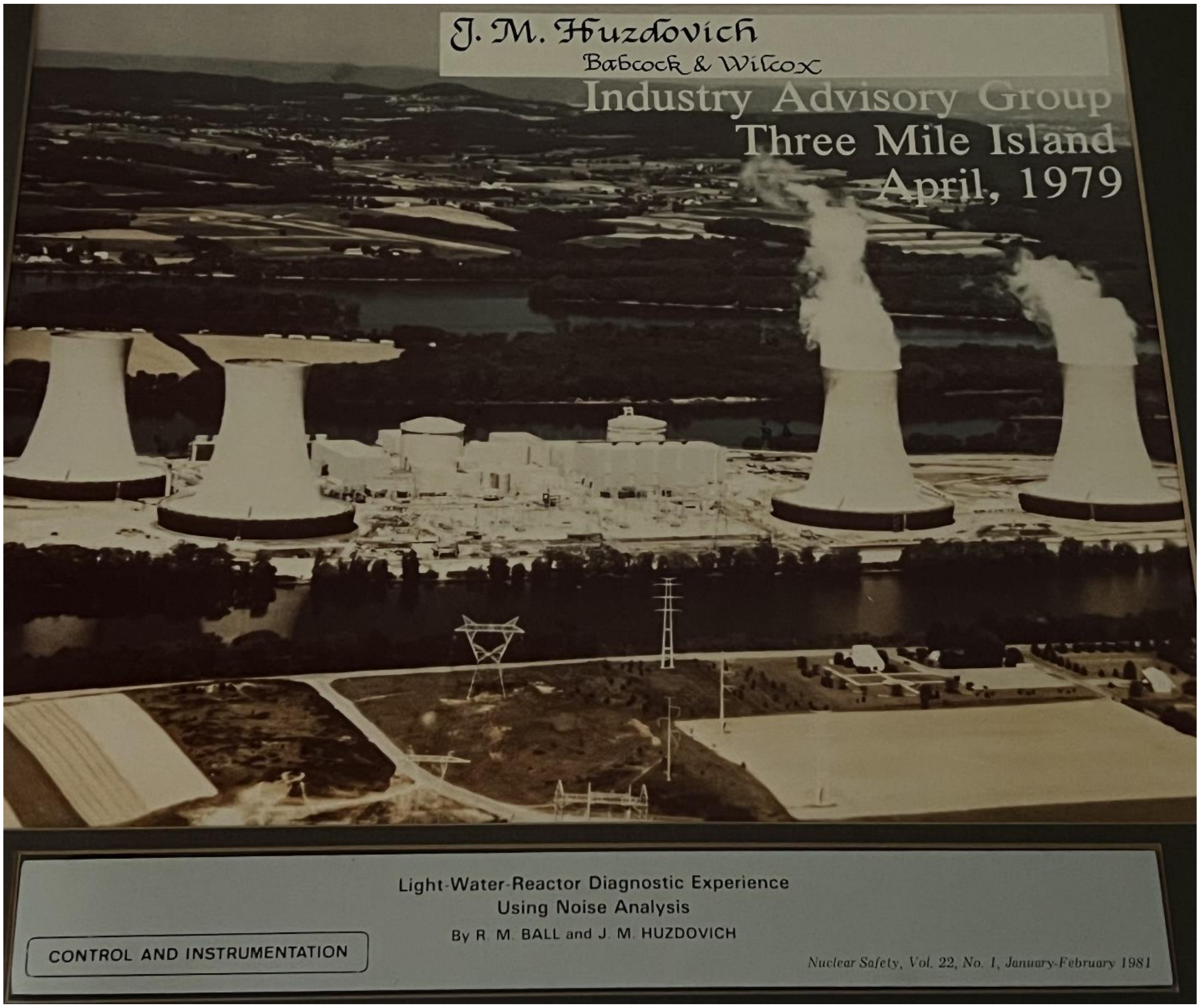
TMI-2 SPAGHETTI SOLUTION THAT HELPED ADDRESS THE HYDROGEN BUBBLE SCARE



TMI-2 SPAGHETTI SOLUTION

This blog post is about the hydrogen bubble scare associated with the TMI-2 nuclear accident that began around 4 AM on March 28, 1979, near Middletown, Pennsylvania. The concern about a hydrogen bubble forming in the reactor pressure vessel is described in the Nuclear Regulatory Commission's Rogovin inquiry report, Volume 1, Section 16, The Hydrogen Bubble Scare.

The hydrogen gas bubble concern turned out to be a non-issue. This was especially true after extremely low but non-zero probability events became addressable through analysis and tests. In the following behind the scene account (to which I was a first-hand witness and participant) we addressed the last of the hydrogen bubble concerns. This last concern involved the generation of oxygen and hydrogen gases resulting from thermochemical water splitting.

The partial melting of the nuclear fuel core resulted in hydrogen gas that formed a bubble inside the reactor pressure vessel. Since there was a chance that oxygen could be introduced by radiolysis into the reactor pressure vessel environment (radiation splits water into hydrogen gas and oxygen gas) the hydrogen bubble could ignite causing an explosion. The other way such an event could occur would be by a thermal hot spot (500°-2000° Centigrade) caused by the residual heat resulting from the radioactive decay products of the nuclear reactions. TMI-2 operated up to 100% power for some time during the year prior to the accident. This meant a remote possibility existed that thermochemical water splitting driven by the decay heat in the damaged reactor core could result in the release of both oxygen gas and hydrogen gas. The alarm about a hydrogen bubble and related explosion within the reactor pressure vessel arose mostly due to the unique circumstances and unknown condition of the damaged reactor core. The Nuclear Regulatory Commission commissioners wanted a group formed to assess the probability that radiation could split water molecules into hydrogen and oxygen gases. Such information would help Pennsylvania Governor Thornburgh decide about an evacuation of the surrounding area.

Industry consultants confirmed by analysis that "the hydrogen overpressure would have suppressed any radiolytic oxygen formation." So, the remaining open item was boiling in the core due to a hot spot. The question posed by the Industry Advisory Group (IAG) was how can one detect boiling in the core? **This is where the spaghetti comes in.**

PHENOMENA VERSUS INSTRUMENTATION

My group was on site the day after the accident and set up our noise monitoring instrumentation. We were known as the "Noise Boys" and were quite good at measuring extremely low-level events regarding metal-to-metal and other impact type events. We had previously instrumented the TMI-2 reactor coolant system with accelerometers and other instruments for the unit's start-up testing that preceded the accident. So, this meant we had very sensitive vibration monitoring instruments on the reactor vessel itself. But, how does one detect boiling in the core inside this vessel that was several inches thick? Just the type of question I pondered while preparing a spaghetti dinner that evening after the IAG task assignment. As I waited for the water in the pot to boil, I heard noise emanating from the area of the pot. It was a hissing, white noise sound that was loud enough to signal a change in the pot. My further examination showed a situation similar to Figure 1, and as I intently examined the situation, I could clearly see steam bubbles forming on the bottom of the pot and collapsing back against the bottom of the pot. This was an impact event since the collapsing bubble would behave as a virtually incompressible fluid slamming into the pot metal surface. This reminded me of the cavitation phenomenon in water pumps that leads to impact noise. We often detected this phenomenon in our rotating machinery analysis work. Once bulk boiling was reached in the pot, the noise abated and returned to approximately the previous level. So, the onset of boiling could be identified as a step change in noise level preceded and followed by relatively quiet conditions. The step change in noise level was caused by impact events that occurred only during the onset of boiling that preceded the water entering a bulk boiling regime. The impact events also presented with corresponding impact signatures in the time domain. This hypothesis was accepted by the IAG the next day. I designed a set-up consisting of heaters spaced in the top, middle, and bottom of a vessel with instrumentation localized at the heater locations. The test was conducted with the staff at the Babcock & Wilcox Alliance Research Center. We demonstrated the ability to locate the impact events and the distinct noise signatures of the conditions at the heaters during onset of boiling and bulk boiling. This test verified the hypothesis and we implemented continuous monitoring of the reactor vessel accelerometers looking for impact signatures in the time domain. Fortunately, there were no impact signatures detected and the IAG concluded that there was no boiling in the core. The last element of the TMI-2 hydrogen bubble scare was gone.

<u>FIGURE 1-THE ONSET OF BOILING ON A HOT METAL SURFACE</u>-STEAM BUBBLES FORM THEN COLLAPSE, QUITE NOISILY, PRODUCING IMPACT SIGNATURES THAT CAN BE DETECTED WITH ACCELEROMETER INSTRUMENTATION USING DETECTION THEORY FEATURING AUTOMATIC GAIN CONTROL AND BANDPASS FILTERING.