Nuclear Theory - Course 227

EXAMPLES OF PRACTICAL REACTOR BEHAVIOUR

In the previous lessons, changes in reactor power and build-up of Xenon poison were discussed as two separate considerations. However, Xenon concentration changes when a change occurs in reactor power and so the one consideration cannot be separated from the other. The way the reactor behaves in practice will be determined by both the load or power changes required and by the change in Xenon concentration that results from the power change.

Another factor which is involved, and which may partially or completely mask the effect of the change in Xenon, for very small power changes, is the loss of reactivity due to fuel burnup. The moderator level rises to compensate for the decrease in reactivity due to burnup of U-235 and plutonium. These practical examples of reactor behaviour are intended to illustrate how the response of the reactor is determined by all the factors involved. There are two categories of examples that will be given: -

(1) Changes in moderator level as full power is approached in steps while Xenon build-up takes place.

(2) Moderator level response to load changes.

Effect of Xenon Delay on the Approach to Full Power

As was seen in the previous lesson, when the reactor is started up following a shutdown, the Xenon concentration is zero. This will result in a much lower critical moderator level than when equilibrium Xenon concentration has been established. With such a low critical moderator level, the thermal neutron flux distribution is such that the reactor operating power is limited to a value well below full power. This delay in being able to operate at full power is known as the XENON DELAY. It represents a loss in energy production which is due entirely to a limitation on operating power because of low Xenon concentration.

It is usually possible to bring the reactor power up to say, 50% of full power. The power is held at this value until the Xenon buildup causes the moderator level to rise and permit the power to be raised further. Therefore, the power is raised in small steps as the moderator level continues to rise as the Xenon concentration continues to increase. The increases in power and the changes in moderator level that occur are shown in Fig. 1.

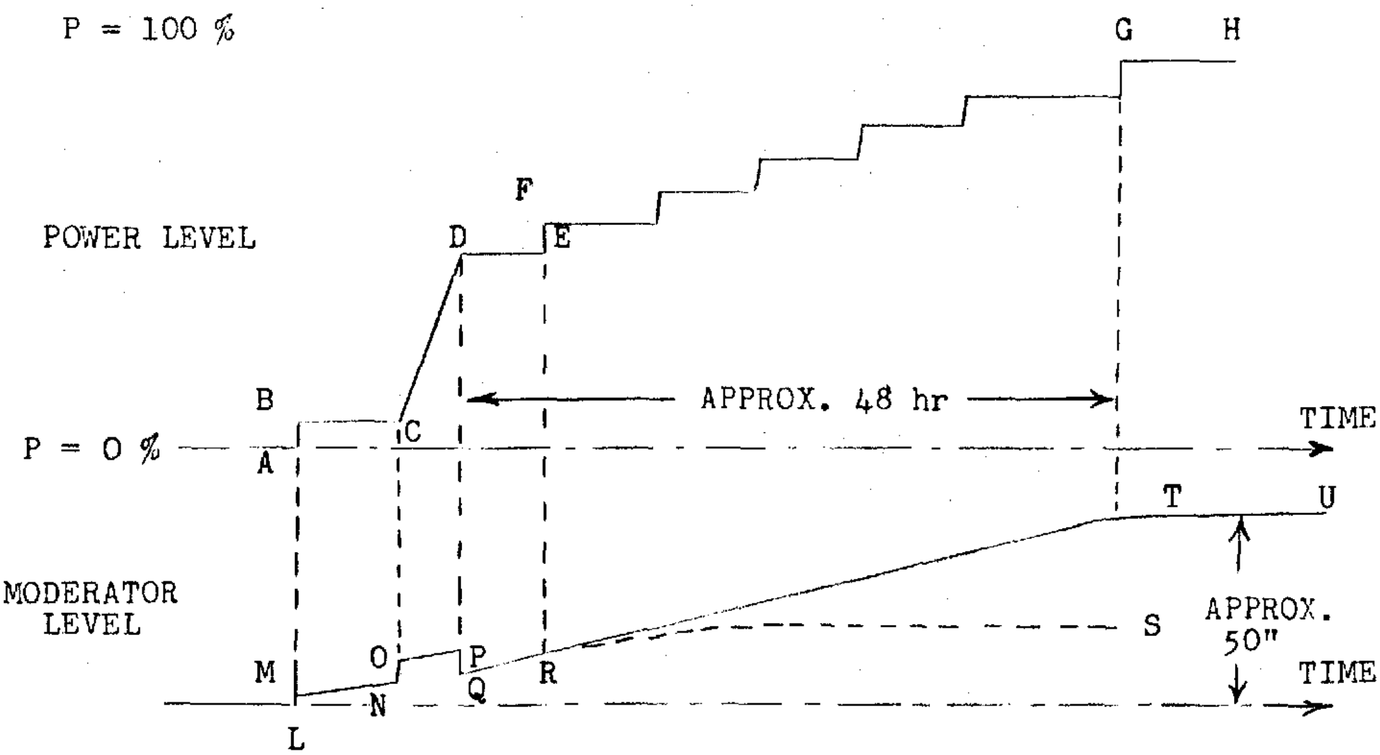

Fig. 1

At L the moderator level rises to M long enough for the power increase A B to take place. The level then returns almost to the previous critical level (plus power coefficient) but rises to N due to the loss of reactivity associated with the heat transport system negative temperature coefficient.

The load is increased at C and the reactor power rises to about 50% of full power. The moderator level rises and remains above critical along O P during the power increase. When the power is levelled off at D the moderator level drops back to the critical level at Q. If the power remained at D the moderator would follow the curve QRS as the Xenon builds up to equilibrium.

In order to reach full power as quickly as possible the power is raised in steps such as E F whenever the moderator level and hence the permissible power is high enough to allow it. This keeps the Xenon buildup continuing until it reaches its equilibrium T U slightly after the power reaches 100% at G H. The fine structure on the moderator curve associated with each individual power step has been ignored for simplicity.

Moderator Level Response to Load Changes

(1) Minor Load Changes

A minor change in load may occur due to some change in setting in the regulating system which changes the steam pressure by a few psi.

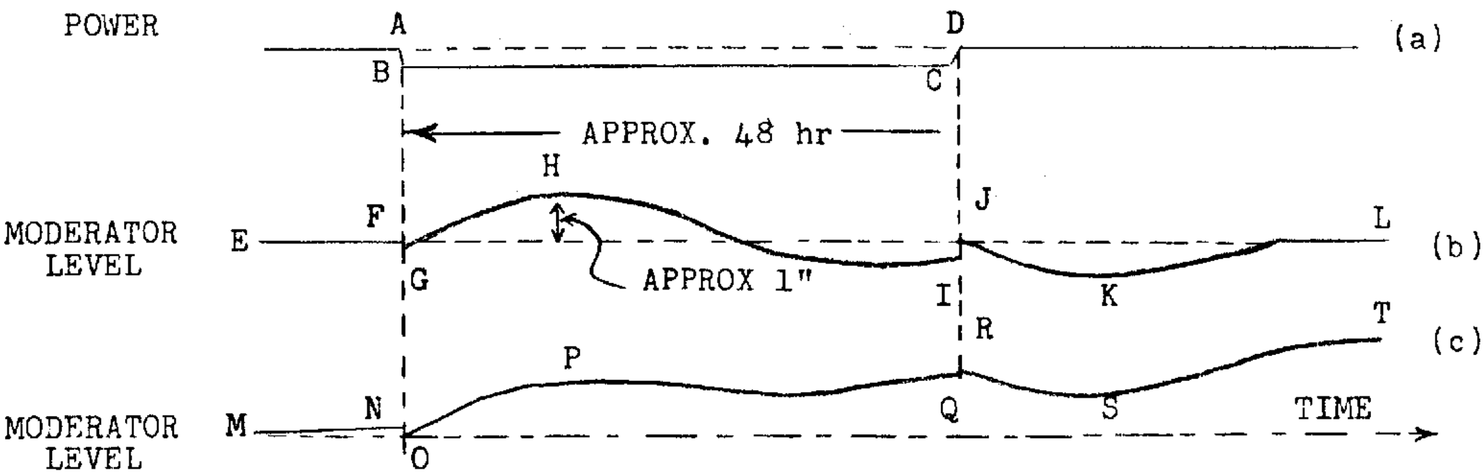

Fig. 2

Fig. 2(a) shows reactor changes following such a minor load change and restoration of full load. Fig. 2(b) shows the response of the moderator level when fuel burnup is ignored and Fig. 2(c) shows the moderator level response when the effect of fuel burnup is not to be ignored.

The reactor power remains steady up to A, when a small decrease in power, AB, occurs due to a load change. Ignoring fuel burnup the level remains constant along E F when a temporary drop occurs to G to provide the necessary negative reactivity. When fuel burnup is taken into account the level rises from M to N and then drops to O. In both cases a rise will then occur due to the Xenon transient. The Xenon will eventually come to an equilibrium which is lower than the original amount and the moderator level is steady at I. In curve (c) the fuel burnup effect may be large enough so that there is no decrease in level from P to Q.

When the power is restored from C to D there is a transient rise in moderator level to J (or R) to supply the necessary positive reactivity during the power change. The level then drops back to critical and a downward Xenon transient starts. This transient is caused by an increase in Xenon burnout which temporarily makes Xenon destruction (burnout and decay) greater than Xenon production. The production rate builds up, however, and the level eventually returns to L or T which corresponds to the original critical level F (or N plus fuel burnup effect in curve (c).

(2) Larger Load Changes

This is the load change that takes place when, for instance, a turbine emergency stop valve is tested by closing it. The reactor power change that occurs may be as much as 15% and the resulting Xenon change is, therefore, much harsher, than in case (a) above.

Fig. 3 shows how the moderator level would respond to such a reduction in power followed by a restoration of full power.

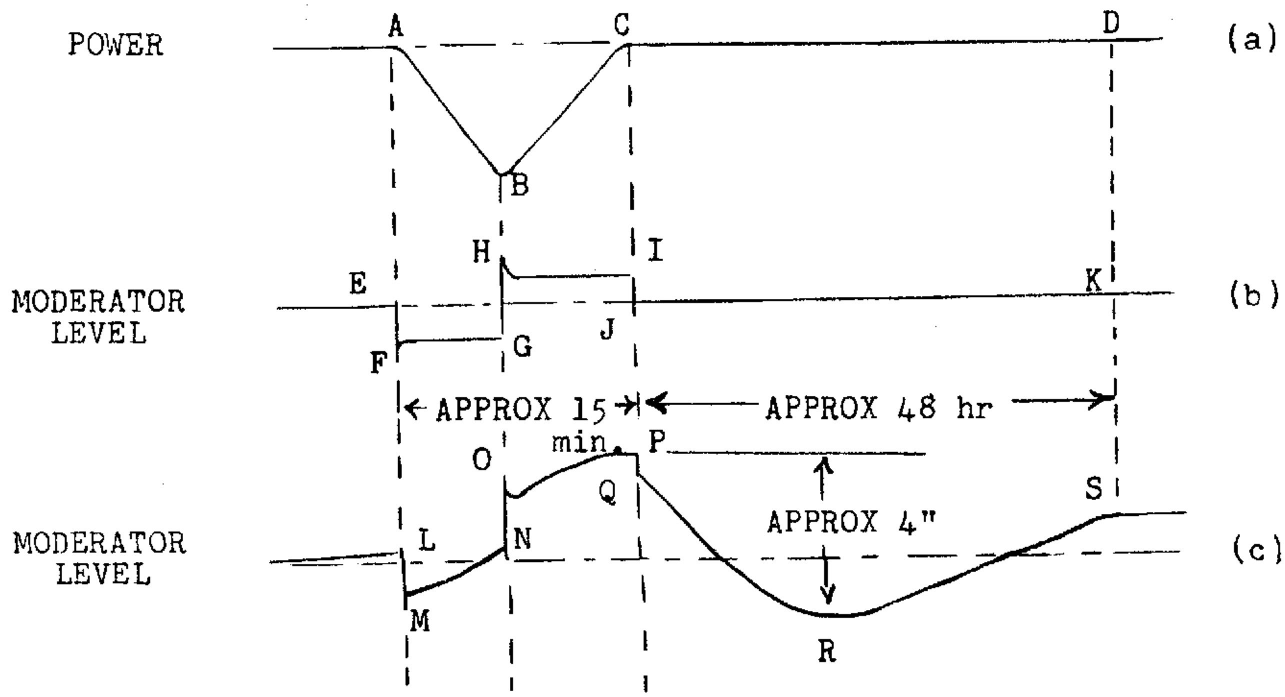

Fig. 3

The load decrease starts at A and continues to B where one stop valve would be fully shut. The load then returns as the valve is opened from B to C. Fig. 3(b) shows the moderator level if Xenon and fuel burnup are ignored. The level decreases from E to F with some overshoot but remains subcritical until G. Positive reactivity is then required and the level rises to H (again with some overshoot) and remains high enough to keep the reactor supercritical while the power is increasing. The level returns from I to J, the original critical level when the power stops rising.

In Fig. 3(c) the effects of fuel burnup and Xenon have been included to show what actually happens. The shape of the curve from L to Q is modified from (b) mainly by Xenon buildup which is most pronounced when the power is lowest (at B in (a)). The transient QRS is due to Xenon burnout and is similar to the transient in Fig. 2. The final level S is higher than L due to fuel burnup.

ASSIGNMENT

1. (a) What is meant by "Xenon Delay"?

   (b) What is the approximate value of the maxium initial reactor power after startup because of Xenon delay?

   (c) Why is it possible to raise power later?

2. In what manner is full power subsequently achieved and what determines the way in which full power is reached?

3. Describe, with the aid of a diagram, the changes in moderator that take place, following a minor load reduction if:

   (a) the effect of fuel burnup is zero

   (b) the effect of fuel burnup is substantial.

4. If the load reduction is substantially larger than in question 3, and full power is not restored, what is likely to be the result, particularly if the initial moderator level is high?

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