# Predicting Hazardous Material Releases Following a Reactor Accident: Experience from Emergency Planning in the Nuclear Industry

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# Outline

- Introduction
- Role of Safety Analysis
- Predicting a Release Following an Event
- Main Elements of an Emergency Plan
- Learning from Experience
- Conclusions

# Introduction

- Ability to deploy appropriate protective measures depends on the adequacy of advanced planning
- Development of Emergency Plan depends on identifying and characterising the hazards
- Safety analysis provides important information needed for planning
- Events with delayed release require some predictive capability, and are the most difficult to plan for
- A simple approach is needed and is available
- Approach is broadly applicable to other fields

# Why a Simplified Approach?

- There are too many possible events to plan for each one in detail
- Actual events differ from the ones that are postulated and analysed (Life 101)
- Actual events do not reveal the detail needed to determine the timing and magnitude of release
- Actual events require a quick determination of the timing and magnitude of release to deploy appropriate protective measures
- Safety analysis can contribute to developing a simplified approach

# Role of Safety Analysis

- Safety analysis is formal and systematic
- Makes use of both deterministic and probabilistic methods
- Confirms the design is capable of meeting safety criteria
- Comprehensive - covers events with wide range of probabilities and consequences
- Demonstrates defence in depth

# Defence in Depth: Level, Objective, Means

| Level | Objective | Means |
|---|---|---|
| 1 | Prevent failures | Conservative Design |
| 2 | Detect Failures | Protection and surveillance |
| 3 | Control accidents within limits | Safety Systems, emergency procedures |
| 4 | Control accident progression, mitigate consequences | Complementary measures, accident management |
| 5 | Mitigation of harm to public, environment | Off-site emergency response |

# Events with Delayed Release

- Difficult to plan for - need to predict the consequence to ensure appropriate protective actions are taken whilst avoiding panic
- When will a release occur?
- What and how much will be released?
- Where and how far will it disperse?
- When can we declare it safe?

# Predicting the Release (Source Term)

- Postulated event - validated computer codes used to calculate the consequences
- Performed as part of the safety analysis
- But, this is not a practical solution following a real event
  - Takes too long
  - Requires a team of experts to assess results
  - Event is largely undefined, code calculations irrelevant
- There is a better way!
- Put the existing safety analysis into service

# Predicting the Release (Cont'd)

- **From the large set of safety analysis cases, select a few representative cases**
  - Include range of probabilities and consequences
- **Review the plant response to the selected events**
  - Control room indications, alarms, safety system response
  - Process system transients
  - Timing and magnitude of the release
- **Pre-determine the appropriate response for each representative case ("Default Cases")**
  - Detailed planning
  - Define all resources and external agencies and services
  - Include some "rare" events

# Predicting the Release (Cont'd)

- Correlate each "default" to the expected control room indications and system transients
- Formalise the defaults and conditions into procedure, flow-chart, computer program
- If an event occurs, use system status and control room indications to determine the best "default" case, and initiate plan and make appropriate notifications
- If a delayed release is expected, a predictive capability is needed ...

# Predicting the Release (Cont'd)

- From the safety analysis for the selected default case, correlate plant response, system transient conditions and other indications preceding a delayed release
- Develop procedure to measure key parameters following an event
- "Correct" the default source term by the ratio of measured parameter to the calculated parameter
- Apply the best available meteorological data (current data from station, forecast from meteorologists, or from seasonal averages)
- Repeat regularly, keeping agencies informed

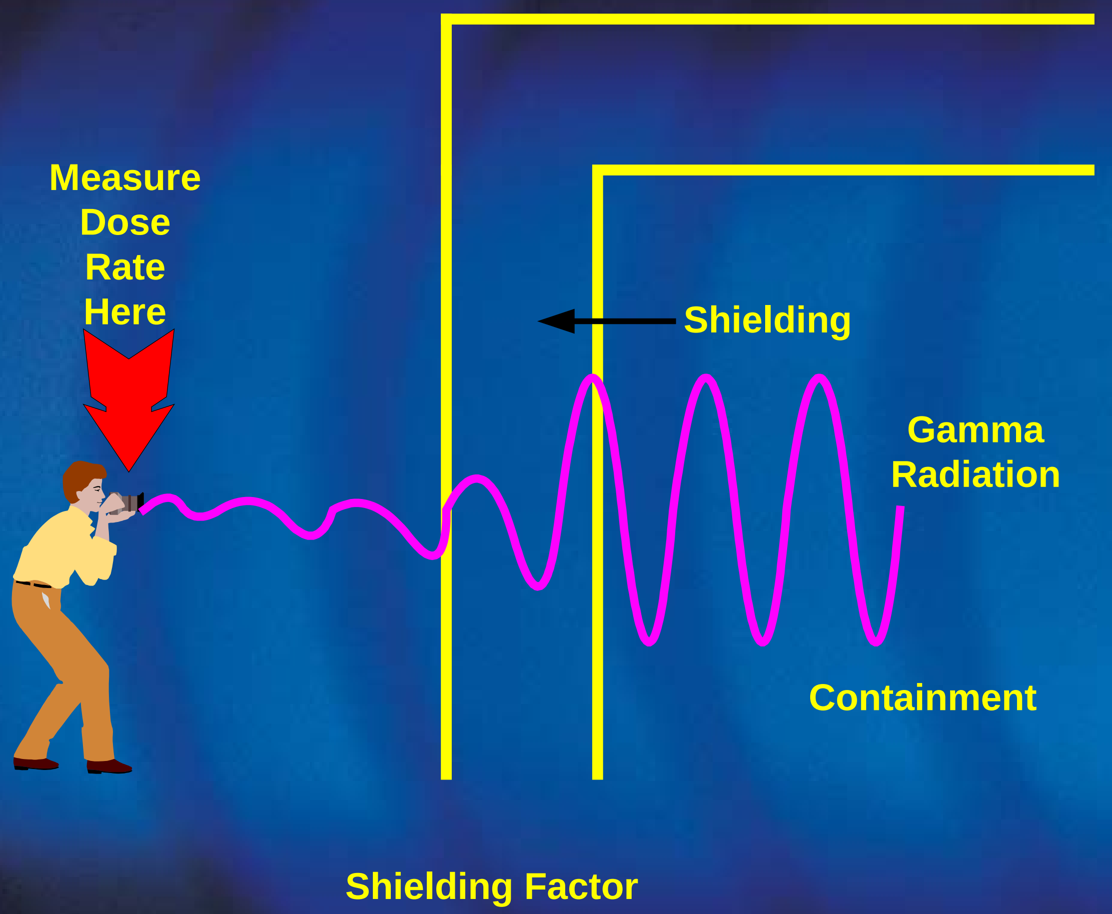
# Example from Nuclear Industry

- **Default scenarios selected from safety report**
- **Plant response analysed in detail**
- **Example - Loss of Cooling Accident (LOCA)**
  - Safety analysis provides detailed plant response
  - Timing of trips, process system transients, safety system response, pressure and temperature inside containment, radiation fields inside and outside containment, timing and characteristics of release
- **System status and control room indications known within minutes to judge that a LOCA has occurred and an off-site release will occur within a few days**
- **Notifications begin, Emergency Plan activated**

# Example from Nuclear Industry (Con't)

- **Source-Term "correction" factors**
  - Safety analysis determines radiation inside containment following an accident with fuel failures
  - Based on calculated radionuclides inside containment, the expected radiation at a point outside containment is calculated
  - The radiation dose rate changes with time due to radionuclide decay - this is the radiation "signature" for the default event
  - Following a real event, the dose rate at predetermined point is measured
  - The measured radiation, and the time it was measured, is used to "correct" the calculated source term
  - A corrected source term is now available
  - Process is repeated

# Source Term "Correction"



# Release Time Correction

- LOCA Example - Blowdown into containment causes temperature and pressure transient followed by a long sub-atmospheric period due to vacuum building response
- Later, as containment pressure rises to near atmospheric, containment is vented through high efficiency emergency filters
- The time to venting depends on the amount of leakage and sources of air ingress
- Safety analysis makes conservative assumptions, but reality would be different
- Method developed to predict the venting time

# Release Time Correction (Cont'd)

- Following the accident, pressure and temperature are measured periodically
- Trend is established by converting P & T into mass and energy, extrapolating using a least-squares fit, and the time of venting is predicted
- The source term is now predicted
- Similar process for dispersion direction and distance - use default weather until a good meteorological forecast is available
- Process will work for high consequence rare events - no need for detailed planning of rare events

# Elements of an Emergency Plan

- Good example in CSA N286.5

- Emergency Classification
- Emergency Response Organisation
- Emergency Plan
- Emergency Facilities, Equipment, Resources
- Personnel Protection
- Public Information Program
- Evaluation of Emergency Program Effectiveness (Learning from experience)

# Learning from Experience

- **Evolved and continually improved since TMI**
  - Manager's Office → Conference Room → Dedicated Facility
- **Roles defined**
  - Recovery, support, communications, security, health, facilitators, co-ordinators, media relations, log keeper
- **Emergency Drills**
  - planned
  - drill objectives (e.g. test assembly time off hours, test shift turnover, identify logistics problems, etc.)
  - realistic script (unknown to participants, known to controllers)
  - puts each role to the test
  - full scale - involves municipalities, police fire and health services, provincial and federal agencies

# Learning from Experience (Cont'd)

- **Some lessons learned:**
  - Non-essential staff are sent home - but cafeteria workers might be essential!
  - Plans must include contingency for agriculture and livestock
  - Have a separate facility for the media
  - Have prepared press releases for all anticipated situations
  - Senior executives need prepared presentations for media and stockholders
  - Must learn what NOT to say (security, economic issues - stick to the technical facts!)
  - Work with municipalities and governments
  - Practice
  - Practice
  - Practice
  - Practice

# Conclusions

- Following an accident, the ability to deploy appropriate protective measures depends on adequacy of advance planning
- Events with delayed release are more difficult and require predictive capability
- Computer codes are not practical during a real emergency
- Simple approach is based on “default” cases selected from the safety analysis
- Simple method of prediction by using plant measurements to “correct” default
- Approach can be adapted to any industry that manages hazardous materials