Reactor, Boiler & Auxiliaries - Course 133

PRACTICAL REACTIVITY MECHANISMS

We will now discuss the various practical devices available for reactivity control, for both regulation and protection, which enable the different reactivity variations previously described to be controlled. The next section will deal with the actual systems used in our stations and the reasons behind the particular choice as we shall now see that there are a number of possibilities to choose from.

All reactivity mechanisms either increase neutron production or increase or decrease neutron absorption in order to change the value of k. As a result then there are two basic methods of operation:

1. Increase of neutron production.

   This is done by the addition of fissile material to the core by either refuelling or in the form of booster fuel rods inserted in-core.

2. Increase or decrease of neutron absorption.

   This can be achieved by:

   - inserting and removing neutron absorbers into or out of core
   - changing moderator temperature, effectively changing moderator density and hence its absorption
   - changing neutron leakage by varying the moderator/reflector level.

The variety of reactivity changes and times involved mean that one type of mechanism cannot meet all the regulation requirements and would be even less likely to meet the protective system requirements as well.

The four different general types of mechanisms used in our stations are now listed with the in-core reactivity change (or changes in some cases) for which they are designed to compensate and/or control.

In some cases it can be seen that the operation of reactivity mechanisms for regulation is not necessarily independent. For example, localized movement of an adjuster rod may result in the short term operation of the zone control system.

1. BOOSTER MECHANISMS

Primarily these provide increased reactivity for:

- Xe override capability following a reactor trip
- and load following regulation or power reductions from rated power to about 50% rated power.

Secondary uses are:

- to allow continued operation of the reactor in the event of fuelling machine unavailability
- to have some flux flattening capability
- to compensate for a situation where there might be excessive poison in the reactor at start up.

One of two types of mechanism which are capable of fulfilling the above requirements of short term, fairly large reactivity changes both mechanically and from a nuclear point of view are:

Booster Fuel Rods

These consist of highly enriched rods which are inserted mechanically in-core when override capability is needed.

Adjuster Rods

These consist of neutron absorbing Co^{59} rods which can be pulled mechanically from core when override capability is needed. Normal operation has these rods fully, or almost fully, inserted in-core.

2. POISON SYSTEMS

These provide large reactivity load, slow time constant, SHIM CONTROL to simulate:

- Xe equilibrium load build up
- Fuel Burn Up.

They consist of a system able to inject solution containing a strong neutron absorber into the moderator which satisfies the relatively slow poison removal capability requirement either by IX column removal or by neutron capture removal. Suitable absorbers can be solutions of
- cadmium sulphate
- boric acid
- gadolinium nitrate.

Advantages of this type of system are:

- absence of flux distortions due to homogeneous distribution of poison in the moderator
- the operating mechanisms do not have to operate in high radiation fields (as is the case for the booster mechanisms)
- the reactivity load can only be lost by loss of moderator.

Other characteristics of liquid systems are:

- The neutron absorption cross section should be such that the concentration of poison required will still satisfy the chemical and metallurgical considerations of pD and depositioning out on in-core materials; the latter causing both radiation and unwanted reactivity load problems.
- The relative rates of depletion by neutron capture and IX column removal. If neutron capture depletion is rapid then poison make up for example, will have to be made continually.
- The type and intensity of radiation produced from the activation products of neutron capture. This will influence maintenance and shielding considerations of IX columns in particular.

3. VARIABLE REACTIVITY LOADS

These reactivity loads provide both TRIM and ZONAL control to compensate for fine variations in reactivity such as:

- power changes
- moderator temperature changes } TRIM
- refuelling
- flux tilts } ZONAL

Methods which are used are:

(a) Moderator Level Control

This is essentially varying the amount of neutron leakage from the core.

(b) Moderator Temperature Change

If the temperature is deliberately varied then this can be considered as a control mechanism in its own right.

(c) Absorber Rods, Control Absorbers

Not to be confused with adjuster rods, these consist of mild or strongly neutron absorbing elements such as stainless steel or cadmium in the form of rods or tubes whose length in the core can be mechanically varied by pulling them in and out of the calandria.

(d) Zone Control Rods

These consist of vertical in-core tubes containing independent cylindrical compartments of light water. The levels of light water in each compartment can be varied:

(i) independently for ZONAL CONTROL

or

(ii) synchronously for TRIM CONTROL.

4. SHUTDOWN MECHANISMS

These insert large negative reactivities within a few seconds, needed for a reactor trip to prevent a reactor excursion, as a result of loss of regulation, which could lead to fuel overrating or even fuel melt down.

The different mechanisms used are:

(a) Moderator Dump

(b) Safety or Shutoff Rods - SOR's

(These are now being called mechanical shutoff rods, MSR's, to distinguish them from (d) below.)

These drop rapidly into core, the rod material being made of either cadmium or boron, both strong neutron absorbers.

(c) Liquid Poison Injection System

With this system a strong neutron absorbing solution, gadolinium nitrate, is injected, via nozzles, at high pressure, into the moderator.

(d) Liquid Shutoff Rods - LSR's

Similar to (c) except the gadolinium solution is injected through in-core vertical tubes passing through the calandria so that the poison is not physically mixed in the moderator.

ASSIGNMENT

1. List the different types of reactivity mechanisms required for station operation and the reasons they are used to control the various Δk changes in the reactor.

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