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Ms Cindy Bladey
Chief, Rules, Announcements, and Directives Branch (RADB), Office of Administration
U.S. Nuclear Regulatory Commission
Mail Stop: 3WFN0644M
Washington DC, 20555-0001

Subject: Comments on "NRC Notice: Conceptual Example of a Proposed Risk Management Regulatory Framework Policy Statement." NRC-2013-0254-0004.

Dear Ms Bladey:

Regarding the NRC risk-management policy statement now under review, we are of the informed opinion that:

> In order to minimize adverse nuclear-reactor events, control their progression, and mitigate consequences,
>
> previously experienced harmful events and inadequate remedial performance should have received much greater significance.

Specifically:

> The past four major loss-of-coolant reactor accidents (TMI-2 and Fukushima) should have resulted in regulatory mandates for remedial, pre-installed capability to autonomously monitor reactor water levels and fuel concentration.

One of us submitting these comments is a nuclear physicist with a half-century of intense empirical experience in nuclear-reactor safety; the other is a nuclear engineer having 46 years nuclear experience and a substantive career in national and international regulatory functions, as well as nuclear operations. We are not affiliated with government or industrial institutions.

We would appreciate consideration of our specific comments (Attachment 1) on the NRC Notice.

Supportive information is provided, starting in Attachment 2, with increasingly detailed materials in Attachments 3 and 4, typifying relevant technical presentations made to professional societies, government agencies, and nuclear organizations. In Attachment 5 is a list of literature cited and technical references, and in Attachment 6 are brief professional biographies.

SUNSI Review Complete
Template = ADM – 013
E-RIDS= ADM-03
Add= M. Drouin (mxd)

Attachment 1: Specific Comments (on NRC-2013-0254-0004.)

Attachment 2: NEI Presentation Highlights "Value-Added LWR Instrumentation Highlights" (Presented to Nuclear Energy Institute, Washington, DC, September 2013)

Attachment 3: ANS 2012 Winter Meeting Presentation, "TMI, LOFT, & Fukushima Loss-of-Coolant Accidents: Lessons NOT Learned" American Nuclear Society Winter Meeting, San Diego, CA (13 November 2012), Session: Lessons Learned from Fukushima Dai-Ichi and other Japanese Plants (Safety System and Containment Performance and Improvement). Presented by Dr. Alexander DeVolpi, physicist (Retired, Argonne National Laboratory)

Attachment 4: Summary of paper presented at ANS Winter Meeting, with References and Supplemental Bibliography

Attachment 5: Professional biographies of the authors

We trust that our experienced-based comments and supplemental documents in evidence will assist in improving the nuclear-regulatory framework.

Sincerely,

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ATTACHMENT 1

SPECIFIC COMMENTS

"NRC Notice: Conceptual Example of a Proposed Risk Management Regulatory Framework Policy Statement." NRC-2013-0254-0004

To minimize adverse nuclear-reactor events, control their progression, and mitigate consequences, much higher significance must be assigned to harmful events and inadequate performance already experienced.

The past four loss-of-coolant reactor accidents (TMI-2 and Fukushima) should have resulted in mandates for remedial, **pre-installed** capability to autonomously monitor reactor water levels and fuel concentration.

> Priorities and recommendations from previous post-accident evaluations have not mandated supplemental dual-purpose instrumentation for: (1) autonomous determination of reactor water level in real-time before, during, after, and long-after a loss-of-coolant accident, and (2) durable estimation of fuel reconcentration after a melt-down accident.

Such pre-installed monitoring capability would improve nuclear risk assessment, accident reduction, and consequence alleviation.

> Instrumentation reducing uncertainty about reactor coolant levels and post-accident fuel concentrations offers much better risk-informed and performance-based defense-in-depth projections.

Autonomous ex-vessel instrumentation would augment level-of-defense programs for preventing adverse events, as well as mitigating their consequences. Coolant and fuel stability are fundamental to safe and efficient operation. Uninterruptible autonomous water-level and fuel-concentration monitoring adds both risk-informed and performance-based defense-in-depth protections.

> A pre-installed ex-vessel array — of autonomous, fixed, independent, high-energy gamma-radiation detectors should be mounted and functioning outside the reactor vessel (ex-vessel). This instrumentation would contribute additional levels of defense independent of other design, operation, and administrative functions in reactor safety, operation, and decommissioning.
>
> This enhancement would provide an independent level of defense, such that the inadequacy or failure of one level of defense should not lead to the near-term failure of other levels of defense.

Emphasis would be on a preventative passive subsystem that augments operational controls and provides monitoring and oversight, verifying real-time performance of other instrumentation and system features. This redundancy would enhance the requirement that failure of one level of defense should not lead to failure of other levels of defense. In addition, performance of normal nuclear operations and functions would be monitored continuously during reactor operation.

Based on uncertainties associated with the Fukushima accident, the recent NRC order 2012-0067 mandated additional spent-fuel-pool instrumentation; however, Fukushima lessons-learned apply more tangibly and beneficially to reactor water-level and fuel-reconcentration variability and uncertainty.

After the Fukushima accident, responders were without means to determine reactor water levels. Operators of Unit 2 lost ability to cool fuel after about 70 hours. Rephrasing NRC spent-fuel-monitoring order 2012-0067, *the lack of reactor water-level information contributed to poor understanding of potential radiation releases and adversely impacted prioritization of emergency response actions. Post-accident operational confusion was aggravated because reactor water-level instrumentation was (and still is) not available.*

Consistent with a more anticipatory defense-in-depth strategy, reactor-safety improvements should adopt installable ex-vessel capability to mitigate beyond-design-basis accidents. Such cost-effective improvements would also reduce potential financial risk and public apprehension. Moreover, continuous real-time ex-vessel monitoring would supply routine operational nuclear-process information that might enhance fuel-consumption efficiency.

Appropriate regulatory and industry response to the Fukushima accident should require LWR/BWR water-level instrumentation consisting of fixed independent high-energy gamma-radiation detectors mounted outside the reactor vessel.

Ex-vessel instruments would provide autonomous and redundant measurements of reactor water level and density at all times, irrespective of power level. Installed within the biological shield — external to the reactor pressure vessel — such independent instruments would be qualified for temperature, humidity, and radiation levels consistent with extended reactor operation. This same survivable instrumentation would monitor post-accident reactor fuel reconcentration.

Trained personnel would monitor reactor water level from the control room, or from external locations during normal or abnormal operation. The information display would continuously indicate reactor water level and density. If a melt-down accident occurred, post-accident decay radiation would provide the basis for long-term indication of fuel reconcentration.

A half-century legacy of published experimental and intellectual technical base exists for autonomous gamma-ray water-level and fuel-motion monitoring. Time- and space-resolved ex-vessel measurements of similar phenomena were systematically evaluated on a smaller scale at two test reactors in the United States and France (TREAT and CABRI), and extensive calculations have been performed in both countries, reinforcing feasibility of full-scale application.

The calculations and experiments were stimulated in part by the TMI-2 loss-of-coolant billion-dollar accident which might very well have been prevented if such ex-vessel instrumentation had been in place. In addition, anticipated difficulties in decommissioning at Fukushima might yet be avoided, as could have been the case at TMI.

– Dr. Alexander DeVolpi and Dr. Mehdi Sarram
(retired nuclear physicist/engineers, each with a half-century of extensive empirical and regulatory experience in nuclear-reactor safety)

ATTACHMENT 3

ANS WINTER-MEETING PRESENTATION

TMI, LOFT, & Fukushima Loss-of-Coolant Accidents: Lessons NOT Learned

Presented at American Nuclear Society, San Diego, CA
Tuesday, 13 November 2012, 1:30p

Session:
Lessons Learned from Fukushima Dai-Ichi and other Japanese Plants – II:
Safety System and Containment Performance and Improvement

Presented by:
Dr. Alexander DeVolpi, physicist
(retired, Argonne National Laboratory)

INTRODUCTION

• The earthquakes and tsunamis in Japan have revitalized interest in instrumentation for preventing nuclear-reactor accidents or minimizing their consequences.

> Three irreparably damaged reactors remain under stressful conditions that could conceivably result in further internal damage.

> Those reactors are to be eventually decommissioned, expectedly in a safe, orderly, and timely manner.

• However, it's a matter of professional responsibility to consider instrumentation that

> should have been installed beforehand,

>and still might be implemented

> at Fukushima

> and

> for operating, water-cooled, power reactors.

PROBLEMS STILL AT FUKUSHIMA

• Significant difficulties now faced at Fukushima

> result from lack of definitive realtime data

> on quantity and location

> of water and fuel within each reactor containment vessel.

• The internal instruments used to infer these parameters during normal conditions are not operational.

• In order to determine present-day coolant and fuel distribution at Fukushima:

> I propose specialized nuclear instrumentation, derived from a 1987 patent.

> The instrumentation had been formulated and analyzed as a result of the TMI-2 reactor accident, but never implemented.

LET'S LOOK AT SOME CONTEXT

• What are the primary instruments in a reactor?

> Reactivity meters, flux indicators, thermocouples, pressure gauges, radiation monitors

> all vulnerable to damage in a loss-of-coolant accident.

• And none of these directly measure water-level !!!

> even now, after four meltdowns in water-cooled reactors.

• **IF** direct, autonomous, independent, monitoring of water level had been installed at TMI,

> it is likely that accident would have been prevented.

• At Fukushima, the operators — for days — did not know that water levels were below the core region.

• What about the international fleet of over 350 water-cooled reactors, plus more than 2 dozen under construction?

SO, WHAT ARE SOME SPECIFIC

LOSS-OF-COOLANT LESSONS

THAT COULD OR SHOULD HAVE BEEN LEARNED?

• As a retired nuclear physicist,

>with 40 years experience at Argonne National Laboratory

> in reactor-safety research and related technology

> here's a summary of specific lessons I've learned

> from TMI and Fukushima:

LESSONS THAT SHOULD HAVE BEEN LEARNED
FROM TMI

• The <u>TMI</u> accident was largely caused by insufficient water coolant,

> but operators didn't realize it from the available instruments.

> (Water levels were indirectly monitored by devices that failed early in the accident sequence.)

• An important lesson

> based on my own technical evaluation of the TMI accident is

> not <u>just</u> nuclear controls and operator training needed to be improved

> but reactor coolant levels should be directly monitored.

• Moreover, because no advance preparations had been made to determine post-accident fuel and debris reconcentration,

> it took about 5 years after the TMI accident before fuel-debris localization was accomplished.

ADDITIONAL LESSONS FROM FUKUSHIMA

- The Fukushima accidents were aggravated by insufficient coolant

> compounded because overburdened operators lacked accessible, functioning instruments that would indicate coolant loss,

> and the problems could not be mitigated by emergency workers limited by what they actually could do about water loss.

- These fateful shortcomings reflect common-mode limitations in available instrumentation,

> in that coolant status was unknown

> during and after the accidents.

- The three affected Fukushima reactors are not yet entirely secure

> against further damage, inasmuch as the amount of water in each reactor is still somewhat uncertain.

> Also unknown is the quantity and location of fuel debris that melted down and reconcentrated.

LESSONS NOT IMPLEMENTED

• Although many (official) lessons were derived and implemented from TMI and Fukushima:

• Instruments to dependably measure reactor water levels

> are still **NOT** mandated for operating commercial reactors

• **NOR** are pre-positioned, post-accident means required

> to directly determine fuel relocation

> inside reactor vessels or containment.

TECHNICAL FOUNDATION

FOR MONITORING WATER AND FUEL

• With those circumstances in mind, let's look at potential nuclear-instrumentation technology for measuring reactor water and fuel.

• The recommended instrumentation is based on two expired patents.

> One was issued for the underlying nuclear-diagnostic technology,

and

> the other was specific to monitoring water levels in commercial reactors.

• Both of these patents address technical means to autonomously monitor fuel and water from outside the reactor pressure vessel.

HERE'S SOME RELEVANT TECHNICAL BACKGROUND

FOR MAKING SUCH MEASUREMENTS

• Starting in the mid 1960s, specialized nuclear-diagnostics instruments were developed at Argonne National Laboratory for in-core reactor experiments.

• What we call the "hodoscope" consisted of parallel arrays

> containing hundreds of collimated and shielded radiation detectors,

> each with their own independent electronic processing channel.

• Altogether, 156 nuclear-safety experiments using the hodoscope were conducted at the TREAT reactor in Idaho.

DECADES OF EXPERIENCE PROVIDE

A PROVEN TECHNOLOGY FOUNDATION

• Hodoscope nuclear diagnostics

> gained relevant and unique experience in nearly 30 years of TREAT experiments,

> accumulated and recorded data before, during, after pulsed-power reactor experiments.

• The patented TREAT hodoscope diagnostic instrument system:

> obtained real-time data from experiments situated <u>inside</u> the TREAT reactor in Idaho;

> monitored fuel, cladding, and coolant in test capsules situated within the reactor core;

> carried out measurements before, during, after power-transient tests;

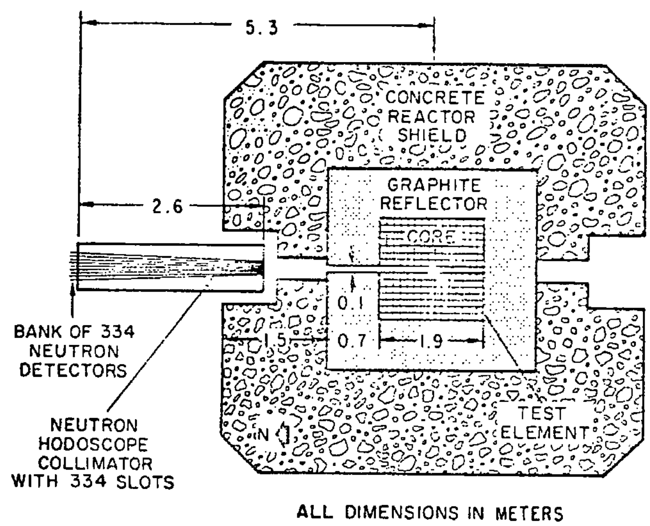
> observed dynamic phenomena directly, such as nuclear-fuel expansion, clad failure, pin distortion, and fuel meltdown;

> and rendered pre- and post-transient digital radiography.

REPRESENTATIVE IMAGES OF THE HODOSCOPE SYSTEM

• Here's a cutaway view of the earliest version of the hodoscope installed at TREAT:

>Note that hodoscope detectors view the test element directly from a distance of over 5 meters from the core center.



ARRANGEMENT OF HODOSCOPE ON NORTH FACE OF TREAT REACTOR VIEWING TEST ELEMENT THROUGH SLOTTED ELEMENTS.

Figure 1. Schematic of TREAT Reactor with Instrumentation Slot

• The second image details a subsequent — more advanced hodoscope version — that was installed within the reactor biological shield:

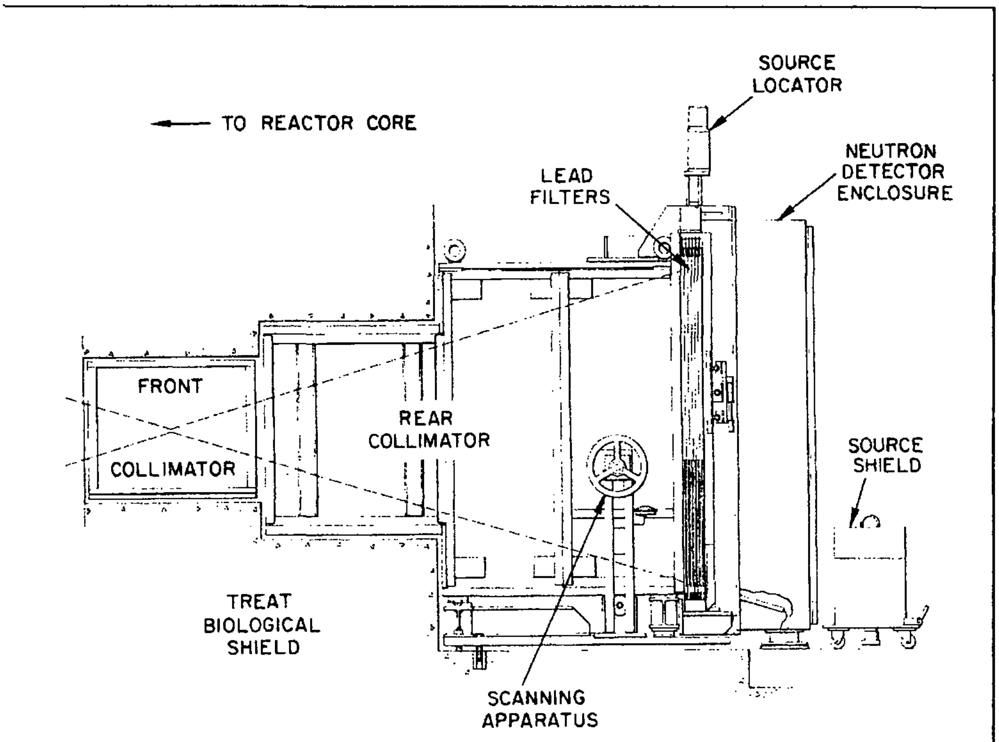


Figure 2. Side View of Hodoscope at TREAT

• And this is a photo of the neutron-detection array:

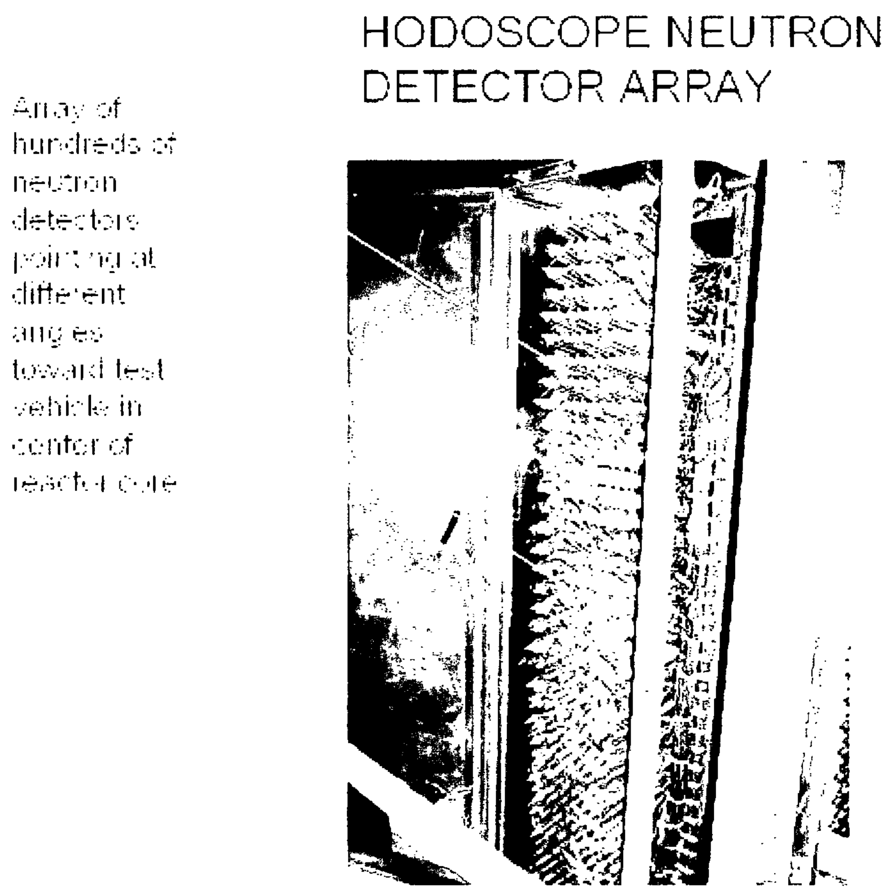


Figure 3. Photograph of Hodoscope Neutron Detection Array

• A 1.2 m vertical detection field of view was designed into a second-generation hodoscope collimation apparatus,

> as displayed in this slide with a little more detail (plan view on top and elevation view below):

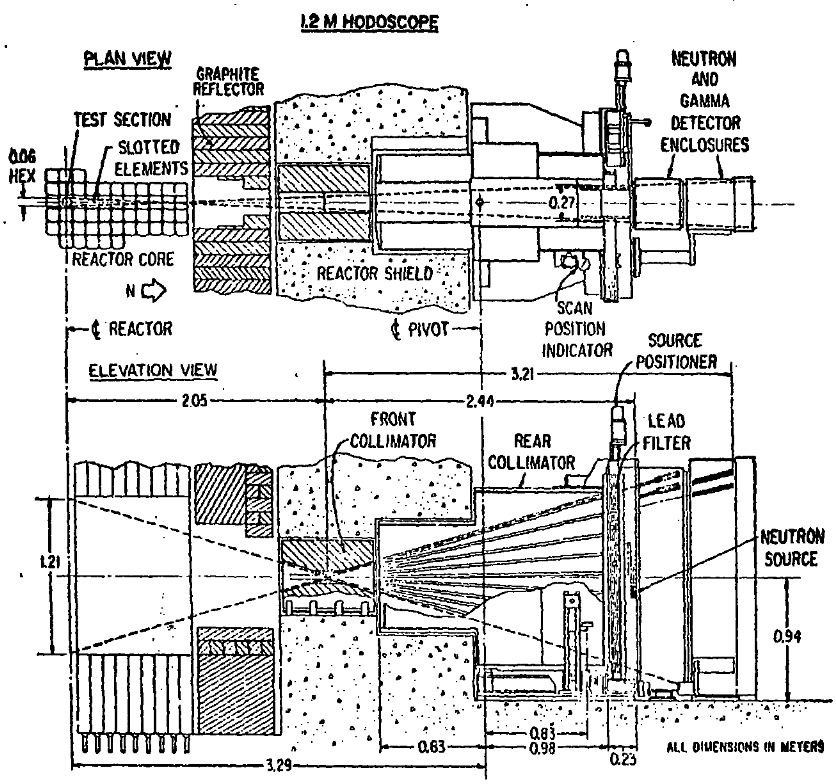


Figure 4. Top and Side Views of TREAT Hodoscope Aimed at Test Section

DIAGNOSTICS-SPECIFIC FACTORS

• Important hodoscope operational requirements included

> redundancy, dynamic range, reliability, and good statistics.

• A patent was issued in 1978 for the diagnostic hodoscope,

• And an additional decade of experience was obtained by another, smaller hodoscope

> installed at the CABRI reactor in Cadarache, France.

A FEW HODOSCOPE RESULTS

• Here's an example of relevant data:

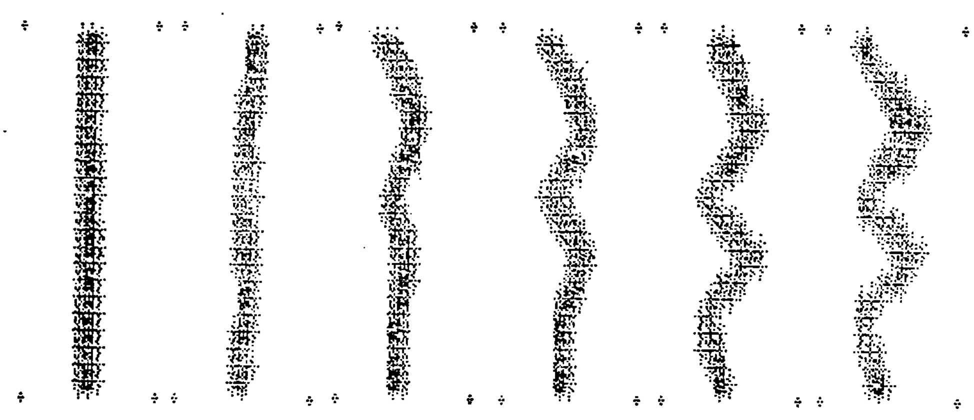


Figure 5. Hodoscope transient data results for R1 Experiment

> This illustrates fuel-pin distortion/twisting
>> under power-transient-induced stress,
>> millisecond time resolution, and
>> extended recording-duration (here over 29 seconds).

> The data also demonstrate millimeter spatial resolution
>> and high signal/background ratio.

• We also routinely measured axial fluxes and fuel concentration profiles.

• Keep in mind that the detectors were about 5 meters outside the reactor, looking directly into its core.

• This figure represents a typical result obtained by mechanically scanning an encapsulated fuel pin across its field of view.

> The hodoscope collimator was pivoted on a horizontal plane.

> The single pin here is surrounded by sodium, cladding, stainless steel, graphite, and more stainless steel.

>Despite the surroundings, we could get a signal/background ratio of almost 1.5

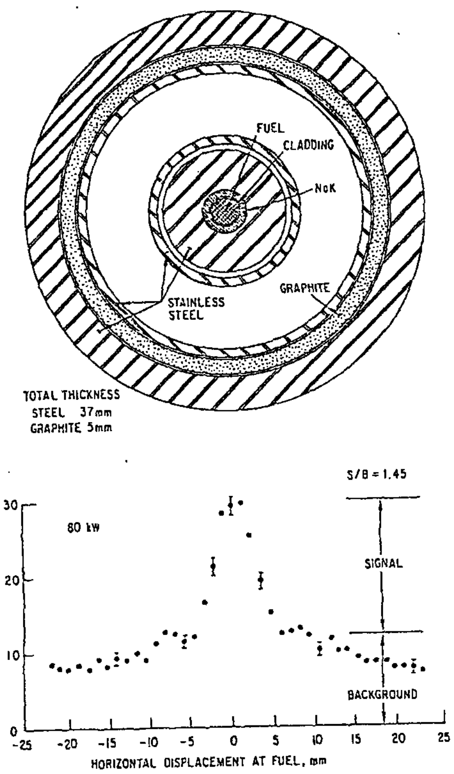


Figure 6. Horizontal Scan of Single Pin in Thick Container

THE FOUNDATION

FOR LWR COOLANT- AND FUEL-MONITORING

IS DERIVED FROM HODOSCOPE DETECTION
OF GAMMA-RAYS

- Our gamma-ray database is particularly relevant to monitoring water levels in a power reactor.

> The data shown in previous slides were obtained specifically from analysis of hodoscope neutron-detector results.

> But we also found that it was possible to obtain parallel, separate data, from gamma detectors operating concurrently.

> Our hodoscope gamma array consisted of 100 small sodium-iodide crystals.

- The specific scheme proposed for monitoring water-level in reactors

> is based detection of gamma rays greater than 5 MeV that are created by neutron capture in the steel pressure vessel.

• As the next slide demonstrates (using gamma detection), we could detect a fuel pin — behind a 1" steel attenuator — as well as the steel itself:

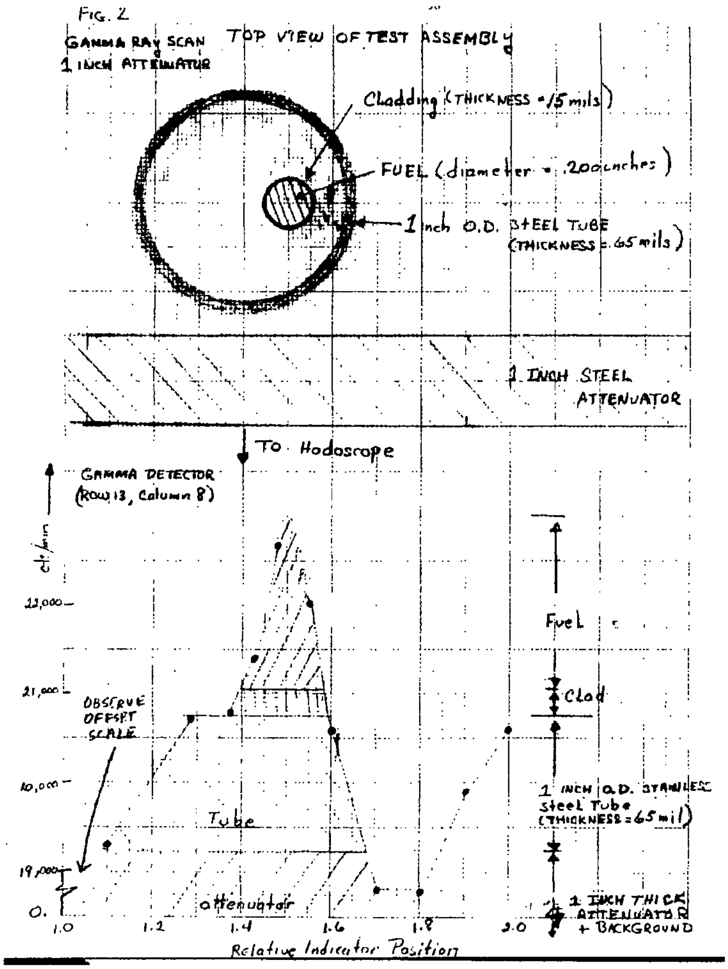


Figure 7. Gamma-Ray Hodoscope Scan of Fuel Pin Behind 1" Steel

CALCULATED GAMMA RESPONSE TO CHANGES IN REACTOR WATER LEVEL

• In the next two slides are some calculations we made,

> showing dependence of gamma-ray flux

> on water boiling and voiding

> within the core and downcomer of an LWR.

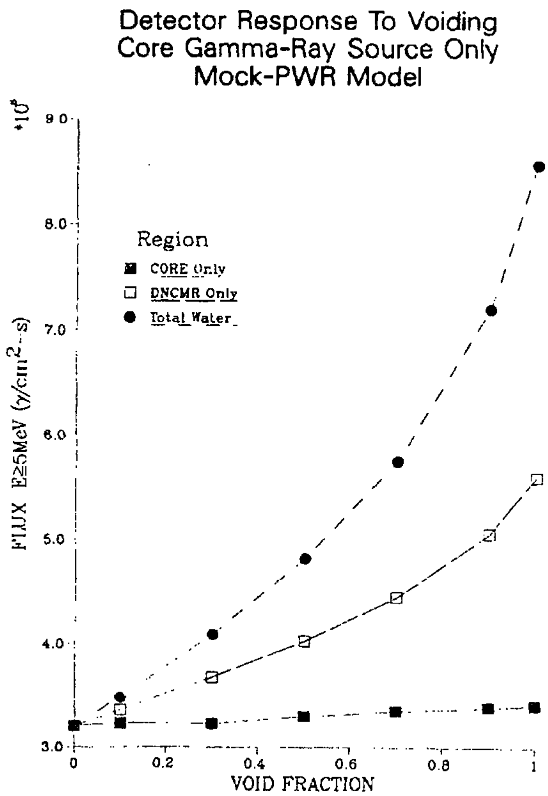


Figure 8. Calculated Gamma Response to PWR Coolant Voiding

• As void fraction in the core and downcomer increases, proportionately more high-energy gamma rays escape the reactor.

LOFT EXPERIMENTS
IN IDAHO

- We also made use of LOFT L2-5 LOCA data (a half-scale LWR coolant break) experiment in Idaho:

> to model gamma-ray monitoring of water-level changes.

> The graphs to the right compare our computer simulation with the measured data.

> The computed results at the top track rather well the actual water-level surges in the core (middle graph) and downcomer (lower graph).

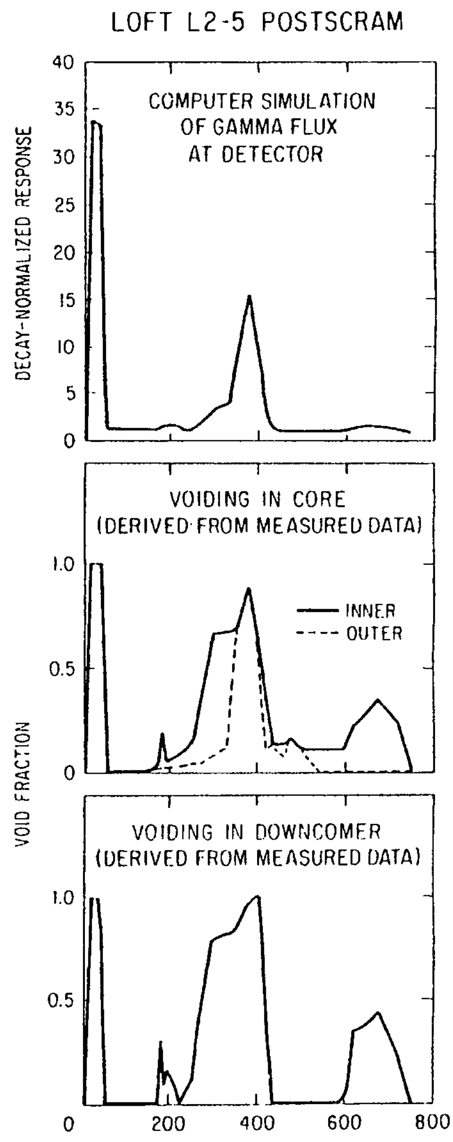


Figure 9. Comparing Loft Gamma Flux with Coolant Voiding

- That effort culminated with an Argonne 1987 patent

> shown in the next slide,

> depicting a multiplicity of gamma detectors (designated “50-n”) installed inside the biological shield,

> at various elevations and circumferential locations.

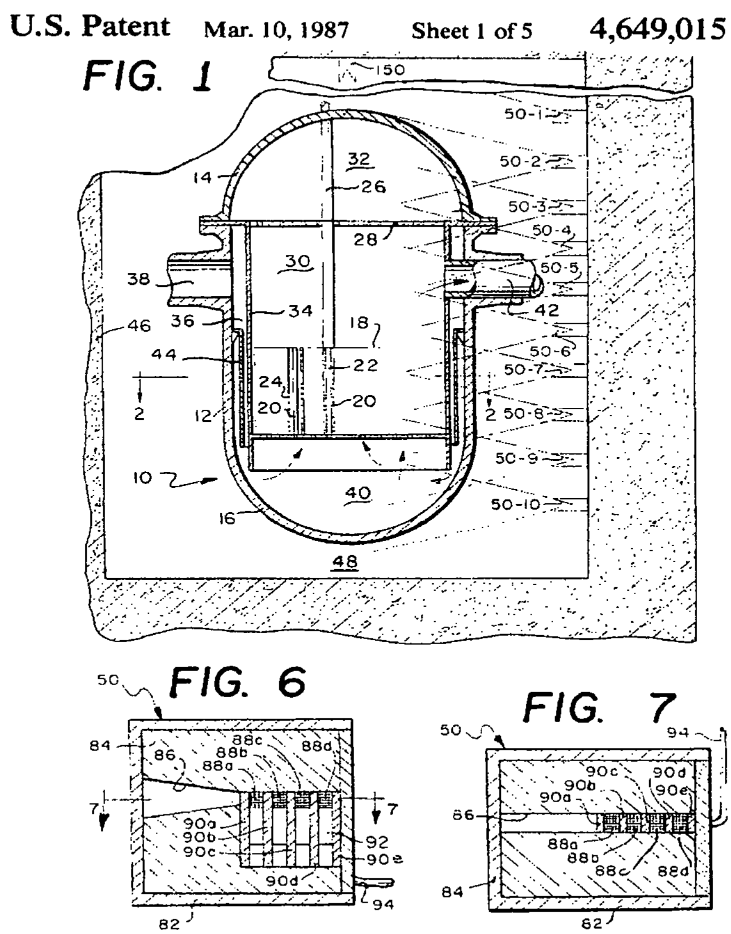


Figure 10. Water-Level Monitoring (Expired) Patent for PWR

WATER-MONITORING CONCEPT

• The specific concept was based on retrospective analysis after TMI:

> It had become a logical goal for us

> to evaluate ex-vessel gamma-ray determination of reactor coolant levels.

• Like many other technical peers at DOE laboratories,

> we looked at possible applications of our specialized experience

> towards preventing a reoccurrence of loss-of-coolant accidents.

IN SUBSEQUENT YEARS

• Just about nothing took place later to take advantage of the patent.

• However, in the 1990s, CEA scientists in France

> obtained similar computational results,

> independently confirming our gamma-ray monitoring concept.

LET'S TURN OUR ATTENTION BACK TO FUKUSHIMA

- Judging from data and analysis:

  > One can expect that fuel concentration and water levels

  > in the Fukushima reactors can be determined

  > using decay gamma rays in the range of 2-3 MeV.

- Two possible hodoscope-instrument-array manifestations

  > — fixed or portable —

  > could be used to make the external measurements.

POSSIBLE IMPLEMENTATION AT FUKUSHIMA

• This slide suggests

> a fixed array installed in narrow penetrations

> drilled through the external biological shield.

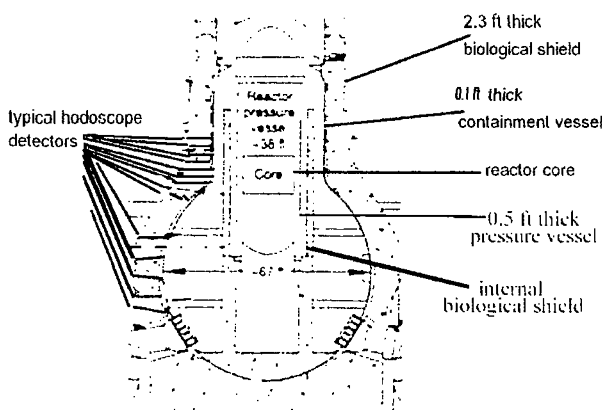


Figure 11. Conceptual Fukushima Fixed Array Detector Locations

SO, WHAT ARE SOME BOTTOM-LINE MESSAGES?

- My technical experience advises

> that there were common factors in the major reactor accidents at TMI and Fukushima,

> and that there is a well-characterized, overlooked means of alleviating these problems.

- Moreover, because of the loss-of-coolant accidents at Fukushima

> There is renewed motivation to activate this dormant water-monitoring technology.

HERE ARE RECOMMENDATIONS

FOR RETROFITTING THE CIVILIAN WORLD-WIDE FLEET

OF OPERATING LIGHT-WATER REACTORS:

• Coolant should be — and can be —

> directly monitored from outside the pressure vessel,

AND

• the capability for determining post-accident fuel concentration can be — and should be —

> retroactively installed,

AND, FURTHERMORE,

• not only would installation at Fukushima now assist their dismantlement,

> the experience would proof-test the potential for worldwide LWR retrofit.

QUESTIONS/COMMENTS?

- Especially about diagnostic technology for enhancing LWR safety?

(BACKUP SLIDE
ABOUT REACTOR DECAY-HEAT AFTER SHUTDOWN)

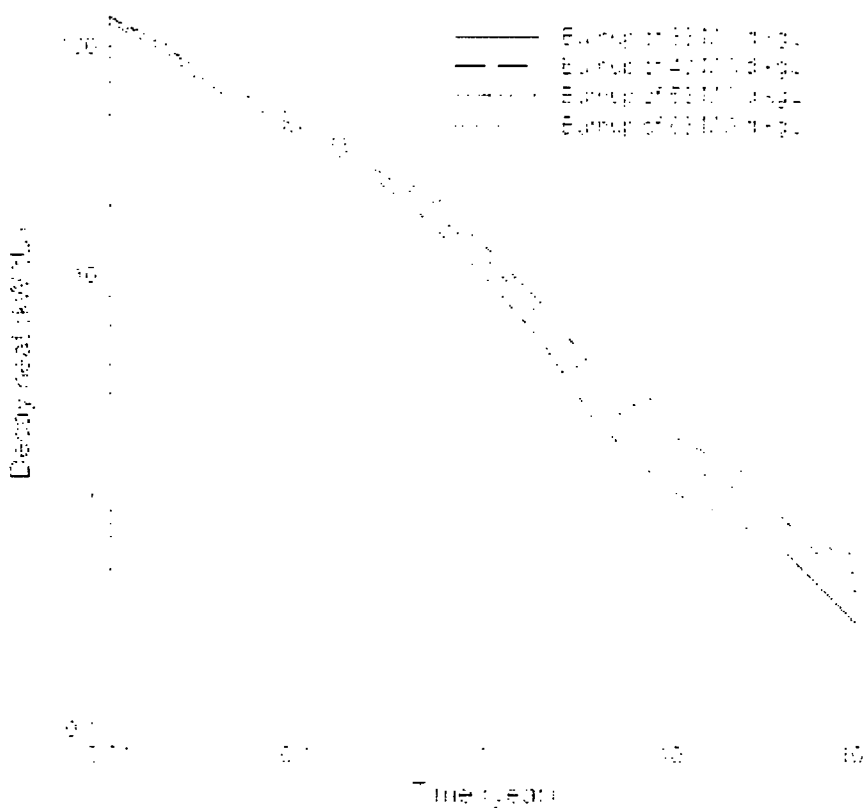


Figure 12. Reactor Decay Heat after Shutdown

WHY HAVE REVIEW PANELS NOT MANDATED WATER-LEVEL MONITORING?

• In terms of public fatalities, nuclear power has proven itself to be the <u>safest</u> large-scale industrial activity ever implemented;

• however, the many and various government, industrial, and academic reviews have chronically failed to recognize a number of additional precautionary improvements:

> Chief among these is the requirement and priority to directly monitor coolant in power reactors,

> but also a requirement to pre-install equipment for monitoring fuel and water after reactor meltdown.

• Although the recent reviews and commissions have responded well to the need for reducing flood risks,

> some — in my opinion — are misguided

> in their attention to monitoring spent-fuel pond water levels,

> rather than the reactors themselves.

TO RECAP:

LESSONS THAT SHOULD HAVE BEEN LEARNED

• Four loss-of-coolant accidents

> No regulatory recommendations for autonomous, external water-level monitoring.

> Many, many millions of dollars spent on technical assessments. Much more on improvements.

• A multiplicity of alphabet agencies, NRC, NEI, USG, UK, AEA — all are missing the boat (again).

> Some assessments advise that fuel-pond water levels need improved monitoring. Really? What did the ponds have to do with the core meltdowns?

• In my opinion, priorities have been misplaced:

> Compared to spent fuel ponds,

> nuclear fuel integrity in the reactor is a much higher risk

> and potential public threat (by orders of magnitude).

END OF PRESENTATION

ATTACHMENT 4

SUMMARY OF PAPER PRESENTED AT ANS 2012 WINTER MEETING,
WITH REFERENCES AND SUPPLEMENTAL BIBLIOGRAPHY

TMI, LOFT, AND FUKUSHIMA LOSS-OF-COOLANT: LESSONS NOT LEARNED

Summary of paper presented at American Nuclear Society meeting, San Diego, December 2012

Alexander DeVolpi and Itacil C. Gomes

Overlooked and/or under-prioritized in post-accident analyses of the TMI-2 meltdown is instrumentation that could have directly monitored water level before, during, and after its accident progression. Such instrumentation could still be implemented at Fukushima and could yet be mandated for water-cooled nuclear-power reactors. A substantial published record exists for the technical development and supportive computations that led to a U.S. patent awarded in 1987 for an LWR ex-vessel water-monitoring system. Subsequent computations reinforce the potential for autonomous monitoring of reactor water and fuel based on correlated high-energy gamma rays that escape from the pressure vessel.

I. PREVIOUS INSTRUMENTATION DEVELOPMENT

As a result of the TMI-2 accident, special external nuclear instrumentation was devised, evaluated, and patented (Figure 1) in 1987 for determining coolant and fuel distribution in nuclear reactors.[1]

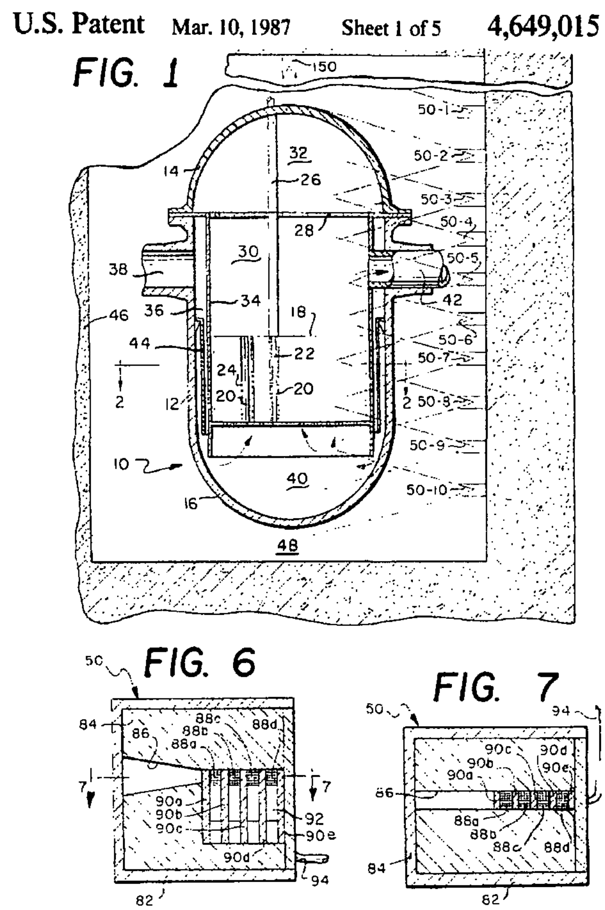


Figure 1. Diagram that was filed with 1987 patent for monitoring water-level in a pressurized-water reactor. Fig. 1 in the patent illustrates axial locations of detectors designated 50–n, while Figs. 6 and 7 in the patent refer to redundant gamma-ray detectors in shielded, collimated enclosures.

The monitoring method depends on correlated leakage of gamma rays from the reactor. Highly penetrating gammas that originate from nuclear interactions are detectable outside the pressure vessel, thus enabling an autonomous means of monitoring water and fuel distribution in a reactor.

II. TECHNICAL FOUNDATION

The water-level monitoring instrumentation concept now proposed for the shutdown Fukushima reactors and for retrofitting commercial water-cooled nuclear reactors has been developed in the United States [2] and independently evaluated in France.[3] Calculations have been performed tracking gamma-emission during the half-scale LOFT loss-of-coolant experiment L2-5 [4]; a strong correlation was found between LOFT coolant void fraction and escaping gamma-ray flux.[5]

Results (shown in Figure 2) demonstrate that the emerging high-energy (above 5 MeV) gamma flux is associated with water-void fraction in the core and downcomer.

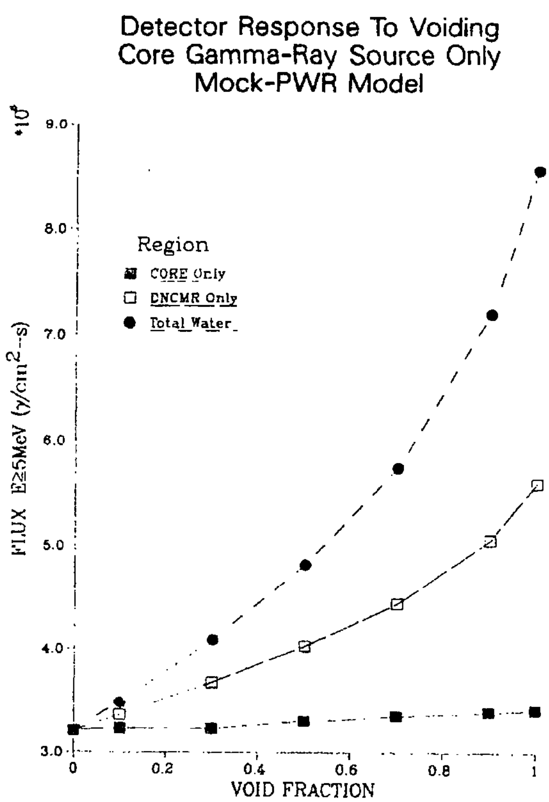


Figure 2. Calculated high-energy gamma-ray flux incident on an ex-vessel detector as a function of core and downcomer water voiding in a PWR.

Calculations graphed in Figure 3 were then repeated for a full-scale PWR. The computer simulation shown at the top track reasonably well the voiding oscillations in the core and downcomer.

In addition, Pennsylvania State University carried out neutron detection experiments [6], and the French CEA [7] later reevaluated the less-informative neutron monitoring of reactor water levels.

III. REQUIREMENTS AND HISTORY

Although many post-accident reports and analyses [8] about TMI and Fukushima have been issued, not much attention or priority has been given to direct ex-vessel monitoring of water level, possibly because it was not realized that the technology had been devised. In fact, the technical foundation is based on decades of relevant TREAT test-reactor diagnostic experience managed by Argonne National Laboratory [9].

TREAT – now temporarily mothballed at the Idaho National Laboratory – was a very productive test platform for in-reactor transient and steady-state experiments and radiography.[10] In the early 1960s, it was realized that much more information could be obtained from expensive destructive nuclear fuel-pin experiments if a means were available for some type of visualization of the fuel and cladding behavior. Under the leadership of Charles Dickerman, [11] several external diagnostic techniques were investigated at Argonne under U.S. Department of Energy auspices.

The original nuclear diagnostics instrumentation at TREAT used photographic means for observing effects of transient fuel-element irradiation; however, the view became clouded by vapor released from its NaK

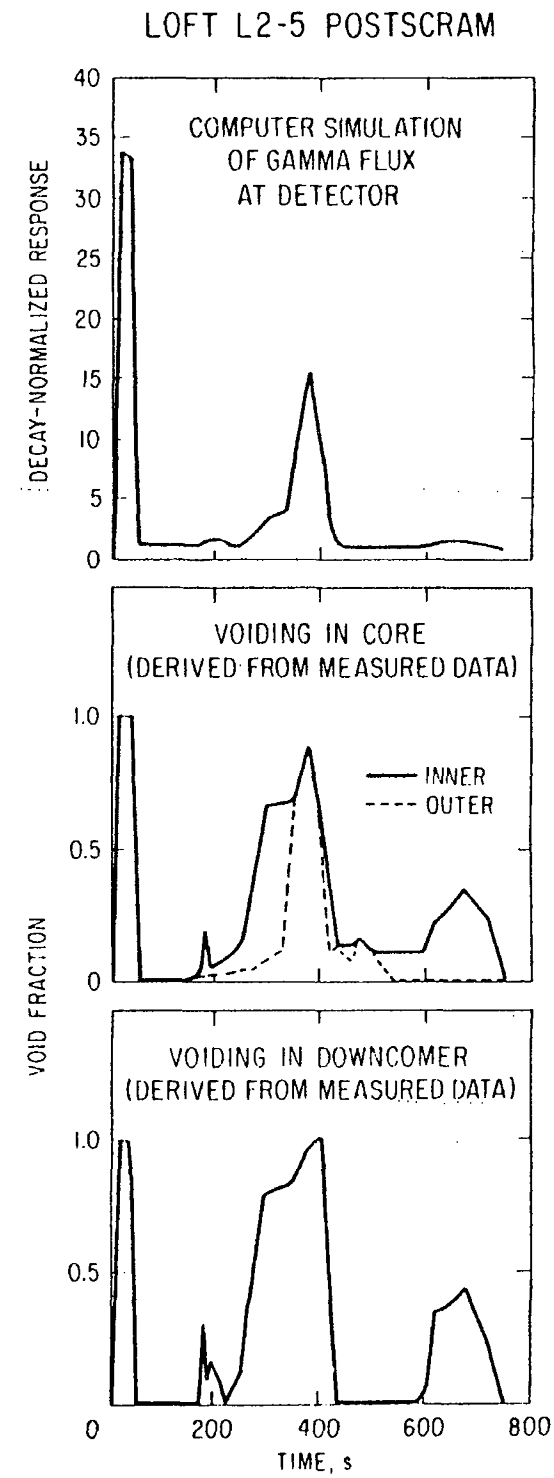


Figure 3. Computed emerging gamma-ray flux (upper curve) during LOFT L2-5 experiment compared with void fraction in core and downcomer (two lower curves).

fuel-pin bond. Sandia National Laboratories then proposed an unsuccessful gamma-ray monitoring method that was tested in cooperation with the U.S. Naval Research Laboratory.

The next investigated technique, a fast-neutron "hodoscope," was successful and became the foundation of nuclear diagnostic instrumentation in TREAT for about three decades.[12] The first hodoscope consisted of a single collimated fast-neutron detector that was horizontally scanned across its viewing angle within the TREAT reactor. This led gradually to three multichannel hodoscope collimator system upgrades to meet increasingly stringent test requirements.[13] In addition, a Euratom collaboration installed a fast-neutron hodoscope at CABRI rector at Cadarache that operated successfully for about ten years.[14]

Because of increased interest in fuel-motion diagnostics, the U.S. Nuclear Regulatory Commission funded possible adaptations of nuclear-weapons program instruments for application at TREAT. However, neither the Sandia coded-aperture nor the Los Alamos pinhole-camera methods were able to achieve the diagnostic resolution and capabilities demonstrated by the hodoscope.[15]

More than 150 experiments were conducted at TREAT using the hodoscope. In addition, many exploratory hodoscope-development measurements were conducted to evaluate sensitivity not only to nuclear fuel displacement, but also to coolant voiding, cladding melt, and delayed-fission-product emission. Particularly relevant to power-reactor loss-of-coolant application were hodoscope gamma-ray experiments and analysis for detection of steel and water.

Resulting from this quarter-century of in-reactor development, experiments, and analysis was a detailed body of technical knowledge that became the foundation for the designated water-monitoring 1987 patent filed on behalf of the U.S. Department of Energy in the aftermath of the TMI-2 loss-of-coolant accident.
A substantial collection of published and unpublished technical analysis, in-reactor diagnostics experience, experiment-based computations, and multi-dimensional analysis now form the underpinnings for applications in operating power reactors.

For perspective, it should be recognized that — while the proposed diagnostic instrument system has a solid foundation in prior research, development, testing, and supportive calculations — it has not been actually assembled and tested in a water-cooled power reactor. An evaluation program is under consideration in the Nuclear Engineering Division of Argonne National Laboratory.

IV. FUKUSHIMA APPLICATION

The main difficulties being faced at Fukushima now, and possibly for many more years, result from a lack of definitive realtime data available on the quantity and location of water and fuel within each reactor containment vessel. Internal instruments originally used to determine these parameters during normal pre-accident conditions are no longer functional. The in-reactor instruments were damaged during the uncontrolled sequence of events. However, for many years after shutdown, radiation from a reactor core decays gradually; and that source should be sufficient for long-term ex-vessel water (and fuel) monitoring, as presented.

The Fukushima loss-of-coolant accidents suggest that independent ex-vessel water-level monitoring instrumentation should have been — and should yet be retrofitted — in operating water-cooled nuclear-power reactors. Moreover, not only could a hodoscope-type system at the Fukushima reactors assist their safe, timely, and orderly dismantlement, but the experience gained in such an application would make a beneficial proof-test of the proposed retrofit to other reactors.

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ATTACHMENT 5

PROFESSIONAL BIOGRAPHIES

Dr. Alexander DeVolpi, a physicist, retired in 1999 after 40 years at Argonne National Laboratory. He was manager of nuclear diagnostics, and later technical manager for their arms-control and nonproliferation program. Areas of research were nuclear fission, radiation, nuclear-reactor safety, arms-control analysis, and verification technology, with special assignments for DOE and DNA.

Professional publications are on nuclear-diagnostic instrumentation, reactor-safety experiments, arms control, and nonproliferation.

Educational and military background includes MS (Nuclear Engineering Physics) and PhD (Physics) from Virginia Polytechnic Institute; U.S. Navy, Naval Research Laboratory, and Naval Radiological Defense Laboratory. Fellow, American Physical Society.

Several patents in nuclear safety and instrumentation granted for inventions related to neutron and gamma-ray ex-vessel hodoscope, an instrument system that yields detailed real-time, high-resolution diagnostic data on in-vessel reactor simulations under a variety of forced test conditions.

Recently presented papers "TMI, Fukushima, and LOFT: Lessons Not Learned,"American Nuclear Society Meeting, San Diego (November 2012) and Argonne National Laboratory (September 2012).

Current affiliation: President/CEO Nuclear Applications Company in California. Patent applications have been filed for nuclear-reactor production of valuable radioisotopes, as well as for radiation detection methods.

Numerous professional publications and review papers on reactor physics, radiation instruments, nuclear safety, plutonium nonproliferation, material diagnostics, spontaneous nuclear fission, nuclear-reactor safety experiments, nuclear arms control, and nonproliferation. Considerable experience with nuclear reactors (subcritical, experimental, testing, and power).

Dr. Mehdi Sarram, post-graduate degrees in nuclear engineering, University of Michigan, 1967. USAEC Senior Reactor Operator License, 1965. His 46 year nuclear experience includes reactor safety and licensing, reactor system design, severe accident and mitigation programs, radiation protection and public health and safety, as well as design certification of Advanced Light Water Reactors, per NRC - 10CFR52.

He began working with NRC at its establishment in 1975. Since 1982, as manager of nuclear engineering, he has undertook assignments for NEI, Raytheon Nuclear, Duke Energy, and AREVA on various nuclear projects. From 1994-1997 he was Chairman of the NEI task force on Appendix J, Option B, Risk-Informed ISI and IST and interfaced with NRC management on these projects.

He has been to 38 countries, mostly with nuclear programs, and has been assigned to the IAEA Department of Safeguards. Since 2008 he has worked as an independent consultant for AREVA, MHI, URS/IAEA, and ABS Consulting on various nuclear projects. His last project was in South Korea on the licensing of APR1400 per NRC 10CFR52, for one year in 2012.