plutonium mass by only 27% for the total flux mode of the 127-cm^2 NaI(Tl) detector (as computed by Sampson). The figures presented in Table III of our paper for the 5-cm^2 Ge(Li) detector should be corrected. The detectability of the 130-keV source would be modified somewhat. Our conclusions are unchanged.

Sampson makes a great deal about using the exact Poisson distribution at very low count rates instead of the square root of the mean. We think it more logical to simply assume a somewhat longer integration time than the arbitrary 10 s in the example. As Sampson points out, the ratios of detectable masses will remain unchanged.

With background assumed constant, sensitivity depends on the window width, which in turn depends on the energy resolution of the Ge(Li) detector. The total flux mode is more sensitive than photopeak counting, at 100 m in air, for window widths >2 keV. The total flux method is considerably more sensitive at greater attenuations, as shown in Fig. 10, for example.

There are actually two major points made in our paper. One has already been discussed: Total flux counting, especially at large attenuations and for low source energies, is more sensitive than detection of the uncollided flux. The second point has to do with the possible superiority of a low-background semiconductor detector over an NaI(Tl) scintillation detector for remote sensing of plutonium. First, the 5-mm-thick Ge(Li) detector is as efficient as the 1.6-mm-thick NaI(Tl) detector for low-energy photons, on an equal area basis, and is superior to the thicker NaI(Tl) sometimes used for sensing of plutonium because of lower background and lower efficiency (hence lower Compton background) for high-energy gamma rays. Second, the intrinsic background is smaller, and even if ambient background is controlling, we think the smaller semiconductor detector is easier to shield over the 2π back hemisphere, at least in terms of smaller mass of shielding (an important consideration in airborne or portable applications).

The sensitivity is also a function of the detector area, which in turn affects the cost. Large area intrinsic and lithium-drifted germanium detectors are being fabricated, and as Sampson mentions, detectors can be grouped in an array. It is true that a thin NaI(Tl) detector is less expensive per square centimeter than germanium, but we feel there are some applications where cost is not the primary consideration.

Finally, we believe that a definitive comparison of the merits of low-energy scattered flux sensing, and comparisons of thin NaI(Tl) and Ge(Li) detectors, would best be done by measurements in the field.

A. E. Profio
G. C. Huth

University of California at Santa Barbara
Department of Chemical and Nuclear Engineering
Santa Barbara, California 93106

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ISSS—AN INTEGRATED SAFE SHUTDOWN SYSTEM FOR LIGHT-WATER-REACTOR PLANTS

A preliminary conceptual design is presented for an integrated safe shutdown heat-removal system (ISSS) for light-water reactors that is completely independent of all components and systems outside the primary containment other than the ISSS itself. The system is predicated on execution of reactor trip (scram) and no within-containment loss-of-coolant accident (LOCA) induced by piping failure. It requires ~10 min to activate. It is intended to serve as a backup to the usual shutdown heat removal systems in case of unusual events, including fire, sabotage, and a loss of currently provided ac or dc power.

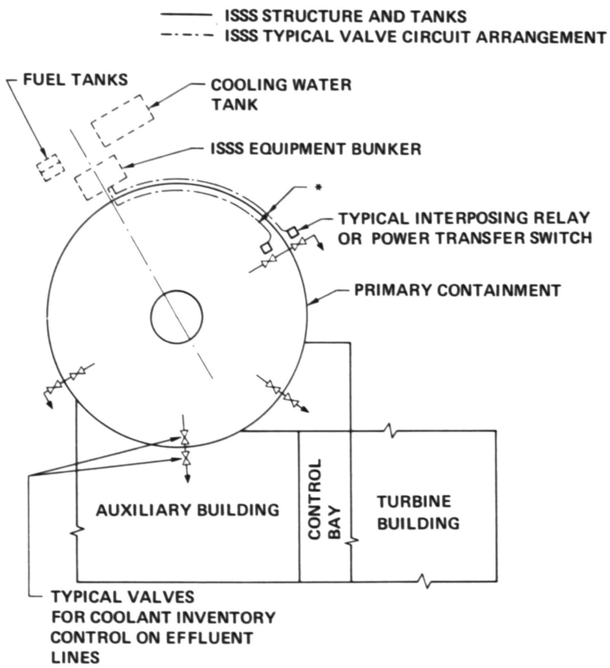
The system has evolved from a goal of achieving simplicity with respect to process and physical layout, as distinct from the large capacity, complex, multipurpose systems that now perform this relatively unsophisticated, small-capacity, but absolutely essential cooling function after reactor trip. Some of the complexities introduced into current designs are a direct result of setting difficult design objectives, such as automatic response to piping and power failures. As a result, the reliability of performing this critical and simple but more frequently needed function can be reduced. And in a physical-layout sense, the current systems for performing post-scram cooling functions are broadly exposed to a large variety of potentially disabling accidents and to sabotage. A main purpose of the ISSS is to minimize such exposure.

The ISSS is normally "dead" or insensitive without direct operator action. It does not depend on any electrical, pneumatic, or hydraulic control system nor on any water supply or steam release system not integral with ISSS.

The major elements of the ISSS are to be housed in a satellite structure or bunker, preferably in an underground configuration. The bunker would be thoroughly protected against environmental hazards and unauthorized entry. The ISSS would have its own integral stored water and fuel supplies. Fuel requirements would be in the range of one-twentieth of the usual diesel fuel storage.

Some of the piping and valves would be within primary containment. Some isolation valves might be dispersed within auxiliary buildings or secondary containments, but in all cases redundant valves would be within primary containment. Figure 1 illustrates one conceptual layout of the ISSS.

For pressurized water reactors (PWRs), natural convection would be used to carry heat to the normal steam generators, using the safety-relief valves (modified as necessary) for secondary steam relief. The ISSS would include independent pressurizer and steam generator level indication, and independent electric-motor-driven manually activated feedwater pumps supplying water to existing feedwater headers. The ISSS would have the ability to positively isolate any lines running outside the containment that might offer a path for undesired through-line coolant inventory loss. Failure during test of the ISSS elements by pipe rupture, equipment failure, or otherwise would not prevent the functioning of equipment currently provided for the emergency core cooling system. The PWR primary



*Circuit routing is for typical PWR design layout. For both PWRs and BWRs these circuits would be run in rigid steel conduit embedded in concrete if in common interior spaces such as BWR secondary containment. Influent lines protected by mechanical check valves (not shown).

Fig. 1. Conceptual layout of the ISSS.

relief valves would be used to expedite depressurization while maintaining appropriate ΔT between primary and secondary loops to expedite reduction of primary system loss through valves and seals that might continue to leak or suffer some increased leakage rate, and to expedite boration of the coolant.

For boiling water reactors (BWRs), the currently preferred design approach provides an ISSS shutdown condenser that would condense steam on the primary (shell) side and flash the condensing ISSS feedwater to atmosphere as clean steam. The primary system would employ natural convection for boiling across the core. Independent level controls would be provided on both primary and secondary sides of the system. The ISSS would include the necessary valves, condensate pumps, and feedwater pumps.

One possible design alternative for BWRs would permit primary system steam, through appropriately valved special piping, to discharge directly to atmosphere, with suitable provisions for inventory makeup. Activity release would exceed *10 CFR 20* limits but might be acceptable, in keeping with the probable infrequency of need for this cooling function.

Other aspects of ISSS include the following:

1. Final valve control at the valve for all valves whose functions are vital to ISSS function.

2. Control power provided by dedicated, redundant battery, charger, and inverter sets.

3. Heavy wall, rigid conduit for power and control distribution systems. The system shall be designed to comply, within itself, to the separative consideration in IEEE 384, *Regulatory Guide 1.75*, and draft Standard ANSI N182 (July 1975).

4. No cooling water for shaft seals of primary system pumps is presently included in the concept. Pumps are assumed to be allowed to stop, and seals should withstand the static but uncooled condition without excessive leakage. Seal leakage would be accommodated by drains and small makeup pumps (with boron, addition, as appropriate).

5. Under normal conditions, ISSS batteries would be disconnected from the distribution system and would be designed to require sequential actions for operation to minimize possibility of interference by ISSS during LOCA or normal conditions.

A system such as ISSS would provide significant additional protection of the public health and safety for a considerable range of events, including major fires in the control room, cable-spreading rooms, and other areas within the normal auxiliary building, extended loss of off-site and on-site ac or dc power systems, damage to the normal ultimate heat sink and coolant discharge structures and systems as currently provided, possible seismic damage to more complicated and exposed systems, and to many forms of sabotage.

A significant advantage of ISSS is the relative ease by which it can be perceived as an entity by design engineers and operator-maintenance personnel in both physical location and functional process aspects. Operators would understand clearly what it could do and where the working elements were located. Therefore, it is hoped they could use this simple system with confidence in such complicated emergencies as fires, without the fear of making situations worse by using effective fire fighting measures.

An emergency feed system for Biblis PWR, as described by Frewer,[1] contains several of the features conceived independently and described herein for ISSS. A paper by Richardson[2] briefly outlines a bunkered system for a PWR in Germany, which appears to have more ambitious objectives than does ISSS. More details on ISSS are available in a forthcoming report.[3]

Jesse C. Ebersole
David Okrent

University of California
School of Engineering and Applied Science
Energy and Kinetics Department
Los Angeles, California 90024

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