# GOOD NEWS ABOUT IODINE RELEASES

Sidebar 3:

One of the elements vital to the proper functioning of the human body is iodine. This element, in trace quantities, is essential for the synthesis of metabolism-regulating hormones by the thyroid gland. To produce these hormones as needed, the thyroid gland selectively absorbs iodide ions from the blood, accumulating and storing 25 to 45% of the body's normal intake of iodine. The thyroid gland is thus particularly susceptible to damage by radioactive iodine isotopes, should these be available to the body.

Such isotopes are present among the fission products within the fuel rods of a reactor, and the possibility of their escape to the atmosphere from damaged fuel rods has dominated considerations of reactor accidents and the design 'of safety systems. The isotope iodine-131 is of particular concern because of its relatively high fission yield (2.77%) and significantly long half-life (8.07 days).

In 1957 an accident at the Windscale reactor in Cumberland, England resulted in escape to the atmosphere of more than 20,000 curies of iodine-131 and a maximum radiation dose to the public (observed in the thyroid glands of several children) of 5 to 15 rads. Despite its rather minimal public consequences, this accident may have had a determining influence on the assumptions adopted for regulatory purposes in the early 1960s by the Atomic Energy Commission and later by the Nuclear Regulatory Commission. It is assumed that 25% of the core inventory of iodine would be distributed as volatile species within the containment as a result of the rupture of a major coolant pipe and, should the containment be breached, would escape to the atmosphere without diminution. A similar fate is assumed for the total core inventory of inert gases, such as xenon-133 and krypton-85, but these chemically inert materials pose a considerably lesser danger to human health.

Information obtained during the accident at the Three Mile Island Unit 2 reactor indicates that, in the case of iodine, these assumptions should be regarded, not as a conservatism, but as an error. Measurements of both xenon-133 and iodine-131 showed that, although the core inventories of both isotopes were roughly comparable (154 million curies of xenon-133 and 64 million curies of iodine-131), the quantity of iodine that escaped to the atmosphere (13 to 18 curies) was less than that of xenon (2,4 to 13 million curies) by a factor of $10^5$ to $10^6$.

In a letter of August 14, 1980 to the Nuclear Regulatory Commission, A. P. Malinauskas and D. O. Campbell of Oak Ridge National Laboratory and W. R. Stratton of Los Alamos National Laboratory have proposed an explanation for this great disparity.* They suggest that iodine exits from damaged fuel rods predominantly as cesium iodide (CsI) rather than as volatile species such as molecular iodine (12). The reducing environment of a water-cooled reactor during a loss-of-coolant accident sustains this chemical state and also converts other iodine species, should they be present, to iodide ions. The escaped CsI will readily

- At 63 minutes, the primary system pressure rises because the steam generators have dried out and no longer remove heat from the primary coolant.
- At about 66 minutes, the relief valve on the pressurizer opens and begins to discharge steam.
- By 80 minutes, water begins to flow through the relief valve because the increased temperature in the primary system has caused the coolant to expand. The pressure remains fairly constant, but the temperature continues to increase.
- At 96 minutes, the emergency core-cooling system is actuated by a containment overpressure signal.
- At 120 minutes, the coolant in the primary system is saturated. The coolant begins to boil, the upper part of the vessel voids, the primary system pressure rises, and safety valves on the pressurizer open briefly.
- By about 130 minutes the partially voided core has begun to refill; thus, the system is recovering.

This calculation shows that the automatic safety systems would bring the reactor to quasi-stable conditions without any intervention. However, actions by the operators can prevent core voiding or reduce the severity of the accident. Below we list some conclusions based on TRAC analyses regarding successful management of the accident.

1. If, within the first hour, the operators notice a drop in the water level of the steam generators and are able to restore at least 30 per cent of the auxiliary feedwater supply, no voiding will occur in the primary system and the core will be adequately cooled.
2. If auxiliary feedwater cannot be restored, the operators can prevent boiling only by initiating the complex sequence of manipulations known as feed-and-bleed cooling near the beginning of the transient. This cooling technique consists of alternately injecting emergency coolant with the high-pressure

condense on available metal surfaces at temperatures at or below 673-773 kelvin (750-930° Fahrenheit) and will enter into solution as cesium and iodide ions upon encounter with water or condensing steam. This situation will persist in the absence of an oxidizing atmosphere. Thus the amount that could escape to the atmosphere from a water-cooled reactor would be considerably lower than has been assumed.

In contrast, during the accident at the air-cooled and graphite-moderated Windscale reactor, metallic fuel and (probably) graphite were burning—clearly an environment favorable to oxidation of CsI to $Cs_2O$ and $I_2$.

In further support of their hypothesis, the scientists cite the following observations.

- Iodine and cesium escape at the same time from leaking fuel rods in pressurized-water reactors during normal power transients. This behavior is completely different from that of the inert gases.
- Of those compounds that could be formed by iodine within fuel rods of water-cooled reactors, CsI is thermodynamically the most stable. Further, because the fission yield of cesium is larger than that of iodine by a factor of 10 to 11, cesium is always available in great excess for reaction with iodine.
- Used fuel rods have been made to fail in experiments simulating accident conditions in water-cooled reactors, and the iodine released has been recovered predominantly as CsI rather than as $I_2$.
- The chemistry of iodine is such that, if water is accessible, iodine species such as CsI react with the water so that the iodine concentration in the gas phase is very much smaller than its concentration in the water.
- An investigation, still continuing, of incidents involving fuel-rod damage at other water-cooled reactors indicates that, as at Three Mile Island, much smaller amounts of iodine escaped to the atmosphere than has been assumed.

This hypothesis must be strengthened by information about the fundamental chemistry—under the conditions within a reactor—of cesium and iodine and of fission products in general, In response to this issue, the Nuclear Regulatory Commission and the Department of Energy have sponsored studies to pinpoint those areas of research that should be pursued.

If further study confirms that cesium and iodine behave in the manner proposed, many criteria for reactor safety must be reevaluated and the reactor systems for fission-product control must be reexamined. In addition, and most importantly, the public could then be assured that the danger posed by even a very severe reactor accident may be significantly lower than previously estimated. ■

***H. J. Kouts of Brookhaven National Laboratory has independently developed a similar hypothesis about the behavior of cesium and iodine.***

injection system and venting steam through the pressurizer relief valve. However, if the containment has been isolated automatically by an overpressure signal due to vented coolant, use of feed-and-bleed cooling is severely restricted because the compressed air that operates the relief valve cannot be replenished.

3. After the steam generators dry out, the operators will see increases in the pressurizer water level and in the primary system pressure and temperature. They should respond by initiating feed-and-bleed cooling. If the containment is not isolated and feed-and-bleed cooling begins between 1 and 2 hours, some core voiding will occur but the system will recover much faster than it would otherwise.
4. If the primary pumps were not tripped at the start of the accident, leaving them running until the emergency core-cooling system actuates automatically will prolong the accident slightly but will not materially alter its ultimate course.

This particular accident and all related accidents, such as loss of feedwater with stuck-open pressurizer relief valve (the Three Mile Island accident) or a loss-of-feedwater with stuck-open atmospheric relief valve, have very characteristic signatures that can help the operators to diagnose the situation. Not all multiple-failure accidents have such characteristic signatures, and in some cases additional instrumentation may be needed for proper identification.

The SASA program is currently focused on accident sequences at large two- and four-loop pressurized-water reactors. The emphasis at the Laboratory is on plant-specific accident delineation, early accident recognition, early accident management, and definition of critical times and actions. By improving the operational safety of reactors, the severity of multiple-failure accidents, and thus the risk to public health, can be reduced. ■