Module 18

UNIT UPSETS

OBJECTIVES:

After completing this module you will be able to:

18.1 For each of the following:

- a) Reactor trip, *⇔ Pages 2-5*
- b) Reactor stepback, *⇔ Pages 6-7*
- c) Reactor setback, *⇔ Pages 8-9*

Explain:

- i) The consequences to unit operation,
- ii) Other major operational concerns,
- iii) The key control room indications which would confirm the event,
- iv) Under what condition it is to be performed manually.

18.2 For each of the following upsets:

- a) Large and small LOCA's, *⇔ Pages 10-13*
- b) Loss of reactor regulation, *⇔ Pages 14-15*
- c) Loss of feedwater, *⇔ Pages 16-18*
- d) Main steam line break, *⇔ Pages 19-21*
- e) Loss of turbine load, *⇔ Pages 22-24*
- f) Loss of Class IV, *⇔ Pages 24-26*
- g) Loss of Class III, *⇔ Pages 27-28*
- h) Loss of Class III with Class IV unavailable, *⇔ Pages 28-29*

Explain:

- i) The consequences to unit operation,
- ii) Other major operational concerns,
- iii) The general indications alerting the control room operator to the upset (including automatic actions in response to the upset),

Areas to be considered include general turbine generator operation; boiler pressure and level; HTS pressure, temperature and inventory; reactor power levels; special safety systems.

* * *

INSTRUCTIONAL TEXT

INTRODUCTION

This module will cover transient and upset conditions, which will not normally be encountered during steady state operation. These conditions include reactor trips, stepbacks, setbacks, LOCAs, LORAs, loss of load, steam/feedwater system upsets and loss of power.

Due to numerous station specific differences, the names and existence of various systems may differ somewhat from those in your station.

In the series of events described for objective 18.2, setbacks and stepbacks * have been purposely omitted due to the station specific differences. Although the setbacks and stepbacks will occur, the trips as indicated, will not likely be avoided.

* These setbacks and stepbacks will be dealt with in your station specific training.

REACTOR POWER REDUCTIONS

In the following section, three methods of reactor power reductions will be discussed:

- Reactor trips,
- Reactor stepbacks,
- Reactor setbacks.

As you recall from Module 11, a reactor trip is a rapid shutdown of the reactor, when a critical plant operating limit is exceeded. A reactor trip is initiated by one of the shutdown systems mentioned in Module 11. This protects against a loss of reactor power regulation and/or loss of heat sink effectiveness. Recall also that the equipment used to detect the parameters is completely separate from the regulating system and all other process systems.

Reactor stepbacks and setbacks are regulating system responses, and reduce reactor power when a unit abnormality occurs. The rate at which they reduce power varies, depending on the urgency of the event. This will be discussed in more detail in the following sections.

REACTOR TRIP

Consequences To Unit Operation

Obj. 18.1 a) i) ⇔

The major **source of heat** (fission heat) will immediately drop to a very low level. This will cause the heat input to the HTS to drop to decay heat levels.

NOTES & REFERENCES

HT temperature will drop due to the reduced heat input, which will cause a coolant shrinkage and a **pressure** decrease.

Boiler pressure and temperature will also reduce due to the reduced heat input. Boiler **level** will be dropping due to shrinkage of boiler inventory and the programmed ramping down of boiler level as the reactor power is decreased.

In an attempt to maintain boiler pressure, the **turbine** will be **unloaded** (runback) and will eventually be followed by motoring *. This prevents excessive reduction of HTS pressure.

* Recall from the 234 course that a runback is an automatic reduction in turbine governor valve opening based on a parameter, such as steam pressure or poor condenser vacuum. Motoring occurs when the turbine is fully unloaded (GVs closed), but the generator is still synchronized.

If the reactor was in the reactor lagging mode of operation, **control reverts** to the **reactor leading** mode of operation.

Major Operational Concerns

⇔ *Obj. 18.1 a) ii)*

High power operation cannot continue without the risk of equipment and/or fuel damage. **Reactor power must be lowered** to avoid damage to the fuel and reactor components.

The reactor must be within the capacity of the available **heat sink** to ensure fuel cooling.

The **HTS pressure and inventory control** must be **restored** by the action of the feed system and pressurizer (where installed), to ensure fuel cooling can be maintained (ie. maintain subcooled conditions to prevent dryout).

The **operator** must **ensure** that all **automatic actions** are occurring to bring the reactor to the **shutdown** state and to **stabilize the** unit * (reactor power decreasing, HT pressure recovering, T-G runback, etc.). This ensures that equipment damage and/or wear does not occur.

* Appropriate manual actions will be taken if auto actions fail to occur.

The **condition** that caused the trip must be **identified and corrected** before authorization to reset the trip will be given by the shift supervisor.

If the condition has not been identified or the problem cannot be corrected within 10 to 35 minutes, depending on the station, a **unit poison outage** will occur (unavoidable if poison injection occurred).

Indications

⇔ *Obj. 18.1 a) iii)*

Many indications are available to the control room operator that a reactor trip has occurred. **Panel indications** and **alarms** will indicate the **parameter** which initiated the trip. Indications will show that the **shutdown system(s)** has/have been **activated** (ie. SOR drop, poison injection, moderator dump, depending on the station).

A rapid **power decrease** will be observed due to the addition of a large amount of negative reactivity to the core.

Heat transport system **pressure and temperature** will indicate that they are **dropping** due to lost heat input, hence shrinkage occurs. Indications of shrinkage are D_2O storage tank and pressurizer level drop (where installed), and feed system action. Pressure and inventory control action will restore HTS pressure. Temperature will stabilize with only decay and pump heat producing a ΔT across the reactor.

A reactor **stepback** (depending on the station) will also occur to add negative reactivity to the core. Note that the stepback (control absorber insertion) occurs to prevent the reactor from going critical when shut-off rods are withdrawn (ie. on trip reset). Indications will show that control absorbers are in core. The **liquid zones** will also indicate that they are **filling** to aid in the negative reactivity addition.

To ensure the reactor remains shut down, positive **reactivity insertion** is **prevented**, ie. adjuster position, booster position, moderator level setpoint is captured by actual level, depending on the station. Annunciations will be given to indicate these conditions.

If the reactor was in the reactor lagging mode of operation, **annunciations** will show that control has reverted to the **reactor leading** mode of operation. Reactor power is held at decay levels.

Indications will show that **boiler pressure** is dropping during the transient and boiler **level** is reducing. Turbine steam valve indications will show that the valves are closing as the turbine unloads.

Use Of a Manual Trip

Obj. 18.1 a) iv) ⇔

The triplicated trip logic makes the reactor trip very reliable. **Manual reactor trips** would be required if an **automatic** reactor trip **did not occur** when it was supposed to, or the operator recognizes an abnormal condition and trips the reactor before any trip set point is reached.

Note that, by design, reactor safety is not dependent on operator action. The requirement for a manual trip would depend on the unlikely failure of both shutdown systems to detect the upset.

Also certain situations as **dictated by your station specific operating documents**, may require a reactor trip, ie. Loss of Class III power. This trip is not to protect against any immediate safety concern, but rather to avoid upcoming problems or actual trip conditions if a rapid power reduction did not occur at that time. For example, it is better to reduce reactor power prior to letting conditions reach the trip setpoint (ie. less potential for equipment damage).

The manual trip is performed by **depressing** the shutdown system trip **button** (this ganged button depresses the contacts for all three trip channels simultaneously). Each shutdown system has its own manual trip button.

SUMMARY OF THE KEY CONCEPTS

- The indications of a reactor trip available to the control room operator are:
  - Annunciation of the parameter initiating the trip;
  - Indications that the shutdown system has activated, ie. SOR's in core, liquid poison injected, moderator dumped;
  - Reactor power rapidly reducing to decay levels;
  - Liquid zones filling and control absorbers fall into core;
  - HTS temperature drops due to reduced heat input, which will also cause a pressure drop due to shrinkage, pressure then recovers;
  - Boiler level, pressure and temperature drop during the transient;
  - Turbine unloads to maintain boiler pressure, followed by motoring;
  - Control will revert to the reactor leading mode of operation, and reactor power is held at decay levels;
  - Annunciations will show that reactivity devices are frozen.
- High power operation cannot continue without the risk of equipment or fuel damage.
- The reactor must have an adequate heat sink to ensure that fuel cooling is not in jeopardy (HT pressure adequate, boiler levels maintained at setpoint, etc.).
- The problem must be identified and corrected before any power increase is attempted. If reactor power is not raised within 10 to 35 minutes, a poison outage will occur.
- The operator must ensure all auto actions occur to stabilize unit operation in the low power state.
  - Reactor power decreasing, HT pressure and inventory control restored;
  - Boiler level controlled and boiler pressure controlled via turbine unloading.
- Manual trips must be performed if an automatic trip fails or as station specific documentation or conditions dictate.

NOTES & REFERENCES

REACTOR STEPBACK

Consequences To Unit Operation

Obj. 18.1 b) i) ⇔

A reactor stepback is a rapid reactor power reduction if certain plant parameter(s) operating limits are exceeded. A stepback is accomplished by dropping the control absorbers (a neutron absorber) into the core. For each control absorber, the clutch coil contacts, which hold the absorber in place, are de-energized, allowing the **control absorber to drop**. This will result in a very rapid reactor power reduction (very much like a reactor trip, but it is much quicker to recover from a stepback than from a trip). The stepback will be terminated when the reactor power reaches the preset endpoint, or when the stepback condition clears, whichever occurs first (note that the endpoint may vary, depending on the initiating event).

The major **source of heat** (fission heat) will immediately be reduced. This will cause the heat input to the HTS to drop.

Reactor control, HT temperature and pressure, boiler pressure, temperature and level will be similar to that described for a reactor trip.

Similar to a reactor trip, the **turbine** will be **unloaded** in an attempt to maintain boiler pressure, and may be followed by motoring if the power drop is large enough.

Major Operational Concerns

Obj. 18.1 b) ii) ⇔

The **operator** must **confirm** that reactor **power** is **reduced** to the new "safe" level and **automatic actions** are restoring stable unit operation. If no stepback was initiated, the condition could lead to a reactor trip (larger upset with less of a chance for recovery).

The reactor must be within the capacity of the available **heat sink** to ensure fuel cooling.

The **HTS pressure and inventory control** must be **restored** by the action of the feed system and pressurizer (where installed), to ensure fuel cooling can be maintained (ie. maintain subcooled conditions to prevent dryout).

The **condition** that caused the stepback must be **identified and corrected** before normal high power operation will be approved by the shift supervisor.

A **poison out** may occur, depending on duration and how much reactor power has been reduced.

Indications

⇔ Obj. 18.1 b) iii)

Upon detection of the stepback parameter, the condition is **annunciated** in the control room.

The **reactor power** will be observed to **rapidly fall** as the control absorbers drop into the core. The reactor power setpoint is also lowered quickly. The control absorber drop will be stopped when either the **endpoint** of the stepback is reached, **or** the stepback **condition clears.**

Unit control, liquid zone*, HTS pressure and temperature, boiler pressure, temperature and level as well as turbine-generator indications will be similar to those of a reactor trip (but may be less drastic for stepbacks that do not go down to zero power).

* **Zones begin to fill but action may occur too quickly to be observed, levels then settle to stabilize power at new setpoint.**

Use Of Manual Stepbacks

⇔ Obj. 18.1 b) iv)

Manual operation of the **stepback** function would only be performed as station procedures dictate. Since the control absorbers drop into the core very quickly, the endpoint of the stepback would be difficult to control without some computer input. Manually, only a full control absorber drop could be assured with any certainty.

No single dedicated pushbutton or handswitch exists for a manual stepback. A manual stepback would be accomplished by turning off the stepback program in both control computers.

SUMMARY OF THE KEY CONCEPTS

- The indications of a reactor stepback available to the control room operator are:
  - Annunciation of the parameter that caused the stepback;
  - Reactor power rapidly drops to a specified endpoint or until the stepback condition clears;
  - Control absorbers drop into core;
  - Liquid zones filling;
  - HTS pressure drops(due to shrinkage), then recovers;
  - If the reactor was in the reactor lagging mode of operation, control reverts to the reactor leading mode of control;
  - Boiler level, pressure and temperature all drop;
  - Turbine unloads to maintain boiler pressure.
- Operation at the previous power level cannot continue without the risk of more drastic action such as a reactor trip.
- The reactor must be within the capability of the available heat sinks.
- The problem must be identified and corrected before any power increase is attempted.

- The operator must ensure all auto actions occur to stabilize unit operation at the new "safe" power level (HTS pressure control, boiler level and pressure, etc.).
- Manual stepbacks are performed only as station procedures dictate.
- The risk of a poison outage may exist, depending on the magnitude and duration of the power reduction.

REACTOR SETBACKS

Consequences To Unit Operation

Obj. 18.1 c) i) ⇔

A reactor setback is a slow, controlled power reduction if certain plant parameters exceed operating limits. A setback is accomplished by adding water (a neutron absorber) to the liquid zone control units in the core (control absorbers, where available, may also lower into the core to aid in power reduction if power error exceeds a preset limit). This will result in a slow reactor power reduction. The setback will be terminated when the reactor power reaches the preset endpoint, or when the setback condition clears.

If a **setback was not initiated** under these circumstances, the condition could lead to a **much faster power reduction** by a reactor **stepback** (where available) or reactor **trip** (ie. the next lines of defence).

The major **source of heat** (fission heat) will immediately be reduced. This will cause the heat input to the HTS to drop, and HTS temperature will drop.

Note that, due to the reduced rate of shrinkage (as compared to a reactor trip or stepback), the **HTS pressure** drop will be minimized, since the pressure and inventory control system will be able to accommodate the shrinkage more closely.

Reactor control, turbine-generator response, boiler pressure, temperature and level will be similar to that described for a reactor stepback.

Major Operational Concerns

Obj. 18.1 c) ii) ⇔

The **operator** must **confirm** that reactor **power is reduced** to the new "safe" level and **automatic actions** are restoring stable unit operation.

The reactor must be within the capacity of the available **heat sink** to ensure fuel cooling.

The **HTS pressure and inventory control** must be **restored** by the action of the feed system and pressurizer (where installed), to ensure fuel cooling can be maintained.

NOTES & REFERENCES

The **condition** that caused the setback must be **identified and corrected** before normal high power operation will be approved by the shift supervisor.

A **poison out** may occur, depending on how much reactor power has been reduced.

Indications

⇔ ***Obj. 18.1 c) iii)***

Upon detection of a setback parameter, the **condition** is **annunciated** in the control room.

The **reactor power setpoint** (and reactor power following) will be **ramped down** at a pre-determined rate (in some stations this rate is fixed, in others the rate is determined by the initiating condition).

The power reduction stops when the **setback endpoint** is reached (ie. the new "safe" power level, depending on the condition) or until the setback **condition clears**.

Unit control, liquid zone (and possibly control absorber), HTS pressure and temperature, boiler pressure and temperature and level and turbine-generator indications will be similar to those of a reactor stepback (but changes will be less drastic than for stepbacks).

Use Of The Manual Setback

⇔ ***Obj. 18.1 c) iii)***

As previously mentioned for reactor trips, a **manual setback** may be required if **an automatic** setback did not occur, or the operator has identified that a reactor power reduction in a controlled manner is required due to a unit abnormality.

Certain situations, as **listed** in station specific **operating documents**, may also require a setback for power reduction to avoid upcoming automatic protective action (reactor trip). For example, a manual setback is required on detection of falling instrument air pressure, ie. air pressure cannot be maintained (this reduces reactor power before control is lost).

The operation of the setback **handswitch** on the control panel initiates a manual setback.

NOTES & REFERENCES

SUMMARY OF THE KEY CONCEPTS

- The indications of a reactor setback available to the control room operator are:
    - Annunciation of the cause of the setback;
    - Reactor power following setpoint down to a specified endpoint, or where condition clears, at a given rate;
    - Liquid zones filling;
    - HTS pressure lowers slightly due to shrinkage, then recovers;
    - Boiler level, pressure and temperature are decreasing;
    - Turbine unloads to maintain boiler pressure;
    - If the reactor was in the reactor lagging mode of control, control reverts to the reactor leading mode.
- Operation at the previous power level cannot continue without the risk of a much faster power reduction by a stepback or trip. The reactor must be within the capability of the available heat sink.
- The problem must be identified and corrected before any power increase is attempted.
- The operator must ensure all auto actions occur to stabilize unit operation at the new "safe" power level (boiler pressure and level, HTS pressure, etc.).
- The risk of a poison outage may exist, depending on the magnitude and duration of the power reduction.
- Manual setbacks must be performed if an automatic setback does not occur or as station specific documentation or conditions dictate.

Pages 31-37 ⇔

You can now **work on assignment questions 1-3.**

LOSS OF COOLANT ACCIDENT (LARGE AND SMALL)

Consequences To Unit Operation

Obj. 18.2
a) i) ⇔

As defined earlier in this course, a LOCA is a loss of D_2O from the HT system causing sustained low HT pressure. This would mean that normal HT pressure cannot be maintained or pressure recovery to normal levels is not anticipated within a defined time period.

The **HT D_2O** required for fuel cooling is **being lost** from the HTS (ie. loss of fuel's heat sink).

The location of the source of HT coolant loss is also very important, ie. in-core or out-of-core (say into the boilers via ruptured boiler tubes). This presents varying concerns listed in the next section.

For a **small LOCA**, the shutdown systems will **trip** the reactor on **HT low pressure** and/or **low pressurizer level**. These trips occur simply due to the loss of coolant inventory beyond the capacity of the pressure and inventory control system. (Note: other trips, where installed, will also occur, eg. containment high pressure).

For a **large LOCA**, the reactor behaves differently. During a large LOCA the HTS depressurizes very rapidly. The rapid depressurization will cause coolant **voiding** in the core. This voiding causes a large insertion of positive reactivity into the core (due to the positive void coefficient). The reactor power quickly increases because the regulating system cannot respond to such quick changes in reactivity (or reactor power). The shutdown systems will **trip** the reactor on **high neutron power** and/or on a **neutronic rate power increase**. (Note: other trips may also occur on HT low pressure, low pressurizer level and/or containment high pressure, where installed).

After the reactor trip, heat input from the fuel will be reduced to decay heat levels and **HTS temperature** will be reduced. This will cause HT coolant shrinkage and a pressure drop.

A **rapid ("crash") cooldown** * will occur by the opening of the boiler safety valves (or large steam reject valves, depending on the station) to ensure the reactor fuel is adequately cooled. The purposes of crash cooling for both small and large LOCAs, although common, vary slightly in relative importance, and are explained below.

* The operation of crash cooldown and ECI were discussed in Module 12.

For a **small LOCA**, the depressurization of the HTS is slow (ie. coolant lost through the break is not sufficient to rapidly depressurize the HTS). Crash cooling reduces the HTS pressure to allow for a more rapid ECI injection to re-wet the fuel. For a small break, the boilers are still the main heat sink, and the boiler pressure/temperature reduction will provide cooling to the HTS (maintains the heat sink). And, since the leak rate is small in the first place, the reduction in leak rate due to depressurization will not be as dramatic as compared to a large LOCA.

For a **large LOCA**, the depressurization of the HTS is very rapid, and the boilers (still pressurized and hot) become a heat source to the HTS (note that the coolant discharged from the break is removing heat from the fuel, but rapid ECI injection is still required to re-wet the fuel). Crash cooling will reduce the boiler pressure/temperature to remove the boiler as a heat source. Since the HTS depressurization is so rapid, crash cooling's effect to reduce HTS pressure to injection pressure may not be noticeable. The overall pressure reduction will result in a reduced leak rate from the HTS.

The **turbine and CSDV's will trip** (on the ECI initiation signal, but not all stations) to prevent turbine/condenser damage from two-phase flow that may result from the boiler swell when the boiler safety or steam reject valves open to depressurize the boilers.

Emergency coolant injection will inject water to replace the lost coolant when HTS pressure drops to 5.5 to 4.2 MPa, depending on the station, followed by low pressure pumped injection (if installed) and low pressure recovered injection.

* The operation of containment was discussed in Module 13.

Depending on the location of the break, **containment** * may **box-up** (button-up) on high containment pressure or activity to prevent releases. Also, depending on the location of the break, indications may show that **dousing** has occurred. This limits the vacuum building/containment (reactor building, for the CANDU 600 design) pressure increase. Longer term responses of the emergency coolant injection system and the containment system are covered in the appropriate sections of this course.

Other Major Concerns

Obj. 18.2 a) ii) ⇔

Reactor power levels, hence fuel temperatures, **must be lowered** to ensure pressure tube/calandria tube integrity is maintained, and allow fuel cooling to be maintained.

Also, with decreasing pressure in the HTS, fuel cooling will be impaired due to excessive localized boiling and voiding, leading to possible dryout conditions. Rapid cooling will be required by ECIS and crash cooling. ECIS maintains HTS pressure as high as possible to minimize the boiling and voiding, ie. prevent pressure tube damage and fuel dryout by maintaining subcooled conditions within the reactor.

A **feedwater** source must be available to maintain a heat sink (for crash cooling). (Note that there should be sufficient boiler inventory to reduce HTS pressure to the point of ECI injection, but your heat sink should be monitored/ensured.)

For an in-core LOCA, when the moderator (with its soluble poison) is being displaced from the calandria by the leaking HT coolant, the reactor must remain **subcritical**. Hence, additional poison will be required to ensure that the reactor does not go critical when HT D_2O displaces the poisoned moderator D_2O.

Releases must be **monitored** to ensure appropriate actions are taken so as not to exceed regulatory release limits. The operator must also evaluate possible radiological hazards around plant equipment, because equipment that is not normally radioactive can be highly contaminated (eg. ECI equipment, etc.). Containment integrity must be ensured to prevent any unmonitored releases (also prevents exceeding regulatory release limits). Other unmonitored releases, via boiler steam or boiler blowdown (if a boiler tube rupture occurs), must be avoided.

Indications

NOTES & REFERENCES

Obj. 18.2
⇔ a) iii)

Indications available to the control room operator of a LOCA include **falling HTS pressure**, the rate depending on the size of the break. A HTS **inventory loss** will be detected by decreasing D_2O storage tank level, decreasing pressurizer level (where installed)* and feed system action.

* assuming that the leak is not from the top of the pressurizer, which would cause the pressurizer level to increase.

The **location** of the HTS breach **may also be detected** (ie. out of core or in core). These indications may include beetle alarms in containment or collection sumps, rising containment pressure and temperature due to the flashing coolant, rising moderator for an in-core LOCA and high D_2O in boiler H_2O alarms for boiler tube ruptures *.

* These are only a list of some of the possible paths for the D_2O, others may exist.

Indications of a **reactor trip** and parameters causing the trip will be annunciated. These were discussed at the beginning of this module.

Indications will show that **crash cooling** is occurring (ie. boiler safety valves open, boiler pressure is low, etc.). Indications will show that the turbine and CSDVs have been tripped to prevent damage from two phase flow.

Indications will show that high pressure **emergency coolant injection**, followed by low pressure pumped injection (where installed) and low pressure recovered injection (pumps running, valve operation, flow indication).

Panel indications will show that **containment** is buttoned-up (boxed-up) and, dousing valves open, pressure relief valves open, dousing is occurring, etc. (depending on type of containment).

SUMMARY OF THE KEY CONCEPTS

- During a LOCA, coolant is being lost a rate sufficient to exceed the capacity of the HTS pressure and inventory control systems.
- Adequate HT pressure must be maintained to prevent dryout, and thus sustain coolant capacity to remove heat.
- Reactor power must be shut down to decay heat levels (and maintained shutdown) to remain within the capacity of the degraded heat sink.
- Indications of a LOCA will be:
  - HT pressure will be decreasing at a rate depending on break size;
  - HT inventory will be reducing as seen by a dropping D_2O storage tank level and pressurizer level (where installed);
  - Location of the HTS breach may be noted, ie. out of core or in core;
  - For a large LOCA, the reactor will trip on high neutron power or high log rate neutron power increase;

NOTES & REFERENCES

- For a small LOCA, the reactor will trip on low HT pressure or low pressurizer level;
- Crash cooldown will begin with the opening of the boiler safety valves (or large steam reject valves) to quickly cool the reactor;
- The turbine and CSDV's will trip, depending on the station, to protect the turbine/condenser from damage due to two phase flow;
- ECI will operate to inject coolant for the reactor as seen by injection valves opening, pumps starting and injection flows starting;
- Containment may box-up on high containment pressure or high activity;
- Dousing may occur to minimize the pressure increase in the vacuum/containment/reactor buildings.

LOSS OF REGULATION

Consequences To Unit Operation

Obj. 18.2 b) i) ⇔

* This section will concentrate on a LORA with a reactor power increase. Although LORAs with power decreases are still a concern, increasing power LORAs have the potential for damage and are discussed in this module.

Let us first define Loss of Regulation Accident (LORA) as "operation of reactivity control mechanisms which leads to unintended or uncontrolled increases (or decrease*) in reactor power". If no actions were taken, this power increase could cause **pressure tube damage** and **fuel dryout** (which may lead to fuel failures). Note that extremely large rates of power increases may cause immediate fuel damage due to the creation of large thermal stresses within the fuel element and fuel sheath, and due to overstressing of the fuel sheath from expanding gases from within the fuel.

This loss of power regulation could also result in **HTS overpressure**, which could result in a **HTS failure causing a loss of coolant and radiological releases**. As we can see, reactor power must be reduced to the safe state, since reactor control has been lost.

Reactor power will be increasing at a rate determined by the nature of the LORA.

Heat transport system pressure and temperature will be **increasing** due to the increased heat input to the coolant from the fuel (D_2O storage tank and pressurizer level increase, where installed). **Boiler pressure** (and temperature) will increase, as heat input to the boilers is increased.

The **heat transport pressure control** system will attempt to control pressure (ie. bleed system or pressurizer action where installed). If this pressure control is not sufficient, the HTS relief valves will operate in an attempt to protect the HTS from damage *.

* Recall that these valves have a limited capacity for pressure relief (ie. mechanical overpressure only).

Boiler pressure will be controlled by steam rejection to atmosphere via steam reject valves or atmospheric steam discharge valves (or opening of GVs in the reactor leading mode of control). (We will assume that if the unit is in the reactor lagging mode of operation, the BPC action to reduce reactor power will be ignored due to the LORA).

The shutdown system(s) will **trip** the reactor on **high neutron power, neutronic rate or high HTS pressure** (or temperature) depending on the rate of the power increase. (Note that no credit will be given to the setback or stepback functions. This is because the reactor regulating system and possibly other components are malfunctioning or have run out of range, and hence, may not be able to reduce reactor power.) **Boiler levels will be ramped down with the decrease in reactor power.**

The effects of a reactor trip have been discussed earlier in the module.

Other Major Concerns

⇔ ***Obj. 18.2 b) ii)***

The cause of the LORA must be identified and corrected before a reset of the reactor trip will be approved. If the problem cannot be identified and corrected immediately, the reactor must be placed in the Guaranteed Shutdown State (GSS), since the regulating system is assumed to be unavailable.

Indications

⇔ ***Obj. 18.2 b) iii)***

Indications will show that reactor **power** is **rising** (unrequested). A **flux tilt** may also be observed if the power increase is limited to portions of the core only.

Indications available to the control room operator will show that one or more of the **reactivity devices** will be observed to be **inserting positive reactivity**. The liquid zones may be draining, control absorbers may be driving out of the core, the adjusters may be driving out of the core, boosters being inserted into the core, moderator level increasing, or moderator poison being removed. It is also possible that a lack of detection is the cause of the LOR, hence these indications may not be available.

HTS and boiler pressures and temperatures will be seen to increase (indications have been mentioned earlier in the module). Boiler pressure will be controlled by ASDVs/CSDVs before the reactor trip and by turbine runback after the reactor trip. HTS pressure will be restored after the reactor trip occurs. **Boiler levels** will show a decrease after the reactor trip.

Indications will show that the **reactor has tripped** on high neutron power, neutronic rate (log or linear), or high HT pressure (or temperature), depending on the rate of power increase.

NOTES & REFERENCES

After the actions listed above, normal HTS pressure control will be regained and reactor power will be reduced to a safe level.

SUMMARY OF THE KEY CONCEPTS

- An unterminated LORA could cause fuel overpowering, leading to dryout and hence, fuel failures. The power increase may also lead to HTS overpressurization, leading to HTS failures and hence, loss of coolant and radioactive releases.
- Indications of a LORA available to the control room operator are:
  - Reactor power will be increasing (unrequested);
  - HTS pressure and temperature increases (for LORA rates that cause HTS swell beyond the pressure and inventory control system);
  - Boiler pressure and temperature will increase due to the increased heat input, steam rejection to atmosphere may be required;
  - Reactivity devices may be observed to be adding positive reactivity to the core;
  - Possible flux tilt formation;
  - The reactor will trip on high neutron power, neutronic rate or high HTS pressure (or temperature), depending on the rate of power increase;
  - After the reactor trip, reactor power will be at a safe level and the unit will stabilize in the zero power hot state.

Pages 37-42 ⇔

You can now **work on assignment questions 4-17.**

LOSS OF FEEDWATER

Consequences To Unit Operation

Obj. 18.2 c) i) ⇔

The loss of feedwater represents a **loss of the major heat sink** for the reactor. This feedwater normally carries the heat away from the reactor via the boilers in the form of steam.

High power operation cannot continue without a continued feedwater supply, otherwise the boilers will be quickly depleted of remaining feedwater. Note that none of the backup heat sinks (eg. shutdown cooling) are capable of removing reactor full thermal power.

Boiler levels will be decreasing due to the large mismatch between steam flow and feedwater makeup.

The heat transfer in the boilers occurs in two stages. The first stage transfers heat to the feedwater (in the preheater) and the second stage

NOTES & REFERENCES

converts the feedwater to steam. The cooling effect of the feedwater in the preheaters (internal or external preheaters) is immediately lost, resulting in a **D_2O temperature** increase into the reactor. The **HTS pressure and inventory volume** increases due to the expanding coolant (swell).

Boiler pressure increases because of a lack of cold feedwater entering the boiler and also because of the increased average temperature of the HT D_2O in the boilers, (ie. with increased D_2O temperature there will be a higher ΔT across the boiler tubes, resulting in an increased heat transfer to the feedwater inventory in the boiler).

For the reactor leading mode of operation, the turbine steam valves will try to accommodate the boiler pressure increase. For the reactor lagging mode, the reactor power will be reduced in an attempt to reduce the boiler pressure. Since **boiler pressure control** via the governor valves is limited, the steam reject valves or atmospheric steam discharge valves, depending on the station, will open to control boiler pressure (indications will show that the valves are open and boiler pressure is returning to normal).

The reactor will trip on **high HTS pressure** (or temperature) **and/or boiler low level.** (Note that the reactor may also trip on low boiler feedwater pressure or high boiler room pressure, depending on the station and the cause of the feedwater loss, eg. feedwater line break inside containment).

Other Major Concerns

⇔ Obj. 18.2 c) ii)

The loss of feedwater can be the result of two basic events. The first being a break in the boiler feedline *, and the second, the stopping of flow due to valve closures, pump trips, etc.

* It is assumed that the break is upstream of the non-return valves in the boiler feedlines (due to their proximity to the boilers). This would prevent the boiler inventory from being discharged from the break.

With failure of the boiler feedline, a deadly personnel safety **hazard** exists due to the hot feedwater and the water flashing to steam. **Electrical problems** may occur as equipment gets hot and wet. This will jeopardize electrical supplies and create further operational problems.

This event represents a degradation of the heat removal capability and eventual complete loss of heat sink, unless corrective action is taken.

Indications

⇔ Obj. 18.2 c) iii)

The loss of feedwater will be noticed by a **decreasing boiler level.** This may affect some or all of the boilers, depending on the cause of the loss of feedwater.

HTS pressure (and temperature) will increase due to the reduced heat removal in the preheaters (and boilers). **HTS swell** will be indicated by high bleed flow accompanied with no feed flow, increasing D_2O storage tank level and increasing pressurizer level, where installed.

Boiler pressure and temperature will be seen to rise due to the increased temperature of the HTS. Panel indications will show that steam is being discharged to atmosphere (steam reject valves or atmospheric steam discharge valves).

Depending on the cause of the accident, feedwater **flow indications** may show that feedwater **flow has stopped** (in the case of pump trip or valve failure or error), **or** indications will show a **very high flow** (in the case of a feedline break). Along with high flows, electrical faults may also be evident due to the hot feedwater and flashing steam.

HTS pressure and inventory control will be restored by feed/bleed action, pressurizer actions and HTS liquid relief valve opening (if required).

SUMMARY OF THE KEY CONCEPTS

- The loss of feedwater represents the loss of the major full power heat sink for the reactor. Full power operation cannot continue since the boilers will eventually be depleted of all water, and no backup heat sink is capable of removing full reactor power.
- Indications of a loss of feedwater are:
  - Decreasing boiler level;
  - Increasing boiler pressure;
  - HTS pressure, temperature and inventory volume increase due to reduced cooling of D_2O in the preheaters and boilers;
  - The atmospheric steam reject valves will open to control boiler pressure;
  - HTS pressure will be regained by normal pressure and inventory control system action;
  - Feedwater flow indications will show that feedwater flow has stopped, or if a feedline break has occurred, feedwater flow indications will be high;
  - The reactor will trip on HTS high pressure or boiler low level.
- A deadly personnel safety hazard exists from hot feedwater/steam in the powerhouse. A search and rescue must be performed to assist injured personnel. Electrical faults may also be evident and cause further problems, and power must be maintained as feasible.

NOTES & REFERENCES

MAIN STEAMLINE BREAK

Consequences To Unit Operation

⇔ *Obj. 18.2 d) i)*

During a main steamline break, the **boiler inventory** required to cool the reactor is being **discharged to the powerhouse** (or into containment in some stations). This rapid depressurization of the boilers results in an uncontrolled cooldown (similar to crash cooling), causing a reduction of HTS pressure and temperature.

Once the feedwater inventory is depleted, the heat sink is lost and excessive HTS boiling will occur. This results in **impaired fuel cooling** capability and eventual fuel dryout could occur. The reactor power must be immediately lowered to reduce fuel temperatures and restore HTS pressure, preventing fuel failures.

After the steam line break occurs, the **boiler pressure** rapidly **decreases.** With a pressure decrease, the amount of boiling will increase. The presence of more steam bubbles will cause the boiler level to rise significantly, resulting in a steam-water mixture being discharged from the boiler outlet (the cyclone separator capacity will be exceeded).

The **HTS pressure and temperature drop** rapidly due to the uncontrolled heat removal in the boilers. **HTS inventory volume decreases** due to shrinkage as can be seen by D_2O storage tank levels and pressurizer levels (where installed). The ECI initiation setpoint may be reached.

For the reactor lagging mode of control (in some stations), reactor power will be increased to try to maintain boiler pressure until the upper power limit is reached, and when a preset boiler pressure error then exists, contro19Yçlverts to the reactor leading mode of control. For the reactor leading mode of control, the **turbine will be unloaded** by BPC to attempt to maintain boiler pressure. (Note in some stations, a low boiler pressure unloader exists in the turbine governing system to unload the turbine if BPC failed to do so. However, this action may be too slow to prevent turbine damage due to water induction. Protection can only be achieved by tripping the turbine.)

An indication of increased feedwater **flow** will be seen, due to the increased flow to the depressurized boiler(s)*. Note that boiler level control will also call for increased feedwater flow due to the apparent decrease in boiler level**.

The **turbine output** will be **reduced** because the turbine inlet pressure is dropping rapidly, and because the governor valves are closing in an attempt to maintain the boiler pressure setpoint. This reduces the work done by each kg of steam. Also, the total amount of steam flowing through the turbine is reduced due to the steamline break.

* Recall that the centrifugal pump flow increases with decreasing discharge pressure.

** Apparent decrease in boiler level results from a decrease in boiler content density. This is discussed further as part of Objective 18.2 d) iii) on the next page.

The reactor will **trip** on **low boiler level or HT low pressure**, depending on the break discharge rate and location. (Note in some stations the reactor may also trip on low boiler feedwater pressure or low pressurizer level, if installed). This will ensure fuel temperature is reduced to enable the HTS to cool the fuel. The tripping of the reactor will also reduce heat input to the boilers, resulting in less steam discharge to the powerhouse. In some stations, the break can be inside reactor building, causing the reactor to trip on high reactor building pressure.

The **BLC** program will attempt to control the **boiler level** on the level term only or may fail completely, since the steam flow term and boiler level terms have gone irrational (due to low boiler level and very high flow rates and/or steam flow backfeed via the balance header).

Condensate make up valves will open on low hotwell level to provide a condensate supply for the boilers. In some stations, the inter-unit feedwater tie will also be able to provide feedwater for the boiler inventory.

Other Major Concerns

Obj. 18.2 d) ii) ⇔

A steamline break into containment will appear similar to a LOCA. Falling HTS pressure and rising containment pressure can confuse this upset with a LOCA. The major difference is that a LOCA may be accompanied by high containment activity and neutronic trips, whereas a steamline break is not.

The discharge of steam will also create widespread **electrical problems** as equipment gets hot and wet. This would jeopardize electrical supplies in all the units, not just the incident unit. Steam in the powerhouse also presents a **deadly hazard** to the station personnel as temperatures increase and air is displaced.

Two-phase flow from the boilers results from the swell in the boilers, which may result in turbine damage. Note that for a large steamline break, the resulting discharge flow from the boilers may be several times the normal full power flow rate.

Feedwater inventories will be **decreasing** ie. deaerator and condenser hotwell levels will decrease, since the plant is operating on an "open cycle" ie. condensate is not being returned to the unit.

Indications

Obj. 18.2 d) iii) ⇔

The **boiler level** indications will show a **rapid level decrease** due to the lost inventory (Note again that boiler level has actually swelled causing two phase flow from the top of the boiler. The false low level indication is because the rapid depressurization causes a decrease in boiler content density, which makes the level instrumentation indicate, falsely, that the level has decreased). Deaerator and condenser hotwell levels will be decreasing.

HTS pressure and temperature will decrease, causing coolant shrinkage, as seen by decreasing D_2O storage tank and pressurizer levels, where installed.

Boiler pressure (and temperature) will decrease rapidly as the steam is discharged through the break. The **turbine generator output** will decrease rapidly.

Noise may be evident in the control room that a steam line break is occurring.

Various **alarms** may indicate that **electrical trips** and/or fault may be seen due to the steam in the powerhouse.

The **reactor** will **trip** on low boiler level and/or HT low pressure, (possibly on low boiler feedwater pressure or low pressurizer level, if installed).

SUMMARY OF THE KEY CONCEPTS

- During a main steamline break, the boiler inventory is being discharged to the powerhouse.
- The steam in the powerhouse is a deadly hazard to station personnel. Electrical faults may also be evident and cause further upsets, and power must be maintained as feasible.
- The rapid boiler depressurization causes an uncontrolled cooldown. When feedwater inventory is depleted, the full power heat sink for the reactor will be lost.
- Turbine damage due to water induction may also result from two-phase flow from the boilers.
- Indications of a main steamline break are:
  - Noise in the powerhouse;
  - Boiler pressure and level decreasing;
  - HTS pressure, temperature and inventory volume decreasing due to the uncontrolled cooldown, ECI initiation pressure may be reached;
  - Turbine generator output decreasing;
  - Reactor trip on HTS low pressure or boiler low level;
  - Boiler inventory will be maintained by the inter-unit feedwater tie, where available, and condensate make-up to the condensate system ;
  - Feedwater flow indications show increased feed to the depressurized boiler.

NOTES & REFERENCES

- The HTS pressure must be maintained by additional feed or the operation of the Emergency Coolant Injection system.

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You can now **work on assignment questions 18-29**.

LOSS OF LOAD

Consequences To Unit Operation

Obj. 18.2 e) i) ⇔

The loss of load (also referred to as a load rejection) is the inability of the grid to accept the power produced by the generator. A full loss of load represents a **loss of a heat sink pathway** of approximately **30%** of the reactor's total full power heat (ie. steam flow through the turbine has decreased to supply unit service loads only. Since the steam flow to the condenser then drops, the overall heat being rejected is quite low compared to normal operation.). For stations not using CSDVs, this will be a loss of approximately 100% of the heat sink. A reactor power reduction may be required to bring the reactor power within the **capacity of the available heat sink.**

During normal operation ~70% of the heat produced is rejected to the condenser. In stations using CSDVs, the condenser is now the reactor's full heat sink (excluding atmospheric discharge). Depending on the capacity of the condenser or CSDVs, a **reactor power reduction may be required** to prevent **thermal overloading** of the condenser (station CSDV and/or condenser capacities vary between ~65 to 100% FP).

For stations using SRVs, the available heat sink is now the atmosphere via steam discharge. Although SRVs are rated for 100% FP, power is reduced to minimize the amount of steam that is discharged, hence **conserving feedwater supply.**

In some stations, the power reduction will occur due to a **stepback** upon the detection of the loss of turbine load.

In other stations, the reactor/turbine power mismatch causes boiler pressure to rise. Since BPC cannot control boiler pressure via the turbine steam control valves (since the turbine governing system is trying to prevent overspeed), the pressure is controlled via steam reject valves and/or boiler safety valve action. A **setback** on steam reject valve action occurs, which would be terminated at a level preventing a poison outage, while minimizing feedwater wastage.

On the loss of line, the **turbine generator speed** will initially increase due to the large power mismatch*.

* This is discussed in the 235 Electrical Systems course.

HT pressure and temperature will increase due to the power mismatch between the reactor and the boilers, causing HTS inventory to swell.

After the above reactor power reductions, **boiler pressure** is controlled by the **steam reject valves** or the **condenser steam discharge (dump) valves** (depending on the station). Boiler level will be ramped down as reactor power is lowered.

Other Major Concerns

⇔ *Obj. 18.2 e) ii)*

Turbine **overspeed** must also be **limited to avoid possible catastrophic equipment damage or an overspeed trip**, both leading to a total **loss of turbine generator output**. An overspeed trip would increase the chances for a total loss of Class IV power, particularly in single unit stations.

To prevent a poison outage, reactor power will need to be maintained ~60% FP via steam discharge to the condenser or atmosphere. In the event of steam discharge to atmosphere, adequate feedwater reserves must be available to supply continued reactor cooling requirements.

Indications

⇔ *Obj. 18.2 e) iii)*

The panel indications will show that the turbine-generator has disconnected from the grid, and turbine speed in increasing.

The turbine governing system will quickly **stop steam flow** to the turbine to avoid a turbine overspeed trip and indications of turbine steam valves closing will be seen. This will be accompanied by a **fast runback** which limits the frequency changes (after the overspeed transient is over) in the power still being supplied by the generator to the unit.

A **boiler pressure increase** will be seen as the steam flow from the boilers is reduced. Boiler pressure will be controlled by steam rejection to the condenser or to the atmosphere, depending on the station.

HTS pressure and temperature increases will be observed.

A reactor **power reduction** will occur via a setback or stepback, depending on the station.

SUMMARY OF THE KEY CONCEPTS

- A loss of load represents a loss of approximately 30% of the high power heat sink. Reactor power must be brought within the capacity of the available heat sink.

NOTES & REFERENCES

- A turbine overspeed must be avoided to prevent possible equipment damage and an overspeed trip would result in a total loss of turbine generator output. An overspeed trip would also increase the possibility of a loss of Class IV power.
- Reactor power must be maintained high enough to avoid a poison outage. In stations using SRVs, final reactor power must be such that steam discharge to the atmosphere is minimized to ensure an adequate feedwater inventory. In stations using CSDVs, the final reactor power may have to be limited to avoid thermal overload of the condenser.
- Indications of a loss of load are:
  - The generator is disconnected from the grid and turbine speed is increasing;
  - Turbine governing system action quickly stops steam flow to the turbine to prevent an overspeed trip. Final turbine generator speed is near normal;
  - Reactor power reduces via setback or stepback to within the capability of the available heat sink, and kept high enough to minimize the chance of a poison out;
  - Boiler pressure is being maintained by the steam reject valves or the condenser discharge valves.

LOSS OF CLASS IV POWER

Consequences To Unit Operation

Obj. 18.2
f) i) ⇔

* An example of this may be on a loss of load followed by a turbine overspeed trip and failure to transfer to the station service transformer.

Upon the total loss of Class IV* power, all **Class IV loads** will be **lost**. Normal high power operation cannot continue without Class IV power, because of the impaired heat sink (explained below).

The **turbine** will **trip** on **high condenser pressure**, since condenser cooling water pumps have lost power (an annunciation will be received and the turbine steam valves will be seen to close). In some stations, the generator excitation system is supplied from Class IV power. Hence, upon the loss of power, the turbine generator trips on loss of excitation, which is much faster than the low condenser vacuum trip. Also in some stations, a turbine trip on loss of governing system hydraulic fluid pressure also occurs.

The **condenser steam discharge (dump) valves** (where installed) **also trip closed** to **prevent** condenser and LP turbine exhaust cover **overpressure**. This, combined with the turbine trip, results in rising boiler pressure.

The HTS coolant circulation is reduced due to the loss of power to the main coolant circulation pumps. The **HTS temperature** increases since the coolant must pick up more heat from the fuel (ie. for the same power level with reduced coolant flow, the coolant ΔT must increase to remove the same amount of heat). The **HTS system pressure will increase** due to the coolant swell. HTS **inventory volume increases** as the coolant expands (due to the increasing temperature and increased amount of boiling), which can be seen by increasing D_2O storage tank level and increasing pressurizer level (where installed) and bleed flow.

The shutdown system(s) will **trip** the reactor on **gross low HTS flow or high HTS pressure** to maintain fuel integrity and avoid overstressing the HTS. Reactivity devices will also operate to insert negative reactivity as described earlier in this module.

The **boiler pressure** will be controlled by the atmospheric steam reject valves. **Boiler levels** will decrease due to the loss of the main boiler feed pumps until makeup is restored from the Class III pumps.

The **emergency transfer system** will attempt to restore power to the dead Class III busses. The required Class III loads will automatically be picked-up. This will ensure that all critical loads will have their power supply to prevent damage as described in the next section. In single unit stations and depending on how widespread the power loss is in multi-unit stations, the standby generators and emergency power generators (if installed) will start to supply the Class III power.

Other Major Concerns

⇔ Obj. 18.2 f) ii)

The **Class III** system will also be **lost**, since it is normally supplied by the Class IV system. Class III power must be restored to the unit to ensure critical loads are restored, such as HT feed pumps, auxiliary feedwater supplies, instrument air, Class II power, service water, shutdown cooling, other Class III feeds, etc. It is also essential to ensure that lube oil, jacking oil, generator seal oil and turning gear are available to **safely shut down the turbine**. This ensures damage to turbine and generator bearings and seals does not occur.

Forced HTS **coolant circulation** has been lost, hence **thermosyphoning** will be required to remove the heat from the fuel.

HTS pressure and inventory must be maintained, since this is essential for thermosyphoning and prevention of voiding in the HTS. The pressurizer heaters (where installed) have lost their power supply.

Indications

⇔ Obj. 18.2 f) iii)

Many **electrical alarms** and indications (ie. dead busses) will be seen to indicate the widespread loss of Class IV and III power in the unit. The emergency transfer scheme will be operating to restore Class III power, standby generators and emergency power generators may also start to restore power, depending on the station.

The parameter that caused the **reactor trip** will be annunciated in the control room. The indications of the reactor trip have been previously discussed.

Heat transport pressure will increase initially, D_2O storage tank and pressurizer level (if installed) will rise due to HTS swell (until the reactor trip occurs).

Condenser pressure will be seen to increase, and will result in **turbine and CSDV trips.**

Boiler pressure will increase due to the HTS temperature increase and due to the reduced steam flow from the boilers due to the turbine trip. **Boiler levels** will drop due to the loss of the boiler feed pumps (and due to the boiler pressure increase caused by the turbine trip).

SUMMARY OF THE KEY CONCEPTS

- The effects of the loss of Class IV power are impaired fuel cooling due to the loss of power to the HT pumps. High reactor power operation cannot continue due to this impairment.
- The normal Class III power supply will also be lost since it is normally fed from the Class IV power system.
- Thermosyphoning will be required because forced coolant circulation over the fuel has stopped.
- Indication available in the control room that a loss of Class IV power has occurred are:
  - Many electrical alarms indicating the loss of Class III and Class IV power;
  - HTS pressure and temperature increase due to the increased heating of the slower moving coolant;
  - D_2O storage tank and/or pressurizer levels increase due to the expanding coolant;
  - The reactor will trip on high HTS pressure or HTS low flow;
  - The turbine and condenser steam reject valves trip (where installed) to protect the condenser and LP exhaust cover from overpressure.
  - Boiler pressure will be controlled by the steam reject valves, or atmospheric steam discharge (dump), depending on the station;
  - The emergency transfer system will attempt to restore power to the dead busses. Essential Class III loads will be re-energized to prevent fuel and equipment damage. The standby generators and the emergency power generators may start, depending on the station.

Pages 48-52 ⇔

You can now **work on assignment questions 30-39.**

UNAVAILABILITY OF CLASS III POWER

This section will deal with two cases,

- Loss of Class III Power with Class IV power available,
- Loss of Class III Power with Class IV power unavailable.

LOSS OF CLASS III POWER WITH CLASS IV POWER AVAILABLE

Consequences To Unit Operation

⇔ *Obj. 18.2 g) i)*

As you recall from previous electrical courses, Class III power supplies Class I power and Class II power (indirectly, through the Class I system). The total loss of Class III power * (ie. all Class III busses dead, and emergency transfer system ** failure after a loss of Class III power) leaves **Class I and Class II power on the battery supplies** (note that this occurs in spite of Class IV power still being available). A 40 ~ 45 minute reserve exists until the batteries will be depleted. After this, the Class I and Class II power supplies will be lost. **Unit control and control room indications will also be lost** with these power supplies. The reactor must immediately be placed in the **safe** (shutdown) state before the Class II and Class I power supplies are lost (i.e. reactor placed within the capacity of the available heat sink). (Note that in some stations, an automatic setback on loss of end shield cooling water pressure will occur to reduce reactor power.)

* Assume all attempts to restore power are unsuccessful.

** Recall that the emergency transfer system will attempt to restore Class III power to the dead busses by connecting to a "healthy" power supply, ie. other busses or standby generators.

Other Major Concerns

⇔ *Obj. 18.2 g) ii)*

If Class IV power is now lost, the full power heat sink would also be lost (this is discussed in the next section of this module).

Class III power must be restored as soon as possible to ensure that critical loads have a power supply such that the reactor has a heat sink (auxiliary feedwater supplies, instrument air, service water, Class II power, end shield cooling, etc.) and the turbine generator can be safely shut down, etc.

A low power **heat sink and a backup** must be established prior to loss of Class I and Class II power, to ensure the fuel will be adequately cooled. The reactor must be transferred to the available heat sink without causing undue thermal stresses (controlled cooldown).

The reactor trip causes a rapid HTS pressure drop due to shrinkage. The loss of Class III results in the loss of the feed pumps. Heat transport system **inventory** must be **maintained** during cooldown to ensure fuel cooling. Note that emergency coolant injection and a crash cool initiation setpoint will be reached.

NOTES & REFERENCES

Indications

Obj. 18.2 g) iii) ⇔

Electrical **alarms** and **indications** (ie. dead busses) will show that the Class III power system has been lost.
Annunciations will show that the **emergency transfer scheme** will be attempting to restore Class III power. Breaker operation will also be seen to attempt to restore the lost power.

SUMMARY OF THE KEY CONCEPTS

- The loss of Class III power will result in the loss of Class I and Class II power supplies. This loss will occur when battery supplies are depleted in about 40 ~ 45 minutes. The loss of these power supplies will result in the loss of unit control and control room indications. The reactor must be placed in the safe (shutdown) state and a low power heat sink placed in service prior to the loss of unit control.
- Inventory makeup will be lost, which may require ECI for makeup.
- The indications for loss of Class III power are:
  - alarms and indications of dead Class III busses;
  - Emergency transfer scheme operating to try to restore Class III power;
  - Eventual loss of unit control and control room indications.

LOSS OF CLASS III POWER WITH CLASS IV POWER UNAVAILABLE

Consequences To Unit Operation

Obj. 18.2 h) i) ⇔

With the additional total **loss of Class IV** power added to the total loss of Class III, further complications arise. The full power **primary heat sink has been impaired** due to the loss of HTS coolant circulation (heat transport pumps are supplied by Class IV power). Note that coolant circulation continues but decreases, due to the rundown characteristics of the HT pumps/motors/flywheels. The reactor must be **immediately tripped** to prevent fuel overheating. Sustained loss of all power would not provide for decay heat removal or allow the monitoring of critical safety parameters.

The effects on boiler pressure and level, HTS pressure and temperature, turbine and CSDV trips, and reactor trips have been discussed in the section covering the loss of Class IV power.

NOTES & REFERENCES

Other Major Concerns

⇔ Obj. 18.2 h) ii)

Also, as discussed in the previous section, **Class I and Class II** power supplies (with unit control and control room indications) **will be lost** (after 40~45 minutes). The reactor must be placed in the safe state before these power supplies are lost (ie. reactor placed within capacity of available heat sink).

Forced HTS **coolant circulation** has been lost, hence thermosyphoning will be required to remove the heat from the fuel.

HTS pressure and inventory control must be restored since the pressurizer heaters (where installed) and feed pumps have lost their power supply (which is essential for thermosyphoning).

Note again that a crash cool will be initiated and emergency coolant injection may be required to maintain HTS pressure and inventory.

Indications

⇔ Obj. 18.2 h) iii)

Refer to the INDICATIONS section on loss of Class IV power on page 25 and to the INDICATIONS section on loss of Class III power on page 28.

SUMMARY OF THE KEY CONCEPTS

- The loss of Class III power with the additional loss of Class IV power results in the impairment of the primary heat sink. This impairment is due to the loss of forced circulation of HTS coolant (due to the loss of power to the HTS Pumps).
- The loss of Class III power (since Class III is normally fed from Class IV power) will result in the loss of Class I and Class II power supplies. This loss will occur when battery supplies are depleted in about 40 ~ 45 minutes. The loss of these power supplies will result in the loss of unit control and control room indications, hence, the monitoring of critical safety parameters cannot continue. The reactor must be placed in the safe (shutdown) state and a low power heat sink placed in service prior to the loss of unit control.

You can now **work on assignment questions 40-44.**

⇔ Pages 53-55

NOTES & REFERENCES

ASSIGNMENT

REACTOR TRIP

1. a) Explain the effect of a reactor trip on each of the following parameters:

i) HT pressure and temperature ____________________

____

____

ii) Boiler pressure and temperature ____________________

____

____

iii) Boiler level ____________________

____

____

iv) Turbine generator operation ____________________

____

____

v) Mode of unit operation ____________________

____

____

b) Reactor power must be lowered when a trip situation occurs because ____________________

____

____

c) Final reactor power must be ____________________

____

d) HTS pressure and inventory control must be restored because ____ ______________________________. Pressure control is regained by the actions of:

i) ______________________________

ii) ______________________________

e) The cause of a reactor trip must be ______________ and ______________ before the trip can be reset and the unit returned to power.

f) If the reactor power is not raised quickly enough after a trip the unit will ______________________

g) Typical indications of a reactor trip are:

i) ______________________________

ii) ______________________________

iii) ______________________________

iv) ______________________________

v) ______________________________

vi) ______________________________

vii) ______________________________

h) A manual reactor trip must be performed under the following situations.

i) ______________________________

____

ii) ______________________________

____

REACTOR STEPBACK

2. a) Explain the effect of a reactor stepback on each of the following parameters:

i) HT pressure and temperature ______________

____

____

ii) Boiler pressure and temperature ______________

____

____

iii) Boiler level ______________________

____

____

iv) Turbine generator operation ______________

____

____

v) Mode of unit operation ______________

____

____

b) Reactor power must be lowered when a stepback situation occurs to avoid ______________________

____

NOTES & REFERENCES

c) Final reactor power must be ______________________________

____

d) After the stepback, HTS pressure control is regained by the actions of:

   i) ____

   ii) ____

e) The cause of the stepback must be ______________________ and ______________________ before the reactor trip can be reset.

f) If the reactor power is not raised quickly enough after a stepback to low power levels, the unit will ______________

____

g) The stepback stops when ______________________________ or ____.

h) Typical indications of a reactor stepback are:

   i) ____

   ____

   ii) ____

   ____

   iii) ____

   ____

   iv) ____

   ____

   v) ____

   ____

   vi) ____

   ____

   vii) ____

   ____

i) A manual reactor stepback (is / is not) normally performed because ____________________

____

REACTOR SETBACK

3. a) Explain the effect of a reactor setback on each of the following parameters:

   i) HT pressure and temperature ____________________

   ____

   ____

   ii) Boiler pressure and temperature ____________________

   ____

   ____

   iii) Boiler level ____________________

   ____

   ____

   iv) Turbine generator operation ____________________

   ____

   ____

   v) Mode of unit operation ____________________

   ____

   ____

b) Reactor power must be lowered when a setback situation occurs to avoid ____________________

____

____

c) Final reactor power must be ____________________

____

d) After the setback, HTS pressure control is regained by the actions of:
   i) ________________________________
   ii) ________________________________

e) The cause of the setback must be ________________ and ________________ before reactor power can be raised.

f) If the reactor power is not raised quickly enough after a setback to low power levels, the unit will ________________
____

g) The setback stops when ________________ or
________________________________.

h) Typical indications of a reactor setback are:

   i) ________________________________
   ____
   ii) ________________________________
   ____
   iii) ________________________________
   ____
   iv) ________________________________
   ____
   v) ________________________________
   ____
   vi) ________________________________
   ____
   vii) ________________________________
   ____

i) Two situations when you would manually setback the reactor are:

i) ______________________________

____

ii) ______________________________

____

LOSS OF COOLANT ACCIDENT

4. Explain the effect of a loss of coolant accident on each of the following parameters:

a) HT pressure and temperature ______________________________

____

____

____

____

b) HT inventory ______________________________

____

____

____

____

c) Reactor power ______________________________

____

____

____

____

d) Boiler pressure and temperature ______________________________

____

____

____

____

e) Boiler level ________________________________

f) Turbine generator operation ________________________________

g) Containment ________________________________

h) Shutdown systems ________________________________

i) Emergency coolant injection system ________________________________

NOTES & REFERENCES

5. For an in core LOCA, an additional concern is ________________ ________________________ because ________________________ ____ ____

6. For a LOCA into the boilers, an additional concern is __________ ____ because ____ ____ ____

7. HTS pressure is maintained as high as possible by the operation of ______________________________. The purpose of this is to maintain _________________ conditions within the reactor.

8. _________________________ will occur by the opening of the large steam reject valves (or boiler safety valves, depending on the station). The turbine and CSDV's will trip to prevent ____________ ____ ____ ____.

9. The ___________ supply must be maintained to ensure crash cooling can be maintained.

10. Typical indications of a LOCA are:
    a) ____
    ____
    b) ____
    ____
    c) ____
    ____
    d) ____
    ____

e)

f)

g)

LOSS OF REGULATION ACCIDENT

11. **Explain the effect of a loss of regulation accident on each of the following parameters:**

    a) HT pressure and temperature

    b) HT inventory

    c) Reactor power

    d) Boiler pressure and temperature

e) Boiler level (after reactor trip) ______________________

____

____

____

____

f) Turbine generator operation ______________________

____

____

____

____

g) Shutdown systems ______________________

____

____

____

____

12. A loss of regulation will cause an ____________ increase in reactor power. This could cause fuel dryout leading to ________ ____________________.

13. A loss of regulation is caused by reactivity devices (adding / removing) reactivity from the core. One or more of the following may be observed:

    a) Liquid zones (filling / draining).
    b) Control absorbers driving (into / out of the core).
    c) Adjusters are driving (into / out of) the core.
    d) Boosters are driving (into / out of) the core.
    e) Moderator level is (increasing / decreasing).
    f) Moderator poison is being (added / removed).

14. A flux tilt (will / will not / may) occur if ______________________

____

15. Boiler pressure will be controlled by a ____________________

____.

16. The reactor will trip on ____________________,

____________________ or ____________________,

depending on the ________ of power increase.

17. Typical indications of a LORA are:

   a) ____________________

   ____

   b) ____________________

   ____

   c) ____________________

   ____

   d) ____________________

   ____

   e) ____________________

   ____

   f) ____________________

   ____

   g) ____________________

   ____

LOSS OF FEEDWATER

18. Explain the effect of a loss of feedwater accident on each of the following parameters:

   a) HT pressure and temperature ____________________

   ____

   ____

   ____

   ____

b) HT inventory ______________________________

c) Reactor power ______________________________

d) Boiler pressure and temperature ______________________________

e) Boiler level ______________________________

f) Turbine generator operation ______________________________

g) Shutdown systems ______________________________

NOTES & REFERENCES

19. Loss of feedwater results in the loss of the ____________________ ____, and normal high power operation (can / cannot) continue.

20. Feedwater flow indications will show that flow has______________ __________________ or that flow has ________________________ if a break has occurred. If a break has occurred a ________________ hazard exists due to hot feedwater and flashing steam.

21. Typical indications of a loss of feedwater accident are:

a) ____
____

b) ____
____

c) ____
____

d) ____
____

e) ____
____

f) ____
____

g) ____
____

22. ____________________ faults may be occurring due to a feedline break.

MAIN STEAMLINE BREAK

23. Explain the effect of a steamline break on each of the following parameters:

    a) HT pressure and temperature ________________

    b) HT inventory ________________

    c) Reactor power ________________

    d) Boiler pressure and temperature ________________

    e) Boiler level (actual) ________________

NOTES & REFERENCES

f) Boiler level (indicated) ______________________

____

____

____

____

g) Turbine generator operation ______________________

____

____

____

____

h) Shutdown systems ______________________

____

____

____

____

24. a) Condensate make-up will be initiated by a ______________ ______________. In some stations, the ______________ ______________ is available to provide feedwater to the boilers.

b) When the feedwater has been depleted, the fuel cooling concern is ______________________

____

____

25. Feedwater flow indications will show that flow has ______________ ______________ because ______________________

____

______________________.

26. The following two hazards exist in the powerhouse due to steam environment:

a) ____________________

b) ____________________

27. Typical indications of a steamline break are:

a) ____________________

b) ____________________

c) ____________________

d) ____________________

e) ____________________

f) ____________________

g) ____________________

28. ____________ faults may be occurring due to the steam in the powerhouse.

29. HTS pressure recovery may require additional feed or action from ____________________.

NOTES & REFERENCES

LOSS OF LOAD

30. Explain the effect of a loss of load on each of the following parameters:

    a) HT pressure and temperature ____________________

    b) HT inventory ____________________

    c) Reactor power ____________________

    d) Boiler pressure and temperature ____________________

    e) Boiler level ____________________

f) Turbine generator operation ______________________________

____

____

____

____

g) Shutdown systems ______________________________

____

____

____

____

31. Turbine overspeed must be avoided for the following two reasons:

a) ______________________________

____

b) ______________________________

____

32. Final reactor power must be high enough to avoid a ____________ ____________, but must also remain low enough to minimize steam ____________ (ie. conserve ____________ ____________) or prevent ____________ ____________ of the condenser.

33. After the loss of load, boiler pressure will be controlled by ____________ or ____________.

34. Typical indications of a loss of load are:

a) ______________________________

____

b) ______________________________

____

NOTES & REFERENCES

c) ______

d) ______

e) ______

f) ______

g) ______

LOSS OF CLASS IV POWER

35. Explain the effect of a loss of Class IV power on each of the following parameters:

a) HT pressure and temperature ______

b) HT inventory ______

c) Reactor power ______

NOTES & REFERENCES

d) Boiler pressure and temperature ______________________

e) Boiler level ______________________

f) Turbine generator operation ______________________

g) Shutdown systems ______________________

h) Standby generators and emergency power generators ______

36. The loss of Class IV power also results in the loss of ________ power. This is indicated by ______________________.

NOTES & REFERENCES

37. Fuel cooling is impaired due to the ________________ coolant circulation. ____________________ will be required to remove the decay heat from the fuel.

38. The _______________ or ______________________ start, synchronize and load to restore _________ power. Critical loads will be ______________ automatically. A few examples of these critical loads are _______________, ______________________ and _________________________.

39. Typical indications of a loss of Class IV power are:

a) ____
____

b) ____
____

c) ____
____

d) ____
____

e) ____
____

f) ____
____

g) ____
____

LOSS OF CLASS III POWER

40. Explain the effect of a loss of Class III power on each of the following parameters:

a) HT pressure and temperature ______

b) HT inventory ______

c) Reactor power ______

d) Boiler pressure and temperature ______

e) Boiler level ______

f) Turbine generator operation ______

g) Shutdown systems ______

h) Standby generators and emergency power generators ______

NOTES & REFERENCES

h) Emergency coolant injection system ____________________

____

____

41. The loss of Class III power leaves Class I & II power on the ________________________. This supply will last approximately ____________________. When Class I & II supplies are lost, unit ________________ and ________________ indications will also be lost. The reactor must be placed in the ____________________ before these power supplies are lost.

42. Typical indications of a loss of Class III power are:

a) ____

____

b) ____

____

c) ____

____

LOSS OF CLASS IV AND CLASS III POWER

43. The additional concern of losing Class IV power with Class III unavailable is that ____________________________________

____

____

____

____

____

44. The reactor must be __________________ and an immediate __________________ must be commenced. Critical cooling loads ____ ____________________________________.

Note that consequences to the unit and indications have been covered in the previous sections of this module

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

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