Reactor Boiler and Auxiliaries - Course 133

COMMON PROBLEMS

Heavy water upgrading is the end stage of the process of heavy water production. There are some auxiliary processing steps which, if carried out, avoid some difficulties in upgrading. There are also some problems associated with the handling of heavy water, which must be considered no matter what upgrading process is used.

Heavy Water Recovery

Heavy water recovery starts with the loss, whether deliberate as in sampling or draining, or inadvertent, as in spills due to equipment failure, of reactor grade heavy water from a reactor system. The system may be a moderator, a heat transport or a purification circuit. Due to the cost of heavy water, an attempt is always made to recover water which has escaped from a reactor system so that it can be returned to the system.

To assist in achieving this, special facilities are provided for heavy water reactor units. First, there is a "closed" collection system with gathering pipes to pick up heavy water leakage from such obvious points as valve stems and pump glands. Secondly, if possible, the plant areas housing equipment containing heavy water are ventilated by a closed circuit system with condensing and drying facilities to permit recovery of heavy water carried in the air stream. Thirdly, the drainage from areas containing heavy water is collected in a sump with facilities provided to pump water from the sump into drums or other containers in the event that it turns out to be heavy water. In all cases the intent is to recover the heavy water with a minimum of downgrading. Inevitably, some of the heavy water is downgraded and, of course, some heavy water is normally deliberately downgraded during the processes of deuterizing and dedeuterizing ion exchange resins used for heavy water purification. As a result, the final stage of the recovery of heavy water is upgrading.

The upgrading unit, no matter what process is used, is itself subject to loss of heavy water through leakage, sampling, etc. Although it may not be possible to provide recovery systems for the upgrading unit, its design, construction and operation must always be such as to minimize heavy water loss. This means that, in a unit where the deuterium is extracted from the heavy water at some intermediate stage in the process, special precautions are also necessary to avoid loss of the deuterium. It is also important that the design and operation of the upgrading unit be such as to minimize the possibility of further downgrading by inadvertent contacting of the heavy water being processed with light water.

Inventory Control

Heavy water is an expensive material and is a prescribed substance under the Atomic Energy Control Act, which means that an organization requires an Atomic Energy Control Board license to possess large amounts of reactor grade heavy water. It is therefore necessary to account for losses and some form of inventory control is required. Normally it is preferable to record the inventory in terms of 100% D_2O. It is necessary to be able to measure the weight and isotopic purity or D_2O content of the water being processed, the water held up in the unit and the water removed from the process either as final product or as low grade waste.

Where batch processing is done, either weigh scales or previously calibrated tanks are used to determine the amount of D_2O being put in, collected from the process and remaining in the unit at the end of the batch run.

If continuous processing is done, in-line measurements may be possible so that a running inventory can be kept. Such a unit would also require facilities for draining the unit to permit a check on the contents by means of either a calibrated holding tank or weigh scales.

Finally where heavy water is transported in 45 gallon drums the normal procedure is to place a drum on a platform scale for either emptying or filling. For proper inventory control it is necessary that a consistant and careful weighing procedure be used. For example when emptying drums the normal emptying device may leave 2 or 3 lbs of heavy water, called a heel, in the drum. A variable procedure of removing the heel, sometimes, and leaving it, at other times, may introduce an error unless a very careful handling procedure is followed.

Freezing Problem

Heavy water freezes at 39°F. Like ordinary water, heavy water expands on freezing with the same danger of rupturing its container. Not only can this disable the upgrading unit but it can lead to direct loss of valuable heavy water when the ice melts or to indirect loss by downgrading if the ruptured container happens to be a light water cooled heat exchanger tube.

In either the distillation or electrolytic method of heavy water upgrading, there are temperature control requirements, resulting in heavy water being cooled with some form of cooling water usually obtained from a nearby river or lake. During the winter and early spring months, it is quite probable that natural surface water temperatures will be as low as 33°F to 36°F. It is therefore necessary to have sufficient control of cooling water flows so that heat exchangers and condensers do not freeze. Although the probability of freezing is perhaps greater during periods of reduced cooling requirements such as during startup or shut down of the upgrading unit, the danger of freezing during a period when the unit is shut down because a temperature control valve does not completely shut off the flow of cooling water can not be ignored. Considering the value of heavy water and the associated radioactivity hazard, it is not acceptable to protect equipment from damaging overpressures, due to heavy water freezing by relieving the pressure to atmosphere.

The freezing problem must be considered when transporting heavy water. If the upgrading unit is located remotely from the heavy water reactor being served, the heavy water must be transported in heated equipment during winter months. Also it is necessary to provide suitable heated storage facilities, for the incoming downgraded heavy water and outgoing reactor grade product, at the upgrading plant.

Radioactivity Problem

Heavy water that has been in or passed through the core of a nuclear reactor contains some radioactive material. There is tritium, a low energy beta emitting isotope of hydrogen, which is produced when a deuterium atom captures a neutron. In addition, there are radioactive corrosion products from the reactor's heavy water system and, if the reactor heat transport fluid is heavy water, there may be radioactive fission products due to fuel sheath imperfections. The radioactive corrosion and fission products can be removed by preliminary purification before upgrading to a considerable extent. However, these materials are often emitters of penetrating gamma rays and so heavy water containing them can be a serious radiological hazard for personnel working nearby. Also these materials, being normally non-volatile, tend to be concentrated with the reactor grade final product. Even though partially removed before upgrading, the concentration may become high enough to require shielding for the portions of the equipment containing the concentrated product.

Tritium is a serious radiological problem only if taken into the body. The low energy of the emitted beta radiation is such that tritium is not an external radiation hazard, but is hard to detect in the presence of other radioactive materials which might be present. Tritium, because it is a hydrogen isotope, occurs in heavy water as a form of "extra heavy" water and cannot be readily separated except by a process similar to the upgrading processes. This means that in the heavy water upgrading unit, tritium concentrates in the final product. Unfortunately tritium in the "extra heavy" water molecule is readily taken into the body either by breathing air containing the vapour or by direct contact with and absorption through the skin. Once absorbed, the tritium containing water readily exchanges with water in the body tissues and brings the tritium into intimate contact with the tissues so that the low energy beta radiation is quite capable of causing damage. To protect personnel against the tritium hazard, the following points should be considered:

1. Minimize loss of tritiated heavy water from containers and equipment by leakage and evaporation.

2. Provide adequate ventilation for the area to protect against the necessary minimum losses.

3. Provide protective clothing and clean, fresh, breathing air for people who may become exposed to tritiated heavy water during operation and maintenance of the equipment.

4. Provide washing and shower facilities so that a person, who has contacted tritium bearing heavy water, can promptly wash thoroughly to minimize the absorption.

Purification Requirements

The purification of heavy water is the removal of impurities other than light water. These consist of dirt, oil, etc., appearing in spilled heavy water after flowing on or over machinery, floors, etc., or which may be present in an unclean container used to collect the heavy water. Lubricating oil and concrete dust are two examples of such contaminants. Radioactive materials other than tritium, are another source of impurity. Since these impurities tend to concentrate in the product of the upgrading process and impair the efficiency of the process, it is preferable to remove them by a preliminary purification step.

Standard cleaning techniques are used including filtration, evaporation, centrifugal separation and ion exchange purification. Each of these steps increases to some extent the loss of the heavy water which is being recovered. It is difficult to recover all the heavy water contained in the filter medium carrying the impurities. Centrifugal separation may not give an acceptable purification without a small portion of the heavy water being discarded with the impurities. Ion exchange purification requires use of deuterized resin to avoid further downgrading of the water and so the spent resin containing impurities must be dedeuterized to recover as much of the contained heavy water as possible. In addition, the extra handling itself tends to increase losses through evaporation or spillage. Where radioactive impurities are present, all of these processes will require suitable shielding. Since tritiated heavy water is involved, facilities must be available to protect personnel from this hazard also.

R. Popple (R-0)