U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

A COMPARISON OF INTEGRATED SAFETY ANALYSIS TO PROBABILISTIC RISK ASSESSMENT

for the

Advisory Committee on Reactor Safeguards

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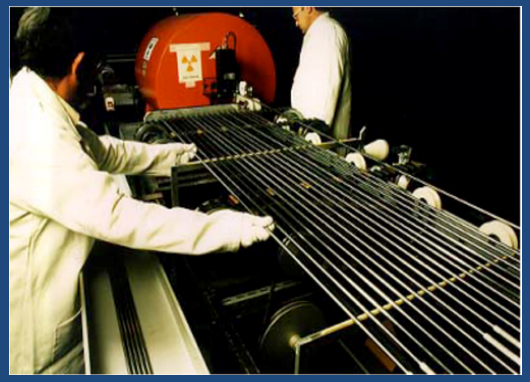
ISA-PRA Key Points

- ISAs are adequate for establishing the safety basis for fuel facilities
- Quantitative analysis to determine risk significance: a case-by-case basis is efficient



ISA – PRA Comparison

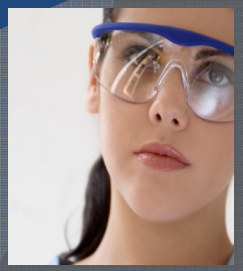
- A comparison and critical evaluation with respect to use…
  - for safety under 10 CFR 70 Subpart H
  - for risk significance determination of inspection findings

Contents of Paper

I. Integrated Safety Analysis
II. Probabilistic Risk Assessment
III. Evaluation for safety under 10 CFR 70
IV. Potential risk significance determination for fuel cycle oversight program
V. Evaluation for use in risk significance determination, with example

Sections I ISAs and II PRAs

- Functions of ISAs under Part 70:
  - Identify hazards, accidents, and items relied on for safety
  - Evaluate compliance with (likelihood / consequence) performance requirements
  - Aid programs to assure safety
- Functions of PRA:
  - Quantify risk metrics as needed to inform regulatory decisions



III. Evaluation for Safety under 10 CFR 70

- ISA consequence-likelihood evaluations differ from PRA: conservative evaluation establishes adequate safety
- ISA concept was based on extensive chemical industry / OSHA Process Hazard Analysis (PHA) experience
- ISAs involved substantial efforts by licensees using PHA methods, including PRA-type fault trees

III. Evaluation for Safety under 10 CFR 70

- NRC staff reviewed ISA summaries. Selected processes reviewed in detail on site.
- Development, review, and revision process for ISAs was substantial
- NRC lessons learned are in NUREG-1520 rev. 1 (SRP)
- NRC staff conclusion: that approved ISAs provide an acceptable safety basis under 10 CFR 70

V. Evaluation for Risk Significance Determination

- This section has an example quantitative risk significance determination, analogous to reactor oversight SDP
- Quantitative risk significance determination requires reasonable quantitative delta risk estimation
- ISAs were not done for this purpose, hence sometimes results need to be supplemented

V. Evaluation for Risk Significance Determination

- Example is typical: few accident sequences, out of hundreds in a plant, are affected by one inspection finding.
- Based on staff screening of actual inspections, very few findings per plant per year require risk evaluation. High risk significance cases rare.
- Key point #2: Thus it is efficient to do risk-significance evaluations on a case-by-case basis

ISA-PRA Key Points

1. ISAs are adequate for establishing the safety basis for fuel facilities
2. Quantitative analysis to determine risk significance on a case-by-case basis is efficient

Questions?

Supplementary Slides

- More detailed discussion of ISA-PRA comparison follows.

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I. Integrated Safety Analysis
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I. What is ISA?

- 10 CFR 70: ISA is a systematic analysis to <u>identify</u>:
  - (1) hazards
  - (2) accident sequences
  - (3) consequence and likelihood of each sequence
  - (4) items relied on for safety (IROFS);and
  - (5) <u>evaluate</u> compliance with performance requirements of sec. 70.61.

I. ISA defined in Part 70

- ISA results are used by other requirements in Part 70
- 10 CFR 70.62(d): "..management measures shall ensure that…IROFS…are available and reliable to perform their function when needed to comply with the performance requirements of §70.61 of this part."

I. What is ISA?

- ISA was based on chemical industry PHA.
- Differences from chemical PHA:
  - Integrated analysis of radiation, nuclear criticality, and chemical hazards
  - Evaluation of compliance with consequence – likelihood "performance requirements" of 70.61

I. ISA Performance Requirements

- High consequence accident sequence must be "highly unlikely"

  - Worker high consequences =
    (1) 100 rem or more (criticality or rad)
    (2) Chemical – 'endanger the life'

  - Public (outside "controlled area") high consequences =
    (1) 25 rem or more
    (2) ≥30 mg soluble U intake
    (3) Irreversible chemical injury

I. Performance Requirements

- Intermediate consequence accident sequence must be “unlikely”

  Worker intermediate consequences:

  (1) 25 rem to 100 rem

  (2) Irreversible chemical injury

  Public intermediate consequences:

  (1) 5 rem to 25 rem

  (2) Chemical transient illnesse

I. Performance Requirements

- Environment (outside “restricted area”)

  Conc. > 5000 times 10 CFR Part 20, Appendix B, Table 2 values
- Evaluation is of single accident sequences, not the sum to an individual as in PRA
- The structure of the evaluation of performance requirements is dictated by the regulation

I. ISA Guidance

- NUREG-1513, “Integrated Safety Analysis Guidance Document,” May 2001
  - Accident identification methods based on extensive experience with chemical industry / OSHA Process Hazards Analysis
- NUREG-1520, “Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility, Rev. 1”, May 2010

III. Evaluation for Safety under 10 CFR 70

- ISAs identify (hazards, accidents, IROFS)
  - This function is, in principle, the same as PRA
  - But fault/event trees only for complex events
  - Problems are mostly in execution, not methods. (e.g. unanticipated scenarios)
- ISAs evaluate likelihoods and consequences; but not fully quantitative
  - quantitative better in some cases, but generally ISAs are conservative, which is acceptable and efficient.

III. Evaluation of Technical Features

- End states:
  - ISA – high or intermediate consequence sequence,
  - PRA – sum of frequencies
- Completeness: in principle no difference.
- Accident quantification:
  - Most ISAs have some sequence frequency information
  - PRA – quantified sequences
- Human error – Simple error lists, sometimes very conservative.
- Hardware failures – ISA at level of IROFS

III. Evaluation of Technical Features

- System interactions – 70.4 Definitions. ISA: "…An ISA can be performed process by process, but all processes shall be integrated, and process interactions considered."
- Dependencies / common cause: Some ISAs evaluate via checklists. Some use dependency factors for likelihoods. Criticality safety: double contingency standard (ANSI/ANS 8.1)
- Uncertainties: ISAs usually handle with conservative assumptions
- Importance metrics: Not used in the safety program under Subpart H

III. Evaluation for Safety under 10 CFR 70

- ISAs have been developed, updated, reviewed, revised, and improved over an extended time frame
- Methods borrowed from chemical industry
- NRC reviews of ISAs were substantial. A risk-informed selection of process designs were reviewed in detail

III. Evaluation for Safety under 10 CFR 70

- PRA methods have been used in certain areas; and could be applied in others as recommended in NRC guidance.
- Difficulties in doing ISAs: anticipating all credible accidents, large number of processes, errors of commission
- Bottom line evaluation: NRC Staff has approved ISA programs as acceptable for safety

V. Evaluation for Risk Significance

- ISAs were not done to provide a good estimate of risk.
- Most ISAs do have some quantitative risk information, but…
- ISA quantitative results sometimes very conservative
- ISA quantitative evaluations not consistent between different licensees

V. Evaluation for Risk Significance

- Common large conservatisms:
  - Not crediting a safety control (non-IROFS)
  - Worst case dispersion for offsite releases
  - No credit for safety margins
- Other risk quantification gaps:
  - No NRC validated hardware failure data
  - Quantifying human errors of commission
  - Probabilistic chemical consequences
  - Criticality magnitudes

V. Evaluation for Risk Significance

- Factors that aid in quantifying risk significance of fuel cycle inspection findings:
  - Very few significant findings per plant per year
  - Simple designs: few accident sequences are affected by one inspection finding
- Risk significance metric: delta frequency of high consequence event caused by deficiency x duration of deficiency
- Fuel cycle needs multiple metrics: worker/public, high/intermediate, other

V. Example Risk Significance Calculation

- Example Risk Significance Evaluation
  - Typical simplicity: few affected sequences
  - Only need delta risk for these sequences
  - but has none of the quantification difficulties (failure data is provided for all quantities).
- Key point: Quantitative risk significance can often be done for fuel cycle inspection findings on a case-by-case basis. A priori re-evaluation of all sequences by licensees would not be efficient.

V. Example Risk Significance Determination

- Process: geometrically safe tank, containment dike
- Potential accident scenarios:
  - fissile solution leaks or overflows into dike, dike leaks, solution accumulates into critical geometry, criticality accident
  - Two scenarios: 1) leak initiator 2) overflow
- Normal accident frequency = initiator frequencies x dike failure probability

V. Example Risk Significance Determination

- Deficiency: dike found to have been in leaking condition for 4 years
- Frequency of accident during these 4 years had increased to frequency of initiators
- Significance metric = delta frequency x duration of deficiency

ISA – Chemical Industry PHA

- 29 CFR 1910.911 Process safety management of highly hazardous chemicals
- 1910.911(e) Process Hazards Analysis (PHA): what-if, what if-checklist, HAZOP, FMEA, fault trees
- OSHA-NRC Memorandum of Understanding