

## Hazard and Operability Study of Condensate Oil Refinery

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### ABSTRACT

Petroleum refineries are multifaceted and complex systems that perform multiple phase operations characterized by a high level of risk. The size and complexity of petroleum refinery, together with the nature of the products handled, require Hazard and operability (HAZOP) methodology. HAZOP is one of the best tools used in various oil refineries globally based on guidewords for all hazardous conditions with strong recommendation. The application of HAZOP has been demonstrated in the condensate oil exploration unit, based in Sindh. In this research paper about 12 deviations were documented with 34 possible causes and 46 predicted consequences. However, to make the system hazard free 3 nodes were selected on the piping and instrumentation diagram of condensate splitter, based on selected nodes 48 actions were proposed in counter of the deviations.

**Keywords:** Petroleum refineries, Hazard and operability, condensate oil, piping and instrumentation diagram

### INTRODUCTION

The Hazard and Operability Study (HAZOP) covers hazard identification and management. The main objective of this study is systematic and structural examination of a condensate-based refinery by evaluating every possible hazard Qureshi and Shakeel (2013). Operational problems and potential hazards in terms of human error and plant design are identified by using HAZOP process. Before the construction commences, the techniques should be applied to a plant during final design. There are many advantages in carrying out a preliminary HAZOP, as it facilitates the design process (Mondlane 2003).

The concept of HAZOP study revolves around analyzing the possible deviations that might occur in plant and drift from the design intent. If, during identification of problems in HAZOP study, a solution becomes apparent then it is recorded as part of the HAZOP result; however, efforts must be taken into account to exclude solutions which are not so apparent, because the prime objective for the HAZOP is problem identification. Although the HAZOP study was developed to supplement experience-based practices when a new design or technology is involved but due to the incidence of major industrial accidents around the world, its use has expanded to almost all phases of an industrial plant's life. HAZOP's basic principle relies on the fact that when several experts with different background gather, they identify problems to a greater extent than when working separately and combining their results (Aspin all 2006). A small multi-disciplinary team undertakes the analysis, whose members should have sufficient experience and knowledge to answer most questions on the spot. The members are selected carefully and are given the authority to recommend any needed changes in design Dunjó et al. (2010).

This research identifies possible deviations from normal operating conditions which could lead to hazardous situations in a refinery. During the hazard and operability study of a unit all the consequences and likelihood of such deviations are examined qualitatively. The efficacy and relevancy of available safeguards to detect undesirable deviations and protect against their resultant effects are also considered. This technique enables a comprehensive evaluation of hazard control systems and produces recommendations for any necessary modifications. The overall process results in reduction of both hazards and potential operational problems, and the possibility of reduced down-time and smoother commissioning (Mubin 2008).

To determine deviation of process from target parameters, guide words: none, more of, less of, as well as etc. are used on parameters such as Temperature, Pressure, Flow, Composition etc. (Table 1). By using such guide words, the team can focus on the process in an integrated form Ehsan et al. (2008).

**Table 1.** Guide Words used in HAZOP study.

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| • Guide Word | Meaning                                  |
|--------------|--|
| • No         | No flow at all                           |
| • Less of    | Less of flow, temperature, pressure etc. |
| • More of    | More of flow, temperature, pressure etc. |
| • Part of    | System Composition different             |
| • More than  | More thing present                       |
| • Other      | Other than normal operation              |
| • Reverse    | Opposite of what is to be                |

This procedure is applied on a particular node as a part of the system, characterized for a nominal intention of the operative parameters. Having determined the deviations, the team experts explore feasible causes of the deviations and their possible consequences. For every pair of cause-consequence, actions must be recommended that could prevent, mitigate or control the hazardous situation. Finally, if the safeguards are insufficient to solve the problem, offering recommendations must be considered Poulouse and Madhu (2012).

The concept of a HAZOP study first appeared with the aim of identifying possible hazards present in facilities that manage highly hazardous materials. The prime purpose of the study was to eliminate any source leading to major accidents, such as fire, toxic release, and explosion. Over the years, HAZOP's application readily extended to other types of facilities due to its success in identifying not only hazards, but also operational problems Chudleigh (1994).

In this work, HAZOP study was conducted on a condensate-based refinery. This research attempts to introduce suitable method of HAZOP analysis for the given process to identify any risk that might be a hazard for the surrounding environment of the unit.

### **HAZOP Methodology for Condensate Oil Refinery**

1. Identify the critical section of process /plant and NODE is marked on proposed Piping and Instrumentation Diagram
2. Identify the deviation with respect to guide words.
3. Identify possible causes, related consequences, available safeguard and deviation in the proposed Piping and Instrumentation Diagram
4. Provide recommendations for improvement and review.

### **Nodes for Condensate Oil Refinery**

The Nodes which are selected are as followed:

Node 1: From Storage tank(S-100) to Outlet of Pump (P-100)

Node 2: From inlet of Heat Exchanger (E-100) to outlet of Furnace (E-103)

Node 3: Condensate Splitter (T-100)

### **Process Description**

#### **Pre-heating Section**

Condensate was stored in the storage tank S-100 at ambient temperature and pressures. The feed was then pressurized to 90 psi by centrifugal pump P-100. It is then passed through the Heat Exchanger Network (HEN) where it first exchange heat with the Naphtha returning from the Distillation Column T-100 and reaches 103°F while absorbing 0.46 MMBtu/hr. of heat, then it went to the Kerosene Heat Exchanger E-101 and then to the gas oil Heat Exchanger E-102 thus achieving a temperature of 198°F. Heat exchange with the obtained product was done in order to reduce the heating duty of the heater while simultaneously reducing the duty of the cooler thus making the process energy efficient. This sequence is possible once the feed has completed 1 cycle. For the first cycle the total amount of heat is provided by the heater E-103. After passing through the heat exchanger network,

process fluid was then passed through the furnace E-103 and the temperature rose to 450°F, this whole sequence causes 50 psi pressure drop.

### Condensate Splitter Section

The feed through pipeline L-06 enter in the column T-100 from sixteenth tray. Feed was heated by means of steam. Naphtha was obtained at the top of tower. At first naphtha was cooled to 228°F by means of air cooler AC-100. After air-cooler naphtha was passed through condenser C-100. In condenser naphtha was condensed out and then passed through three phase separator V-100. In V-100 off-gasses, water and hydrocarbon streams were separated. Column reflux ratio for naphtha obtained from V-100 was maintained as 1:1, this allowed one part of naphtha reflux to the column T-100 and one part to the naphtha heat exchanger E-100.

Kerosene was obtained as the side product from tenth tray of T-100. Since the initial boiling point (IBP) of obtained side streams are generally low, due to this reason side stripping is required in order to maintain the initial boiling point (IBP) of respective side streams Nelson (1969). Therefore, lighter components present in kerosene were stripped out by means of steam. Kerosene was then pumped to the E-101. Gas oil was then obtained as the bottom product from T-100, which was then pumped to E-102. The process flow diagram (PFD) of condensate Oil Refinery is shown in figure 1.

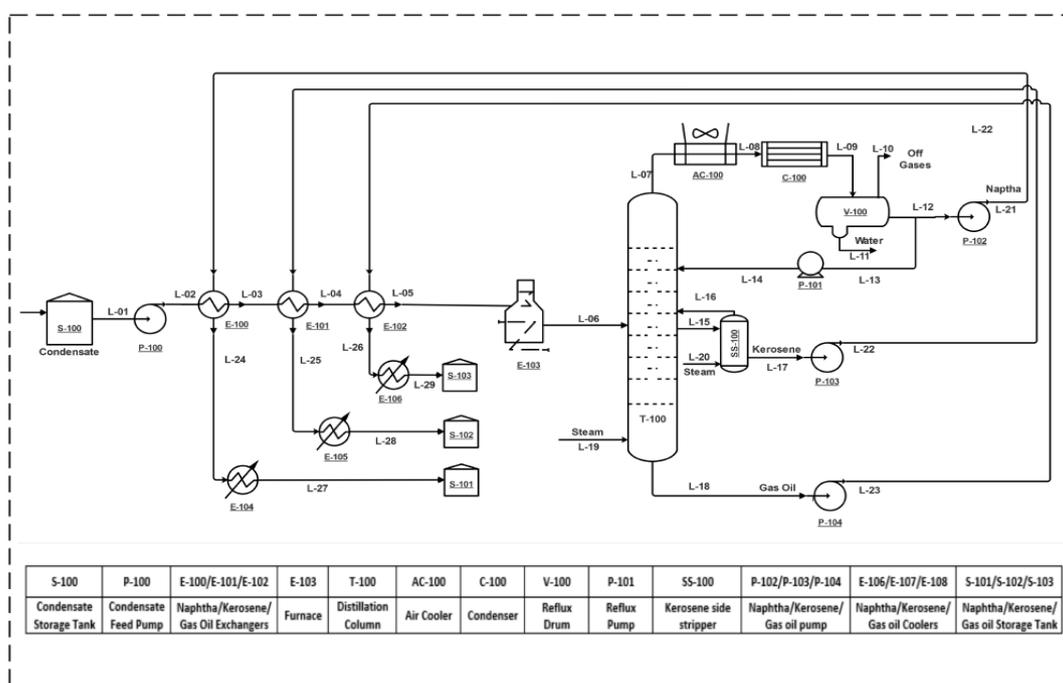


Figure 1. Process Flow Diagram (PFD) of Condensate Oil Refinery.

### Storage Section

Naphtha from V-100 was then pumped to E-100, where it exchanged heat with the process fluid and then passed through E-104. In E-104 temperature of naphtha was reduced to ambient temperature and then it was stored in storage tank S-101.

Kerosene from side stripper SS-100 was pumped to E-101, where it exchanged heat with the process fluid and then passed through E-105. In E-105 temperature of kerosene was reduced to ambient temperature and then it was stored in storage tank S-102. Also, gas oil from bottom of T-100 was pumped to E-102, where it exchanged heat with the process fluid and then passed through E-106. In E-106 temperature of gas oil was reduced to ambient temperature and then it was stored in storage tank S-103.

## RESULTS AND DISCUSSION

The HAZOP study was conducted using the procedure described above. For simplification, each important equipment was considered as a Node.

### Node 1: From Storage tank(S-100) to Outlet of Pump (P-100)

First node starts from the ‘Storage Tank (S-100)’ in which the condensate was stored and ends at Outlet of Pump (P-100). In this case 04 consequences were predicted for 06 possible causes. The malfunctioning of storage line (4’’-C-CS-101-40).and failure of pump (P-100) were found responsible for major deviations. Total 04 action were recommended to overcome the deviations (Table 2).

**Table 2.** Hazard and Operability (HAZOP) Sheet of Node 1.

| Node 1: Storage Tank (S-100) to Pump (P-100) |             |  |   |  |
|--|-------------|--|---|--|
| Process Parameters                           | Guide Words | Possible Causes  | Consequences  | Action Required  |
| FLOW   | No/Less     | <ul style="list-style-type: none"> <li>Leakage in stream (4’’-C-CS-101-40).</li> <li>Drain valve of storage tank(S-100) remained open.</li> <li>LT-01 malfunction</li> </ul> | <ul style="list-style-type: none"> <li>Failure of Pump (P-100).</li> <li>Cavitation in Pump (P-100).</li> </ul>                                       | <ul style="list-style-type: none"> <li>Installation of Flow indicator controllers at stream (4’’-C-CS-101-40).</li> <li>Installation of level indicator at storage tank(T-100).</li> </ul> |
|  | More        | <ul style="list-style-type: none"> <li>High pressure in stream (4’’-C-CS-101-40).</li> <li>Increase level in storage tank (S-100).</li> <li>LT-01 malfunction</li> </ul>     | <ul style="list-style-type: none"> <li>Damage of Pump (P-100).</li> <li>Over pressurization leading to rupture of stream (4’’-C-CS-101-40)</li> </ul> | <ul style="list-style-type: none"> <li>Install high level alarm at T-100</li> <li>Drain valve are installed on upstream and downstream of pump (P-100).</li> </ul>                         |

### Node 2: From inlet of Heat Exchanger (E-100) to outlet of Furnace(E-103)

Second node covers the area starting from “Heat Exchanger (E-100) to Furnace Outlet (E-103)”. In this case 05 consequences were predicted for 03 possible causes. Total 04 action were recommended to overcome the deviations. The malfunctioning of heat exchanger was found responsible for major deviations in the particular node. Node 1 and 2 for Hazop study are indicated in in Figure 2.

Third node covers the area of “Condensate Splitter (T-100)”. In this case 29 consequences were predicted for 25 possible causes. Total 20 action were recommended to overcome the deviations. The major malfunctioning included failure of vent valve, tower temperature & pressure (Table 3). The Table 4 is indicating Hazop spread sheet of Node 3 (Figure 3).

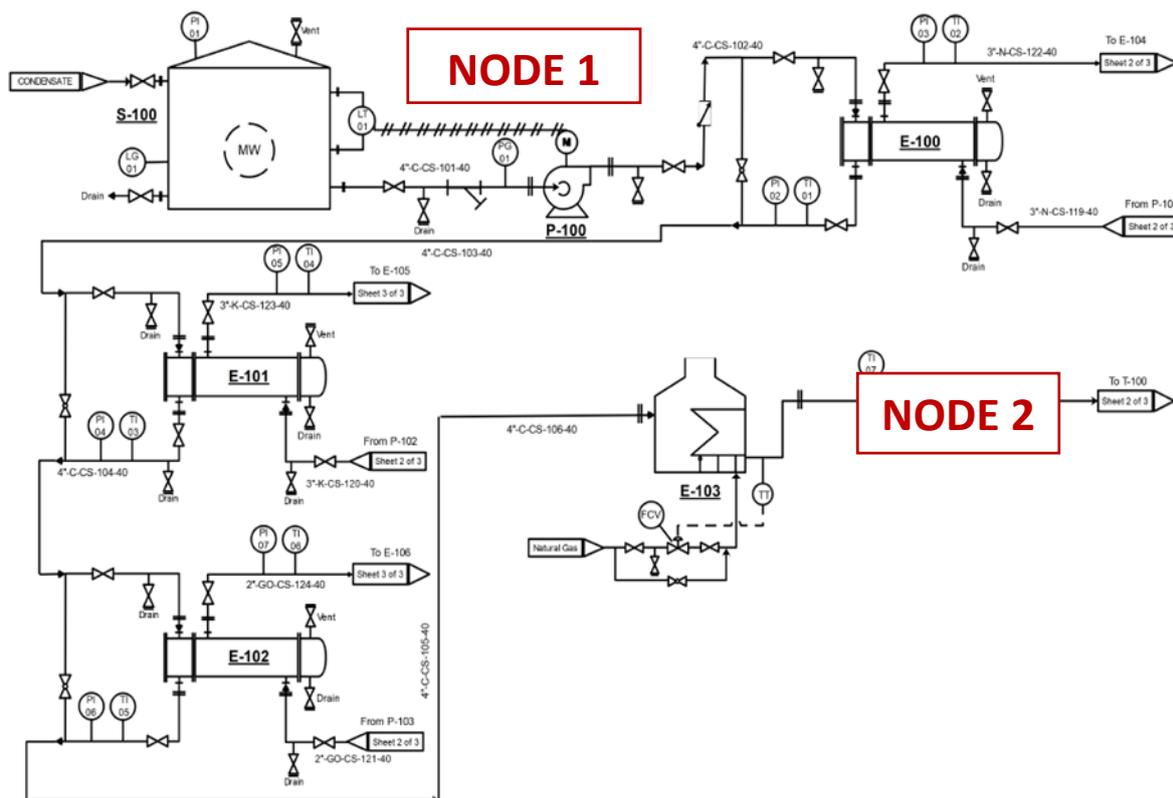


Figure 2. NODE 1 and 2 For Hazard and Operability (HAZOP) Study.

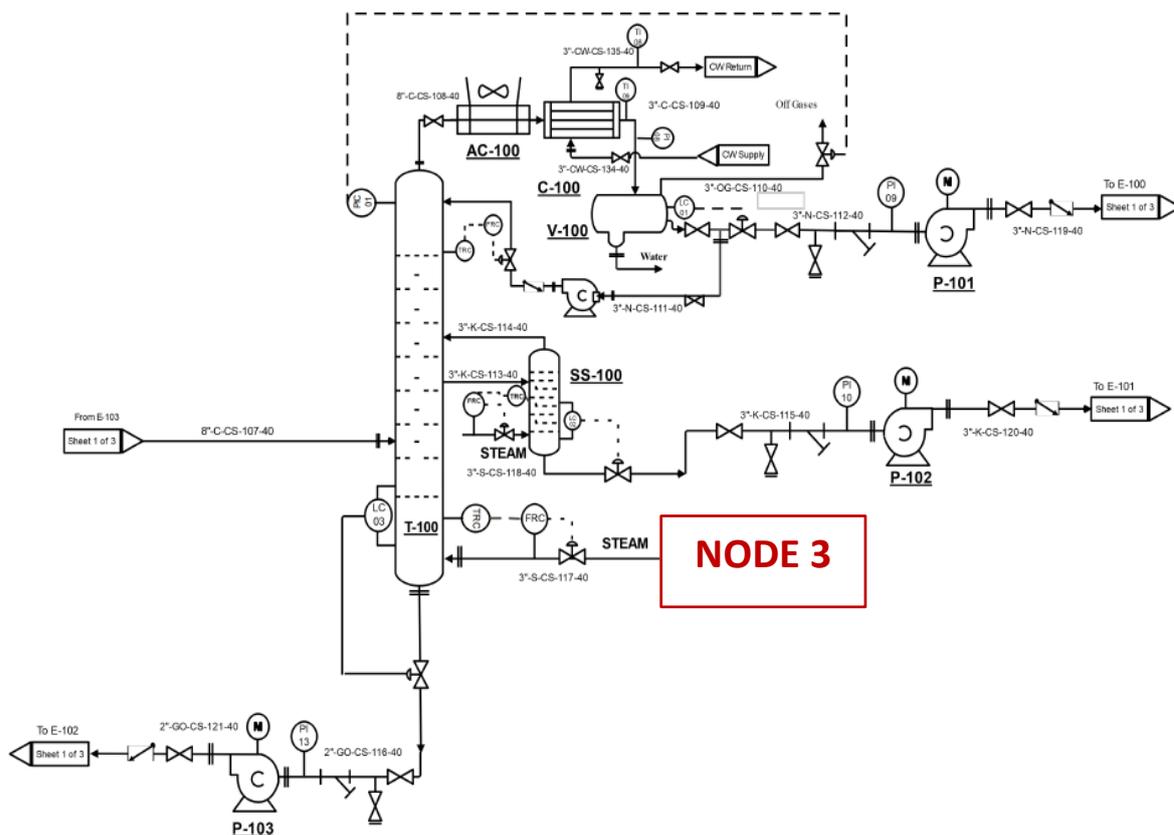
Table 3. Hazard and Operability (HAZOP) Sheet of Node 2.

| Node 2: Heat Exchanger (E-100) to Furnace (E-103) |             |  |  |   |
|---|-------------|--|--|---|
| Process Parameters                                | Guide Words | Possible Causes  | Consequences   | Action Required   |
| TEMPERATURE                                       | High        | <ul style="list-style-type: none"> <li>High flow of heating medium in stream (3"-N-CS-119-40).</li> </ul>  | <ul style="list-style-type: none"> <li>Overheating of process fluid results in vapor formation.</li> <li>Rupture of(4"-C-CS-104-40).</li> <li>Corrosion in tubes of heat exchanger in (E-100 to E-103).</li> </ul> | <ul style="list-style-type: none"> <li>Installation of High temperature alarm on downstream of (E-103).</li> <li>Install TI on downstream of P-101, P-102 and P-103.</li> </ul> |
|   | Low         | <ul style="list-style-type: none"> <li>Low flow of heating medium in stream (3"-N-CS-119-40).</li> <li>Scaling in tubes of heat Exchangers.</li> </ul> | <ul style="list-style-type: none"> <li>Increase in furnace load (E-103).</li> <li>Process fluid temperature too low.</li> </ul>  | <ul style="list-style-type: none"> <li>Installation of LTA on upstream and downstream of (E-103).</li> </ul>  |

**Table 4.** Hazard and Operability (HAZOP) Sheet of Node 3.

| <b>Node 3: Condensate splitter (T-100)</b> |                    |   |   |   |
|--|--------------------|---|---|---|
| <b>Process Parameters</b>                  | <b>Guide Words</b> | <b>Possible Causes</b>  | <b>Consequences</b>   | <b>Action Required</b>  |
| <b>FLOW</b>                                | No/Less            | <ul style="list-style-type: none"> <li>Blockage in stream(8"-C-CS-107-40).</li> <li>Control valve failure.</li> </ul>   | <ul style="list-style-type: none"> <li>Condensate splitter T-100 dry out.</li> <li>No operation in T-100.</li> </ul>  | <ul style="list-style-type: none"> <li>Install low level alarm at T-100</li> <li>Check maintenance procedure and schedule.</li> </ul>   |
|  | More               | <ul style="list-style-type: none"> <li>Control valve is fully opened</li> <li>Pump (P-100) malfunction.</li> </ul>  | <ul style="list-style-type: none"> <li>Flooding in the column T-100</li> <li>Changes in product quality</li> <li>Damage of pump (P-100) head and shaft.</li> <li>Temperature decrease T-100.</li> <li>T-100 level increases.</li> </ul> | <ul style="list-style-type: none"> <li>Install high level alarm at T-100</li> <li>Install FRC at (8"-C-CS-107-40).</li> <li>Drain valve are installed on upstream and downstream of pump (P-100).</li> <li>Check maintenance procedure and schedule.</li> </ul> |
| <b>Process Parameters</b>                  | <b>Guide Words</b> | <b>Possible Causes</b>  | <b>Consequences</b>   | <b>Action Required</b>  |
| <b>LEVEL</b>                               | High               | <ul style="list-style-type: none"> <li>Blockage of stream (8"-C-CS-108-40).</li> <li>Control valve is fully opened.</li> <li>No Steam Supply.</li> </ul>  | <ul style="list-style-type: none"> <li>Condensed liquid flow back to T-100.</li> <li>Flooding in T-100.</li> <li>Off Spec Product</li> </ul>  | <ul style="list-style-type: none"> <li>Install high level alarm at T-100</li> <li>Check maintenance procedure and schedule.</li> </ul>  |
|  | Low                | <ul style="list-style-type: none"> <li>Control Valve malfunctioned.</li> <li>Blockage in stream (8"-C-CS-107-40).</li> <li>Low level in storage tank (S-100).</li> </ul>                        | <ul style="list-style-type: none"> <li>Condensate splitter T-100 dry out.</li> <li>No operation in T-100.</li> <li>Cut distribution disturbed.</li> </ul>   | <ul style="list-style-type: none"> <li>Install low level alarm at T-100</li> <li>Check maintenance procedure.</li> </ul>  |
| <b>Process Parameters</b>                  | <b>Guide Words</b> | <b>Possible Causes</b>  | <b>Consequences</b>   | <b>Action Required</b>  |
| <b>PRESSURE</b>                            | High               | <ul style="list-style-type: none"> <li>No or less feed flow</li> <li>Failure of vent valve</li> <li>Blockage in stream (8"-C-CS-108-40).</li> </ul>   | <ul style="list-style-type: none"> <li>Off specification products</li> <li>Excessive entrainment</li> <li>Vapor velocity increases</li> <li>Steam valve malfunction.</li> </ul>   | <ul style="list-style-type: none"> <li>Install high pressure alarm and PIC.</li> <li>Check maintenance procedure and schedule</li> <li>Install PSV at T-100.</li> </ul>   |
|  | Low                | <ul style="list-style-type: none"> <li>Control valve is fully opened</li> <li>Vent remained open</li> <li>Vent malfunction.</li> </ul>  | <ul style="list-style-type: none"> <li>Off specification products</li> <li>Weeping will occur in T-100.</li> <li>Products collection stop.</li> </ul>   | <ul style="list-style-type: none"> <li>Install low pressure alarm and PIC</li> <li>Check maintenance procedure and schedule</li> </ul>  |
| <b>Process Parameters</b>                  | <b>Guide Words</b> | <b>Possible Causes</b>  | <b>Consequences</b>   | <b>Action Required</b>  |
| <b>TEMPERATURE</b>                         | High               | <ul style="list-style-type: none"> <li>Failure of temperature controller</li> <li>AC-100 malfunction.</li> <li>Blockage in stream(8"-C-CS-108-40).</li> <li>Steam valve malfunction.</li> </ul> | <ul style="list-style-type: none"> <li>Off specification products</li> <li>Vapor velocity increases</li> <li>Pressure of column increases.</li> </ul>   | <ul style="list-style-type: none"> <li>Install high temperature alarm</li> <li>Install TRC as well as FRC.</li> <li>Check maintenance procedure and schedule.</li> </ul>  |

|  |     |  |   |
|--|-----|--|---|
|  |     |  |   |
|  | Low | <ul style="list-style-type: none"> <li>• High feed rate</li> <li>• Failure of vent valve</li> <li>• Steam valve closed.</li> </ul> | <ul style="list-style-type: none"> <li>• Off specification products</li> <li>• Pressure decreases</li> <li>• Reflux ratio increases.</li> </ul> |
|  |     |  | <ul style="list-style-type: none"> <li>• Install LTA and TRC.</li> <li>• Check maintenance procedure and schedule.</li> </ul>                   |



**Figure 3.** NODE 3 For Hazard and Operability (HAZOP) Study.

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