Scenario Statement

Process Technician – John

Lead Process Technician – Tony

Weather Conditions – September 10, outside temperature 93 degrees, clear skies

After taking the first set of readings John notes that the unit is running well. All flows, levels, temperatures, and pressures are within normal ranges.

At approximately 9:00 PM John receives an alarm for high base level on distillation column C-301. He quickly receives alarms for low reflux flow, low reflux tank level, low top temperature, and low mid temperature. John then notes that steam flow to the column was at the top of the scale with the controller showing the control valve to have an output signal of 100%.

Table 1. Normal and Abnormal Operating Conditions

Tag ID	Normal	Eng. Units	Abnormal 1	Return to Normal
LIC-301	52	%	100	
LIC-302	48	%	20	
TIC-301	65	DEG F	55	
TI-302	78	DEG F	72	
TI-303	88	DEG F	84	
PI-302	10	PSI	10	
PI-303	14.5	PSI	20	
PDC-304	4.5	PDI	10	
FI-303	48	GPM	8	
FI-302	55	GPM	22	
FI-301	12	GPM	40	
FIC-304	60	GPM	60	

John checks steam flow and notes that steam flows to other equipment is normal, ruling out a steam supply problem.

He contacts Tony, his lead operator, for assistance. Tony watches the panel board/DCS while John goes outside to put the top Take-Off flow on reject and investigate the problem.

John sees that the steam pressure on the column is 160 PSI and suspects the steam trapped has malfunctioned.

John blocks in the condensate return line from the trap to the condensate return header to prevent backflow from the header. The blow down valve after the trap is opened, and no flow or low flow is noted. The bleed valve before the trap is then opened and a large amount of condensate flows out.

He then reports his observations to Tony by radio. Tony watches the C-301 temperatures while John puts the spare steam trap in service. As the temperatures start to come up in the column, Tony starts to reduce the steam flow to the column.

John goes back inside and operates the column until variables are back in range. He then takes the column top Take-Off flow off reject and returns the column to normal operations.

He performs a Lockout/Tagout procedure on the steam trap, generates a work permit, and contacts maintenance personnel for repair.

Table 2. Normal and Abnormal Operating Conditions

Tag ID	Normal	Eng. Units	Abnormal 1	Return to Normal
LIC-301	52	%	100	50
LIC-302	48	%	20	52
TIC-301	65	DEG F	55	65
TI-302	78	DEG F	72	78
TI-303	88	DEG F	84	88
PI-302	10	PSI	10	10
PI-303	14.5	PSI	20	14.5
PDC-304	4.5	PDI	10	4.5
FI-303	48	GPM	8	48
FI-302	55	GPM	22	57
FI-301	12	GPM	40	11
FIC-304	60	GPM	60	62

Troubleshoot this problem to determine the most likely cause of the upset and what corrective actions to take. Complete the Troubleshooting Form.

Observations

Discuss with students steps to take when faced with loss of heat to column, whether it is loss of steam, Thermoil, furnace, or electrical coils.

Process technicians need to remember that they still have a unit to run; C-301 column is only part of the operating unit, so they can't get tunnel vision. Asking for help is expected and encouraged. Tony was able to monitor the rest of the column while John worked on the problem at hand. Tony was also able to watch C-301 and take appropriate actions as heat was returned to the column.

If no spare steam trap had been available, the steam trap by-pass valve could have been opened.

If no by-pass was available, the condensate could have been put to the air temporarily while the trap was repaired.

Closely monitor the column steam pressure when controlling the condensate flow manually. Put the steam controller on manual and manipulate the bypass or bleed valve to hold the steam pressure to the appropriate pressure (the steam pressure reading before the problem was observed).

TROUBLESHOOTING FORM

1. **Recognize (and write) the problem.**
   *(What **is** happening that should not be or what **is not** happening that should be?)*
   The column has lost boil up. Check steam system to see if it is localized or department wide. If only affecting one column, start investigating steam traps, steam supply valves etc.
2. **Stabilize the system.**
   (Does it need fixing? Stabilize the unit. Can we keep the unit running? Do we need to shut it down?)
   Steam must be started back to the column as soon as possible to minimize effects on column and downstream equipment.
3. **Collect and analyze the data.**
   (Look for changes, differences, readings that have not changed, etc. Write down all observations. After every observation, write down the reason why. Then answer why for each reason.
   Ex. Observation why? because Reasoning why? because Reasoning why? because Reasoning...)

Y N **q.** ***Lower column temperatures and lower reflux flow***
why? because ***steam trap malfunction***
why? because
why? because

Y N ***r.*** ***Higher base level***
why? Because ***lost boil up in column due to steam trap malfunction. Feed to column is collecting in the base of the column because there is not sufficient heat to boil it.***
why? because
why? because

Y N s. **Lower reflux tank level**.
why? Because ***loss of boil up in column will mean vaporized material is not going out the top of the column and into the reflux tank.***
why? because
why? because

Y N ***t.*** ***Lower reflux flow***
why? because ***lost boil up in column due to steam trap malfunction***
why? because ***the reflux tank has a level controller on it. If less material is going into the tank, the controller will reduce the amount of material coming out of the tank.***
why? because

Y N ***u.*** ***Column temperatures are coming down.***
why? because ***lost boil up in column due to steam trap malfunction***
why? because
why? because

Y N v.
why? because
why? because
why? because

Y N w.
why? because
why? because
why? because

Y N x. ______________________________

why? because______________________________

why? because______________________________

why? because______________________________

4. After initial observations and reasoning, **reword the problem** as specifically as possible.

Column is losing overhead boil up.

5 List **possible causes** of the problem.

Y N ***a. Steam supply problem***

Y N ***b. Steam supply valve at the column malfunction***

Y N ***c. Steam trap malfunction***

Y N ***d. Feed composition change***

Y N

*****Would each possible cause explain the problem? Circle **Y** or **N** beside each possible cause.

6 List the **most probable cause** of the problem. *(Use your knowledge, experience and best judgment.)*

Steam trap malfunction

***** Does this cause explain every observation? Circle ***Y*** or ***N*** beside every observation.

7 Determine alternative solutions and select solution.

a. What would be an **investigative** action you could take at this point? What would be the effect?

Put the trap discharge to the air to see if the trap is functioning properly.

b. What would be a **compensating** action you could take at this point? What would be the effect?

Bypass the trap.

c. What would be a **corrective** action you could take at this point? What would be the effect?

If a spare trap is available, switch to it. Prepare the other for maintenance to change out.

d. What will be the **effect** of the above actions? *(Would any of the actions cause other problems?)*

The column should be able to return to normal operation after the temperatures, flows, and levels are back in normal ranges.

8 Take the **corrective action** *(if empowered or within your responsibility).*

9 **Follow-up.** *(Was the problem eliminated? Was the "real" cause eliminated? What caused the real cause? You may need to start the problem-solving process again.)*

Yes

10 **Document and share** with others.
(Document problem and actions taken in logbook or report; communicate with others.)

DISTILLATION TROUBLESHOOTING MODULE
SCENARIO #3 (PAPER BASED)

Scenario Statement

Process Technician – Jack

Lead Process Technician – Nancy

Weather Conditions – April 1, 9:45 AM, outside temperature 48 degrees, raining

After Jack takes initial readings, C-301 is operating normally. Jack is a little concerned about the rainy conditions. Heavy rains sometimes cause operational problems due to the effects of ambient conditions causing lower steam temperature and pressure and loss of heat from cold rain and wind.

At 9:30 AM, Jack goes outside to help prepare a job for maintenance scheduled for later in the day. At approximately 9:45 AM, an alarm is received on the DCS indicating a loss of reflux flow to C-301.

- Lead process technician Nancy acknowledges the alarm and immediately calls Jack to see if he was near P-4, the C-310 reflux pump.
- Jack acknowledges he is and asks what the problem is.
- Nancy informs Jack of lost reflux flow to C-301, C-301 top temperature going up quickly, and the reflux tank filling rapidly.
- Jack checks P-4 and informs Nancy that the pump is running.
- Nancy instructs Jack to open the valves to put P-3 online, which Jack does.

Flow is reestablished to the column barely avoiding a spill. Upon further investigation, Jack notices that even though the pump motor was running, the pump itself was not rotating. Jack found the coupling tying them together had sheared apart. Jack then switched valves to put CU-301 top Take-Off on reject until column conditions could be returned to normal. Jack performs a Lockout/Tagout procedure on the pump so it can be repaired.

Table 3. Normal and Abnormal Operating Conditions

Tag ID	Normal	Eng. Units	Abnormal 1	Return to Normal
LIC-301	52	%	25	
LIC-302	48	%	100	
TIC-301	65	DEG F	76	
TI-302	78	DEG F	85	
TI-303	88	DEG F	88	
PI-302	10	PSI	10	
PI-303	14.5	PSI	14	
PDC-304	4.5	PDI	4	
FI-303	48	GPM	55	
FI-302	55	GPM	0	
FI-301	12	GPM	0	
FIC-304	60	GPM	60	

After the spare is online, Nancy lines the column out and Jack takes the column off of reject. No spill occurred.

Table 4. Normal and Abnormal Operating Conditions

Tag ID	Normal	Eng. Units	Abnormal 1	Return to Normal
LIC-301	52	%	25	50
LIC-302	48	%	100	50
TIC-301	65	DEG F	76	65
TI-302	78	DEG F	85	79
TI-303	88	DEG F	88	87
PI-302	10	PSI	10	10
PI-303	14.5	PSI	14	14.5
PDC-304	4.5	PDI	4	4.5
FI-303	48	GPM	55	48
FI-302	55	GPM	0	55
FI-301	12	GPM	0	11
FIC-304	60	GPM	60	60

Troubleshoot this problem to determine the most likely cause of the upset and what corrective actions to take. Complete the Troubleshooting Form.

Observations

Make sure students understand the importance of good observations when they are inspecting equipment when problems are encountered. Students need to realize that 1-2 minutes may make the difference in whether or not a spill occurs that could result in a fire or a reportable event.

Discuss the importance of using all senses when making rounds, sight, smell, hearing, and feel. Sometimes a vibration can be felt near a piece of equipment that is on the verge of failure. Always be aware of what is going on around you.

Cause

The pump coupling was sheared apart.

Investigating Actions

If Jack had noticed that the coupling was sheared when the pump was first inspected, the spare pump might have been put online a little quicker.

Also, the pump coupling might have been making an unusual noise before it failed that would have been audibly recognizable to operators that something was wrong.

Corrective Action

Repair or replace the faulty equipment.

TROUBLESHOOTING FORM

1 **Recognize (and write) the problem.**

*(What **is** happening that should not be or what **is not** happening that should be?)*

Loss of reflux flow. Loss of top take off flow. Reflux tank level rising.

2 **Stabilize the system.**

(Does it need fixing? Stabilize the unit. Can we keep the unit running? Do we need to shut it down?)

Switch to spare reflux pump. The unit can continue running.

3 **Collect and analyze the data.**

(Look for changes, differences, readings that have not changed, etc. Write down all observations. After every observation, write down the reason why. Then answer why for each reason.

Ex. Observation why? because Reasoning why? because Reasoning why? because Reasoning...)

Y N ***a.*** ***Loss of reflux flow***

why? Because ***of sheared coupling from pump motor to the pump***

why? Because ***of normal wear and tear. Should be a preventive maintenance item.***

why? because

Y N ***b.*** ***High reflux tank level***

why? Because ***of sheared coupling from pump motor to the pump. The column is still boiling. Material is going into the reflux tank but nothing is coming out.***

why? because

why? because

Y N ***c.*** ***High top temperature***

why? Because ***of sheared coupling from pump motor to the pump. The cool reflux flow back into the column helps keep the top of the column cooler. The top temperature will be most affected.***

why? because

why? because

Y N *d.* *Low base level.*

why? Because ***some of the reflux material was migrating down the column, helping keep the base level at the proper level.***

why? because

why? because

Y N e.

why? because

why? because

why? because

Y N f.

why? because

why? because

why? because

Y N g.

why? because

why? because

why? because

Y N h.

why? because____________________
why? because____________________
why? because____________________

Y N i. ____________________
why? because____________________
why? because____________________
why? because____________________

Y N j. ____________________
why? because____________________
why? because____________________
why? because____________________

4 After initial observations and reasoning, **reword the problem** as specifically as possible.

<u>Loss of reflux flow to the column</u>

5 List **<u>possible</u> causes** of the problem.

<u>Y</u> N ***a. <u>Reflux pump malfunction</u>***
<u>Y</u> N ***b. <u>Reflux pump loss of electrical power</u>***
<u>Y</u> N ***c. <u>Reflux pump loss of coupling connecting the motor to the pump</u>***
Y N d. ____________________
Y N e. ____________________

*******Would each possible cause explain the problem? Circle ***<u>Y</u>*** or ***<u>N</u>*** beside each possible cause.

6 List the **most probable cause** of the problem. *(Use your knowledge, experience and best judgment.)*

<u>Pump malfunction. Losing the coupling could be a type of pump malfunction.</u>

******* Does this <u>cause</u> explain every observation? Circle ***<u>Y</u>*** or ***<u>N</u>*** beside every observation.

7 Determine alternative solutions and select solution.

a. What would be an **investigative** action you could take at this point? What would be the effect?

<u>Find out if the department has a preventive maintenance program to change out pump couplings periodically.</u>

b. What would be a **compensating** action you could take at this point? What would be the effect?

<u>Put the spare pump online.</u>

c. What would be a **corrective** action you could take at this point? What would be the effect?

____

d. What will be the **effect** of the above actions? *(Would any of the actions cause other problems?)*

<u>Column operations should return to normal.</u>

____

8 Take the **corrective action** *(if empowered or within your responsibility).*

9 **Follow-up.** *(Was the problem eliminated? Was the "real" cause eliminated? What caused the real cause? You may need to start the problem-solving process again.)*

<u>Yes</u>

____

10 **Document and share** with others.
(Document problem and actions taken in logbook or report; communicate with others.)

PERFORMANCE ASSESSMENT ACTIVITY #1
PAPER-BASED PROBLEM

Learner Directions: In this assessment, you will analyze and solve a paper-based distillation problem. Your instructor will provide you with the problem scenario and supporting materials. Complete and submit all documentation requested including an Abnormal Operating Conditions table and Troubleshooting Form to your instructor.

Competency: Troubleshoot problems with distillation.

Performance Criteria: Performance will be satisfactory when:

- Learner recognizes the problem and captures the problem in written form.
- Learner evaluates HSE risks involved with continued operation.
- Learner recognizes when the HSE hazard/s warrants shutting down equipment.
- Learner collects and analyzes data associated with the problem.
- Learner rewords problem based on initial observations and reasoning.
- Learner identifies possible causes of the problem.
- Learner selects most probable cause of the problem, one that explains every observation.
- Learner proposes corrective action that is rational and eliminates true cause (when possible).
- Learner accurately and completely documents problem and corrective action/s.

Conditions: Given a paper-based problem (which may include a process description, equipment specifications, normal and abnormal operating conditions and appropriate tools), competence will be demonstrated by the completion of troubleshooting steps and subsequent documentation.

Assessment Strategy: Skill-based Performance Test

Standard: To be determined by the instructor. Example: Satisfactory performance requires learner must meet all criteria on the checklist.

Distillation Troubleshooting Rubric
Paper-based Problem

Competency: Troubleshoot problems with distillation.

Criteria	Scale			
Product				
1. Documentation is accurate.	4	3	2	1
2. Documentation is complete.	4	3	2	1
3. Documentation reflects correct use of terminology.	4	3	2	1
Process				
1. Learner recognizes the problem and captures the problem in written form.	4	3	2	1
2. Learner evaluates and documents HSE risks involved with continued operation.	4	3	2	1
3. Learner recognizes and documents when the HSE hazard/s warrants shutting down equipment.	4	3	2	1
4. Learner collects and analyzes data associated with the problem.	4	3	2	1
5. Learner rewords problem based on initial observations and reasoning.	4	3	2	1
6. Learner identifies possible causes of the problem.	4	3	2	1
7. Learner selects most probable cause of the problem, one that explains every observation.	4	3	2	1
8. Learner proposes corrective action that is rational and eliminates true cause (when possible).	4	3	2	1

Key

4 =	Met and/or surpassed criteria
3 =	Met criteria
2 =	Showed progress toward meeting criteria
1 =	Did not meet criteria

Bibliography

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