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HYDROGEN IN NUCLEAR ACCIDENTS
WHAT IS THE ROLE OF THE GAS IN FUKUSHIMA?

The extremely serious accidents in the Japanese nuclear power station at Fukushima involved a number of hydrogen explosions. Four reactor blocks have been seriously damaged at this time. DWV considers it to be important to inform about where this hydrogen came from, where it did not come from and how the explosions happened.

Hydrogen is not part of the normal means of operation of a nuclear system. When the plant runs normally it is nowhere to be found at or near the fuel rods. Cooling of the fuel is done by means of water.

Small amounts of hydrogen and oxygen are continuously generated near the core by means of radiolysis of water (splitting by ionizing radiation). These amounts are harmless, however. In most cases they are quickly removed by catalytic converters at which they react to form water without a flame.

Neither is the hydrogen generated by thermolysis of water (splitting by high temperatures). This requires temperatures of at least 2500 °C which are not reached even in case of an accident.

The source of the hydrogen is a quite different one: The claddings of the fuel rods which keep the fuel together are made from alloys of zirconium. When the rods are no longer covered by water during an accident they reach temperatures much higher than they designed for, and the metal starts to oxidize at about 1000 °C. Since there is no free oxygen around the reactor core the metal reacts with the water vapour and takes the oxygen from there. When oxygen is removed from the water molecule hydrogen is left.

What is generated is hydrogen, not oxyhydrogen gas. The latter is defined as a mixture of hydrogen and pure oxygen in a ratio of exactly 2:1. Here the oxygen is not released, however, because it is used up for the oxidation of the zirconium. Radiolysis generates oxyhydrogen gas, but in small amounts only. Thermolysis would generate oxyhydrogen gas as well, but does not happen here.

In spite of the presence of hydrogen there is no danger of explosion in the reactor vessel because there is no oxygen around. Hydrogen itself is not explosive, only its mixtures with oxygen (either pure oxygen or air) can be. Additionally a sufficient amount of ignition energy must be provided. But even after shutdown of a reactor the fuel still generates heat, and the exothermal oxidation of the metals by the vapour additionally raises the pressure. At the same time the pressure resistant system components are further heated, reducing their strength. The danger exists that the containment is overloaded mechanically.

When the water vapour/hydrogen mixture is released from the containment to reduce the pressure in it the hydrogen mixes with air, and ignitable mixtures can be formed easily. (No oxyhydrogen gas is formed here either because there are also other gases in the mixture.) Ignition energy is

found easily under the conditions of an accident, and for the concentrations which can be expected here the necessary amount of it is rather low. The most easily ignitable hydrogen/air mixture has a concentration of 23 %; the presence of water vapour, however, reduces the ability to ignite until it becomes impossible at vapour concentrations of around 60 %.

The explosions in block 1 and 3 in Fukushima happened outside the reactor containments in the buildings which enclose them. The buildings were severely damaged, the containments were not. This leads to the conclusion that the process described above happened. In the case of block 2 components in the containment apparently were damaged as well. The amount of information at hand is not sufficient at this time to allow an exact judgement of the circumstances. The hydrogen generation in block 4 did not occur in the reactor but in a spent fuel storage pond which was not sufficiently filled due to the earthquake effects; so the gas was in the building right from the start and not initially in the reactor containment.

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