Navy Centrifugal Chiller Diagnostician Developed

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Objective

Provide auto-analysis and diagnoses of most probable causes of inefficiencies of centrifugal chiller operations caused by most common failures.

The program objective was to develop an automated, sophisticated, multi-level, real-time centrifugal chiller diagnostician. This diagnostician provides auto-analysis and diagnoses of most probable causes of inefficiencies of centrifugal chiller operations caused by common failures. It provides a generic diagnostic tool applicable to most major brands of centrifugal chiller units. Diagnostics are available under partial load conditions.

Key Accomplishments

The chiller diagnostics have been developed and integrated with the front end display. Display screens for the Chiller Diagnostician have been developed using Rockwell Software Systems Studio Special Edition software. This front end provides instrument monitoring, alarm monitoring, and trending. Displays have been developed for each chiller unit (Figure 1) and 87 diagnostic, alarm, and warning conditions (Figure 2), which indicate the problem identification, impacts, likely causes, and corrective actions. Five chiller units in remote PNNL buildings are currently being monitored over a LAN.

Diagnostics have been developed for:

- Compressor High Starts
- Compressor High Load
- Evaporator High Flow
- System Low Charge
- System Over Charge
- Condenser High Flow
- Evaporator Low Flow
- Condenser Low Flow
- Evaporator Fouling
- Running Non-condensables
- Off-Line Non-condensables
- Condenser Fouling.

The following instruments and calculated values are monitored on the live screen display with associated diagnostics for high alarm, high warning, low warning, and low alarm conditions:

- Chilled water in
- Chilled water out
- Chilled water delta temperature
- Evaporator refrigerant pressure
- Evaporator refrigerant temperature
- Evaporator approach temperature
- Condenser refrigerant pressure
- Condenser refrigerant temperature
- Condenser approach temperature
- Condenser water in
- Condenser water out
- Condenser water delta temperature
- Load percentage rate
- Chiller efficiency in KW/Ton
- Chilled water flow
- Condenser water flow.

Each instrument and calculated value are also available for extensive trending either as a single instrument or value, or several instruments and values can be analyzed together on the trend display. All instruments, calculated values, and problem identifications have a diagnostic screen that will provide alert and alarm notifications with the following information:

- Problem Identification - what the problem is.
- System Impact - what the potential impact of the problem is on the system operation.
- Likely Causes - what the three most probable causes of the problem are.
- Corrective Action - what the three most probable steps the operator should take to mitigate the problem are.
- Actual Condition - what the current condition is.
- Desired Condition - what the current condition should be.

Additional information displayed:

- Diagnostic status
- Custom trends option button for the evaporator
- Custom trends option button for the condenser
- Chiller running/off status
- Chiller location
- Chiller model number and design tons
- Alarm and alert summary screen
- Chiller water flow design rate
- Condenser water flow design rate.

The following lists unique capabilities developed into this software:

- Event analysis
- Event counter
- Event based data logging
- Innovative TCP/IP data acquisition for string type data
- Improved OPC communications
- Advanced intuitive graphical user interface
- Developed diagnostic factory-engineered curve fit algorithms for a centrifugal chiller
- Developed ability to interpret string data (text messages) for faults vice just numerical data
- Applied a polynomial function generator to support partial load diagnostics vice full load diagnostics (industry standard) allowing diagnostics under partial load conditions.

The software has been monitoring five centrifugal chiller units at PNNL via a LAN connection since March 1, 2003. All of the diagnostic algorithms are developed, but most have yet to be tested on an actual unit due to unavailability of a unit for testing purposes. Proof of principal was accomplished when the diagnostician did determine a problem. On May 21, 2003, one of the monitored Carrier machines faulted in our software with a low refrigerant charge indication. After looking at the data, it appeared to the Principal Investigator (PI) that indeed it was running with a low charge. The PI contacted the operations personnel who immediately checked the machine under part load conditions and stated that everything was fine. The PI waited until later in the day and then met the operations personnel over at the chiller. They set the chilled water temperature down to load up the machine. The chiller eventually started to limit out on freeze protection. The operations staff agreed at that point that it probably was in a low charge condition and would be adding some more refrigerant. This machine was recently serviced for summer and everyone thought it was ready to run. The operations staff added approximately 50 lbs of refrigerant. In Figure 3, you will see the dips and rises in pressure and temps that we trapped to see our fault condition. It is apparent that we can see this kind of fault in real time, but we do need to tune the model some to eliminate some false alarms we have seen in the past. You can also notice the dips and rises just before the 5:46 time stamp on May 21 and then again near the right of the chart. This is when the machine limited out. Figures 4, 5, and 6 indicate the logic trees for three of the diagnostics.

Current expectation is to continue to monitor operation of PNNL chiller units to confirm it identifies, in the early stages, any problems with these units. A Beta version of the Chiller Diagnostician will be available on a compact disk; however, due to the vast array of centrifugal chillers and refrigerants, the software does require some amount of modeling of the monitored chiller and its factory data to allow for the training of the diagnostician.

Additional documentation can be obtained by contacting:

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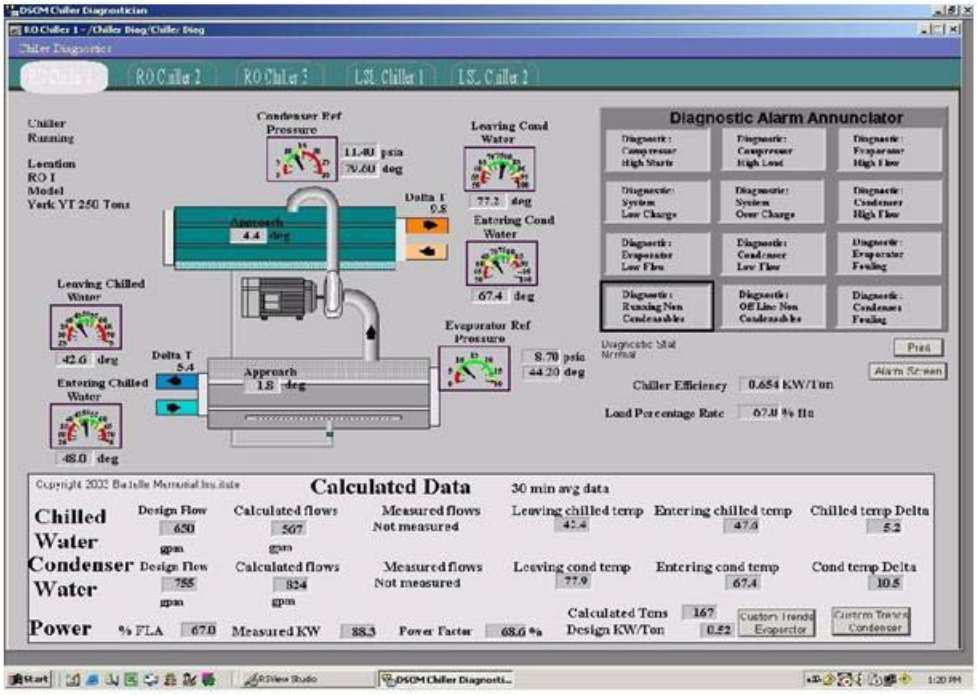

Figure 1: Main Chiller Display

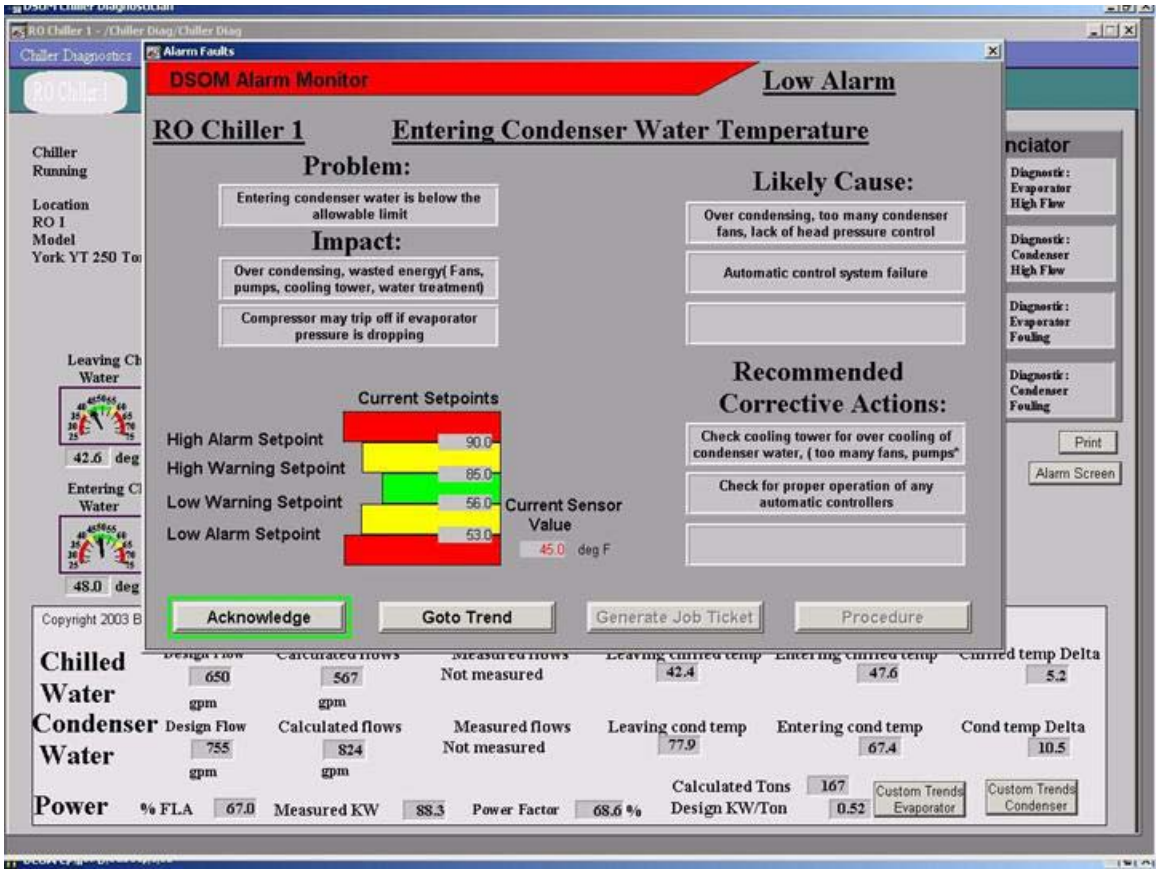

Figure 2: Chiller Diagnostician Alarm Display

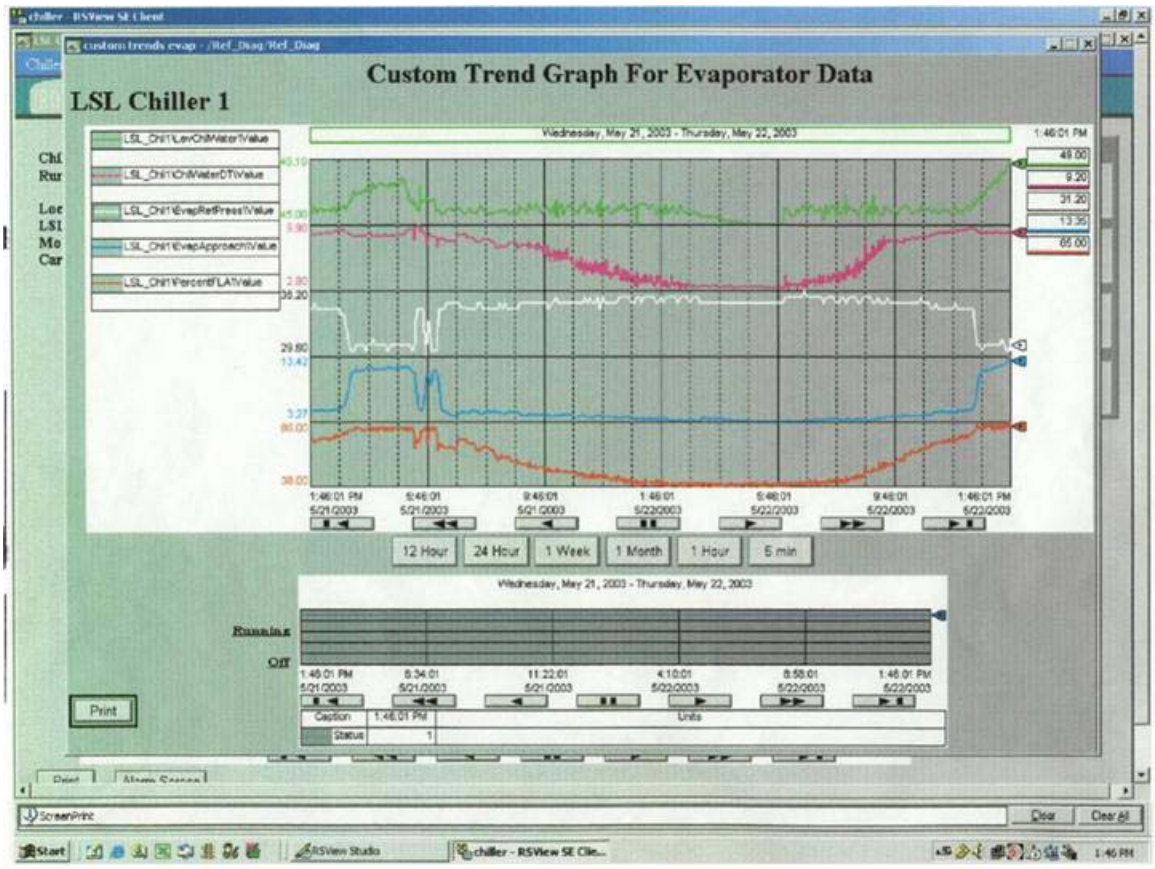

Figure 3: Trend graph indicating conditions for low refrigerant diagnosis

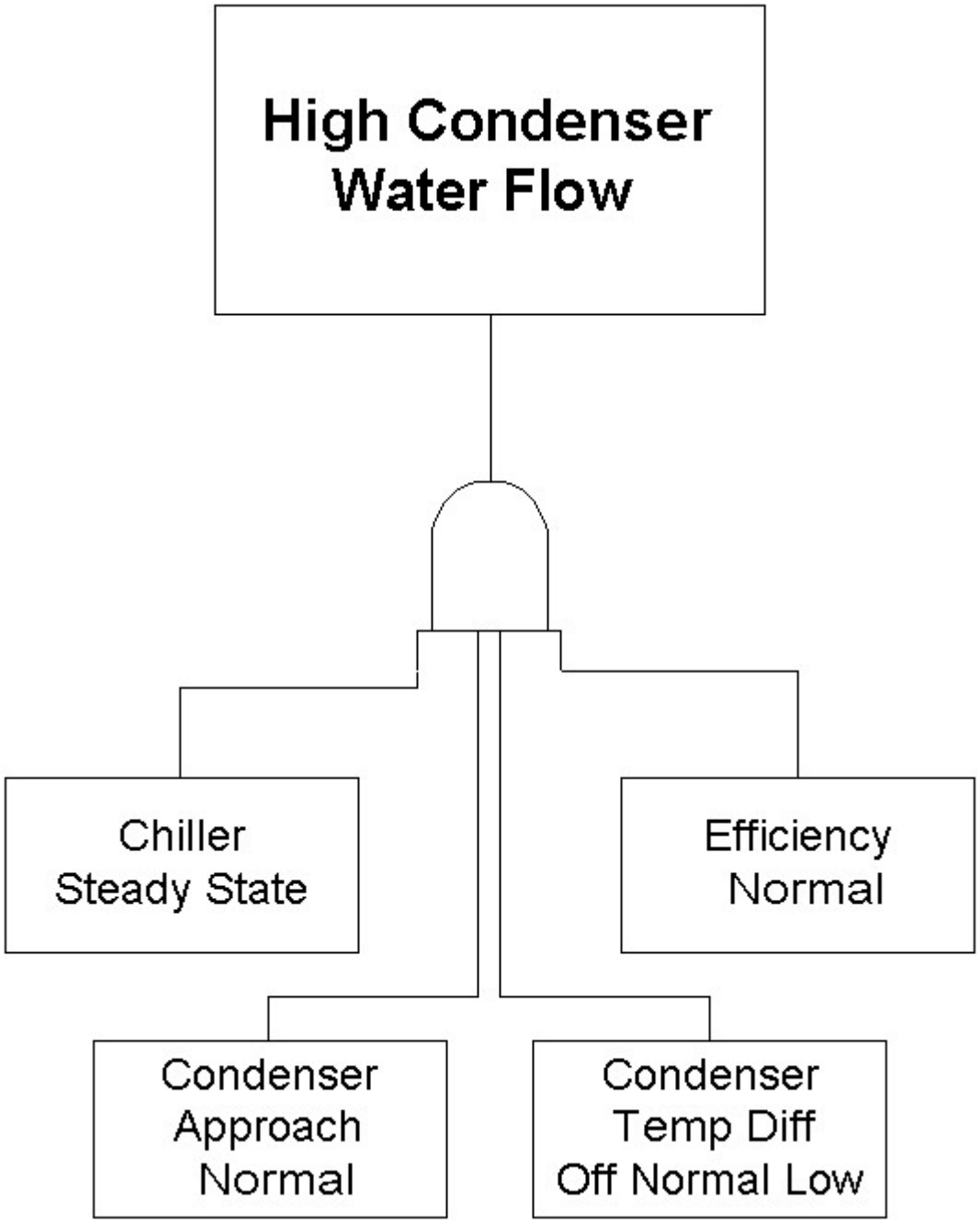

Figure 4: Logic block diagram for High Condenser Water Flow

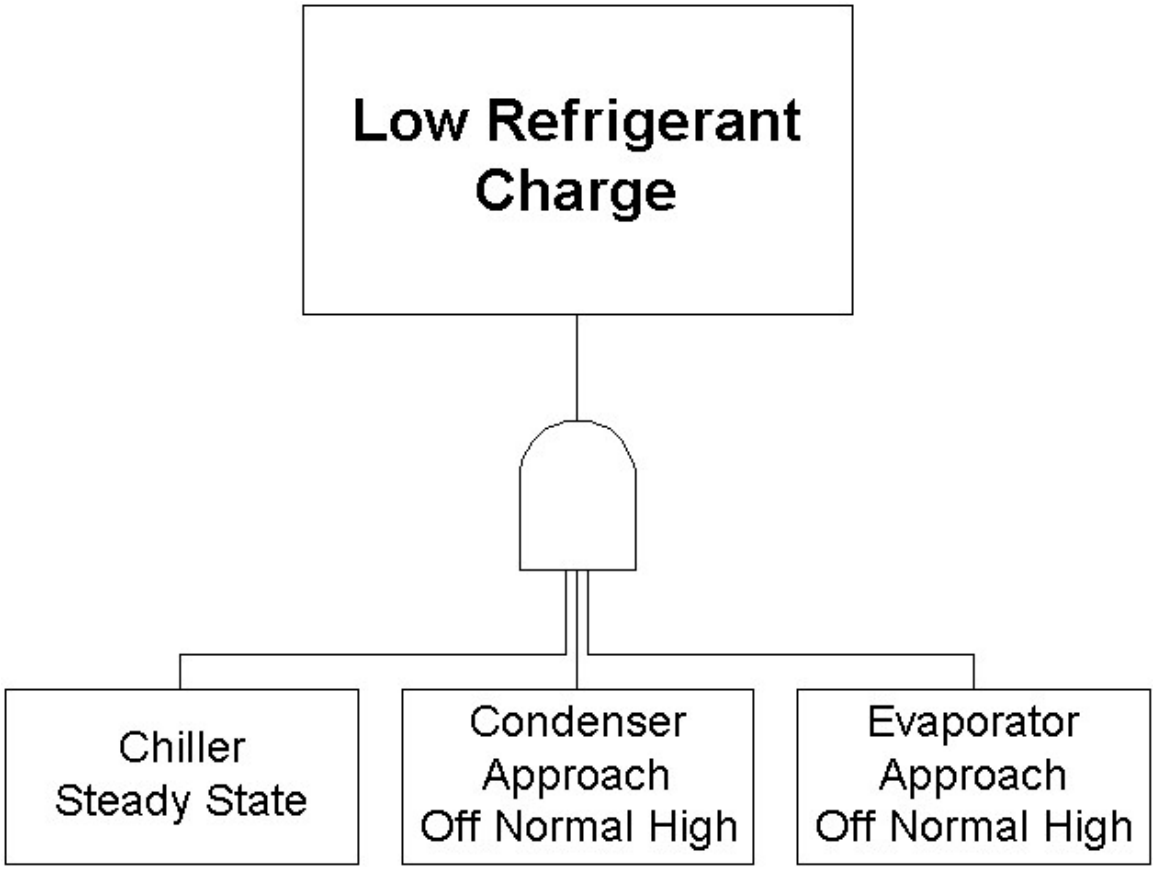

Figure 5: Logic Diagram for Low Refrigerant Charge Diagnostic

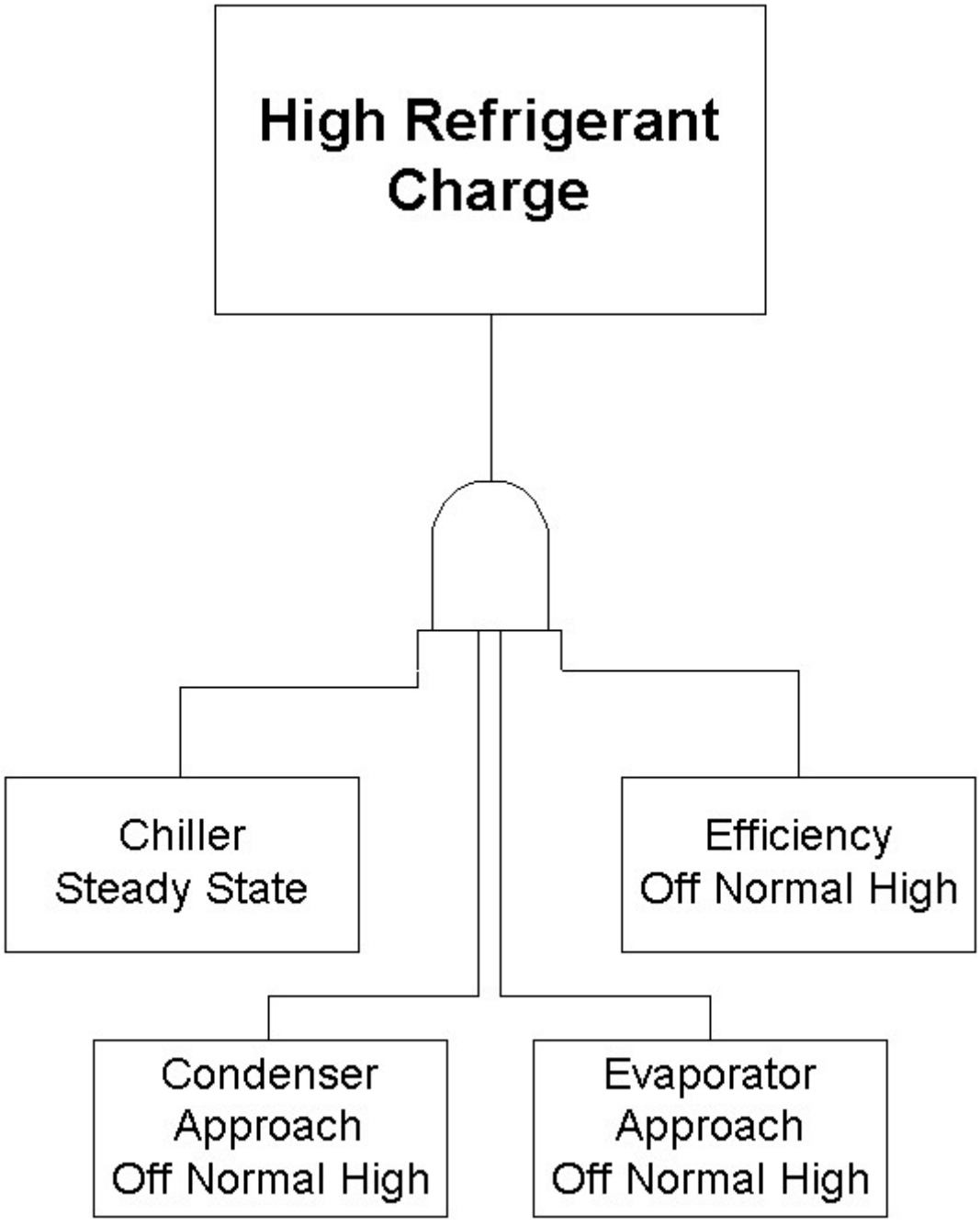

Figure 6: Logic Diagram for High Refrigerant Charge Diagnostic