Principles of Nuclear Safety

Module 7

LICENSING PRINCIPLES
&
SAFETY ASSUMPTIONS

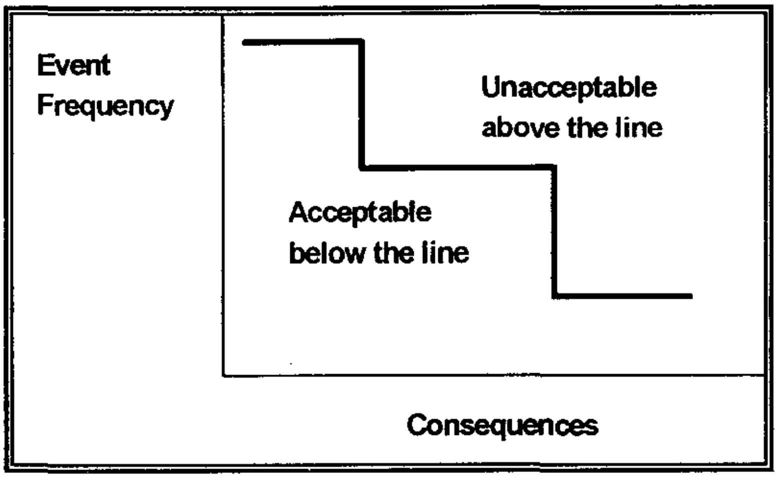
Slide 1

Risk = Frequency X Consequences

- Therefore, for a defined limit of risk, the more serious the consequences, the lower the tolerable frequency of occurrence
- This concept can be shown on a graph of frequency versus consequences

Slide 2

Frequency vs Consequences Diagram



Basic Requirement on License Applicants

- To provide evidence that public dose risks are within licensing limits
  - chronic risks due to normal operation
  - acute risks due to nuclear accidents
- Licensing limits apply to both frequency and consequences
- The Utility completes a *Safety Analysis* and publishes the results in the *Safety Report*

Siting Guide

- An AECB document
- Defines limits of acceptable risk to Public:
  - due to chronic and acute (accidental) releases
  - serious process system failure frequency (<1/3y)
  - Special safety system unavailability ($<10^{-3}$)
  - individual & population dose limits for single & dual failures

Slide 5

Siting Guide Limits on Public Risk

Operating Condition	Maximum Frequency	Individual Dose Limits	Population Dose Limits
Normal operation	Continuous	0.5 rem/y whole body 3 rem/y to thyroid*	10^4 man-rem/y 10^4 thyroid-rem/y
Serious process system failure (single failure)	1 per 3 years		
Serious process system failure coincident with a failure of a special safety system (dual failure)	1 per1,000 years	25 rem whole body; 250 rem to thyroid**	10^6 man-rem 10^6 thyroid-rem

Slide 6

Additional Siting Guide Requirements

- Each Special Safety System tested to demonstrate $Q < 10^{-3}$
- Independence amongst SSSs themselves, and between SSSs and process systems, to prevent failures from escalating
- Failure rate estimates based on real operating experience
- Design & maintain to ASME, ANSI & CSA codes & standards
- Life cycle QA program per CSA standards

Slide 7

Consultative Document C-6

"Requirements for the Safety Analysis of CANDU NPPs"

- An evolution of the Siting Guide
- Used for licensing Darlington
- Defines 5 classes of failures
    - to the Siting Guide's 2 classes--single and dual
    - corresponding to 5 regions of acceptable public risk on the frequency-consequence graph
    - class 2 and 5 events correspond roughly to single and dual failures, respectively

Slide 8

Why is Change Approval Necessary?

- Changes can have unintended impact on Nuclear Safety
  - due to unforeseen effects on other systems,
  - due to impaired capability under abnormal conditions
  - due to unanalyzed configuration
- Management Supervisors can authorize minor deviations to procedures
- Otherwise, minimum level to approve changes is SS
- Manager approves jumpers to Special Safety Systems
- AECB approves changes affecting safety analysis assumptions

Why must Changes be Procedurally Controlled?

- to facilitate good *configuration management*
  - ie, consistency between actual field conditions and those described in the licensing documents
  - ie, between the *real* plant and the *paper* plant
- to preserve the integrity of the safety analysis
  - ie, to ensure changes do not invalidate the safety analysis, nor compromise design intent
- to ensure compliance with legal codes & standards

SS's Concerns when Approving Changes

- Will the change give the desired result with minimal risk?
- Will it affect the 3C's (including abnormal conditions)?
  - complies with OP&Ps? PROL?
- Are operating instructions adequate?
- Do staff need retraining?
- Are tests/verifications specified to ensure that the change will meet performance expectations?
- What notifications are required?
- Have the necessary reviews & approvals been obtained?

CRO Change Control Responsibility

- to log the change, and include it in shift turnover
- to become familiar with any new operating requirements
- to inform SS of any concerns--eg, unexpected operational effects

C-6 Limits of Public Risk

Event Class	Event Frequency (Occurrences per reactor-year)	Individual Dose Limit	
		Whole Body rem	Thyroid rem
1	$> 10^{-2}$	0.05	0.5
2	10^{-3} to 10^{-2}	0.5	5
3	10^{-4} to 10^{-3}	3	30
4	10^{-4} to 10^{-5}	10	100
5	$< 10^{-5}$	25	250

Siting Factors affecting Licensing

- Demographics affects population dose for a given release
  - population density
  - land use (residential, industrial, park land...)
- Meteorological conditions affect public dose due to chronic emissions
  - prevailing wind direction
  - average wind velocity as a function of direction
  - precipitation pattern
- Seismic stability affects risk of common mode incidents
  - DBE qualification of key process & safety systems

The safety Analysis

Includes: -Safety Report
-Safety Design Matrices
-Probability Risk Assessments

Demonstrates to AECB that plant design

- meets serious process failure frequency < 1/3y
- meets individual & population dose limits for single & dual failures

Safe Operating Envelope

- Defined by the safety analysis assumptions
- Embodied in the OP&P
- To operate outside of the SOE is to operate in a state which has not been analyzed to be safe, and violates the Operating License

Examples of Safety Analysis Assumptions

1) HT lower isotopic limit
   - limits fuel channel void coefficient
2) HT I-131 inventory limit
   - limits public thyroid dose in event of LOCA via boiler tube rupture
3) Reactivity banking limit
   - limits effect of diluting moderator poison during in-core LOCA
4) Reactivity mechanism configuration
   - ensures adequate SDS protection

Safety Design Matrices

- Developed in late 1970's to refine Siting Guide approach, accounted for...
  - more event combinations, including human error
  - widely differing event frequencies
  - cross-link failures--eg, safety support systems
  - common mode events
- Event tree for each Design Basis Accident
- Event tree terminated when safe state reached, or when frequency < 10^{-7}

Prababilistic Risk Assessments

- Developed mid 1980's
- Still more comprehensive accounting for...
  - initiating event combinations
  - human reliability
  - validation of assumptions
- Quantify both public and economic risk
  - Estimated Darlington annual public dose risk (rem/y) due to accidents was less than that due to normal emission targets, and annual economic risk (costs of repairs and replacement power) were a small fraction of annual operating costs

SS Responsibilities re Safety Analysis

- know the limitations on the validity of the safety analysis
- continually confirm that plant is operating within those limitations

The Power Reactor Operating License (PROL)

- Issued by the AECB
- Contract between the Utility and AECB as to how the station will be operated
- Specifies about 20 generic conditions under which the license is granted

Generic Conditions of PROL

- Comply with the OP&P
- Secure access to fissionable material
- AECB to authorize Key positions
- Maintain minimum complement
- Maintain & drill emergency procedures
- Limit bundle, channel & reactor power

Generic Conditions of PROL II

- SDS trip set points fixed at approved values
- Radioactive emissions monitored & controlled
- Obey all relevant Provincial laws
- AECB to approve all uses of exclusion zone
- Maintenance standards to be rigorous
- Actions on Utility completed expeditiously

Generic Conditions of PROL III

- Test to substantiate claimed system reliability
- AECB to approve SSS changes
- AECB to approve changing nature of hazards
- AECB to approve fuel design
- Report plant performance per R-99
- Maintain records--O&M, tests, SERs
- Keep register of all licensing documentation

Licensed Staff Positions

- Operations Manager
- Production (Generating Units) Manager
- Engineering Services Manager
- Senior Health Physicist
- SS/SOS/ANO on shift

Ensures key personnel have appropriate knowledge, experience and commitment to operate safely

Minimum Complement

Provides capability to:

1. Operate plant safely under normal conditions
2. Perform emergency response operations credited in the safety analysis
   - event diagnosis, manual initiation of NPC...
   - execution of AIM procedures
   - execution of radiation emergency procedures (notifications, search & rescue, off-site surveys, public dose projection, ...)