Consider the reactor system shown in Figure 10-6. The reaction is exothermic. A cooling system is provided to remove the excess energy of reaction. In the event the cooling function is lost, the temperature of the reactor would increase. This would lead to an increase in reaction rate leading to additional energy release. The result could be a runaway reaction with pressures exceeding the bursting pressure of the reactor.

The temperature within the reactor is measured and is used to control the cooling water flow rate by a valve.

Perform a HAZOP on this unit to improve the safety of the process.

Solution The guide words are applied to the cooling coil system. The design intention is cooling. The results of the investigation are shown in Table 10-4.

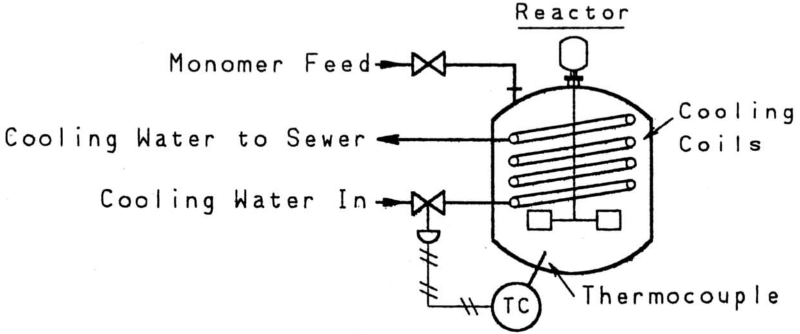

Figure 10-6 Temperature control of an exothermic reactor.

TABLE 10-4 HAZOP STUDY ON DEVIATIONS FROM COOLING FLOW. APPLIED TO REACTOR OF FIGURE 10-6

Guide word	Deviation	Possible causes	Consequences	Action
NO	No cooling	1. Control valve fails closed 2. Plugged cooling line 3. Cooling water service failure 4. Controller fails and closes valve. 5. Air pressure to drive valve fails, closing valve	1. Temperature increase in reactor 2. Possible thermal runaway	1. Install back-up control valves, or manual bypass valve. 2. Install filters to prevent debris from entering line 3. Install back-up cooling water source 4. Install back-up controller 5. Install control valve that fails open 6. Install high temperature alarm to alert operator 7. Install high temperature emergency shutdown 8. Install cooling water flow meter and low flow alarm
MORE	More cooling flow	1. Control valve fails to open 2. Controller fails and opens valve	1. Reactor cools, reactant builds-up, possible runaway on heating	1. Instruct operators on procedure
LESS	Less cooling flow	1. Control valve fails to respond 2. Partially plugged cooling line 3. Partial water source failure	1. Covered under "NO"	1. Covered under "NO"
AS WELL AS	Cooling water in reactor	Leak in cooling coils, pressure in reactor less than pressure in coils	1. Dilution of contents 2. Product ruined 3. Overfilling of reactor	1. Install high level and/or pressure alarm 2. Install proper relief 3. Check maintenance procedure and schedule
AS WELL AS	Reactor product in coils	Leak in coils with reactor pressure greater than coil pressure	1. Product lost thru coils 2. Loss of product yield 3. Reduction in cooling function 4. Possible contamination of water	1. Check maintenance procedure and schedules 2. Install upstream check valve in cooling water source

PART OF	Partial cooling flow	Covered under "LESS COOLING FLOW"		
REVERSE	Reverse cooling flow	1. Failure of water source resulting in backward flow 2. Backflow due to backpressure	1. Improper cooling, possible runaway	1. Install check valve in cooling water line 2. Install high temperature alarm to alert operator
OTHER THAN	Another material besides cooling water	1. Water source contaminated 2. Backflow from sewer	1. Possible loss of cooling with possible runaway	1. Isolation of cooling water source 2. Install check valve to prevent reverse flow 3. Install high temperature alarm

The potential process modifications resulting from this study are the following.

- Installation of a high temperature alarm to alert the operator in the event of cooling function loss.
- Installation of a high temperature shutdown system. This system would automatically shutdown the process in the event of a high reactor temperature. The shutdown temperature would be higher than the alarm temperature to provide the operator with the opportunity to restore cooling before the reactor is shutdown.
- Installation of a check valve in the cooling line to prevent reverse flow. A check valve could be installed both before and after the reactor to prevent the reactor contents from flowing upstream and to prevent the backflow in the event of a leak in the coils.
- Periodically inspect the cooling coil to insure its integrity.
- Study of the cooling water source to consider possible contamination and interruption of supply.
- Installation of a cooling water flow meter and low flow alarm. This will provide an immediate indication of cooling loss.

In the event that the cooling water system fails (regardless of the source of the failure), the high temperature alarm and emergency shutdown system prevents a runaway. The review committee performing the HAZOP decided that the installation of a backup controller and control valve was not essential. The high temperature alarm and shutdown system prevents a runaway in this event. Similarly, a loss of coolant water source or a plugged cooling line would be detected by either the alarm or emergency shutdown system. The review committee suggested that all coolant water failures be properly reported. In the event that a particular cause occurs repeatedly then additional process modifications are warranted.

This example demonstrates that the number of process changes suggested is quite numerous although only a single process intention is considered.

The advantage to this approach is that it provides a more complete identification of the hazards, including information on how hazards can develop as a result of operating procedures and operational upsets in the process. The disadvantages are that the HAZOP approach is tedious to apply, requires considerable manpower and time, and can potentially identify all of the hazards independent of the risk.