Module 11

SHUTDOWN SYSTEMS

OBJECTIVES:

After completing this module you will be able to:

11.1 State the two general abnormal conditions which the shutdown systems are designed to protect against. ⇔ ***Page 2***

11.2 Explain the requirement for a shutdown system. ⇔ ***Page 3***

11.3
- a) State two types of shutdown systems (excluding moderator dump) in a typical CANDU station and, ⇔ ***Pages 3-4***
- b) Explain the reason why two shutdown systems are installed. ⇔ ***Page 4***
- c) Explain the reason why each system must be independent of the other and of all other process systems. ⇔ ***Page 5***

11.4 List three features incorporated in a typical shutdown system to increase its reliability. ⇔ ***Page 5***

11.5 State when the shutdown systems must be available. ⇔ ***Page 6***

11.6 Identify the preferred state of the shutdown systems during a unit shutdown. ⇔ ***Page 6***

11.7 Explain the reason why a shutdown system should be a fail-safe system. ⇔ ***Page 7***

11.8 Explain the reason why additional safety interlocks are tied into the shutdown systems. ⇔ ***Page 8***

11.9
- a) Explain the difference between an absolute and conditional trip. ⇔ ***Page 8***
- b) For a conditional and an absolute trip: ⇔ ***Pages 8-9***
  - i) State one example of a parameter that will cause a reactor trip.
  - ii) Explain why each of the parameters you have used as an example has been selected.

11.10 For the following situations:

Page 10 ⇔ a) Slow loss of reactor regulation,

Page 10 ⇔ b) Fast loss of reactor regulation,

Pages 10, 11 ⇔ c) Loss of primary heat sink effectiveness.

i) State the common absolute trip parameter (excluding manual) provided to protect against the event.

ii) State the reason why the parameters in (i) were chosen.

Page 12 ⇔ 11.11 Explain the importance of redundant parameters for shutdown system actuation.

Page 13 ⇔ 11.12 State two reasons why SDS No. 1 and/or SDS No. 2 can be actuated manually.

* * *

INSTRUCTIONAL TEXT

INTRODUCTION

The purpose of the shutdown systems (SDS) is to quickly shut down the reactor by a rapid insertion of large amounts of negative reactivity into the core. This may be required during major process system failures that cannot be safely handled by the Reactor Regulating System (RRS), stepback or setback functions, or other safety related systems.

Obj. 11.1 ⇔ The shutdown systems protect the unit against **two major types of process system failures**:

a) Loss of reactor control.
b) Loss of reactor heat sink effectiveness.

Some of the possible causes of loss of reactor control can be:

a) Removal of negative reactivity from the core (driving adjusters out, draining liquid zones, etc).

b) Failure of the reactor regulating control program.

Some of the possible causes of loss of heat sink can be:

a) Loss of coolant accident (LOCA).
b) Loss of Class IV power (loss of main HTS circulation pumps).
c) Loss of secondary heat sink (loss of boiler feedwater).

Effectiveness of Shutdown Systems

The shutdown systems must be capable of responding to the **worst unit failure or combination of failures** and safely shutdown the reactor to a level which will maintain cooling capability to the fuel. For example, a large LOCA will cause a large increase in reactivity due to voiding of fuel channels. This will produce a large increase in reactor power. It will also reduce heat sink effectiveness by reducing HTS system pressure. A Loss Of Regulation Accident (LORA) can cause a fast increase in reactivity, and consequently a fast rise in reactor power. The shutdown systems must be capable of responding both **quickly** enough and with **enough negative reactivity** depth to **prevent failure of the coolant system boundary** following a process system failure.

⇔ Obj. 11.2

The trip setpoints chosen reflect parameters to prevent fuel melting and subsequent failure. Since we don't have operational experience with fuel centerline melting, we cannot say, with any confidence, that pressure tube failure will not occur if centerline melting occurs. Hence, fuel centerline melting dictates the choice of setpoints for the trip parameters. The only way we can be reasonably sure that centerline melting will not occur is to prevent 'dryout'.

Let us consider another problem. If there is a mismatch between heat production and heat removal, ie. heat production > heat removal, should the reactor be tripped or should the power be brought down through a setback in order to restore the balance between heat production and heat removal? The key to answering this question is time. Typically, a reactor trip will bring the reactor power down to ~6-7% FP in a few seconds while a setback at a typical rate of 0.5%/sec will do the same thing in ~3.5 minutes. It is clear that we cannot afford a serious imbalance in heat production versus heat removal for ~3.5 minutes. Therefore, the reactor must be tripped.

Basically the shutdown systems must insert a larger amount of negative reactivity faster than the positive reactivity buildup created by the unit failure.

Note that both SDS1 and SDS2 are typically actuated in less than one second and that in less than two seconds enough negative reactivity is inserted to terminate any unit failures.

Types of Shutdown Systems

In most CANDU reactors the two types of shutdown systems used are:

⇔ Obj. 11.3 a)

a) Shut-Off Rods (SORs)

This shutdown system uses **shut-off rods** which are stainless steel encased, hollow cadmium (a strong neutron absorber) rods which drop, under gravity, into the core. Vertical guide tubes are located within the calandria to guide the rods while they fall into the core. These rods are normally held above the core by electrically energized clutches, located on the reactivity mechanism desk. When this shutdown system is actuated, the clutches holding the rods above the core de-energize (channelized electrical contacts), allowing the rods to fall into the core (the initial acceleration is assisted by springs, which are compressed by the retracted rods). This makes the reactor deeply subcritical, and thus, reactor power drops quickly to a low level.

b) Liquid Poison Injection

The liquid injection shutdown system operates by **injection of gadolinium nitrate**, under pressure, through horizontal dispersion lines into the moderator. Gadolinium, like cadmium, is a strong neutron absorber. This system consists of several gadolinium nitrate (poison) tanks, which can have their contents driven into the core by pressurized helium. When this shutdown system is actuated, helium pressure is applied to the poison tanks through channelized valves. The poison is then displaced and distributed into the moderator, causing the same effect as the SORs, a rapid drop in power to a low level.

It is possible to quickly reset the shutoff rod trip (if the cause of the trip is known and corrected), thus avoiding a poison outage. Recovery immediately after a liquid poison injection trip is impossible, due to the length of time required for the moderator purification system to remove the poison. This is why the SOR trip (SDS1) is the preferred SDS and is actuated first.

Other Shutdown Systems

A few early CANDU units use moderator dump to provide a shutdown. This is accomplished by dumping the moderator into a separate "dump" tank below the calandria. With the moderator out of the calandria, the fast fission neutrons are not slowed or thermalized, hence, reactor power drops to a safe, low level.

Because of its relatively slow action time, moderator dump is not a primary method of achieving a shutdown . It will only be used if the shut-off rods do not reduce reactor power quickly enough.

Safety Design Principles

Obj. 11.3 b) ⇔

For additional **safety, two** shutdown **systems** are provided. SDS1 must be capable of safely shutting down the reactor in the absence of SDS2, and likewise, SDS2 must be capable of safely shutting down the reactor in the absence of SDS1.

In order to prevent faults in one safety system from affecting another system, the shutdown systems are **functionally independent** from:

⇔ *Obj. 11.3 c)*

- Each other,
- The reactor regulating system,
- Any process system, for example, SDS1 uses power to cause the contacts to open, SDS2 uses air actuated valves to cause the poison injection,
- The other safety related systems, ie. ECIS, containment.

Each SDS is independent from the other in two aspects:

1. Functional independence is achieved by designing the two shutdown systems on two different principles: mechanical insertion of a strong neutron absorber and chemical poisoning of the moderator by a neutron absorber.
2. Geometric independence is achieved by the vertical insertion of shut-off rods while the liquid poison is injected through horizontal tubes into the core.

To increase its reliability, the following three features are incorporated in a typical SDS:

⇔ *Obj. 11.4*

1. The means of measuring the unit variables and actuating the two shutdown systems are separated and duplicated (**independent**). For example, the detectors for each channel are separated and independent with their power, air and water supplies from different sources. The individual instrumentation channels for each shutdown system also follow a physically separate route through the station. This approach reduces the probability that any credible event will simultaneously affect both safety systems on more than one channel.
2. Each shutdown system is configured in a **triplicated** channel format (also called "2 out of 3 logic") (**redundant**). Shutdown action is initiated when the setpoint of any two of the three shutdown (trip) channels are exceeded by any unit variable or combination of variables. This triplication has the following advantages:
    - **On-line testing** and maintenance of individual channels is possible.
    - The unit is not shut down due to a single spurious trip signal.
    - One channel can fail without disabling the system.

   If a component fails unsafe (ie. channel, or parameter, does not trip), there are still two channels which will cause a trip. If the component fails in a safe state (ie. channel (or parameter) trips), the reactor does not trip, because 1 additional channel is required to trip. (Note that the probability of failure is small, which makes two simultaneous failures highly improbable). The safe failure will be annunciated because it trips the channel or parameter. The unsafe failure may only be discovered by testing. The test frequency has been chosen to demonstrate that the required reliability targets are met (ie. minimize unavailability).

3. The selection of **quality** components for the shutdown system also increases the probability that the system will function as designed.

Availability

Obj. 11.5 ⇔

Because the SDSs are so essential for reactor safety, the reactor must not be operated if either shutdown system is not functional. Sufficient shutdown capability has to be **available at all times** to safely terminate any unit failure or combination of failures.

The reactor must be placed in the guaranteed shutdown state (GSS)* if a SDS is to be removed from service. Note that only one SDS would normally be removed from service at any given time.

Obj. 11.6 ⇔

During unit **shutdowns**, it is **preferred** to keep the shutdown systems **poised**. This ensures that the shutdown systems are ready to trip the reactor, should the need arise (eg. to stop a LORA from low power).

* The guaranteed shutdown state places the reactor in a condition where the reactor cannot go critical due to worst credible process failures. The specific details will be provided in your station specific training.

SUMMARY OF THE KEY CONCEPTS

- The shutdown systems protect against loss of reactor control and loss of heat sink effectiveness.
- The shutdown system must insert enough reactivity depth quickly enough to counteract any unit failure or combination of failures to prevent coolant system boundary failures.
- Two shutdown systems are provided for additional safety. The two systems use shut off rods and liquid poison injection. The shutdown systems are independent of each other, all process systems and all other special safety systems to prevent faults in one system from affecting another.
- Three features incorporated to increase shutdown system reliability are:
  - Independence of components,
  - Use of triplicated channel format, allowing for on-power testing,
  - Selection of high quality components for use in the shutdown system.
- The shutdown systems must be available at all levels of reactor operation. During shutdowns the shutdown system protects against unexpected power increases.

Fail Safe Feature

⇔ *Obj. 11.7*

We have to ensure that the shutdown systems are fail-safe. This means that, in the **event of equipment, power or other failures** of the shutdown systems, **they will shut down the reactor** (even though it may not be the result of an actual trip). This assures that reactor power will be reduced if the shutdown system fails. Fail safe, in this case, means that failure of a component or channel should cause the device(s) to go to the position that they would go to if the system was tripped.

For example, in the case of SDS1, the SORs are held above the core by energized clutches. If a power failure to the clutches occurs, the clutches are de-energized and the SORs drop into the core, shutting down the reactor.

In the case of SDS2, helium under pressure is isolated from the poison storage tanks by pneumatically actuated air-to-close valves. If an instrument air failure occurs, and the valve actuator loses pressure, the valves will open. The pressurized helium will then drive the poison from the storage tanks into the core, shutting down the reactor. (Note that in practice, these valves are provided with air reservoirs (connected to the actuator) which fill under normal operating conditions to instrument air system pressure via a non return valve . The non return valve prevents the air in the reservoir from re-entering the failed air system. A loss of air supply will not then automatically cause a trip, since the stored air will keep the valve in its closed position. Also note that a genuine trip will dump the air in a normal manner).

This fail safe feature cannot accommodate all failures. Examples of failures that cannot be guarded against are helium injection valves sticking closed or SOR being stuck out of the core. This type of failure would be detected by the safety system tests, and is one reason why we perform tests on these passive systems (ie. this type of failure is not annunciated).

Interlocks

When a shutdown system trips the reactor, the reactor regulating system is signalled and will not attempt to raise power levels. It will also take the following additional safety steps to augment the trip:

- Fill the liquid zones,
- Drop control absorbers (CA) into the core,
- Lower the reactor power setpoint.

The main purpose of these additional safety steps is to ensure that the reactor regulating system is supporting the actions of the shutdown system (note also that CA insertion prevents the reactor from going critical on withdrawal of the SORs when the trip is reset).

While the reactor is tripped, interlocks prevent the removal of moderator poison and the driving out of control absorbers and adjuster rods and prevents insertion of boosters (depending on the station). **This prevents an inadvertent reactivity increase.**

Obj. 11.8 ⇔

The interlock restrictions remain in force until the shutdown systems are functional again (poised).

Absolute and Conditional Trips

Reactor trips are of two types:

- Absolute and,
- Conditional.

Obj. 11.9 a) ⇔

An **absolute trip is a trip that is functional at all states of reactor power.**

Obj. 11.9 b) ⇔

Rate Log is an absolute trip. Its trip value for SDS1 is set at 10% Present Power (PP)/second at any power. If the reactor power increase is too fast to be safely handled by the reactor regulating system, the shutdown systems will trip the reactor.

Further examples of absolute trips are:

- High Neutron Power, which will provide protection against fuel overrating at all times.
- Heat Transport High Pressure, which will provide protection against HT overpressure and damage resulting in a LOCA.

Obj. 11.9 a) ⇔

A **conditional trip** is valid **only above a certain power limit.** Conditional trips allow the unit to be shutdown without tripping the reactor, keeping the shutdown system poised for use. Depending on the parameter, these trips can be conditioned out at different levels.

Obj. 11.9 b) ⇔

The conditional trips also protect against reactor power increases from low power by being reactivated at the conditioning level. As reactor power increases, the trip conditioning parameter will be met at the appropriate power level and will trip the reactor preventing any further power increase.

For example, low HT pressure is a conditional trip. This low HT pressure trip protects against dryout at high power conditions (ie. prevent film boiling/dryout *). During a reactor shutdown and cooldown, HT pressure can be lowered. As reactor power is lowered to below the conditioning level, the low HT pressure trip is conditioned out. This prevents an unwanted reactor trip. At low power levels, the fuel will be "cold", and dryout is less likely to occur. At the lower HT pressure, reactor safety is not compromised because heat removal capability from the fuel is not impaired. But say that the reactor power increases

* Dryout is discussed in Module 16.

unexpectedly from the low power state with low HT pressure. At powers above the conditioning level, boiling and dryout may occur in the HT system as the fuel temperature increases. The power increase would cause the reactor to trip when power reached the trip conditioning level, preventing dryout.

Another example of a conditional trip is heat transport gross coolant low flow. For example, the trip setpoint for this variable is typically set between 75% and 90% nominal flow, provided the reactor power is greater than ~1% FP. If reactor power is below ~1% FP, then this trip is conditioned out. Full coolant circulation is not required to remove this heat, ie. alternate heat sinks have this capacity. Even with the reduced circulation, dryout will not occur, since the fuel is "cold". This conditioning trip allows the main HT pumps to be shut down during a unit shutdown. An increase in reactor power above the conditioning level without adequate coolant circulation would cause the reactor to trip, preventing dryout.

Further examples of conditional trips are:

- Boiler Low Level,
- Pressurizer Low Level.

SUMMARY OF THE KEY CONCEPTS

- The shutdown system must be a fail-safe system to trip the reactor should any component or energy supply for the system fail.
- The purpose of interlocks with shutdown systems is to prevent inadvertant reactivity increases.
- An absolute trip parameter is a trip parameter that is valid at all levels of reactor operation. A conditional trip parameter is only valid above a certain reactor power level. This allows the shutdown system to remain poised (its desired state) during a shutdown.

Trip Protection

Key neutronic and process system variables are monitored at all times. These unit variables have "trip" setpoints. When the key unit variables exceed the trip setpoints on two of three channels, the shutdown system is actuated and will trip the reactor.

Note that the shutdown system trip setpoints for SDS1 and SDS2 are staggered to allow SDS1 to trip first, thus making a trip recovery possible. This is discussed further in the Staggering of Trip Setpoints section on page 13.

The most common key variables are listed on the next few pages.

1. **High Neutron Power**

   Obj. 11.10 a) ⇔

   The trip value is set below the level at which the fuel bundle power ratings (critical channel power) would be exceeded. This prevents excessive power increases resulting from a large LOCA (where channel voiding has taken place) or during a **LORA** (where the rate is low enough to not trip on neutronic rate and not increase HTS pressure beyond the pressure and inventory control capabilities).

2. **Neutronic Rate (Log or Linear)**

   Obj. 11.10 b) ⇔

   Its trip value is set to a level which prevents the reactor power from increasing too fast. ie. rate that RRS cannot effectively limit the peak power reached (loss of reactor control). This could occur during a large LOCA as mentioned above or during a fast **LORA**.

3. **Heat Transport Pressure High**

   Obj. 11.10 a & c) ⇔

   This trip is used to protect against excessive overpressurization of HT system due to the **loss of heat sink effectiveness.** This also protects against accidents like a slow (or "moderate") **LORA** (ie. pressure and inventory control system cannot accommodate swell), loss of feedwater and loss of Class IV power.

4. **Heat Transport Pressure Low**

   It trips mainly to cope with the effects of LOCAs and steamline breaks (ie. causing a rapid collapse of HTS pressure). This prevents the critical channel power from decreasing due to a decrease in HT pressure. This will prevent dryout and the resultant fuel overheating and failure.

5. **Heat Transport Gross Coolant Low Flow**

   It is used as a trip variable to cope with the effects of LOCAs and loss of Class IV power (ie. reduced HTS circulation due to pump trip). This prevents the critical channel power* from decreasing due to a decrease in HT coolant flow. This will prevent dryout and the resultant fuel overheating and failure.

   * More about critical channel power can be found in the 225 Thermodynamics course and in Module 16.

6. **Pressurizer Low Level**

   It trips to deal with the effects of accidents causing a shortage of HT D_2O inventory, like LOCAs or steamline breaks (causing coolant shrinkage and pressure reduction, see also HT Low Pressure trip).

7. **Boiler Low Level**

   It is used as a trip variable to deal with the effects of failures in the steam and feedwater system, ie. steamline breaks and feedwater breaks. This parameter trips the reactor if the boilers are lost (or anticipated to be lost) as a heat sink.

8. **Boiler Feedwater Low Pressure**

   It trips to cope with the effects of failures in the feedwater system, ie. feedline breaks, pump failures, etc. This parameter trips the reactor if the boilers are lost (or anticipated to be lost) as a heat sink.

9. **Moderator Temperature High**

   It trips to deal with the effects of the loss of heat sink to the moderator *. In stations using boosters, high booster coolant (moderator) temperature will trip the reactor to prevent booster damage.

10. **Reactor Building High Pressure**

    This trip deals with the effects of a LOCA or feedwater/steamline breaks inside containment.

11. **Heat Transport High Temperature**

    It is used to cope with the effects of fuel overheating and HTS overpressure protection (ie. as a back-up) for a **loss of heat sink effectiveness**. (Non-boiling reactors only).

* Note that the moderator also will serve as an ultimate heat sink to the HTS in a major accident (where fuel channels overheat and sag until they contact the calandria tube). It also prevents excessive thermal stresses between the end shield and the calandria.

⇔ ***Obj. 11.10 c)***

SUMMARY OF THE KEY CONCEPTS

- A fast LORA will cause the reactor to trip on NEUTRONIC RATE. Rate parameter was chosen because the rapid power increase will be detected and will trip the reactor.
- A slow LORA will trip the reactor on HIGH NEUTRON POWER and/or HIGH HEAT TRANSPORT PRESSURE (depending on the rate of power increase). If reactor power increases cause a large HTS swell as heat input is increased, the HTS pressure will increase, hence, this is the reason for this choice of parameters. If the reactor power increase is slow enough to keep the pressure increase within the capacity of the pressure and inventory control system, the reactor power will rise to the high neutron power trip setpoint, hence, this is the reason for this choice of parameters.
- A loss of heat sink effectiveness will trip the reactor on HIGH HEAT TRANSPORT PRESSURE OR HIGH HT TEMPERATURE. These parameter have been chosen because the reduction in heat sink effectiveness will cause the HTS temperature to increase, causing an immediate swell in the HTS. The boiler low level trips and boiler feedwater low pressure will also protect against the reduction of heat sink capability (as backup trip parameters).

Redundant Parameters

The unit has many combinations of possible trip parameters:

For excessive heat production (beyond the capacity of heat sinks),

- Neutronic Rate,
- High Neutron Power.

For **mismatch between heat production and heat removal,**

- Heat Transport Pressure High,
- Heat Transport Temperature High

Impending mismatches are protected by

- Boiler Low Level,
- Boiler Feedline Low Pressure,
- Moderator Temperature High ensures that heat balance is maintained in the moderator.

For **loss or impending loss of HT system,**

- Heat Transport Gross Coolant Low Flow,
- Boiler Room Pressure High,
- HT Low Pressure,
- Pressurizer Low Level.

Obj. 11.11 ⇔

The point to make here is that, for the same unit failure, the unit has a **combination of trip protections**. Should one or more trip protections fail, others will shut down the reactor. These **redundant parameters are an important design feature which contribute considerably to the safety of CANDU** reactors.

As an example, a combination of effects/trip protections **for a LOCA** could be:

a) Voiding in the pressure tubes. This causes a steep rise in reactor power due to positive void reactivity coefficient. **Neutronic rate** and **high neutron power** trips provide protection.

b) Depressurization of HT system due to loss of D_2O coolant. **Heat transport pressure low** trip provides protection.

c) Increasing boiler room pressure. The HT system D_2O, escaping at high pressure and temperature flashes into steam causing an increase in pressure. **Boiler room high pressure** trip is available.

d) Decrease in the coolant flow if an inlet header should rupture. D_2O designated for channel flow would be lost from the break. **Heat transport gross coolant low flow** trip is available.

e) Decreasing level in the pressurizer through the loss of HT system D_2O. **Pressurizer level low** trip is available.

Staggering of Trip Setpoints

Note also that the trip setpoints are staggered for SDS1 and SDS2 to avoid actuation of both shutdown systems in the same time. This keeps the SDS2 poised and ready to fire, should SDS1 fail to lower reactor power. Also, a recovery from a trip is possible with SDS1 if the cause of the trip can be identified and corrected quickly. With SDS2 we do not have this option because poison removal from the moderator takes too long. Therefore, once SDS2 has fired, a poison outage cannot be avoided.

For an example of the above, typically the RATE LOG trip value is set at 10% PP/second for SDS1 and 15% PP/second for SDS2 .

Manual Trips

If the operator has reason to believe that a serious unit failure has occurred or an automatic trip has failed, the **reactor must be tripped manually** even if an automatic trip has not occurred (yet). This is an extra safety feature added to CANDU reactors.

⇔ *Obj. 11.12*

SUMMARY OF THE KEY CONCEPTS

- Redundant parameters ensure that the reactor trips even if a trip parameter should fail. This is an additional safety feature for the shutdown system design.
- For enhanced reactor safety, the reactor is to be tripped manually if the operator believes that a serious unit failure has occurred, even if the reactor has not tripped on its own.

You can now **work on the assignment questions.**

⇔ ***Page 15***

ASSIGNMENT

1. The two situations that the shutdown systems are designed to protect against are:

   a) ____________________

   b) ____________________

2. a) The requirement for a shutdown system is:

   ____

   ____

   b) These requirements are put in place in order to ____________________

   ____

   ____________________.

3. a) Two typical types of shutdown systems are:

   i) ____________________

   ii) ____________________

   b) Two shutdown systems are provided because ____________________

   ____________________.

4. A shutdown system must be completely independent of:

   a) ____________________.

   b) ____________________.

   c) ____________________.

   d) ____________________.

   This is because ____________________

   ____

   ____________________.This

   independence is achieved by ____________________

   ____

   ____

   ____

   ____________________.

5. Three features incorporated to increase the reliability of the shutdown systems are:

   a) ______________________________

   b) ______________________________

   c) ______________________________

6. The shutdown system must be available ______________ ______________. During periods of reactor shutdown, the shutdown systems must be ______________________ to prevent ______________________________.

7. a) The shutdown systems must be fail-safe systems because ______________________________.

   b) The system has additional interlocks in order to ______________________________.

8. An absolute trip parameter is valid for ____________ levels of reactor power operation. A conditional trip parameter is valid ______________________________.

   Conditional trips are required because required because ______ ______________________________.

9. A fast loss or reactor power regulation will trip the reactor on ______________________. This parameter was chosen because ______________________________.

10. A slow loss or reactor power regulation will trip the reactor on

    ____________ or ____________.

    These parameters were chosen because ____________

    ____

    ____

    ______________________________.

11. A loss of primary heat sink effectiveness will trip the reactor on

    ____________ or ____________.

    This parameter was chosen because ____________

    ____

    ____

    ______________________________.

12. Redundant parameters are important because ____________

    ____

    ____

    ______________________________.

13. The reactor should be tripped manually when

    a) ______________________________

    b) ______________________________

Before you move on, **review the objectives** and make sure that you can meet their requirements.

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