Nuclear Theory - Course 227

DECREASING POWER AND SHUTTING DOWN A REACTOR

As was mentioned in a previous lesson, the control system must be able to lower the reactivity sufficiently to cause the power to decrease and it must also be able to rapidly decrease the reactivity by large amounts to lower the power quickly when the need arises.

The two functions are controlled by two separate systems. The regulating system lowers the reactivity by small amounts for power decreases and the protective system decreases the reactivity by large amounts or trips the reactor. Both of these aspects of power changes will, therefore be considered, separately, in this lesson.

Lowering Reactor Power

In a reactor, using moderator level control, the value of the multiplication factor, k, is reduced by lowering the moderator level. If the reactor is operating at steady power the lowering of moderator level causes the reactivity, k, to become negative and the power starts to decrease. Lowering or decreasing reactor power is, therefore, accomplished by the reverse of the method of raising reactor power, described in the previous lesson.

Fig. 1 illustrates how this is done. The reactor is operating at steady power up to the point A. At A it is decided to reduce power and the moderator is lowered to make k slightly less than unity and k slightly negative. The reactor power decreases exponentially until the required power level is reached at B. The moderator level is then raised back to its original level so that the reactor is again just critical. The reactor will then continue to operate at the lower power level.

At C is shown the beginning of a reactor shutdown controlled by the regulating system. The moderator level drops slowly and the reactor vessel takes perhaps seven or eight minutes to empty. The reactivity decreases slowly as may be seen in Fig. 2. The reduction in neutron power is not rapid compared to what it would have been if the total loss of reactivity has occurred in a few seconds.

It must be remembered, again, that we are talking about neutron power and not thermal power. There is a considerable delay in thermal power reduction, behind the neutron power reduction, because of the heat released by the fission products. This will be discussed later in the lesson.

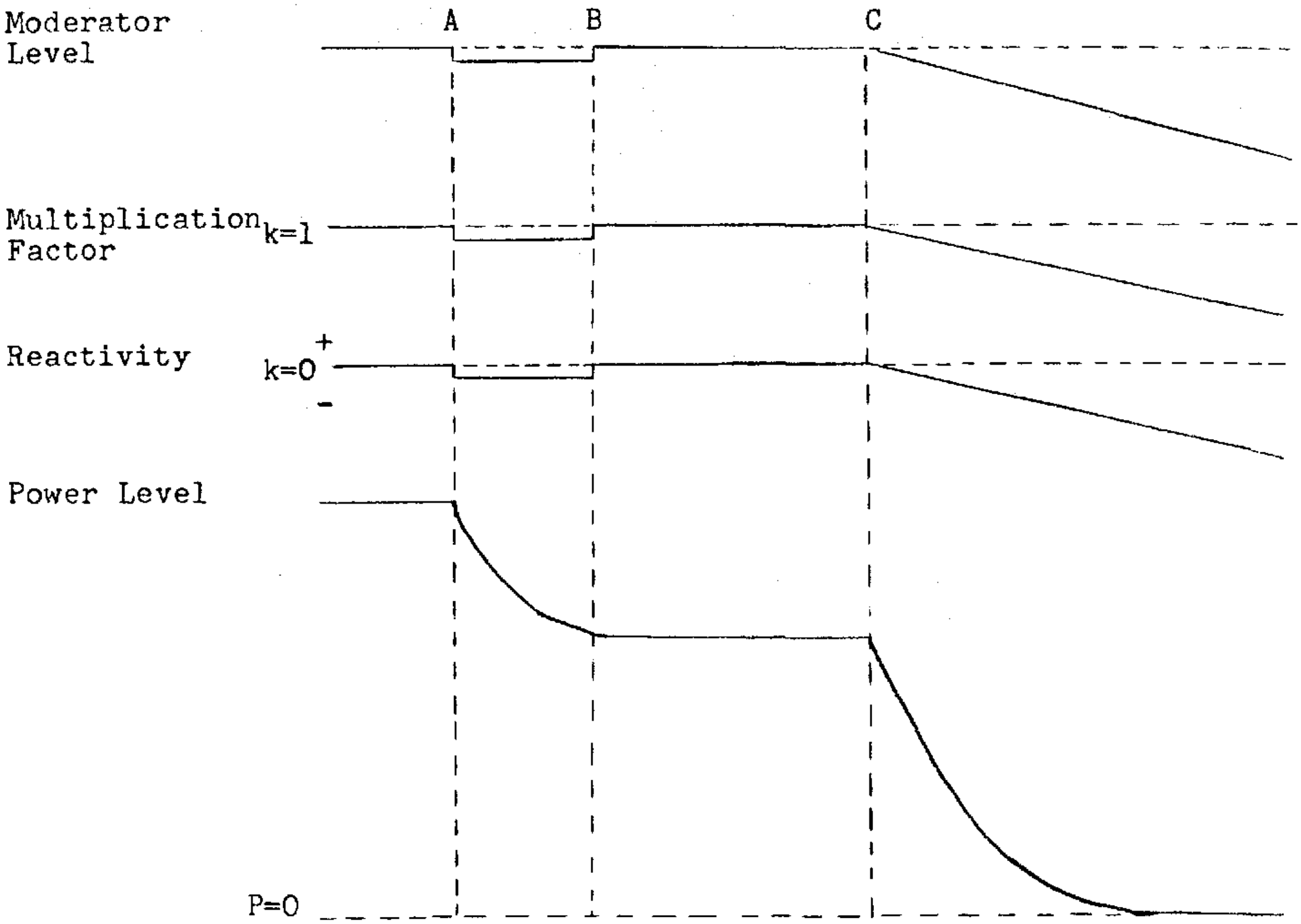


Fig. 1

Reactor Shutdown Due to a Trip

When a reactor trip occurs there is an immediate equalization of pressure between the dump tank and the top of the reactor vessel. The moderator level falls rapidly and the whole of the reactor vessel is emptied in, perhaps, 10 secs. This is called DUMPING the moderator. The loss of reactivity during a trip is shown in Fig. 2 (a) whereas the loss of reactivity during a shutdown controlled by the regulating system is shown in. Fig. 2(b) for comparison.

As may be seen, during a controlled shutdown it takes over two minutes for the reactivity to decrease to -70 mk whereas it takes only 5 seconds during a moderator dump following a trip.

During a trip the reduction in neutron power will be as shown in Fig. 3.

Reduction of Total or Thermal Power

As has already been mentioned, the total or thermal power in a reactor includes both the neutron or fission power and the power released by the fission products in the form of heat. The neutron power is produced at fission whereas the fission product power is released as a result of the decay of the fission products.

From the point of view of reactor control and reactor safety, the neutron power is the important factor. However, since the thermal power decreases much more slowly, decrease in the total thermal power is of great importance as far as the heat transport system is concerned.

Fig. 3 shows how the neutron power, the fission product power and the total power, (ie, the sum of the two), decrease after a reactor trip. Logarithmic scales have been used for the power and time scales to allow a greater range to be covered in both cases.

Note that the total power decreases to 6% of full power in just over 10 seconds but decreases slowly after this. This explains why there may be a flywheel on the heat transport pumps. If the pump trips, the reactor trips and the flywheel gives the pump a rundown time to allow for this rapid decrease in reactor power ie, the pump still maintains some circulation during the initial power decrease. Thermosyphon flow can subsequently be used to remove heat from the fuel. The graph also shows why some cooling of the fuel must be maintained all the time and, if the main heat transport system has to be isolated, a standby cooling system must be provided.

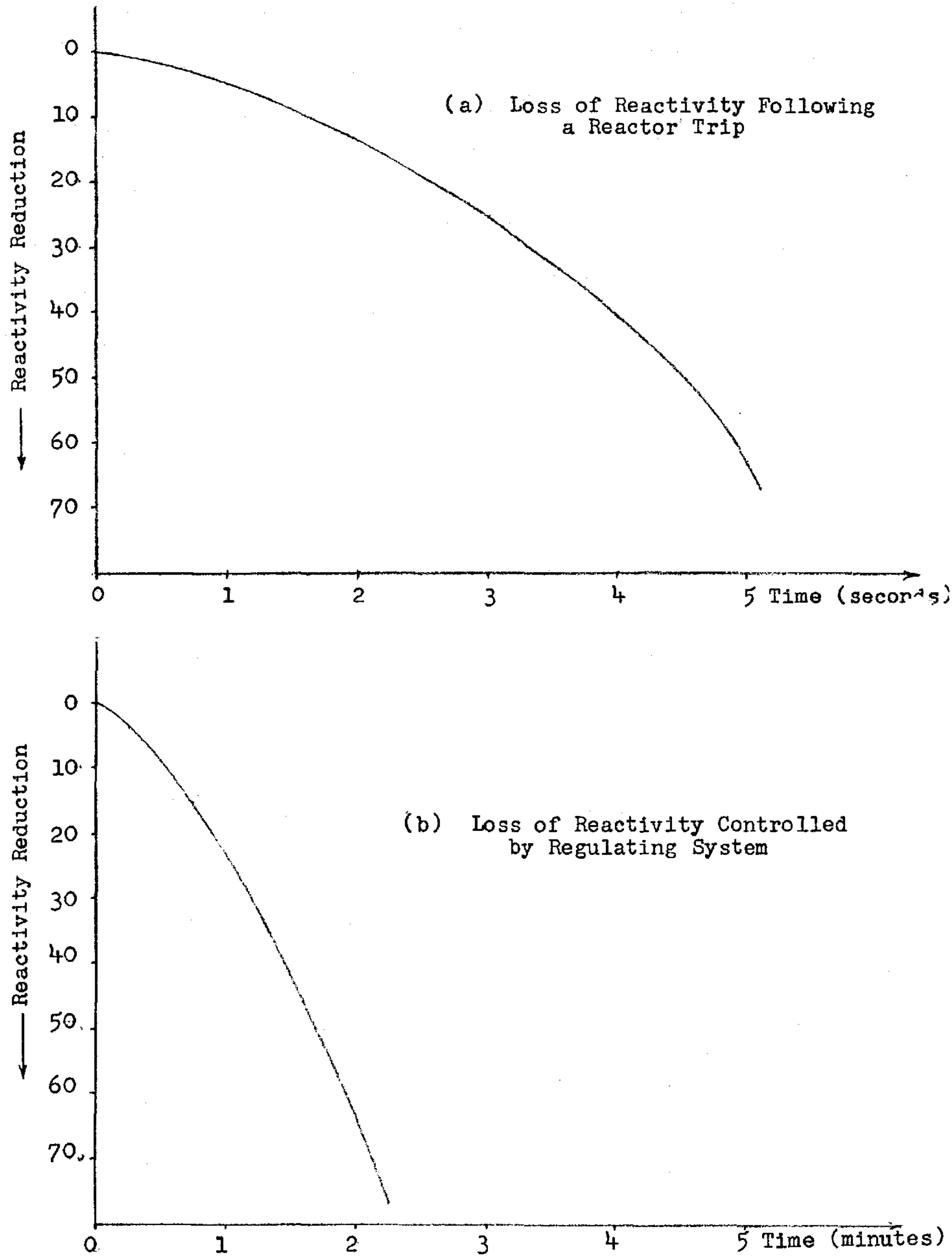
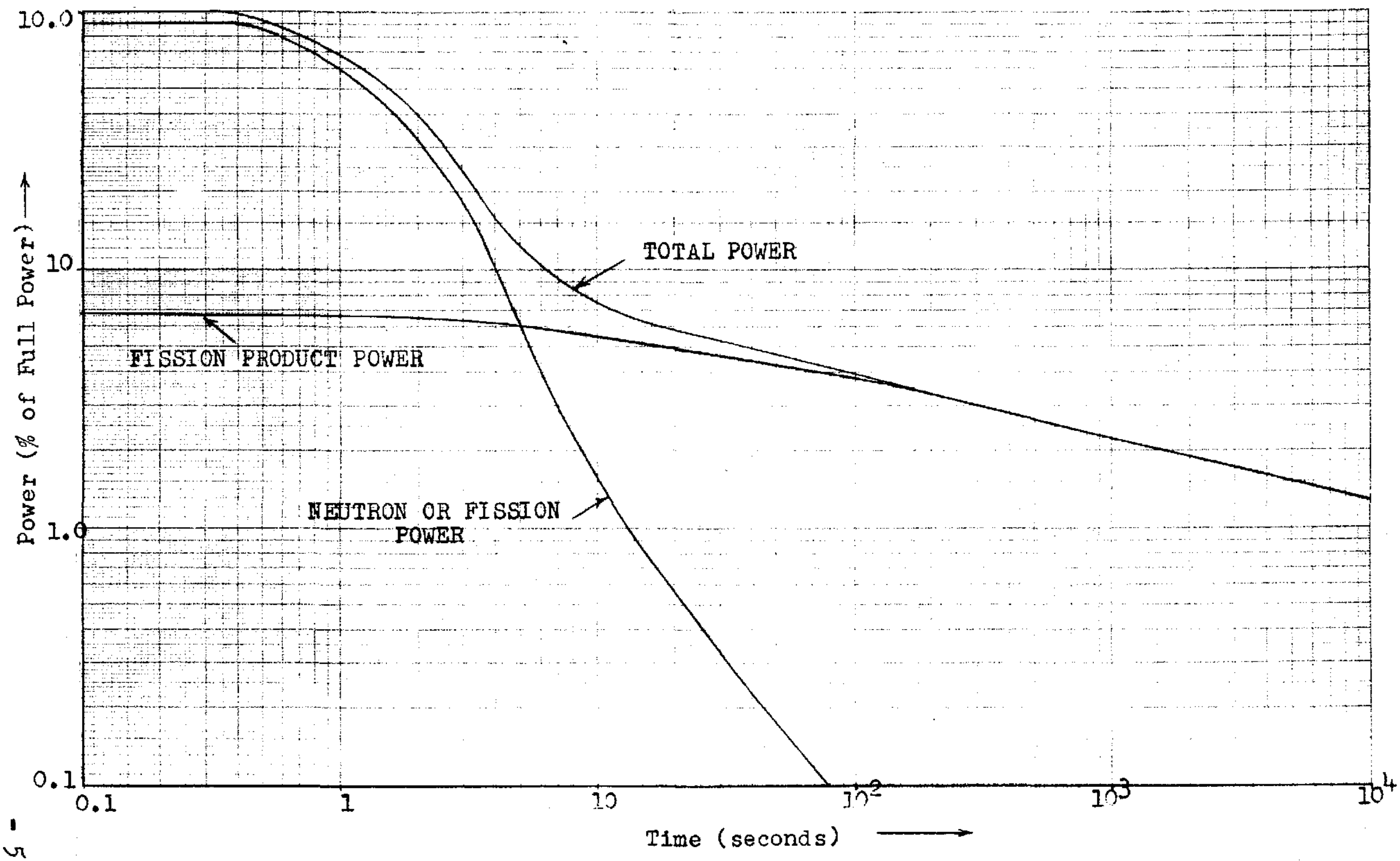

(a) Loss of Reactivity Following a Reactor Trip
Reactivity Reduction
0
10
20
30
40
50
60
70
0
1
2
3
4
5 Time (seconds)
(b) Loss of Reactivity Controlled by Regulating System
Reactivity Reduction
0
10
20
30
40
50
60
70
0
1
2
3
4
5 Time (minutes)

Fig. 2


TOTAL POWER
FISSION PRODUCT POWER
NEUTRON OR FISSION POWER
Power (% of Full Power)
Time (seconds)
10.0
10
1.0
0.1
0.1
1
10
10^2
10^3
10^4

ASSIGNMENT

1. How is reactor power reduced, by the regulating system, from one power level to another?

2. What takes place during a reactor shutdown controlled by the regulating system?

3. How does a reactor trip differ from a controlled reactor shutdown?

4. (a) Why does thermal power decrease less rapidly than neutron power?

   (b) Name two important consequences of the way the total or thermal power decreases.

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