Reactor-Boiler and Auxiliaries - Course 433

MODERATOR SYSTEMS

The lessons on fission in the nuclear theory course explained that Uranium-235 can be most efficiently fissioned by slow or thermal neutrons. Since the neutrons given off at fission are fast neutrons, some method of slowing down is required. This slowing down process is called Moderation and the material used to do it is called a Moderator. The materials which are normally considered to be moderators are light water, heavy water, graphite and beryllium. These materials will be briefly discussed and then more detail given to the requirements of a heavy water moderator system since this is the only moderator presently proposed for use in the Canadian nuclear power program.

Moderator Materials

Light water is attractive as a moderator because of its availability and low cost even in a very pure state. It is also very good at slowing neutrons down, but unfortunately, also captures a large number of neutrons at it slows them down. This loss of neutrons is so large that it is not possible to maintain a chain reaction with light water and natural uranium.

Beryllium and its oxide (ie, beryllium combined with oxygen to make a compound) are good moderators. In spite of many technical advances in the past few years, beryllium is still an expensive metal and is bodily attached by air and water at light temperatures. It is therefore, used only in very special or experimental designs.

Carbon in the form of graphite blocks, has been used as a moderator in a number of natural uranium reactors, particularly in the United Kingdom. Carbon is relatively cheap and easily machined, but its moderating properties are only mediocre and it therefore, requires a very large reactor core.

Heavy water is by far the best moderating material available It slows down neutrons quickly and captures very few of them. Very satisfactory performance is obtained with natural uranium and it has no serious undesirable effects in a low pressure system. It can also be used as a heat transport fluid but then of course, must be pressurized to prevent boiling. The only serious fault of heavy water is its cost. At present, it is worth approximately \$28 per pound which results in a 8¼ million dollar expenditure for the moderator material in a station like Douglas Point.

The Heavy Water Moderator Circuit

The high cost of heavy water does not end with the initial purchase, but must also be considered in connection with losses from any heavy water system. The effort made to minimize and recover leakage is apparent throughout the system and must be considered for each new piece of equipment.

One of the main reasons for having a moderator system or circuit, rather than just filling the reactor vessel and leaving it stagnate, is that considerable heat is generated in the moderator. This heat comes from the effects of nuclear radiation on the water, plus heat transferred from the hotter heat transport system. The total heat generation in the moderator is typically about 6 or 7% of the reactor thermal output. This would quickly boil the heavy water if it were not cooled. The simplest type of circuit is shown in Figure 1 and consists only of a pump, a heat exchanger and associated piping. As noted above, this circuit will be as leak-proof as possible, with most joints welded

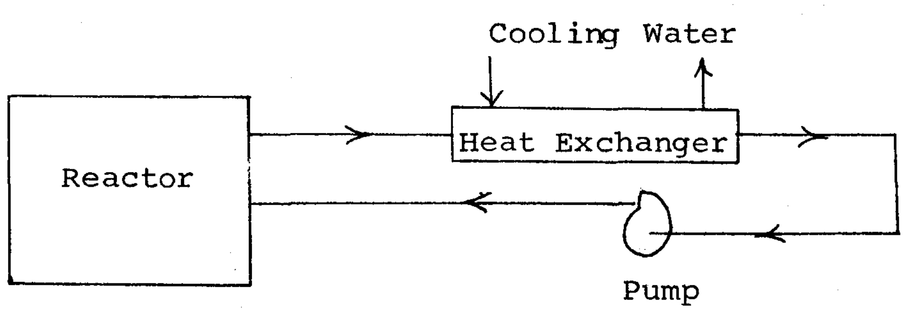

Fig. 1

and possibly double seals on the pump shafts and heat exchanger tubes. There will also be some detection system which will alarm if leakage is detected.

The circuit materials may vary, but the various materials which are used in the circuit must be compatible. For example, if aluminum is used in part of the calandria (remember from the previous lesson that aluminum is acceptable in the core because it does not capture too many neutrons) then neither mild steel nor copper can be used elsewhere in the circuit. The reason for this, is that the water chemistry which prevents corrosion with mild steel is quite different than the correct chemistry for aluminum, while the presence of copper on the other hand can cause deterioration of the aluminum.

The heavy water becomes radioactive while it is in the reactor core and the system equipment must therefore, be shielded. The two main sources of radioactivity are N-16 and 0-19 which are formed in the water. Fortunately, these isotopes both have very short half-lives and disappear a few minutes after the reactor is shut down. This means that while shielding is necessary during operation, when the reactor is shut down, the equipment can be worked on without receiving high radiation exposures. Some protection is needed, however, to prevent the internal uptake of tritium (H-3). The problems of working with tritium in heavy water are dealt with in detail in the radiation protection and procedures training.

The moderator system may also be used to either control the reactor by varying the level in the reactor, or to shut down the reactor by dumping out the moderator. This of course, requires additional equipment, such as a tank into which the moderator can be dumped, but these will not be dealt with in the level 4 lessons.

ASSIGNMENT

1. Since heavy water is much more expensive, why is it used for a moderator instead of light water?
2. Why is a cooling circuit necessary for a moderator?
3. When can maintenance work be done around a moderator pump?

E.P. Horton