Troubleshooting Two Vacuum Problems

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INTRODUCTION

In both cases presented, problems associated with condensers and vacuum systems are examined. These cases were chosen to illustrate how two completely separate problems can exhibit quite similar symptoms and how a formalized approach can assist in obtaining an accurate diagnosis. Accurate troubleshooting requires good data, careful analysis and attention to detail. As illustrated by these two cases, the differences in symptoms of problems may be quite subtle, and knowing what data to collect can be as important as the interpretation of the data

Because troubleshooting evaporator problems can be so esoteric, a formal logic tree was developed - a “troubleshooting chart”. For those of us who frequently are involved in troubleshooting evaporator problems, this organized approach has become instinctive. However, we have found that the discipline of a troubleshooting chart is quite useful to operating personnel by reducing some of the blind alleys that many times bedevil a troubleshooting situation.

Accurate troubleshooting requires accurate data. It is usually necessary to obtain vapor temperatures by converting vapor pressures into saturation temperatures. For this reason, the pressure readings are required to be as accurate as possible. The calculated temperatures are usually back checked with a hand held infrared temperature gun. Mill instrumentation is unusually inadequate for accuracy of data required. Therefore, it has been found expedient to provide our own portable instrumentation. Pressure data is usually collected with a Fluke Model 245 portable pressure transducer that plugs directly into a common volt-Ohm multimeter. We have found it advisable to back-check calculated temperatures with an infrared temperature gun. We use a Raytech RayngerST model

CASE 1

Case 1 occurred at a major southern Kraft mill where the customer noted a gradual condenser vacuum loss and corresponding capacity loss. The condenser and vacuum system consisted of a single surface condenser with an integral precooler, a two stage steam jet ejector with indirect contact intercooler and aftercooler. **Slide 1**

The integral precooler consisted of a baffled section of the condenser shell with its entrance at the most hydraulically remote point from the vapor inlet. Non-condensable gases and residual vapor enter the precooler section from the bottom of the condenser. The residual vapors are condensed and the vapors are cooled by cooling water as they travel upward in the baffled section to the outlet near the top of the condenser shell. The precooler exits directly into the primary steam jet ejector suction. The intercooler and aftercooler perform the same function as the precooler, but are stand alone heat exchangers. **Slide 2**

The initial data points were: **Slide 3**

1) vapor pressure in the vapor duct immediately before the condenser
2) vapor pressure and temperature in NCG line between integral precooler and first stage steam jet ejector
3) condenser cooling water inlet and outlet temperatures.

Data collected at those points indicated:

a) The approach temperature of 33°C (60°F) greatly exceeded the expected value of approximately 11°C (20°F), indicating that the condenser heat transfer coefficient was poor.
b) The gas inlet temperature of 60°C (140°F) at the first stage greatly exceeded an expected value of approximately 32°C (90 °F), indicating that the internal precooler was also not functioning properly.

Using the troubleshooting chart, we determined that the following additional data was required: **Slide 4**

a) Temperature profile of the condenser shell
b) Condenser condensate level

It should be noted here that a temperature profile of the condenser shell can be a powerful tool in evaluating surface condenser operation. For this case, with a top vapor entry condenser, one would expect there to be a small temperature gradient vertically from top to bottom for most of the shell. For that area of the shell containing the precooler, one would expect a larger gradient to be reversed and somewhat greater. The vapor temperature at the precooler section should be at vapor saturation temperature, and the vapor temperature at the top of the precooler section to be within ~five°C (ten °F) of the cooling water inlet temperature.

The secondary data showed a 28°C (50°F) temperature gradient on the condenser both outside the precooler section and inside the precooler section. This gradient indicated either an accumulation of non-condensable gasses or of condensate in the lower portion of the condenser. The normal condensate level observation ruled out an accumulation of condensate – indicating non-condensible gas accumulation. Again, from the troubleshooting chart indications were that uncooled vapor and non-condensible gasses bypassing the cooler and were venting higher up on the condenser shell. **Slide 5**

In this case, apparently a hole had corroded in the vapor side pass baffle and allowed vapor from near the top of the condenser to flow directly into the precooler section without having first gone through the main condensing section. The vapor bypass allowed a large volume of vapor to enter directly into the first stage steam jet ejector and prevented non-condensible gases in the lower portion of the cooler from escaping. **Slide 6**

As an interim repair, the mill installed a vapor line from the bottom of the condenser directly to the first stage steam jet ejector. This line bypassed the defective precooler, but did allow increased removal of non-condensable gasses. **Slide 7** With this modification, the evaporator was able to operate with a condenser vacuum of 17 kPa (2.5 psia) and a condenser vapor temperature of 57°C (135 °F). As a permanent solution, the mill installed a new ejector system with an external precooler. **Slide 8** The condenser is now operating at near design vacuum and capacity.

CASE 2

As in case 1, this customer was a major southern Kraft mill that experienced a gradual evaporation capacity loss due to reduced condenser vacuum. The configuration of the condenser and vacuum system was identical to case 1 – with a surface condenser and a two stage steam jet ejector system with shell and tube intercooler and aftercooler. The condenser also had an internal precooler section. **Slide 9**

The first set of data collected was similar to that collected in case 1 - vapor pressure in the vapor duct immediately before the condenser, vapor pressure and temperature immediately before the first stage steam jet ejector, vapor pressure immediately before the second stage steam jet ejector and condenser cooling water inlet and outlet temperatures. It was also observed that the condensate level was normal. **Slide 10**

This initial set of data indicated that:

a) The approach temperature of 58°C (105 °F) greatly exceeded the expected value of approximately 11°C (20°F), - indicating that the condenser heat transfer coefficient was poor.
b) The low temperature of gases approaching the first stage jet indicated that the internal precooler was functioning normally.

The troubleshooting chart indicated that either the ejectors were overloaded with excess NCG or there was a physical problem with the steam jet ejectors. **Slide 11** If an NCG overload existed, it would have most likely been caused by an air leak somewhere in the vacuum effects. Finding a vacuum leak usually requires an extended outage for a hydrostatic test of some kind to find. The decision was made to try to first determine if there were problems with the ejectors.

Page 3 of the troubleshooting chart indicated that additional data was required. **Slide 12** The temperature of the NCG line immediately adjacent to the first stage steam jet ejector body was read and found to be 71ºC 160 °F. This reading is in contrast to the 34ºC (94°F) temperature for the majority of the line. **Slide 13**. The high temperature at the suction of the ejector indicated excessive steam passing through (or around) the steam nozzle. - either because of a worn nozzle or a leak around the nozzle itself.

Although not listed on the troubleshooting chart, a final test was conducted to verify the preliminary conclusion that a mechanical problem existed with the ejector itself. This test determines the ejectors' vacuum under "deadhead" conditions, i.e. with NCG suction valve closed. This test indicated a maximum vacuum of 28 kPa (4.0 psia). **Slide 14** Normally a two stage ejector can evacuate to an absolute pressure of 5.2 kPa (0.75 psia). At this point it had been determined that the low vacuum was due to a mechanical problem with the ejector - most likely due to a worn steam either nozzle or steam bypassing the nozzle.

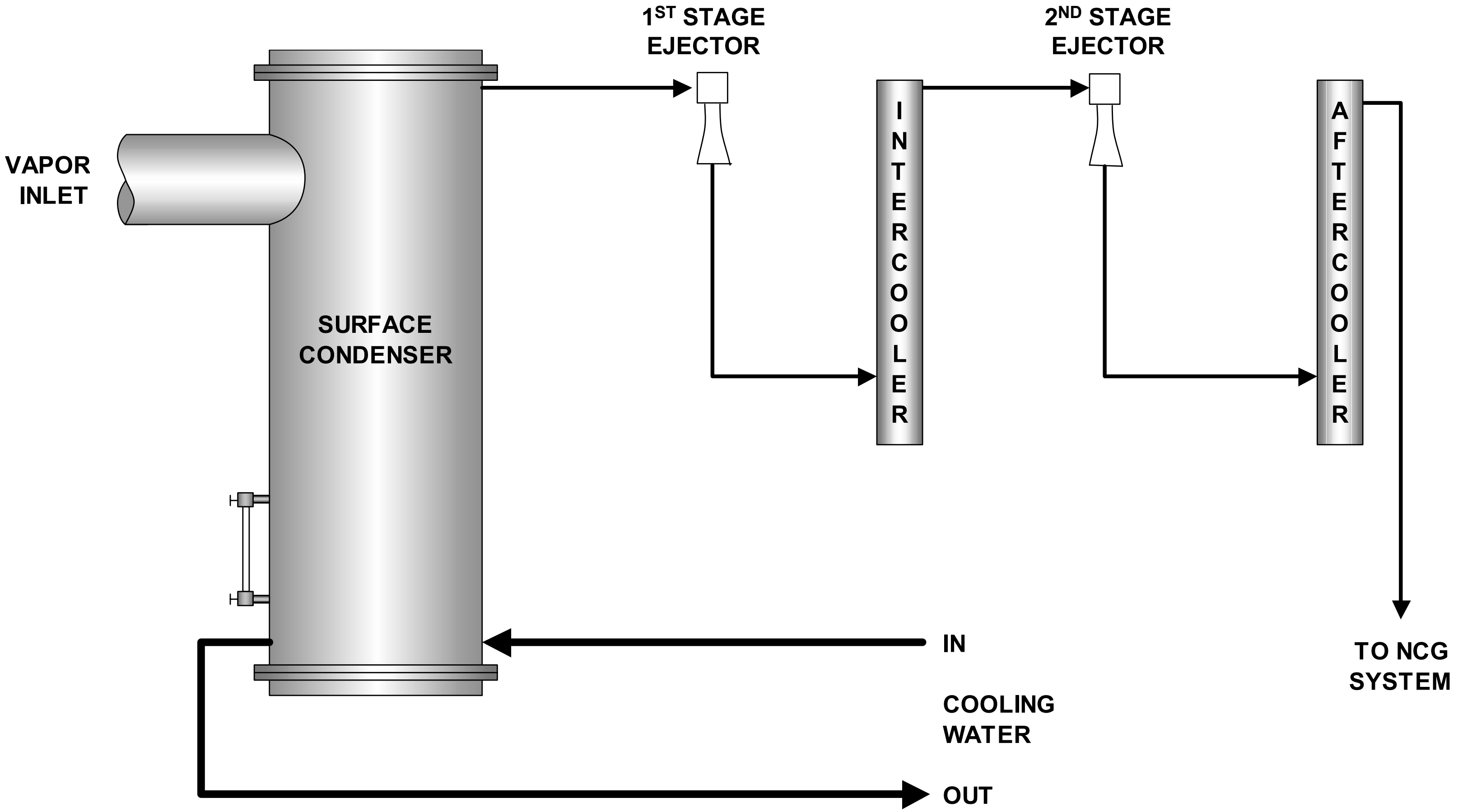
The evaporator was shut down and the first stage ejector was disassembled. A "wormhole" was observed in the ejector housing around the steam nozzle. **Slide 15** The "wormhole" is caused by a small steam leak through the threaded portion of the housing. The flow of the high pressure steam through the leak erodes the metal and forms a path for a significant amount of steam to bypass the nozzle.

After the repair, the evaporator was restarted and it was able to operate at near design vacuum and capacity.

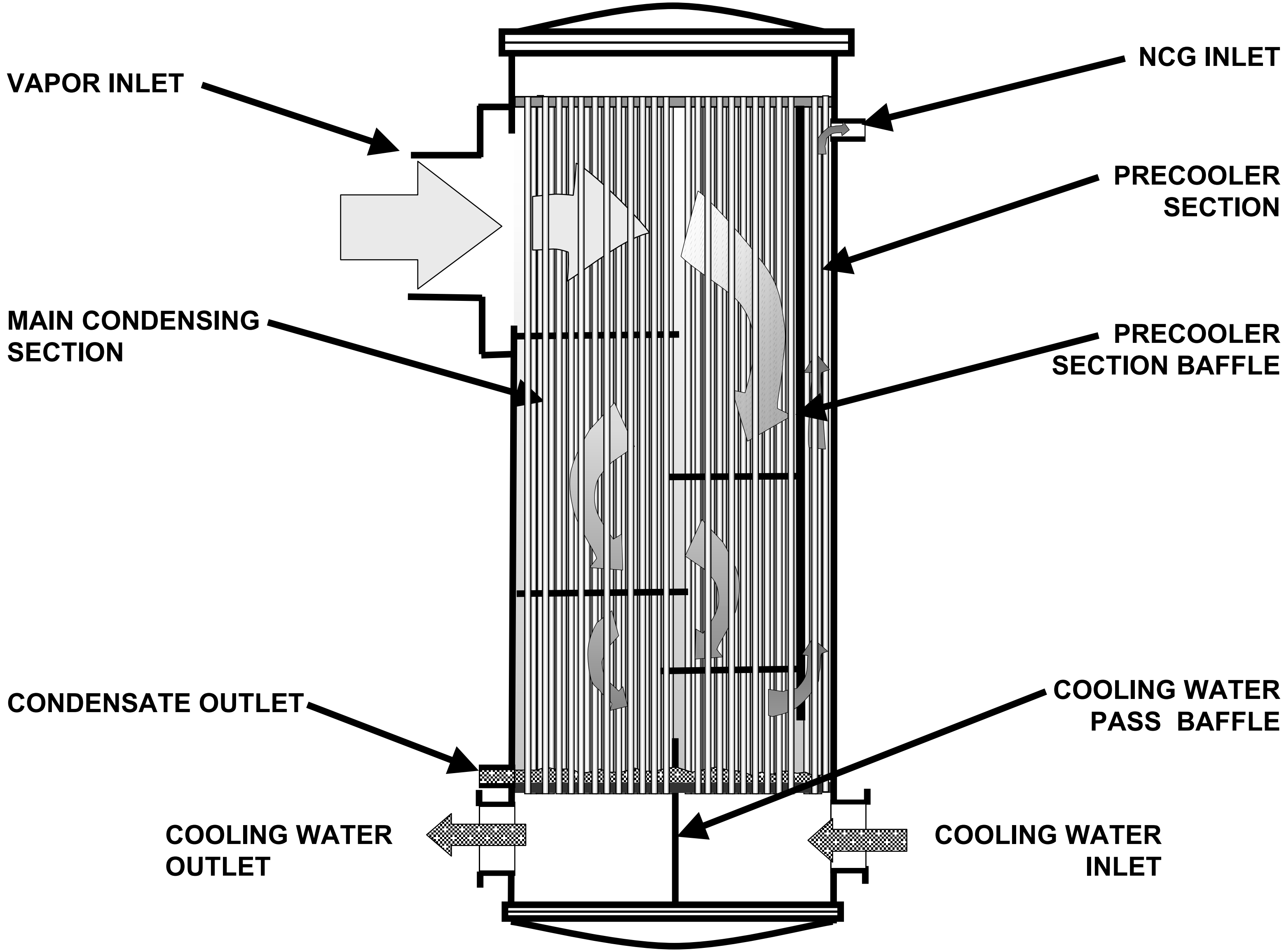
CONCLUSION

As stated in the introduction, these examples were chosen primarily to illustrate that different problems can exhibit similar symptoms and how an organized procedure is required to efficiently determine the cause. Please note from the two examples that the only observable difference between the two sets of initial data was the temperature of the NCG going to the first stage ejector.

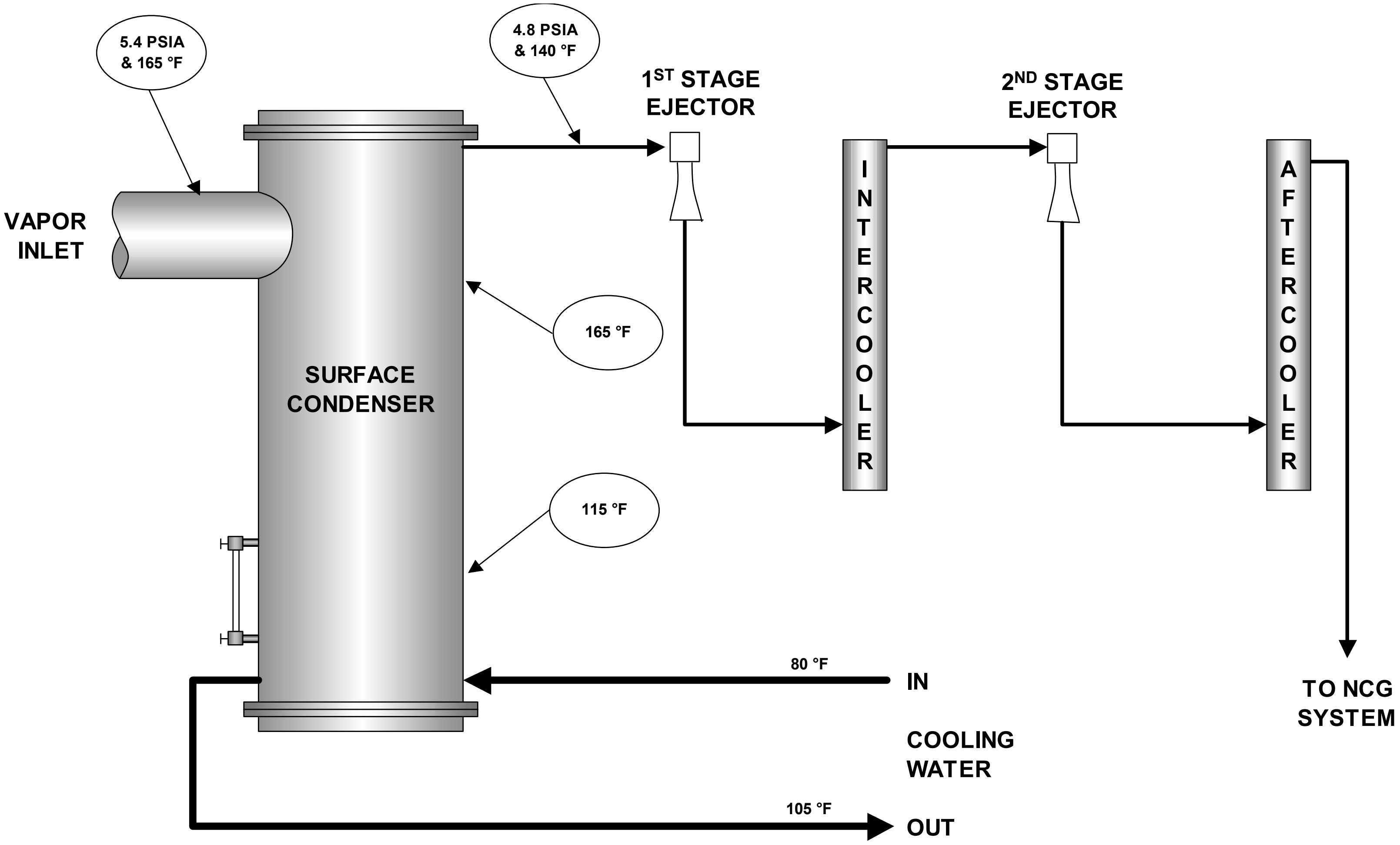
Secondarily, these examples were chosen because they were the only problems the two evaporators had at the time. The difficulty of troubleshooting an evaporator malfunction is greatly increased when there are multiple problems, especially if they show conflicting symptoms. As an example, if the condenser in case 2 had been fouled on the water side in addition to the ejector problem, the NCG to the first stage would have been hot from the condenser to the first stage ejector – symptoms similar to case1. This complication of case 2, would have made it much more difficult to identify the real problem.



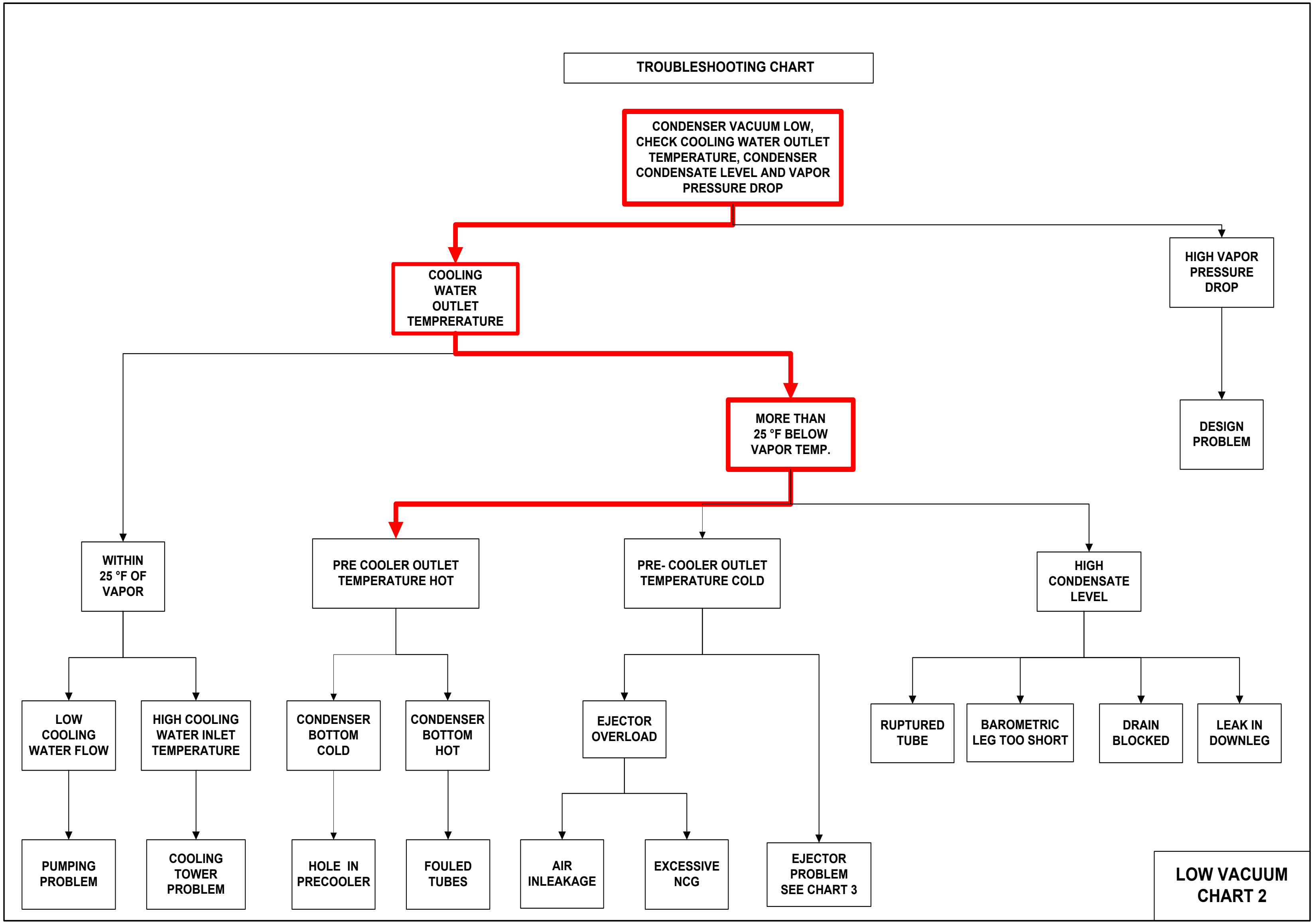
CASE 1 SURFACE CONDENSER AND VACUUM SYSTEM CONFIGURATION



VERTICAL SHELL AND TUBE CONDENSER WITH INTEGRAL PRECOOLER CROSS SECTION



CASE 1 SURFACE CONDENSER WITH EJECTOR SYSTEM – INITIAL DATA



TROUBLESHOOTING CHART

CONDENSER VACUUM LOW, CHECK COOLING WATER OUTLET TEMPERATURE, CONDENSER CONDENSATE LEVEL AND VAPOR PRESSURE DROP

COOLING WATER OUTLET TEMPRERATURE

HIGH VAPOR PRESSURE DROP

MORE THAN 25 °F BELOW VAPOR TEMP.

DESIGN PROBLEM

WITHIN 25 °F OF VAPOR

PRE COOLER OUTLET TEMPERATURE HOT

PRE- COOLER OUTLET TEMPERATURE COLD

HIGH CONDENSATE LEVEL

LOW COOLING WATER FLOW

HIGH COOLING WATER INLET TEMPERATURE

CONDENSER BOTTOM COLD

CONDENSER BOTTOM HOT

EJECTOR OVERLOAD

RUPTURED TUBE

BAROMETRIC LEG TOO SHORT

DRAIN BLOCKED

LEAK IN DOWNLEG

PUMPING PROBLEM

COOLING TOWER PROBLEM

HOLE IN PRECOOLER

FOULED TUBES

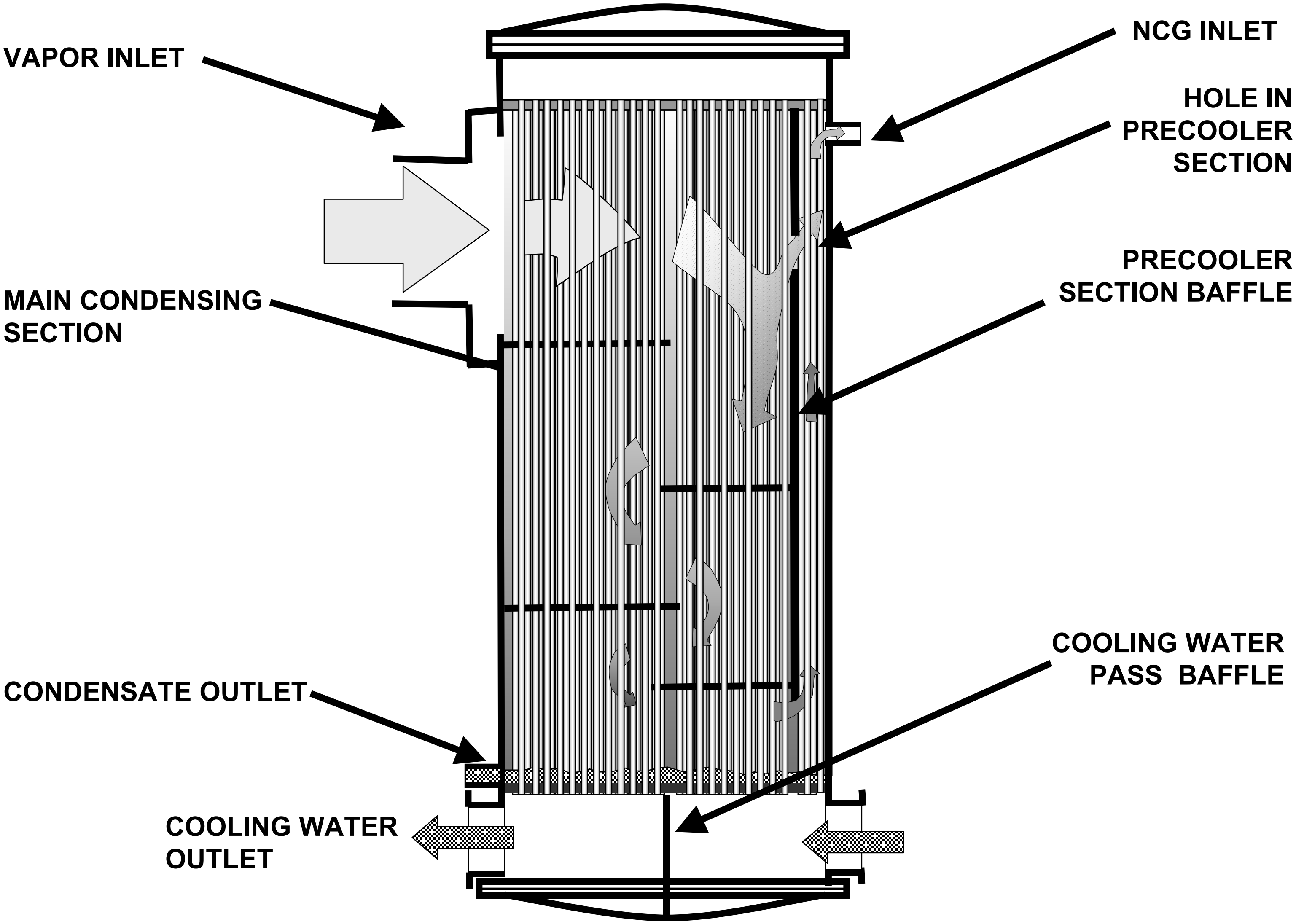
AIR INLEAKAGE

EXCESSIVE NCG

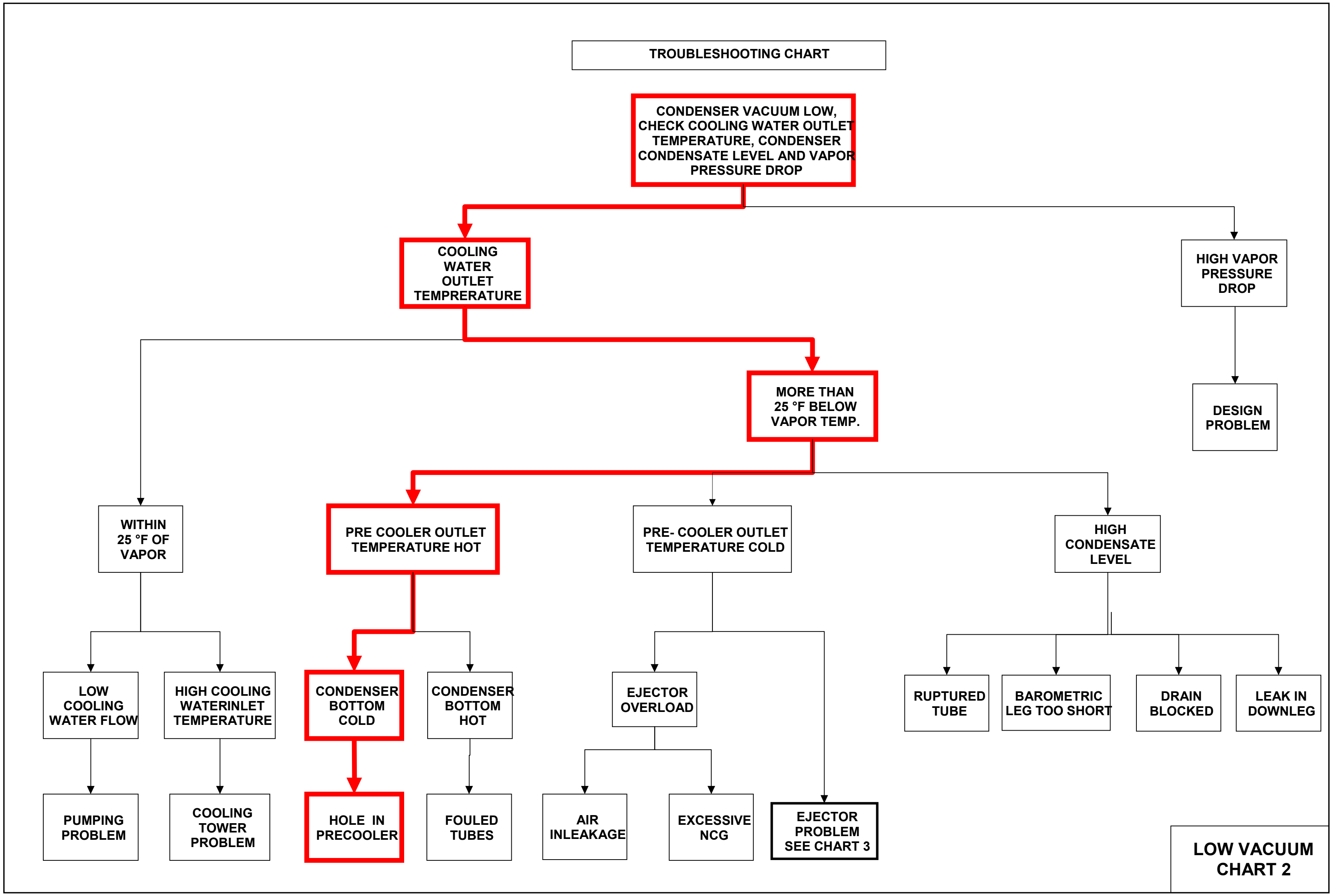
EJECTOR PROBLEM SEE CHART 3

LOW VACUUM CHART 2

CASE 1 RESULTS FROM INITIAL DATA



VERTICAL SHELL AND TUBE CONDENSER WITH HOLE IN PRECOOLER CROSS SECTION



TROUBLESHOOTING CHART

CONDENSER VACUUM LOW, CHECK COOLING WATER OUTLET TEMPERATURE, CONDENSER CONDENSATE LEVEL AND VAPOR PRESSURE DROP

COOLING WATER OUTLET TEMPRERATURE

HIGH VAPOR PRESSURE DROP

DESIGN PROBLEM

MORE THAN 25 °F BELOW VAPOR TEMP.

WITHIN 25 °F OF VAPOR

PRE COOLER OUTLET TEMPERATURE HOT

PRE- COOLER OUTLET TEMPERATURE COLD

HIGH CONDENSATE LEVEL

LOW COOLING WATER FLOW

HIGH COOLING WATERINLET TEMPERATURE

CONDENSER BOTTOM COLD

CONDENSER BOTTOM HOT

EJECTOR OVERLOAD

RUPTURED TUBE

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HOLE IN PRECOOLER

FOULED TUBES

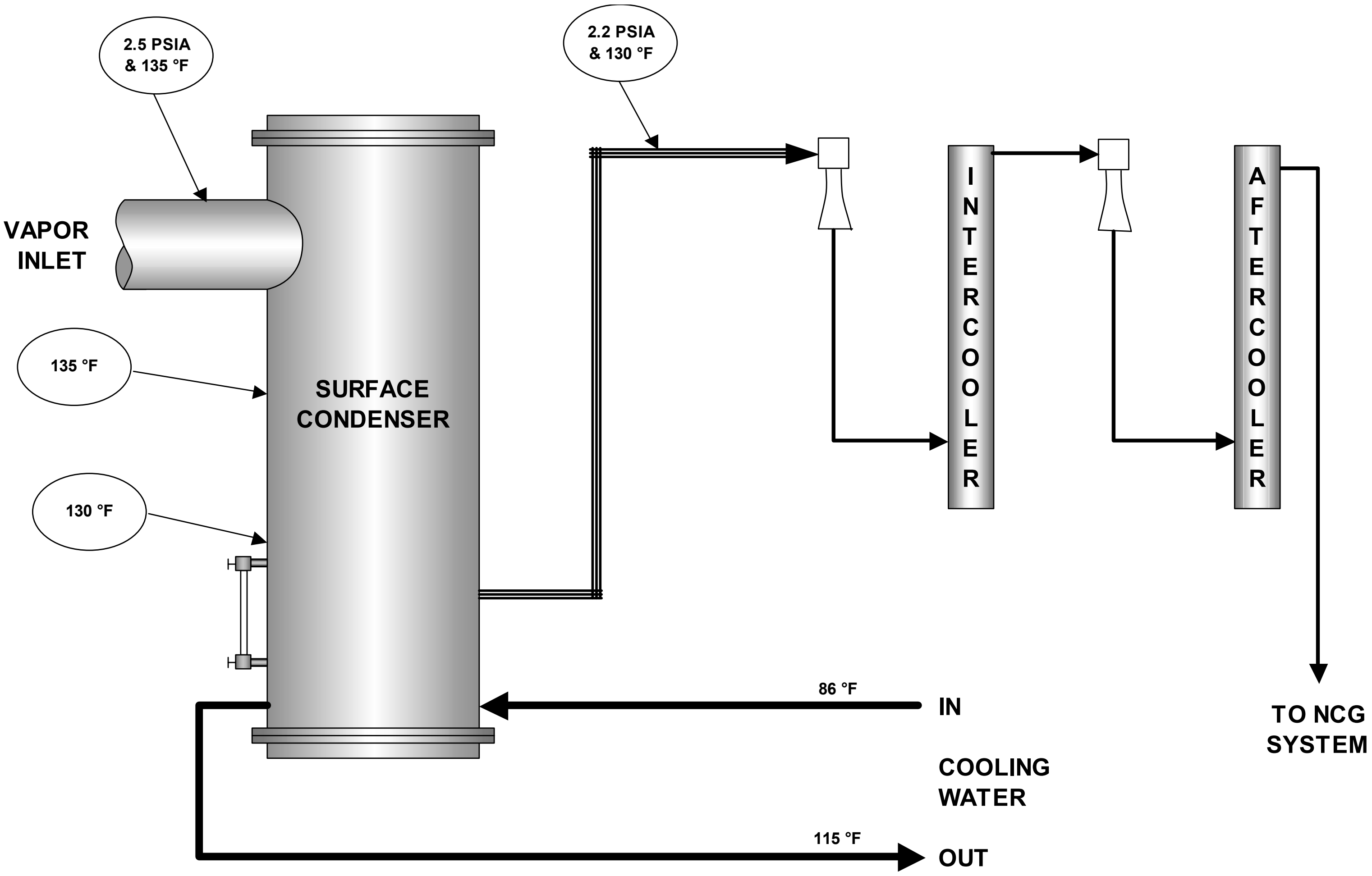
AIR INLEAKAGE

EXCESSIVE NCG

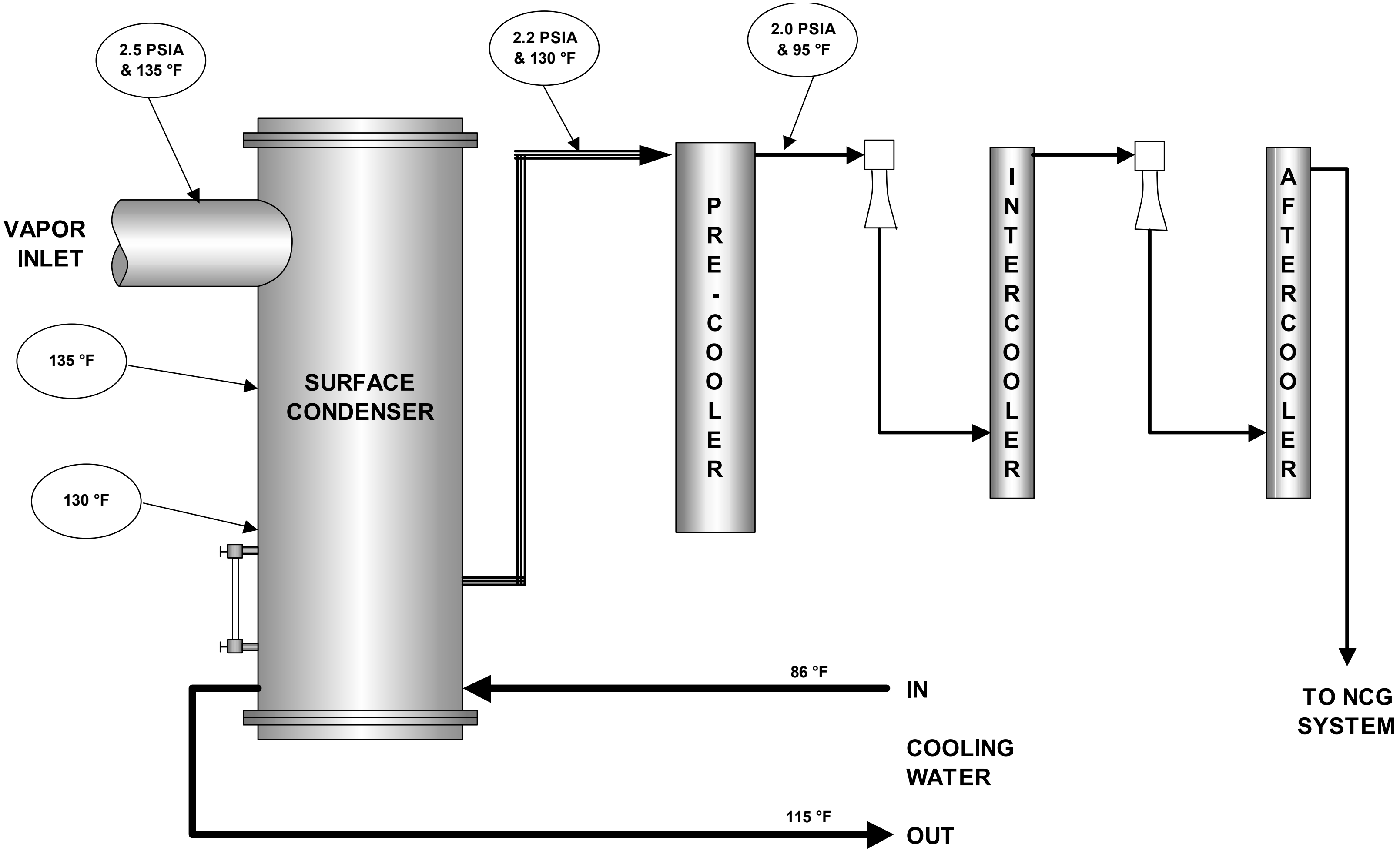
EJECTOR PROBLEM SEE CHART 3

LOW VACUUM CHART 2

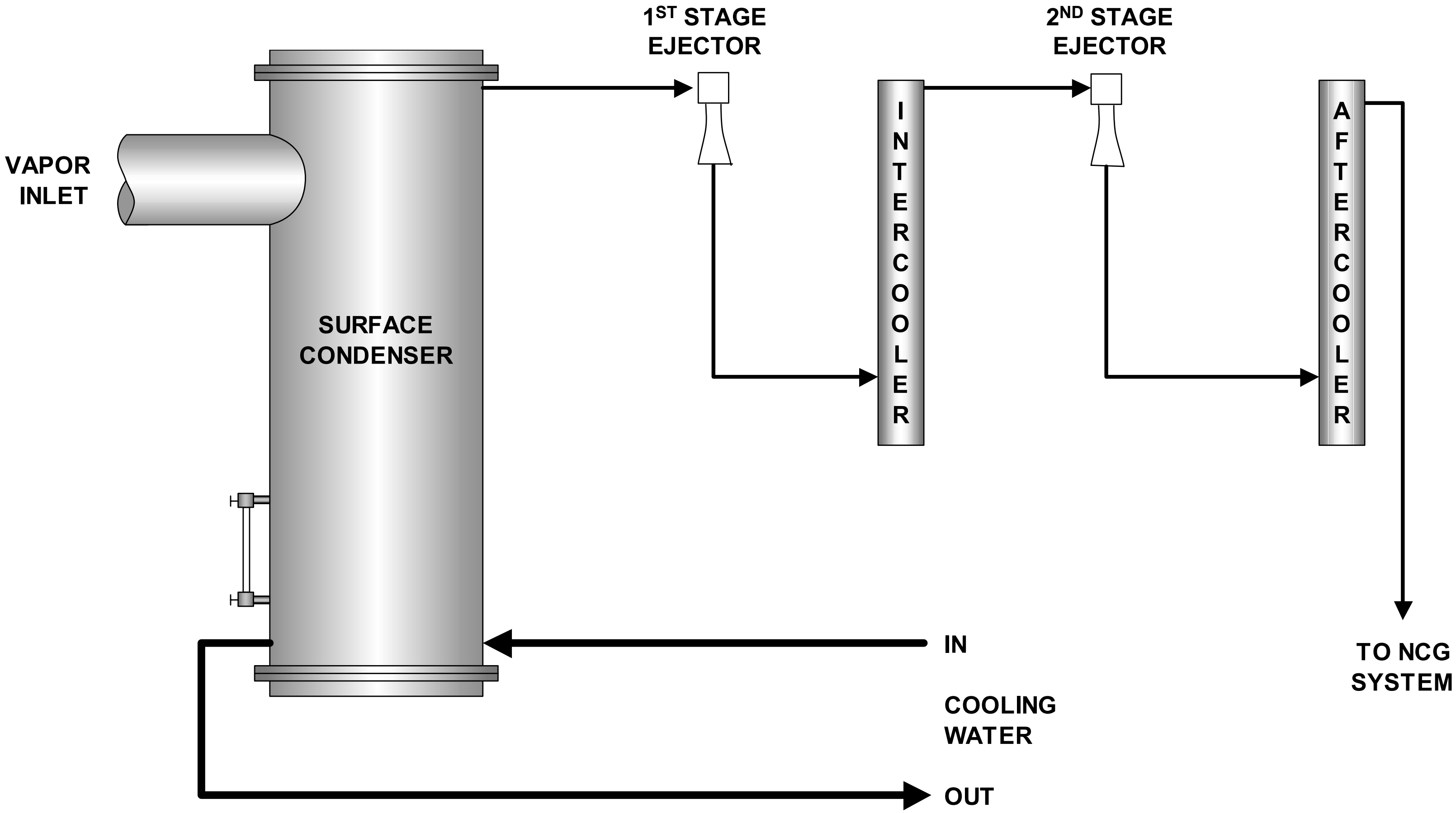
CASE 1 SOLUTION



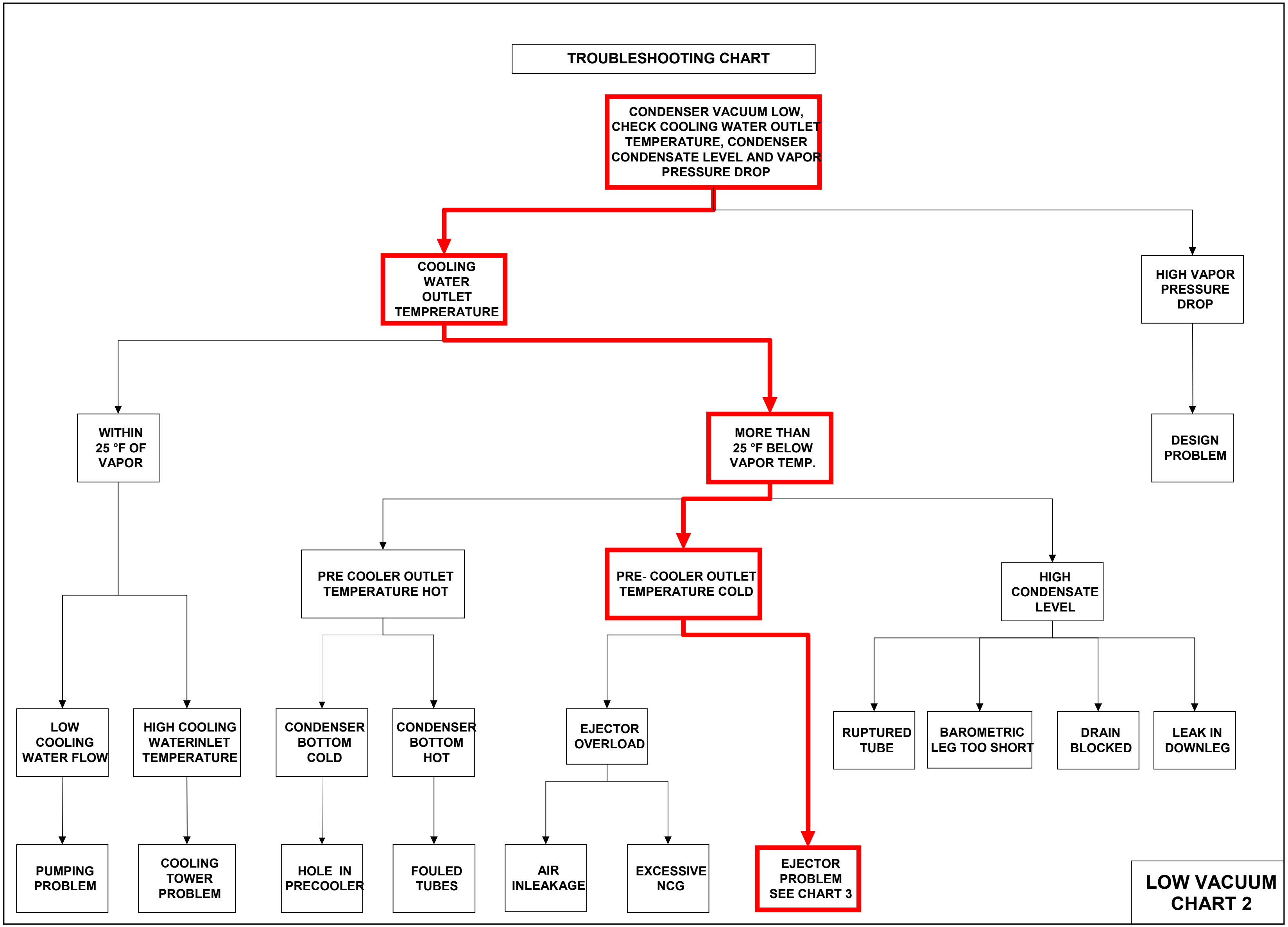
SURFACE CONDENSER WITH EJECTOR SYSTEM INTERIM SOLUTION DATA



CASE 1 SURFACE CONDENSER WITH EJECTOR SYSTEM FINAL SOLUTION DATA



CASE 2 SURFACE CONDENSER AND VACUUM SYSTEM CONFIGURATION



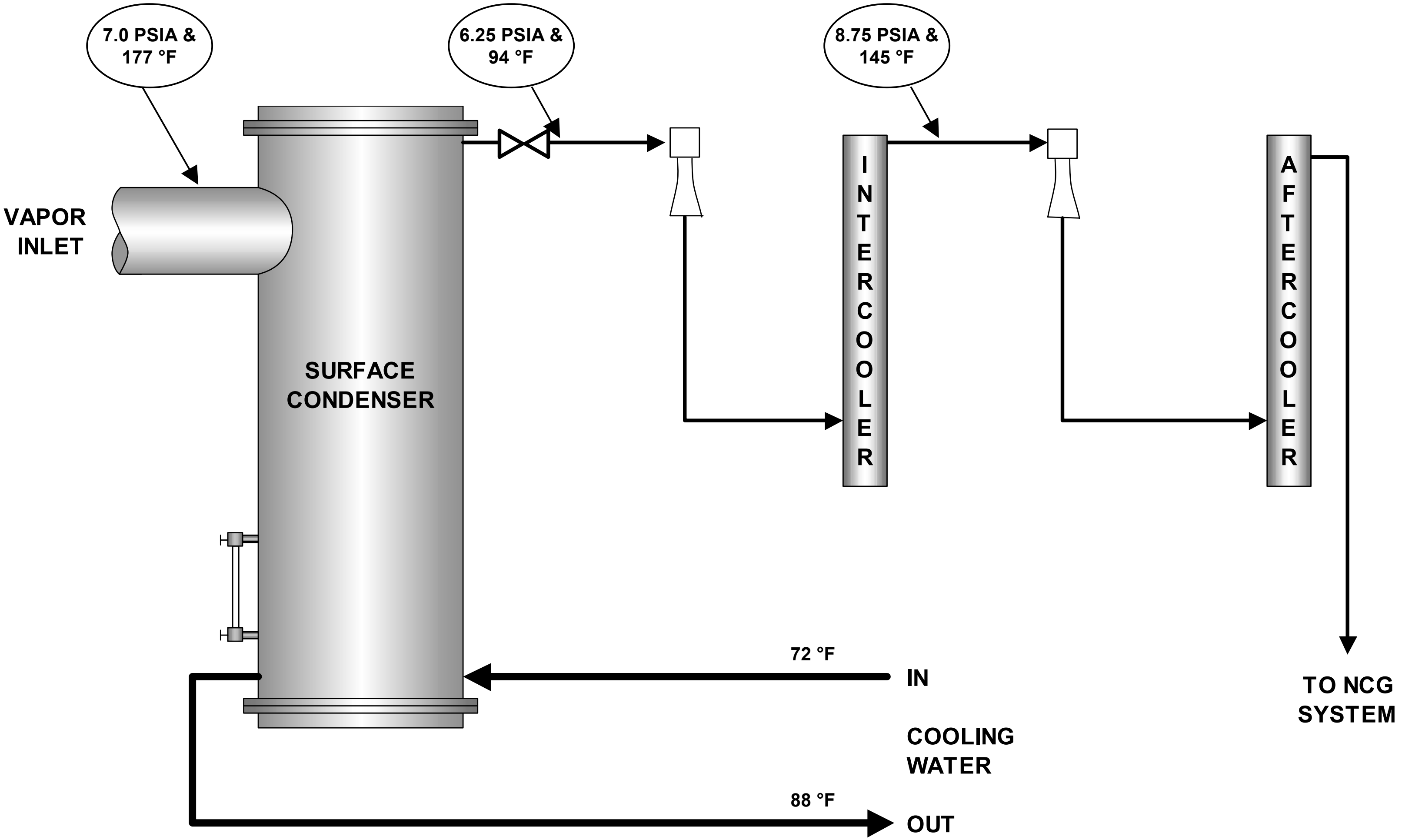
TROUBLESHOOTING CHART

CONDENSER VACUUM LOW, CHECK COOLING WATER OUTLET TEMPERATURE, CONDENSER CONDENSATE LEVEL AND VAPOR PRESSURE DROP

- COOLING WATER OUTLET TEMPRERATURE
  - WITHIN 25 °F OF VAPOR
    - LOW COOLING WATER FLOW
      - PUMPING PROBLEM
    - HIGH COOLING WATERINLET TEMPERATURE
      - COOLING TOWER PROBLEM
  - MORE THAN 25 °F BELOW VAPOR TEMP.
    - PRE COOLER OUTLET TEMPERATURE HOT
      - CONDENSER BOTTOM COLD
        - HOLE IN PRECOOLER
      - CONDENSER BOTTOM HOT
        - FOULED TUBES
    - PRE- COOLER OUTLET TEMPERATURE COLD
      - EJECTOR OVERLOAD
        - AIR INLEAKAGE
        - EXCESSIVE NCG
      - EJECTOR PROBLEM SEE CHART 3
    - HIGH CONDENSATE LEVEL
      - RUPTURED TUBE
      - BAROMETRIC LEG TOO SHORT
      - DRAIN BLOCKED
      - LEAK IN DOWNLEG
- HIGH VAPOR PRESSURE DROP
  - DESIGN PROBLEM

LOW VACUUM CHART 2

CASE 2 RESULTS FROM INITIAL DATA



7.0 PSIA &
177 °F

6.25 PSIA &
94 °F

8.75 PSIA &
145 °F

VAPOR
INLET

SURFACE
CONDENSER

INTERCOOLER

AFTERCOOLER

TO NCG
SYSTEM

72 °F

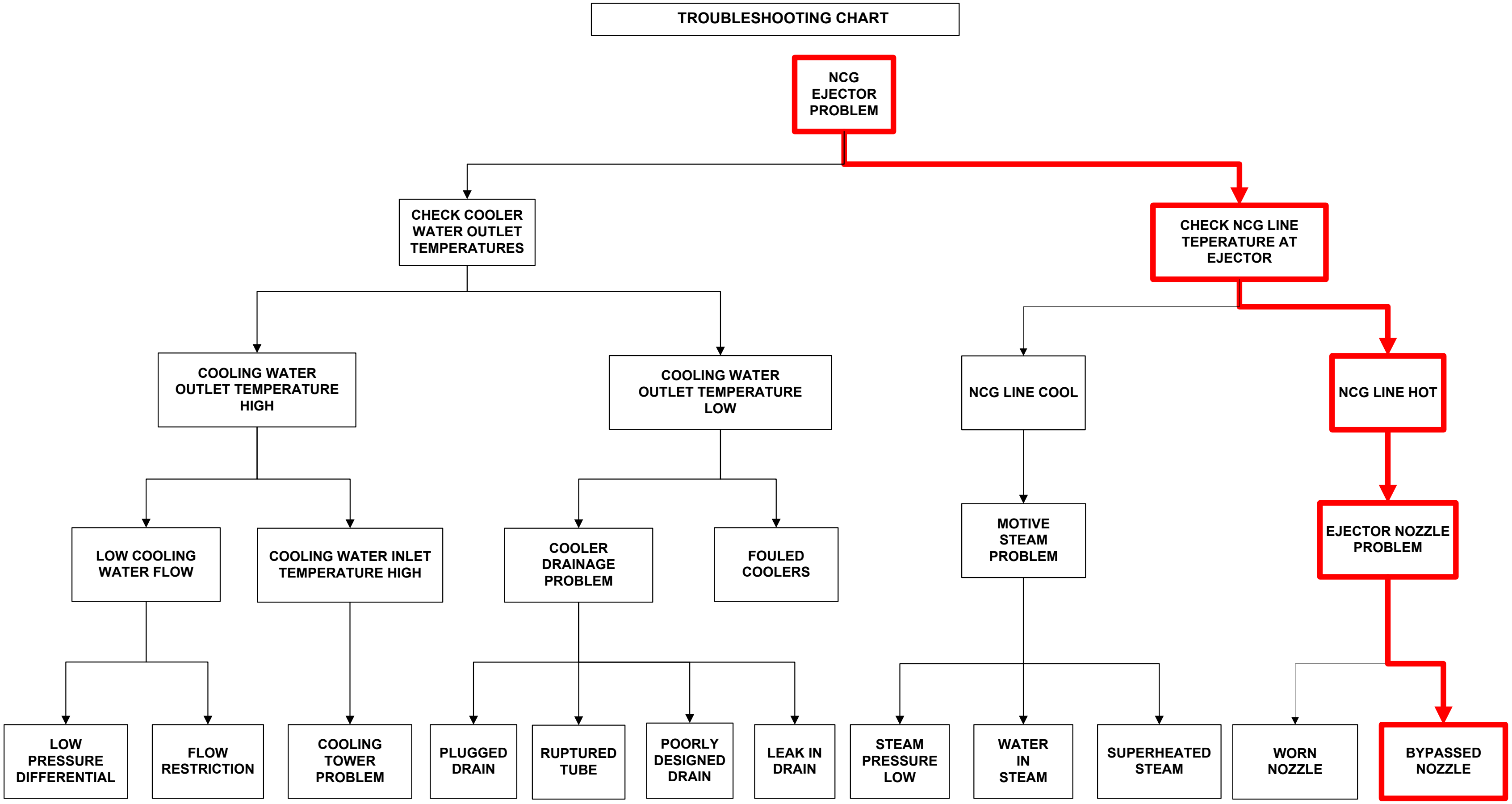
IN

COOLING
WATER

88 °F

OUT

CASE 2 SURFACE CONDENSER AND VACUUM SYSTEM INITIAL DATA



TROUBLESHOOTING CHART

NCG EJECTOR PROBLEM

CHECK COOLER WATER OUTLET TEMPERATURES

CHECK NCG LINE TEPERATURE AT EJECTOR

COOLING WATER OUTLET TEMPERATURE HIGH

COOLING WATER OUTLET TEMPERATURE LOW

NCG LINE COOL

NCG LINE HOT

LOW COOLING WATER FLOW

COOLING WATER INLET TEMPERATURE HIGH

COOLER DRAINAGE PROBLEM

FOULED COOLERS

MOTIVE STEAM PROBLEM

EJECTOR NOZZLE PROBLEM

LOW PRESSURE DIFFERENTIAL

FLOW RESTRICTION

COOLING TOWER PROBLEM

PLUGGED DRAIN

RUPTURED TUBE

POORLY DESIGNED DRAIN

LEAK IN DRAIN

STEAM PRESSURE LOW

WATER IN STEAM

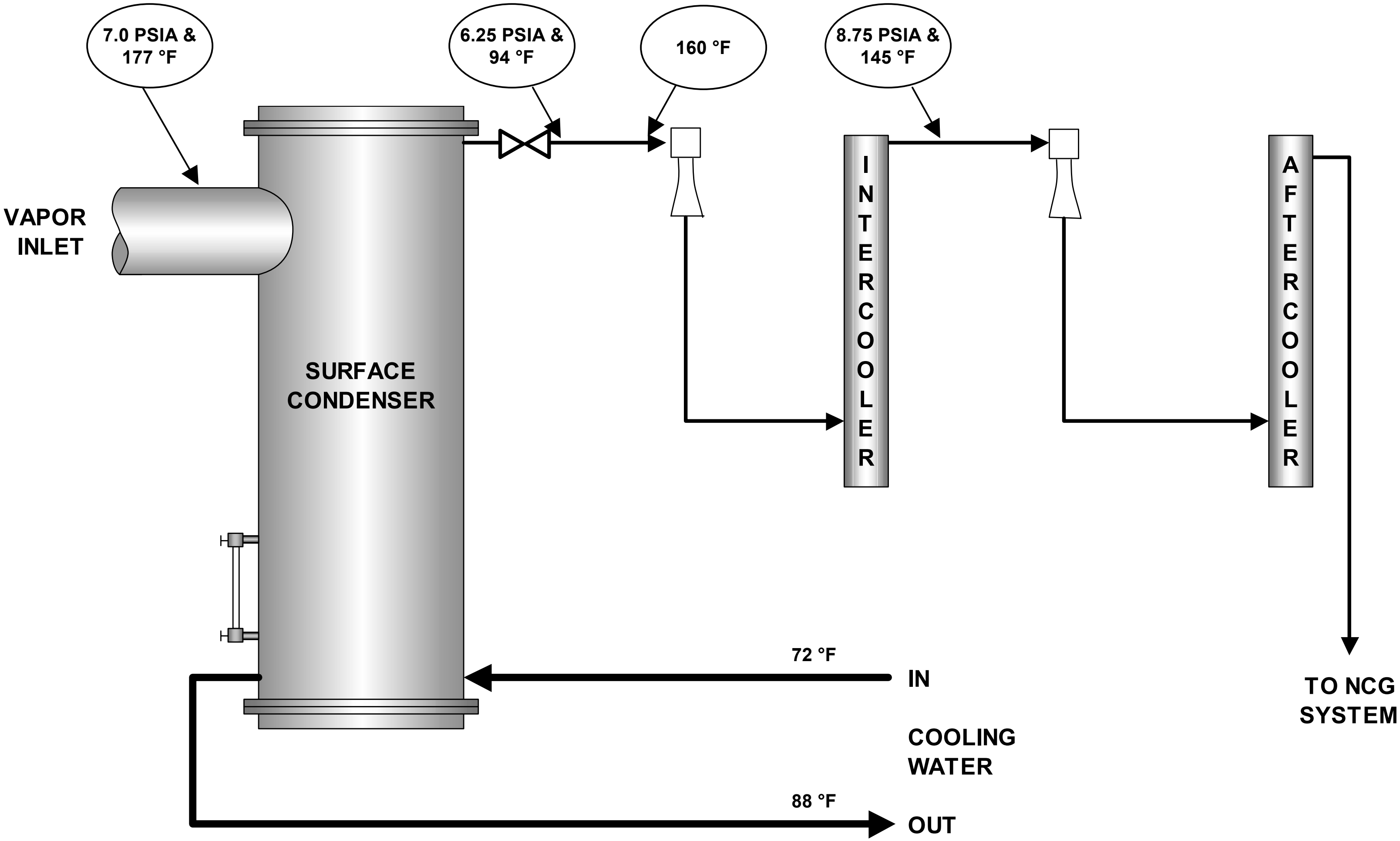
SUPERHEATED STEAM

WORN NOZZLE

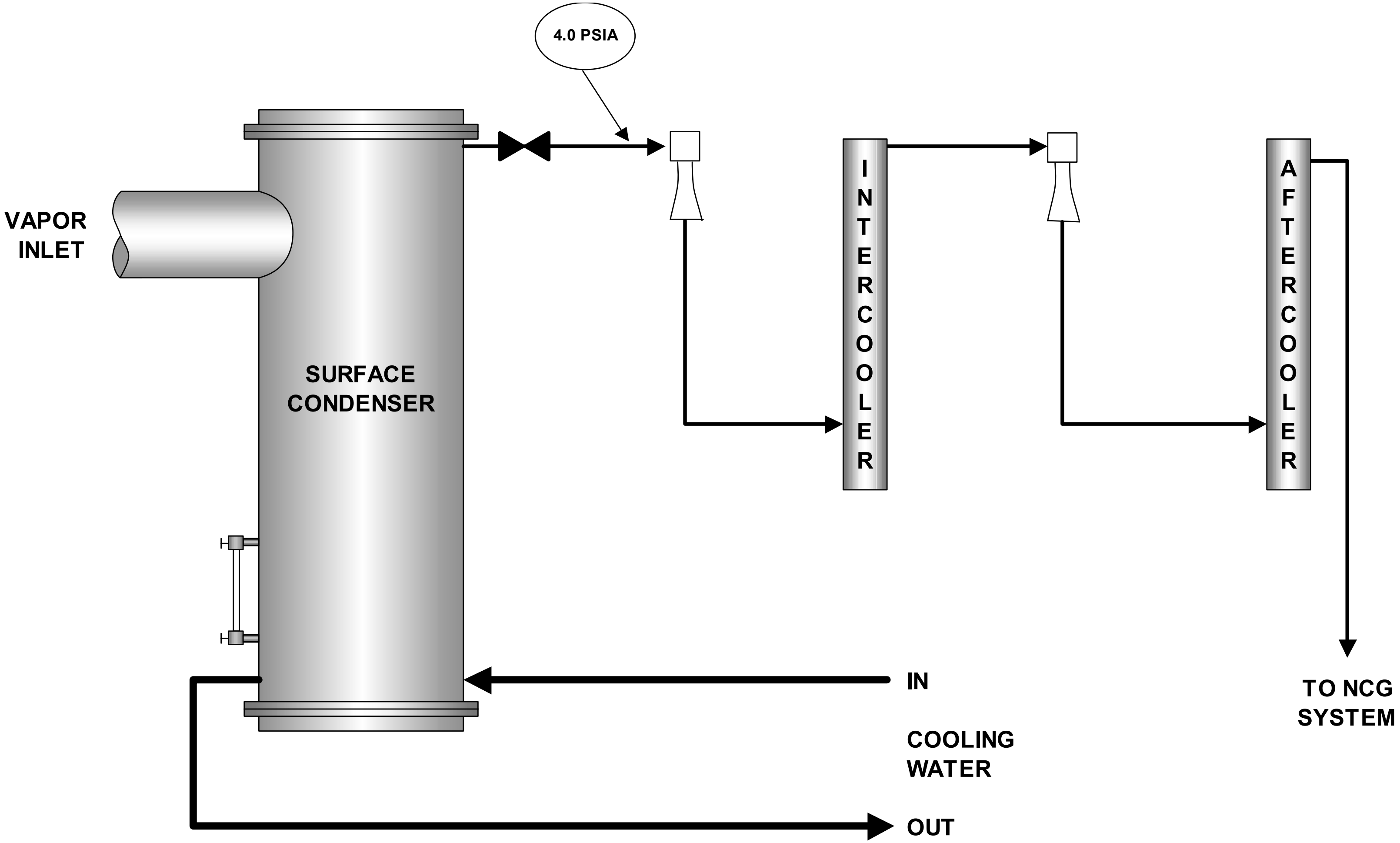
BYPASSED NOZZLE

LOW VACUUM CHART 3

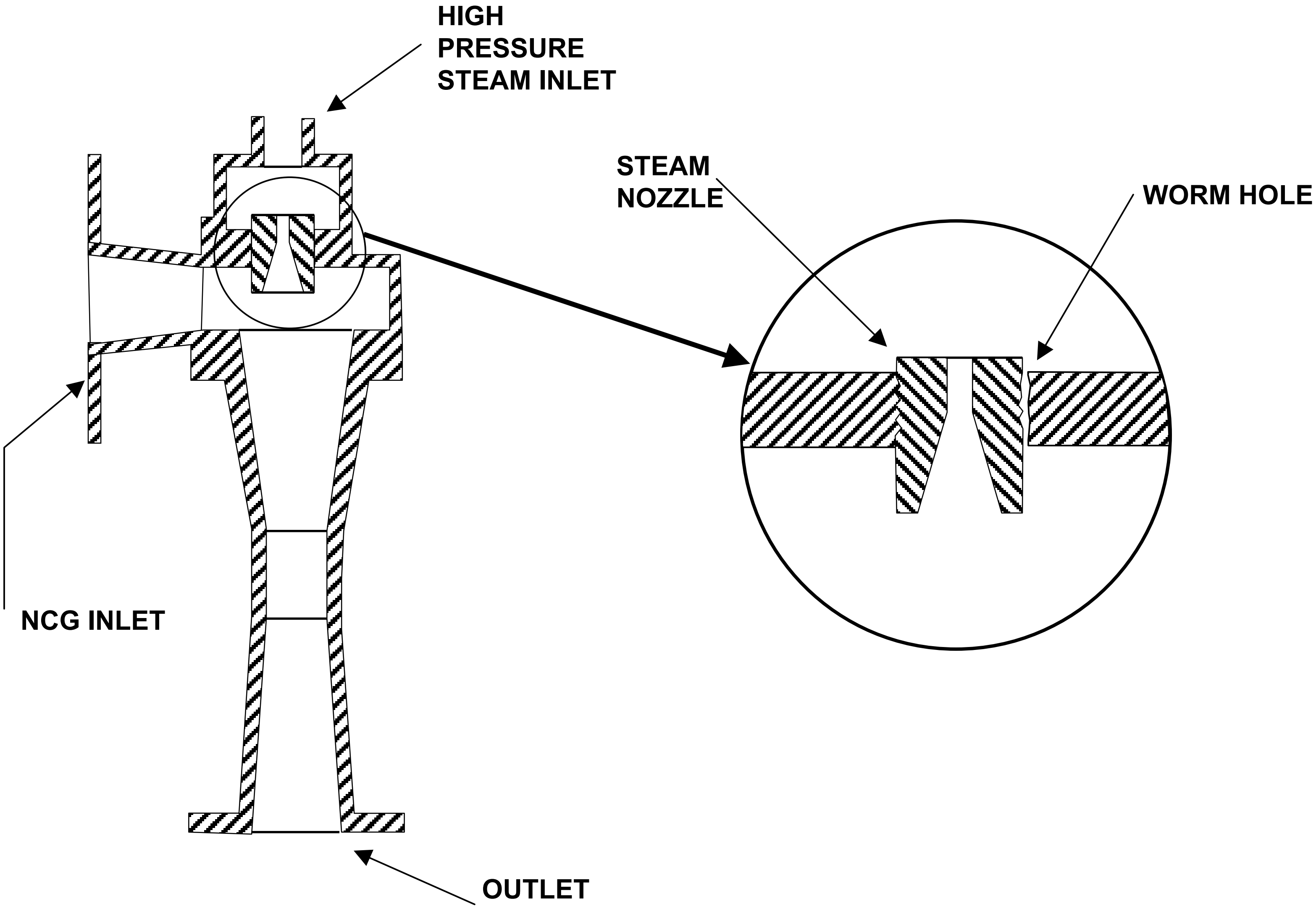
CASE 2 RESULTS FROM SECONDARY DATA



CASE 2 SECONDARY DATA COLLECTION



CASE 2 SURFACE CONDENSER AND VACUUM SYSTEM DEADHEAD TEST



STEAM JET EJECTOR CROSS SECTION