

Reactor Operations and Safety

Andrew C. Kadak
Professor of the Practice

22.39

How is Nuclear Plant Safety Managed?

- There is a close link between:
 - Core Design
 - Plant Design
 - Safety Analysis
 - NRC Requirements
 - Operating Requirements
 - Organizational Structure
 - Management
 - Safety Culture

Plant Design to Licensing to Operations

- Vendor proposes reactor plant design
- Vendor performs core and plant design analysis demonstrating power and safety
- Vendor summarizes all analyses in a Safety Analysis report which demonstrates compliance to NRC regulatory requirements – 10 CFR Part 50.
- Utility submits Safety Analysis and Environmental Report to NRC for review and acceptance.
- Possible adjudicatory licensing hearings before the Atomic Safety and Licensing Board

Contents of Safety Analysis Report

- General Description
- Site Characteristics
- Design Criteria SSC
- Reactor Design
- Reactor Coolant Sys.
- Engineered Safety Features.
- Instrumentation & Controls
- Electric Power
- Auxiliary Systems
- Steam & Power Conversion System
- Radioactive Waste Management
- Radiation Protection
- Conduct of Operations
- Initial Tests and Operations
- Accident Analyses
- Technical Specifications
- Quality Assurance

Roughly 15 - 3 inch thick Notebooks

Chapter 15 Accident Analyses

- Based on Requirements of 10CFR Part 50 and all appendices – Appendix K – LOCA
- Includes:
 - Normal Operation and Operational Transients
 - Loss of feedwater
 - Infrequent Faults
 - Small pipe breaks
 - Limiting Faults
 - Loss of Coolant Accidents

Design Basis Accidents

- Overcooling – increase in secondary side heat removal – steam line break – Pressurized thermal shock
- Undercooling – decrease in above
- Overfilling – reactor water
- Loss of flow
- Loss of cooling – LOCA (large and small) STGR
- Reactivity – rod ejection, power anomalies
- Anticipated Transients Without Scram (ATWS)
- External events – tornadoes, earthquakes, floods, etc.

- Beyond Design Basis – Class 9 > leading to meltdown

NRC Requirements

- Deterministic and prescriptive as to how to analyze accidents and allowed assumptions.
- NRC reviews and licenses computer codes used in analysis.
- The results of the analyses identify operational limits, limiting conditions for operation, test and surveillance requirements - all of which are contained in the Technical Specifications

Key NRC Appendices to 10 CFR 50

- A – General Design Criteria
- B – Quality Assurance
- G – RV Fracture Toughness Requirements
- H – Reactor Vessel Surveillance Requirements
- I – Allowed release limits from plant
- J – Containment leak rate testing
- K – ECCS rule
- R – Fire Protection

Other Requirements on Licenses

- Generic Letters
- Bulletins and Orders
- Information Notices
- Maintaining Plant Design Basis current
- Confirmatory Action Letters
- Commitments made in response to the above

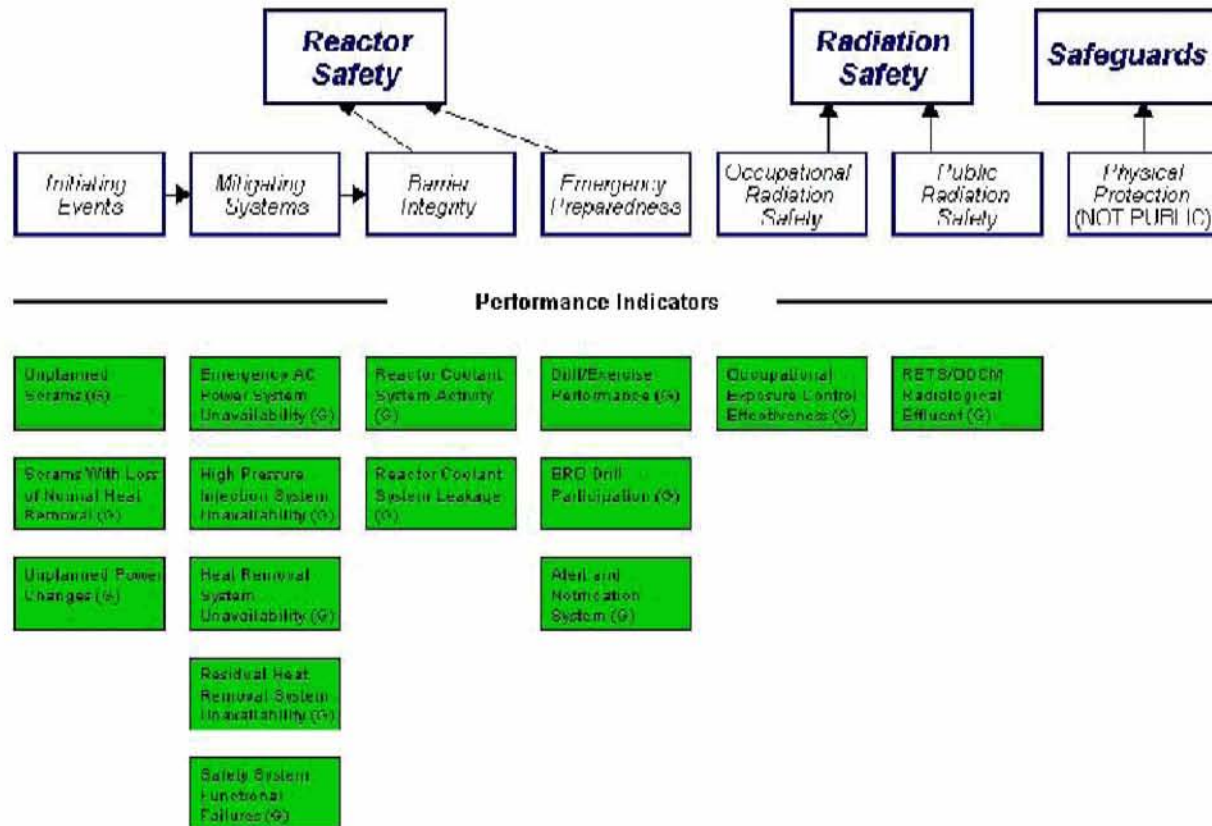
Design Basis – Licensing Basis

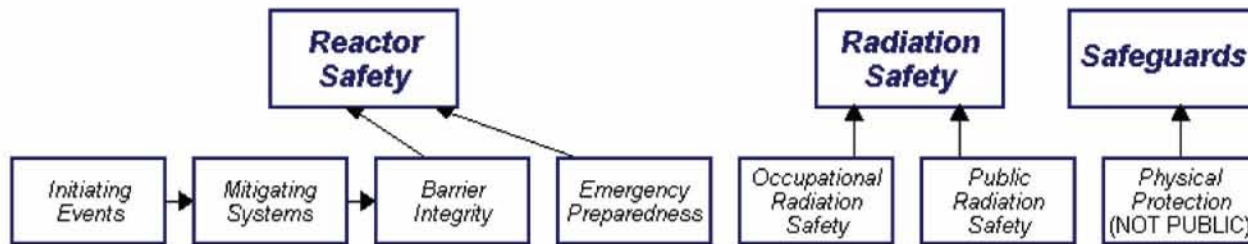
- Design Basis
 - How the plant is actually designed and works.
- Licensing Basis
 - All the collected commitments of the licensee to the NRC including the safety analysis reports, technical specifications, etc.

NRC Oversight

- NRC requires compliance to licensing basis:
 - Two resident inspectors per site (plant)
 - Special inspections on key regulatory issues
 - Licensee event reports (LERs)
 - Enforcement actions based on performance
 - Reactor Oversight Process – “risk informed – performance based”
 - Highly transparent – web based

Reactor Oversight Process





Most Significant Inspection Findings

	Initiating Events	Mitigating Systems	Barrier Integrity	Emergency Preparedness	Occupational Radiation Safety	Public Radiation Safety	Physical Protection (NOT PUBLIC)
3Q/2005	No findings this quarter	G	No findings this quarter	No findings this quarter	No findings this quarter	No findings this quarter	No findings this quarter
2Q/2005	No findings this quarter	No findings this quarter	G	No findings this quarter	No findings this quarter	No findings this quarter	No findings this quarter
1Q/2005	G	G	No findings this quarter	No findings this quarter	No findings this quarter	No findings this quarter	No findings this quarter
4Q/2004	G	G	No findings this quarter	No findings this quarter	No findings this quarter	No findings this quarter	No findings this quarter

Miscellaneous findings

Additional Inspection & Assessment Information

◆ **Assessment Reports/Inspection Plans:**

3Q/2005

2Q/2005

1Q/2005

4Q/2004

◆ **Cross Reference Of Assessment Reports**

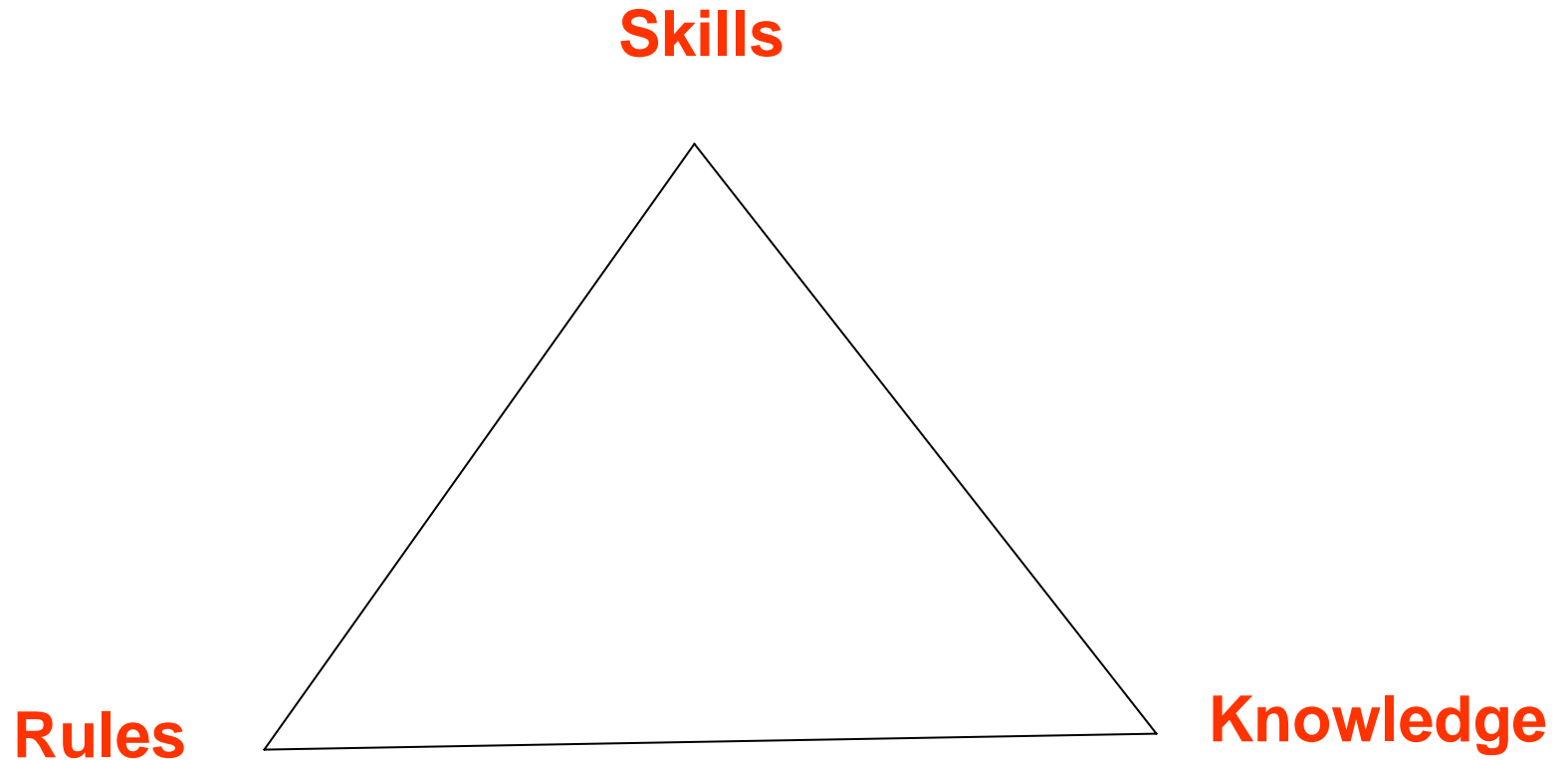
◆ **List of Inspection Reports**

◆ **List of Assessment Letters/Inspection Plans**

Managing Safety

- Technical Specifications are the key operational criteria
- Procedure Based
 - Operating
 - Abnormal Operating Procedures
 - Emergency Operating Procedures
 - Maintenance
 - Engineering
 - Security
 - Radiation Protection (As Low As Reasonably Achievable)

Requires Balance



Objective

- Maintain Compliance to all NRC Regulations
- Operate within safety envelope
- Maintain Critical Safety Functions
 - Reactivity Control
 - Core Heat Removal
 - Secondary Heat Removal
 - Containment Integrity
- Make Electricity !

Safety Envelope

Figure removed for copyright reasons.

Graph from IAEA Publication NS-G-2.2. "Figure A-1. Interrelationship between a safety limit, a safety system setting and an operational limit."

Control Room

Photo of control room removed for copyright reasons.

- Tools include
 - Automatic Trips
 - Safety Parameter Display System of Critical Safety Functions
 - Risk Monitors
 - Key Process and control parameters

Risk Monitor

Reactor Protection System

Table 2.3.1

Reactor Protective System Trip Settings

	Four Reactor Coolant Pumps Operating	Three Reactor Coolant Pumps Operating	Two Reactor Coolant Pumps Operating Same Loop	Two Reactor Coolant Pumps Operating Opposite Loops
1. High Power Level (1)	$\leq 105.5\%$ of Rated Power	$\leq 80\%$ of Rated Power	$\leq 47\%$ of Rated Power	$\leq 51\%$ of Rated Power
2. Low Reactor Coolant Flow (2)	$\leq 95\%$ of Reactor Coolant Flow with 4 Pumps Operating	$\leq 73\%$ of Reactor Coolant Flow with 4 Pumps Operating	$\leq 47\%$ of Reactor Coolant Flow with 4 Pumps Operating	$\leq 50\%$ of Reactor Coolant Flow with 4 Pumps Operating
3. High Pressurizer Pressure	≤ 2400 Psia	≤ 2400 Psia	≤ 2400 Psia	≤ 2400 Psia
4. Thermal Margin/Low Pressure (2)	Trip Point Set at Applicable Limits to Satisfy Figure 2-4	Trip Point Set at Applicable Limits to Satisfy Figure 2-3	Trip Point Set at Applicable Limits to Satisfy Figure 2-1	Trip Point Set at Applicable Limits to Satisfy Figure 2-2
5. Low Steam Generator Water Level	50" Below Normal Water Level	50" Below Normal Water Level	50" Below Normal Water Level	50" Below Normal Water Level
6. Low Steam Generator Pressure (3)	≤ 500 Psia	≤ 500 Psia	≤ 500 Psia	≤ 500 Psia
7. Containment High Pressure	≤ 4 Psig	≤ 4 Psig	≤ 4 Psig	≤ 4 Psig

(1) Below 5% rated power, the trip setting may be manually reduced by a factor of 10.

(2) May be bypassed below $10^{-4}\%$ of rated power provided auto bypass removal circuitry is operable.

(3) Manual inhibit permitted below 600 psig; automatically removed above 650 psig.

Additional trips not credited in safety analysis:

8. High rate of change of 2.6 DPM, functional between $10^{-4}\%$ and 15% power
9. Loss of turbine load, bypassed when $\leq 15\%$ power
10. Manual (2 locations)

15.4-106

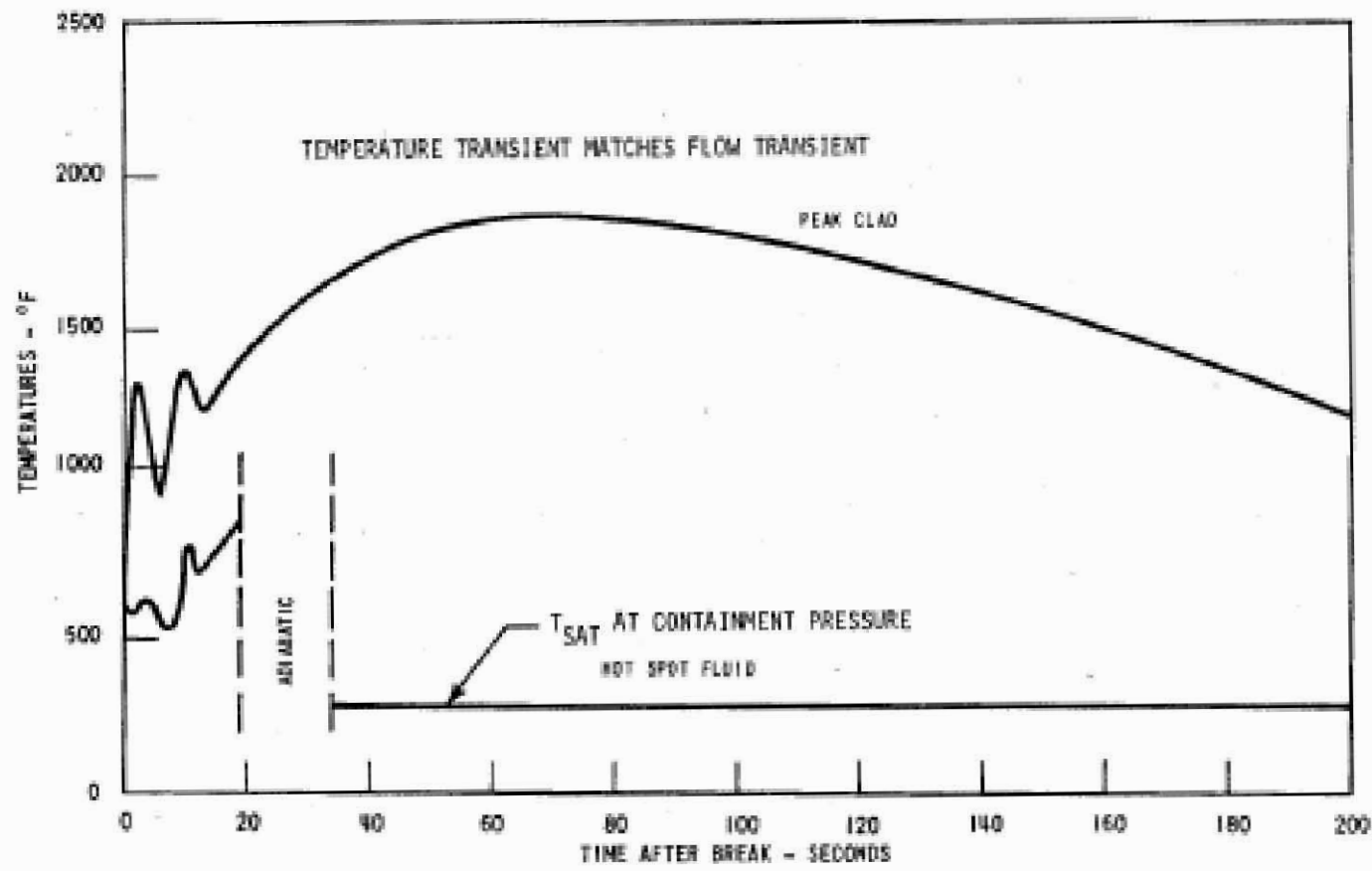
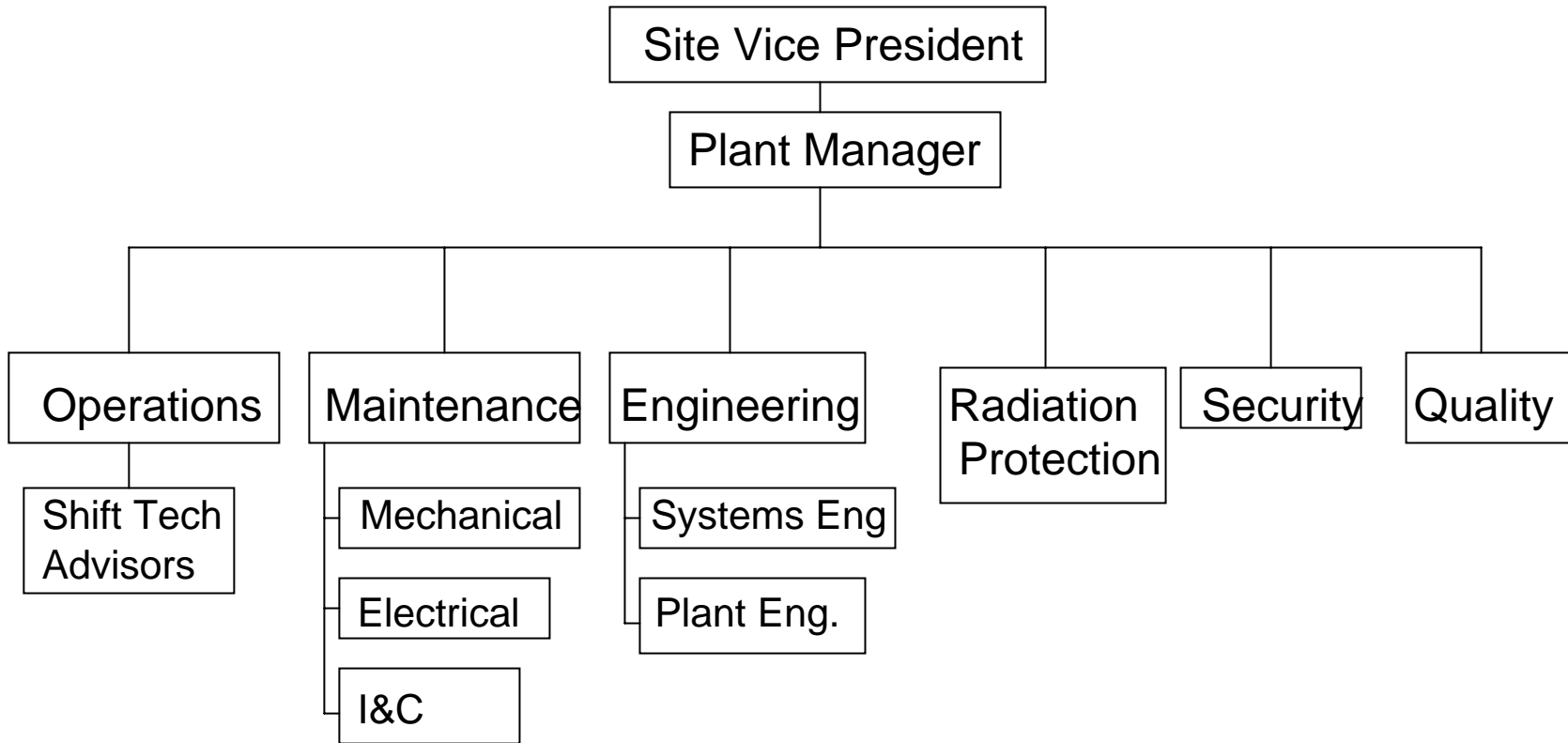


Figure 15.4-16. Double Ended Cold Leg Break (Guillotine)

5274-104

Organizational Structure



Some companies have a centralized engineering and support organization that provides technical support to a number of plants.

A Typical Non-Outage Day

- Morning call – what happened yesterday, overnight – issues – operability status – days since last human error - LCOs
- Risk monitor status – Plant vulnerabilities
- Plan for the day shift – maintenance, tests surveillances
- Electric Generation

Plant Oversight Processes

- Corrective Action Program
 - Corrective Action Review Board
- Quality Assurance Department Plant Operations Review Committee
- Nuclear Safety Advisory Review Com.
- External Review Boards
- Institute of Nuclear Power Operations

Key Success Safety and Performance Factors

- Safety Culture
- Basic Design of Plant – Fault tolerant
- Training – Operations, Engineering, Mgt.
- Quality Assurance – Self Assessment
- Organizational Factors – Sustain Safety
- Regulations – Motivate Safety (Risk Informed Regulations)

Culture

- “The totality of socially transmitted behavior patterns, arts, beliefs, institutions and all other products of human work and thought characteristics of a community or population.”

– Dictionary

Application in a Nuclear Plant - Safety Culture

- Need to create a “community” that has socially transmitted behaviors, beliefs and work ethics that focus on safety.
- Management must create this community by transmitting behavior patterns that support the safety mission with clarity and without confusion. (production vs safety)

Safety Culture

- Vital ingredient of successful nuclear operations
- Essential to protect plant investment
- If you have it, you know it
- If you don't have it, everyone knows it !

Attributes of A Good Safety Culture

- Trust People to:
 - Operate conservatively
 - Make the right technical decisions
 - Perform preventive maintenance
 - Make design and operational improvements not because someone ordered you to do it, but because it was the right thing to do.

Basic Attributes

- 1. A prevailing state of mind...
 - Always looking for ways to improve safety
 - Constantly aware of what can go wrong
 - Strong feeling of *personal accountability*
 - Sense of pride and ownership in the plant

- 2. Disciplined and crisp approach to operations
 - Confident and highly trained staff that is *not* complacent
 - Good team work
 - Crisp communications (clear)

- 3. Insistence on sound technical basis for actions.
 - Procedures, design basis and technical documentation is up-to-date.
 - Plant design basis well understood by all
 - Plant operated within the design basis

- 4. Rigorous Self- Assessment
 - Organization should be open to problem *finding* and facing
 - *Management* should be capable of dealing with bad and good news
 - Problems should be dealt with immediately and not put off

Example: Plant A

- Staff rigorously follows procedures
- Little overtime
- Unplanned shutdowns rare
- Plant shutdown to fix safety problems even though tech specs permit operations
- Professional decorum exist in control room
- Plant clean
- Low maintenance backlog

Example Plant B

- Procedures are viewed as guidelines
- Many management and staff vacancies exist
- Frequent scrams
- Equipment allowed to run until it breaks
- High maintenance backlog
- Plant runs routinely under LCO
- Equipment out of service for a long time
- Plant has many high radiation areas.

Recent Examples of Failures of Safety Culture

- Davis Besse
 - Unwillingness to find out what was going on
 - Focus on Production - not safety
 - Management set wrong tone
 - Complacency - thought they were good
 - Oversight groups internal to utility, INPO, NRC failed to question
 - Plant staff didn't push concerns

Davis Besse Pictures

Photos removed for copyright reasons.

April 17, 1998

February 2002

- Millstone Nuclear Power Station
 - Thought they were good
 - Management focus on reducing costs
 - Significant staff reductions without a plan
 - Many slogans but actions not consistent
 - Employee concerns raised but dismissed
 - No trust in management
 - Employees thought it was just a “job”

Nuclear Plants are Businesses

- Policies and directions established by the Board of Directors and implemented by CEO.
- Chief Nuclear Officer is the field person
- Pressures of competition and cost are real
- Budgets need to be maintained - investments
- Plants need to operate well
- If not, they will be shut down
- Public support is needed

How do you get a good safety culture ?

- Developed over time
- Cannot be regulated, mandated or delegated
- Awareness of the importance of each and every job
- Awareness of dependency on other to do the right thing
- Keen understanding that you are personally responsible for the people who work at the plant and the public

Role of Top Management

- Set tone and example
- Know what is going on
- Do not delegate safety
- Attention to detail
- Staff must believe in and respect top management
- Hire people who have good work ethic
- Commitment to safety that goes beyond slogans and posters and meetings.

How to Keep a Safety Culture ?

- Avoid complacency - hard to do..
- Safety culture is fragile - delegate balance of people, problems and pressures
 - *Requires strong internal communications*
- Foster identification and resolution of problems - no shooting messenger !
- Maintenance of trust in the organization and its value system
- *Motivate people to do the right thing*

Maintenance of Safety Culture

- People are an important “safety system”
- Organizational behavior issues are as important as plant components in assuring safety
- Managers and supervisors must be trained in dealing with people and open communications.
- People should understand the importance of their job in the overall success of the plant.

Summary

- Nuclear plants are complex man-machines.
- NRC regulations do not ensure safety – they establish requirements which if met will help.
- The utility determines whether the plant is safe or not.
- The management of the utility is part of the plant's safety system as are all the employees.
- Safety culture as set by senior management will determine the plant's economic and safety success.

Homework Assignment

- Review NRC Bulletin 2002-01 to identify the events that lead to the Davis Besse reactor vessel head degradation.
- Research the studies performed following the discovery of the degradation and provide a summary of the breakdowns by the utility, INPO and the NRC that could have avoided this situation.
- Prepare a short summary highlighting the failures of each organization.
- Provide a rough estimate of the cost to FENOC of this lapse in both lost revenue and cost.