Resolution of CATS Items R03267 and R05767, "Review NUREG/CR-5759 & NUREG-1364 Re: Hydrogen Storage" and "Submit Evaluation of Hydrogen Storage Issue"

The following addresses the referenced CATS items, originally identified on 6/24/93. An analysis is provided which concludes that an explosion in the Ginna Hydrogen Storage Area poses negligible risk at Ginna. These CATS items originally requested that a review be performed of the Idaho National Engineering Laboratory risk estimates and findings pertaining to Ginna as summarized in NUREG/CR-5759 and NUREG-1364. The NRC subsequently addressed these concerns as part of the resolution of Generic Safety Issue 167, "Hydrogen Storage Facility Separation," which was created to cover an exclusion from Generic Safety Issue 106, "Piping and Use of Highly Combustible Gases in Vital Areas." The analysis provided below utilizes the more recent findings from resolution of Issue 167 in conjunction with a plant-specific evaluation for Ginna. This analysis, therefore, covers all concerns associated with the original CATS items, as well as any specifically identified in the resolution to Issue 167.

In a September 29, 1994 memorandum to Joseph Murphy, Acting Director of the Division of Safety Issue Resolution, Office of Nuclear Regulatory Research (RES), Eric Beckjord, Director of RES, stated that "the prioritization of Generic Issue No. 167, 'Hydrogen Storage Facility Separation,' shows that the issue has a LOW priority ranking." As per NUREG-0933, Prioritization of Generic Safety Issues (Ron Emrit et al. [eds.], 1983-98), an issue ranked LOW indicates that "little or no prospect of worthwhile safety improvement is foreseen (eliminate issue with responsible NRC Office Director approval)." Attached to the Beckjord memorandum was the prioritizatiion analysis for Issue 167, performed by Dr. Gary Burdick of the USNRC with support from Dr. Raymond Gallucci of Pacific Northwest National Laboratory. This analysis compared the cost of implementing a hardware fix (construction of concrete walls to enclose a hydrogen storage facility) with the reduction in risk that could be gained by this implementation, on a generic basis.

The analysis, which postulated the explosion of at least one large hydrogen storage tank (8,000-scf capacity), estimated a maximum possible reduction in core damage frequency (CDF) of 4E-6/reactor-year if the potential for explosion damage were completely eliminated. This was based on an initiating frequency of 1E-5/tank-yr for a total release of liquid hydrogen from a large container (the reference plant in the prioritization analysis had six large containers, yielding a total initiator frequency of 6E-5/reactor-yr, apportioned over different explosive intensities). This resulted in a risk reduction of 2.9 person-rem/reactor-yr, or 1,200 person-rem total for the assumed population of affected reactors, integrated over their remaining lives. The associated costs to implement the hardware fix were estimated at $1.1E+5/plant to the utility and $1.1E+4/plant to the USNRC, with an additional one-time expenditure of $1.0E+5 to the NRC). For the assumed population of affected reactors, integrated over their remaining lives. the total implementation cost became $2.3E+6. The impact/value ratio of $1,900/person-rem, when coupled with the CDF reduction of 4E-6/reactor-yr, place this issue within the LOW category based on NUREG-0933.

The RG&E CATS items dealing with the hydrogen storage issue, ID#s R03267 and R05767, were identified in 1993, prior to the completion of the NUREG-0933 analysis for the hydrogen storage safety issue. Subsequently, an additional CATS item, ID# R03171 was completed as a result of concerns raised by a USNRC inspector, also in 1993. The concern arose from the proximity of the hydrogen storage area (HSA) to the storage areas for turbine lube oil and emergency diesel fuel oil. The HSA contains 46 "bottles" of pure hydrogen, pressurized to 2,015 psi, each with a capacity of 239 scf (note that it requires 34 of these bottles to match the 8,000 scf contained in one storage tank in the Issue 167 prioritization analysis). The explosive power of one bottle was estimated at 6.5 lbs of TNT (compared to 220 lbs for the 8,000-scf tank). To protect adjacent areas from damage, at least seven feet of separation distance from a reinforced wall eight-inches thick are required. The distances and wall structures between the HSA and each oil storage area identified above match or exceed these minima. Therefore, it was concluded that "a single vessel rupture of hydrogen containers in the HSA will pose negligible hazards to the safe operation or safe shutdown of Ginna." This CATS item was closed in 1995.

To estimate an upper bound on the potential contribution of an explosion in the Ginna HSA to the CDF, it is assumed that a hydrogen explosion of sufficient intensity to cause a transient occurs with a frequency of 6E-5/yr.[1] The conditional probability that this explosion is of sufficient intensity to produce enough structural damage to prevent the supply of diesel generator fuel oil is assumed to be 0.1 (the default beta factor used in the Ginna PSA for common-cause failure [CCF]). A review of the Ginna PSA cut sets indicates two basic events corresponding to loss of fuel supply to each diesel generator (DG): DGMM0FUELA - Failure of the Fuel Supply to DG A; DGMM0FUELB - same for DG B. Each was assigned a failure probability of 0.00614 in the PSA. CCF of both fuel supplies was not specifically included, although other CCFs which would prevent supplying fuel oil were specifically included (e.g., CCF of both fuel pumps). Further review of the cut sets indicates that these two events occur only after the initiator TIGRLOSP - Loss of Offsite Power via Grid Instability. The initiator frequency was set at 0.0228/yr. Cut sets containing DGMM0FUELA contributed 1.1% to the CDF. Cut sets containing DGMM0FUELB contributed 1.3% to the CDF. Since nine cut sets contained both these failures, and contributed 0.1% to the CDF, the combined contribution of both events was 1.1% + 1.3% - 0.1% = 2.3%.

It is assumed that a TIGRLOSP initiator occurs with a frequency of 6E-5/yr due to an explosion in the HSA, perhaps by inducing a turbine trip, which subsequently causes grid instability and resulting loss of offsite power. It is further assumed that subsequent CCF of both fuel supplies to the DGs occurs with a conditional probability of 0.1. Under these assumptions, the estimate of the maximum potential contribution to the Ginna CDF from an explosion in the HSA follows.

- The original 2.3% of the cut sets containing DGMM0FUELA or DGMM0FUELB, but not both, assumed an initiator frequency of 0.0228/yr for TIGRLOSP and a conditional failure probability of 0.00614 for either DGMM0FUELA or DGMM0FUELB. These were multiplied together with other basic events to yield the frequency of each cut set,

---

[1] This frquency is assumed to bound that for seismic-induced explosion of hydrogen.

whose sum amounted to the 2.3%. Now, assuming that TIGRLOSP occurs with a frequency of 6E-5/yr, specifically due to an explosion in the HSA, and DGMM0FUELA or DGMM0FUELB follows with a conditional probability of 0.1, the contribution to the CDF from these cut sets becomes [(2.3%)(6E-5/yr)(0.1)]/[(0.0228/yr)(0.00614)] = 0.1%.

- The original 0.1% of the cut sets containing both DGMM0FUELA and DGMM0FUELB assumed the same TIGRLOSP frequency of 0.0228/yr and DGMM0FUELA and DGMM0FUELB conditional failure probability of 0.00614 each. CCF of the fuel supplies was not specifically included. Now, assuming that TIGRLOSP occurs with a frequency of 6E-5/yr, as above, and the CCF of both fuel supplies occurs with a conditional probability of 0.1 (as above), the contribution to the CDF from these cut sets becomes $[(0.1\%)(6E\text{-}5/yr)(0.1)]/[(0.0228)(0.00614)^2] = 0.7\%$.

- Together, all cut sets containing DGMM0FUELA and/or DGMM0FUELB, now modeled as a CCF of both fuel supplies due to an explosion in the HSA which initiates a loss of offsite power via grid instability (TIGRLOSP) contribute 0.1% + 0.7% = 0.8% at a maximum. It is believed that the initiator frequency of 6E-5/yr for TIGRLOSP and the probability for CCF of both fuel supplies of 0.1 due to an explosion in the HSA are both conservative. Thus, 0.8% would be an upper bound.

Considering both the disposition of Issue 167, "Hydrogen Storage Facility Separation," as LOW in NUREG-0933 and the low potential contribution to Ginna CDF estimated above, it is concluded that an explosion in the Ginna HSA poses negligible risk.

Raymond HV Gallucci

Dr. Raymond HV Gallucci
Senior PSA Engineer
Nuclear Safety & Licensing