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Regulatory Leadership Absent in Reducing Severe Accident Risk from PHWRs

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ABSTRACT

While the next chapter on consequences of the unfortunate accident at Fukushima is still being written, look for the next nuclear disaster to likely happen again in a place with weak nuclear regulatory rulemaking, enforcement and technical leadership. One recalls the conclusions of the Japanese parliamentary commission investigating the Fukushima disaster (reference 1) and sees eerie similarities in a number of countries in the incestuous, cozy relationship between the regulator and the utilities.

Under the current management, the regulators not only routinely rubber stamps all requests for ever longer license extensions, they also quietly grant modifications, exceptions and relief to compliance with ever so weak regulations without much of an inquiry. As an ever louder mouthpiece for the industry, Canadian regulator CNSC , for example, puts position papers on the glorious inherent safety of the reactors it regulates, touts benign nature of consequences of a severe power reactor accidents (reference 2); tells the first responders to worry not of large radiation releases (reference 3) and creates elaborate excuses to not have to require the utilities to modernize the obsolete CANDU reactors it regulates (reference 4). It has created conditions that discourage innovation and design improvements and are ripe for a nuclear disaster in a country where one of the largest nuclear stations in the world sits smack in the middle of a sprawling metropolis near Toronto where 4 million unsuspecting Canadians live.

To a Canadian nuclear safety engineer with 30 years direct experience in design reviews and modeling PHWR severe accidents, the signs on the wall of an impending disaster are troubling. As professional engineers who are the members of the Korean Nuclear Society, it is our continued responsibility to warn of the dire consequences of a misplaced servitude role the regulators have typically adopted and to challenge the status quo with professional integrity.

BACKGROUND

Recall that the three worst nuclear power reactor accidents occurred in three technologically advanced countries with a frequency that is far more than the 1 in a million reactor year design target and economic consequences that can retard progress for decades.

Currently operating PHWRs were designed essentially in the 60s and 70s and have barely seen any substantial upgrades even 7 years after Fukushima, although there has been a lot of hoopla around a few improvements such as the hydrogen recombiners and the filtered containment venting systems since the accident that many call preventable. The recombiners installed in CANDUs are at best dangerous flame throwers under high Deuterium containment conditions predicted to occur after a severe core damage and the venting system may be totally inadequate for the anticipated source term.

At less than 0.7 atm (g) design pressure and design leakage about 500 times the norm in the rest of the world, the reactors sport some of the weakest containments which in the multi unit CANDU reactors resemble slab industrial buildings and not classic cylindrical power reactor containments.

Figure 1 : Industrial low pressure rectangular 'containment' buildings that house 4 reactors in a contiguous volume at the multi unit PHWR station at Bruce. The round building is the vacuum building.

These reactors have an average of 10 km of low carbon steel piping susceptible after an accident to early air and steam oxidation, twice the Zircaloy of typical LWRs and combustible gas detection and mitigation systems designed not exactly for the Deuterium gas that any accident in these D_2O cooled and moderated reactors will generate following a loss of heat sink accidents. In absence of a reactor pressure vessel to contain accident

debris, the containment layout causes the reactor vaults to become immediate repositories and traps for combustible Deuterium and fission products. The leaky containments and the illogical placement of the pressurizers below the core in the 12 reactors at Bruce and Darlington are only some of design elements that need immediate remediation or thoughtful counter measures (reference 5).

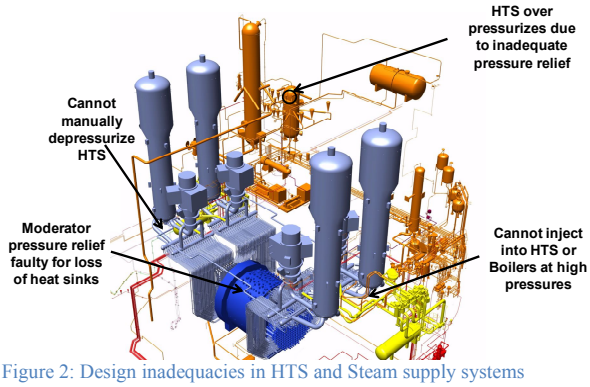

Figure 2: Design inadequacies in HTS and Steam supply systems

There are other well publicized issues that have been ignored by the regulators. The pressure relief systems in all primary and moderating systems are dangerously inadequate, resulting in likelihood of early containment bypass and vessel failures.

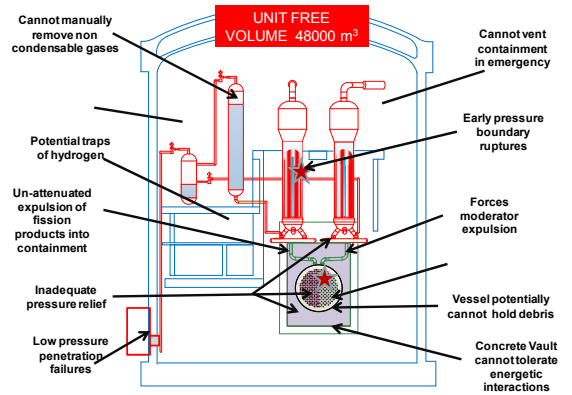

Figure 3: Further notes on some of the many design vulnerabilities for severe accidents

A number of serious inadequacies in design with respect to severe accident mitigation have been well documented. It is a long list and financial interests and regulatory arrogance combined with industry intransigence have outweighed safety concerns. In most countries, including Canada, the excuses to not do anything meaningful are created largely by the regulator and the industry trade organizations like COG.

List of issues that affect public risk goes beyond the reactor. For example, the CANDU spent fuel is kept in fish basket like configurations in water pools with bundles stuffed like sardines in a tin can. On a loss of water inventory, whether by neglect, sabotage or earthquake, Zircaloy fires in these pools will potentially release long lived radio isotopes such as Cs-137 in quantities that will choke the nation and kill tens of thousands.

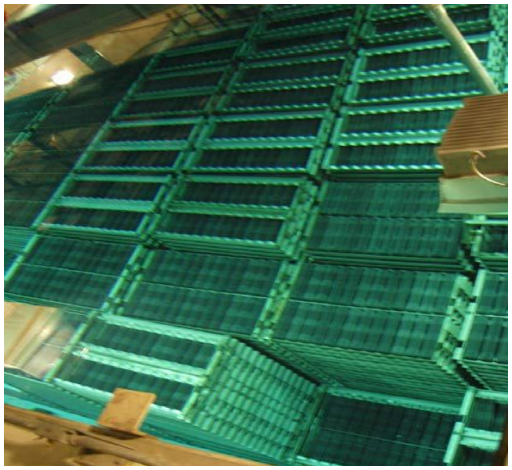

Figure 4: Spent Fuel Pool with horizontally stacked fuel bundles like in fish baskets.

The life management issues of the ever embrittling pressure tubes is yet to be resolved. Still, the regulator in Canada has accepted new life limits based on a faulty Effective Full Power Hour (EFPH) criteria and rubber stamped utility life extension applications to some of the oldest power reactors in the world at Pickering by another 5 years and extend the license of almost similarly obsolete Bruce reactors by another 10 years without ever fully debating the consequences of exposing the country to risks that are un-necessary. It has perfected the art of sham public hearings and all it's decisions are preordained in support of the power industry it facilitates rather than regulates. Public interests have long been damned. Fukushima has taught us that there is practically nothing worse than a regulator that has gone rogue.

There actually are engineering fixes that can be undertaken to overcome the design deficiencies in these relatively obsolete designs in a responsible manner. However the main aim in any public interaction between the regulator and utility seems to be in preserving the status quo. The presentation will likely include, to support the above

observations, further examples of irresponsible regulatory behaviour.

Meanwhile the industry is stagnating; unable to design advance natural uranium fuelled PHWRs; undertake serious research; complete any project on time or on budget. A severe core damage accident in a CANDU PHWR caused by a simple station blackout will cause irreparable damage to the host nation. It is hoped that the impending implosion in the nuclear industry can be avoided prior to another disaster which in the case of an unmitigated station blackout in a CANDU reactors will make Fukushima look like a walk in the park.

If the Korean regulators do follow the Canadian example and close their eyes to the glaring examples of known vulnerabilities in Wolsong reactors as they seem to have done with impunity and without challenge, a small incident that will highlight the same design and regulatory issues that this paper summarizes will force the nuclear industry to terminate operations prematurely in Korea. It will be an unfortunate end to an industry that holds such good promise, an unjustified punishment to thousands of professionals who have dedicated their life and careers to it and damage to the country that will not be forgiven by its citizens.

There is no inalienable right or power granted to the regulators to look the other way as the reactors age and their inherent vulnerabilities to severe accidents have now become obvious. Granted these were never considered in the design basis or known to the PHWR designers from 60s and 70s. While utilities like KHNP may find it convenient to ignore the issues related to severe accidents, they should examine closely the fate that befell TEPCO who, according to the Japanese parliamentary commission investigating the Fukushima disaster, colluded with the erstwhile regulators and engineered acceptance of its faulty submissions.

There are voices of reason and concern for public safety in every country. For example the following summary observations on the root causes of Fukushima from Reference 6 still hold true:

- Institutional and regulatory failure
- Inappropriate safety culture; over confidence on NPP safety
- Insufficient expertise with decision makers
- Insufficient understanding of severe accident phenomenology & progression
- Improper accident management
- Improper and insufficient understanding of reactor conditions
- No timely advice sought or available from external experts
- Insufficient exchange/transfer of information among and within organizations

SUMMARY

A good self examination by the regulatory bodies overseeing PHWRs is in order before an accident retards all reactor operations like it did in Japan. As an industry we must hold ourselves to high standards of honesty, integrity and professionalism. This has always required strong leadership. Unfortunately the regulatory bodies have failed to provide the necessary leadership in encouraging honest discussions on the design weaknesses that have been uncovered after Fukushima and have contributed to a decline in safety culture that threatens not only the future of our industry but also the safety of our fellow citizens the regulators have been entrusted for by the unsuspecting governments.

INFORMATION ABOUT THE AUTHOR

A KNS reviewer has requested that summary of the author's background, qualifications and work history be added. Here it is:

Senior nuclear reactor safety engineer / analyst with over 35 years consulting experience in nuclear reactor safety, licensing and design analysis for CANDU PHWRs, US PWR/BWRs. Russian RBMKs as well as research and medical isotope reactors.

Special interest in deterministic evaluation of accident progression and consequence assessments following severe accidents, design review of advanced reactors, regulatory issues and safety evaluations for licensing.

Professional engineering consulting activities over the last 30 years with AECL, OPG and overseas CANDU organizations include advanced reactor design evaluations, methods development, probabilistic safety assessments including consequence analysis for severe core damage accidents and severe accident management. Conversant with the full cycle of reactor response analysis from thermal hydraulics, fuel

behaviour, fission product release and transport, containment response to dose evaluations.

Developed various original computer software packages for reactor licensing safety analyses submissions and for evaluation of severe accident progression & mitigation in research and power reactors and familiar with many international computer codes used for reactor thermal hydraulic analyses and in interpretation of data from experiments.

Extensive computational modeling, research and hands-on experimental background. Academic background includes 5 years of undergraduate and graduate school teaching and research in the U.S and Canada.

Deeply committed to real public safety from nuclear power operation and a vocal proponent of responsible fact based nuclear regulation in public interest alone.

References

1 . The National Diet of Japan, The official report of The Fukushima Nuclear Accident Independent Investigation Commission, Executive Summary, Kiyoshi Kurokawa chairman, 2012.
2. Study of Consequences of a Hypothetical Severe Nuclear Accident and Effectiveness of Mitigation Measures, Sept 2015, http://nuclearsafety.gc.ca/eng/resources/health/hypotheticalsevere-nuclear-accident-study.cfm.
3Severe accident progression without operator action; www.nuclearsafety.gc.ca/eng/resources/research/technicalpapers-and-articles/2015/2015-severe-accident-progressionwithout-operator-action.cfm
4 Regulatory Actions That Hinder Development Of Effective Risk Reduction Measures By The Nuclear Industry For Enhanced Severe Accident Prevention And Mitigation Measures After FUKUSHIMA, Proceedings of the 2016 24th International Conference on Nuclear Engineering ICONE24, June 26-30, 2016, Charlotte, North Carolina.
5 Conversations about Challenges in Multi-Unit CANDU Reactor Severe Accident Mitigation Strategies, Paper N11P0543, NUTHOS-11: The 11th International Topical Meeting on Nuclear Reactor Thermal Hydraulics, Operation and Safety, Gyeongju, Korea, October 9-13, 2016.
6 Causes of and Lessons from Fukushima Accident, Dr. Won-Pil Baek, VP Nuclear Safety Research, KAERI, NUSSA 2012.