Risk Assessment: Chapter 12
Barriers and barrier management
Status and challenges in the Norwegian offshore industry

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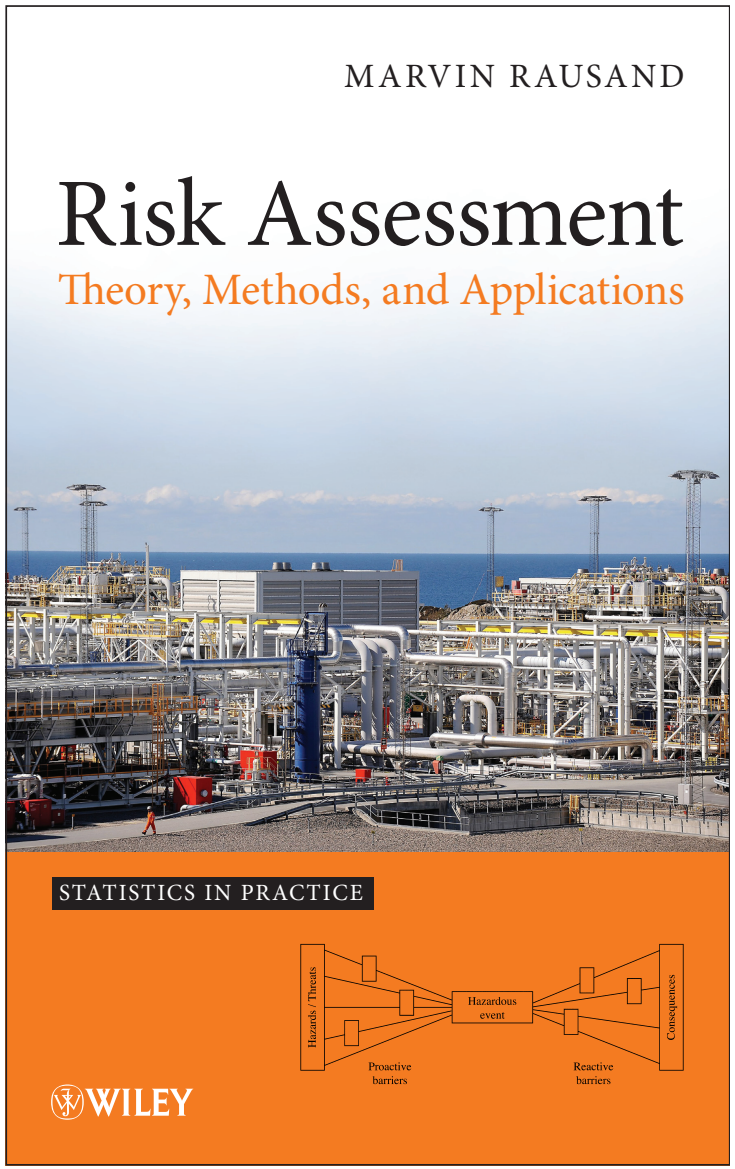
Slides related to the book

Risk Assessment
Theory, Methods, and Applications

Wiley, 2011

Homepage of the book:
http://www.ntnu.edu/ross/books/risk



Why barriers and barrier management?

- A well-known topic in the Norwegian offshore industry
  - 1970's: Requirements for barriers in drilling and well operations
- Essential in major accident prevention
  - Deepwater Horizon: Lack of systematic barrier management
- Main priority of the Norwegian Petroleum Safety Authority (PSA)
  - Barrier management framework

Learning objectives

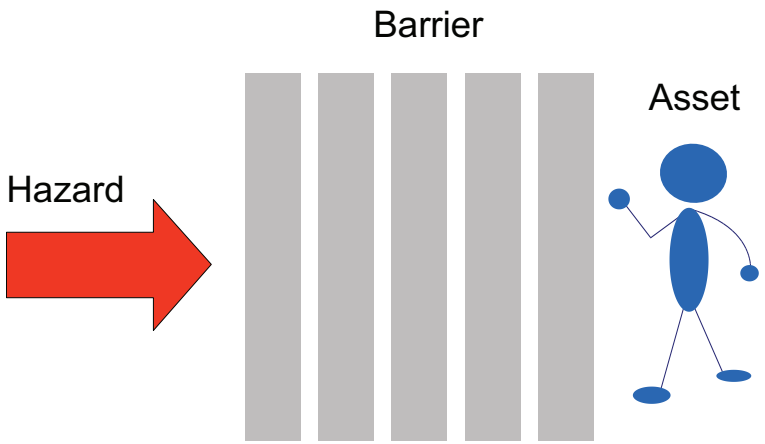
- Understand what is meant by barrier functions, elements, and performance
- Understand the principles of a systematic approach to barrier management
- Gain overview of requirements and challenges to barrier management in the Norwegian offshore industry

Reading material

- "Principles for barrier management in the petroleum industry" (PSA, 2013)
- "Barrier management in operation for the rig industry – Good practices" (DNV GL, 2014)
- Chapter 12 in "Risk assessment: Theories, methods, and applications" (Rausand, 2012)
- Chapter 23 in "Offshore risk assessment, vol. 2" (Vinnem, 2014)
- "Barriers and accident prevention" (Hollnagel, 2014)

Rationale for safety barriers

- The energy-barrier principle (Gibson, 1961)
  - Separate vulnerable assets from a hazard
  - *Hazard: A source of danger that may cause harm to an asset*
- Defense in depth (IAEA, 1999)
  - Failure of a single barrier should not lead to a major accident
  - Multiple, redundant, and independent barriers



Barrier concepts

- Safety barrier
  - Physical and/or non-physical means planned to prevent, control, or mitigate undesired events or accidents (Sklet, 2006)
- Barrier function
  - The task or role of a barrier (PSA, 2013)
  - E.g., pressure relief
- Barrier system
  - A system that has been designed and implemented to perform one or more safety functions (DNV GL, 2014)
  - E.g., Pressure protection system
- Barrier element
  - Technical, operational, or organizational measures which play a part in realizing a barrier function (PSA, 2013
  - E.g., pressure safety valve (PSV)

Barrier elements

- Technical barrier elements
  - Engineered systems, structures, or other design features which realize one or several barrier functions (DNV GL, 2014)
  - E.g., fire extinguisher
- Operational barrier elements
  - A task performed by an operator, or team of operators, which realizes one or several barrier functions (DNV GL, 2014)
  - E.g., operating procedure for the (manual) fire extinguisher
- Organizational barrier elements
  - Personnel responsible for, and directly involved in, realizing one or several barrier functions (DNV GL, 2014)
  - E.g., fire fighter

Categorization

- By function or role in accident sequence
  - Preventive/controlling/mitigating
  - Proactive/reactive
- By nature
  - Physical/non-physical
  - Technical/operational/organizational
- By technology
  1. Safety instrumented systems (SIS)
  2. Safety systems without integrated logic
  3. External risk reduction facilities
- By realization
  - Active/passive

What is (not) a barrier?

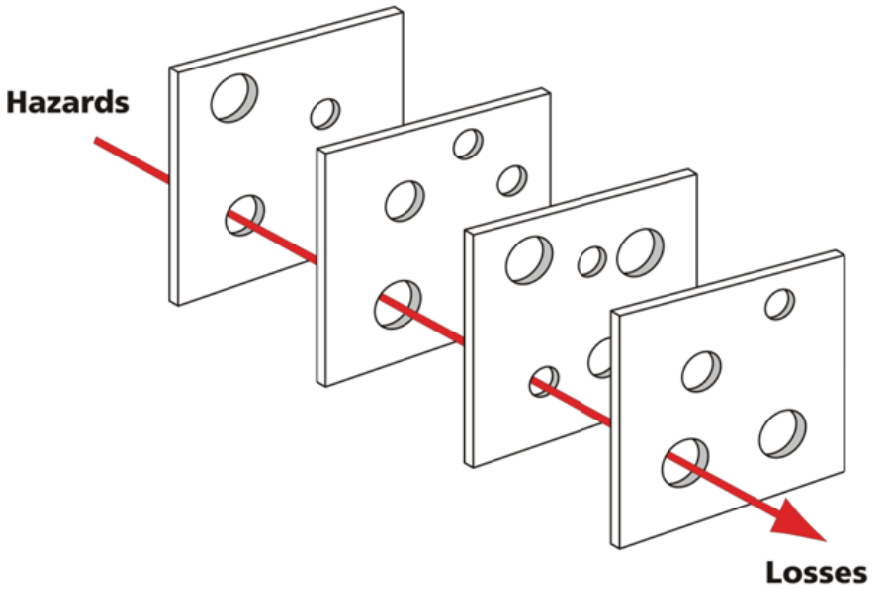
- Confusion
  - Are procedures, verification tests, and training barriers?
  - Element vs. function or system
  - Direct vs. indirect influences
    - Performance shaping factors/risk influencing factors
  - Other safety measures
    - Inherently safe design, process control, precaution

Barrier properties and performance

- Functionality
- Reliability
- Specificity
- Capacity
- Durability
- Response time
- Robustness
- Audit-ability
- Independence

The Swiss cheese model

- "Holes" in the barriers allow hazards to penetrate the system (Reason, 1997)
- Degradation/drift
- Need for barrier management!

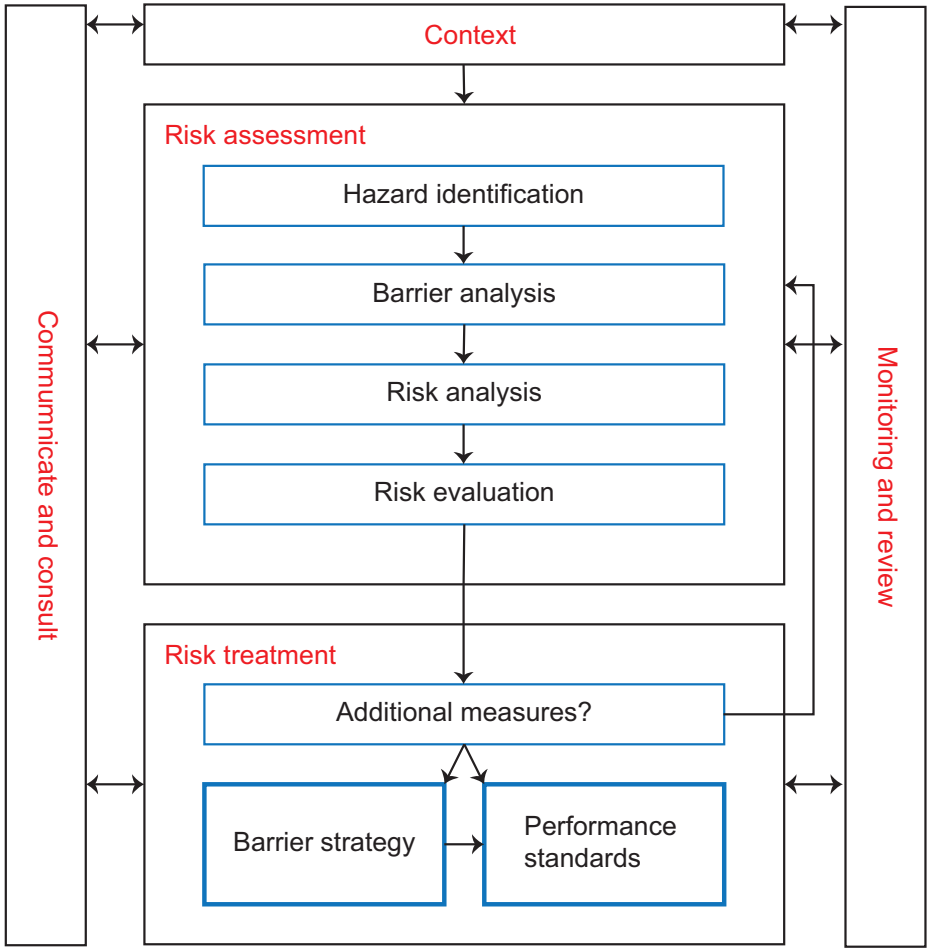


Barrier management

- An integrated part of risk and safety management
  - *Barrier management: Coordinated activities to establish and maintain barriers so that they maintain their function at all times* (PSA, 2013)

The PSA framework

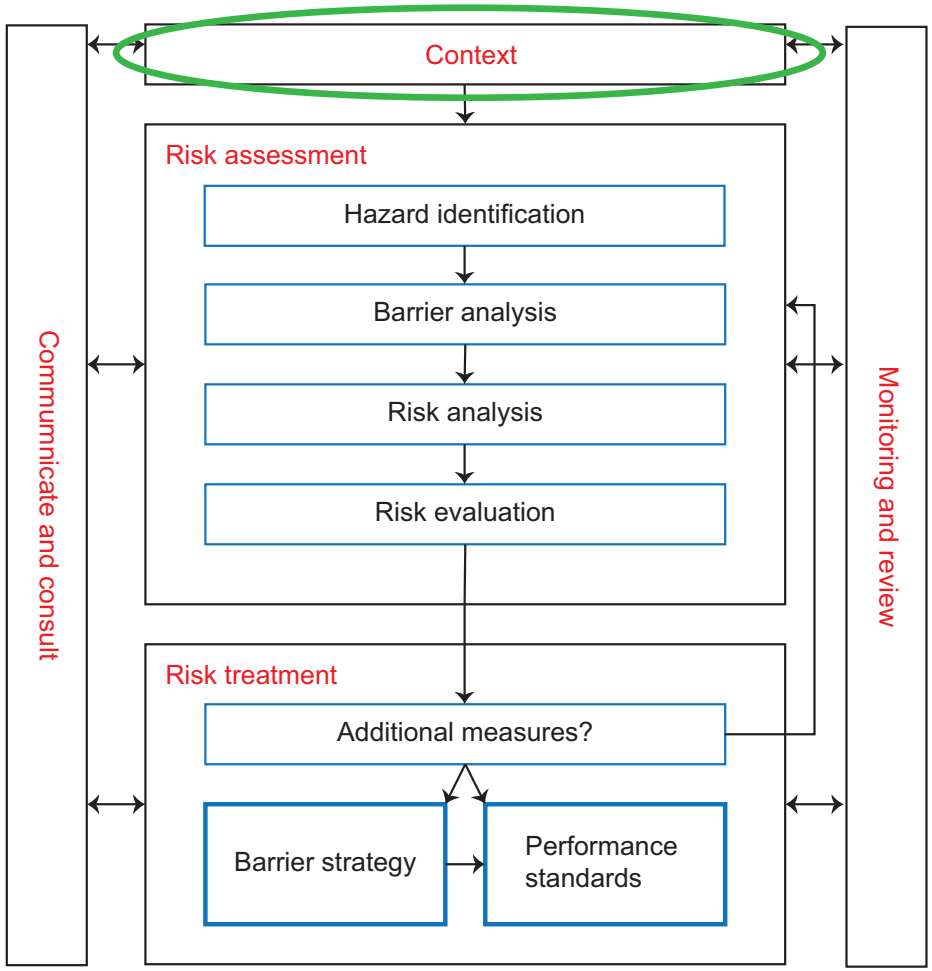
Based on ISO 31 000 "Risk management: Principles and guidelines" (2009)



Determine the context

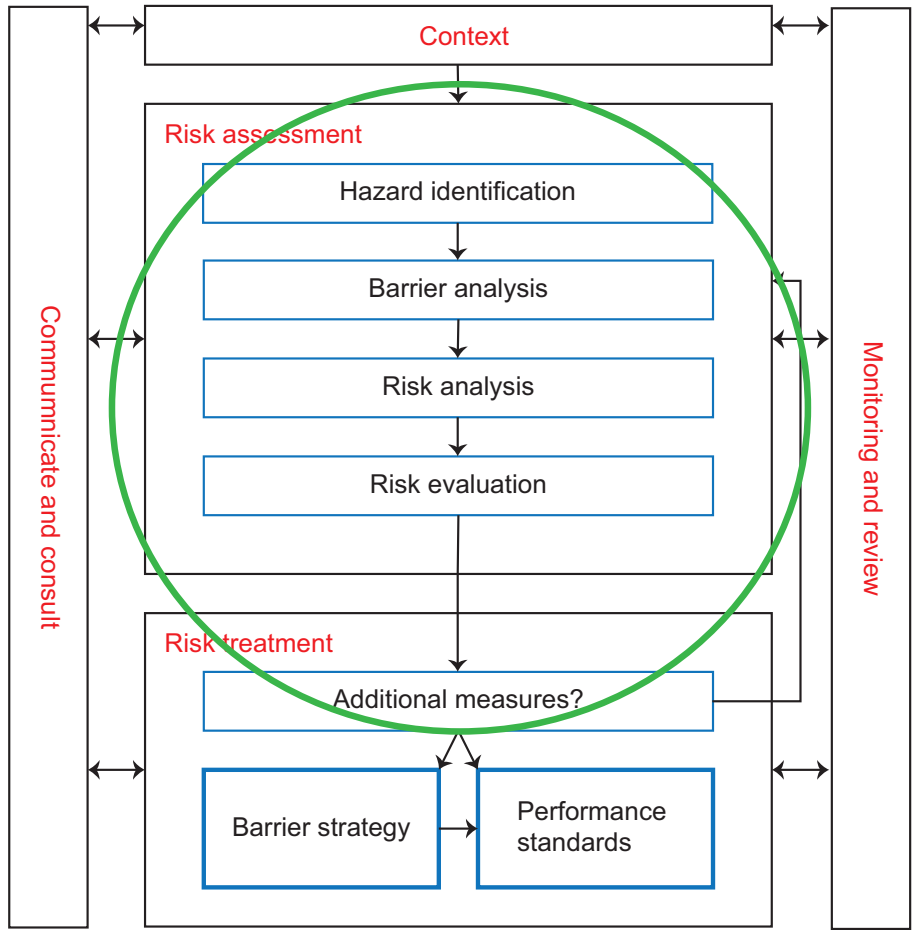
Context: External and internal frame conditions which must be taken into account in barrier management (PSA, 2013):

- Regulations and standards
- Company guidelines and goals
- Actual design and condition
- Stakeholder values
- Drivers and trends



Risk assessment

- Hazard identification
- Barrier analysis
  - Identify barrier functions
  - Identify barrier systems and elements
  - Identify performance requirements
- Risk Analysis
  - Identify barrier functions
- Risk evaluation
  - Evaluate need for additional measures
- Integration and iteration!



Methods for barrier analysis

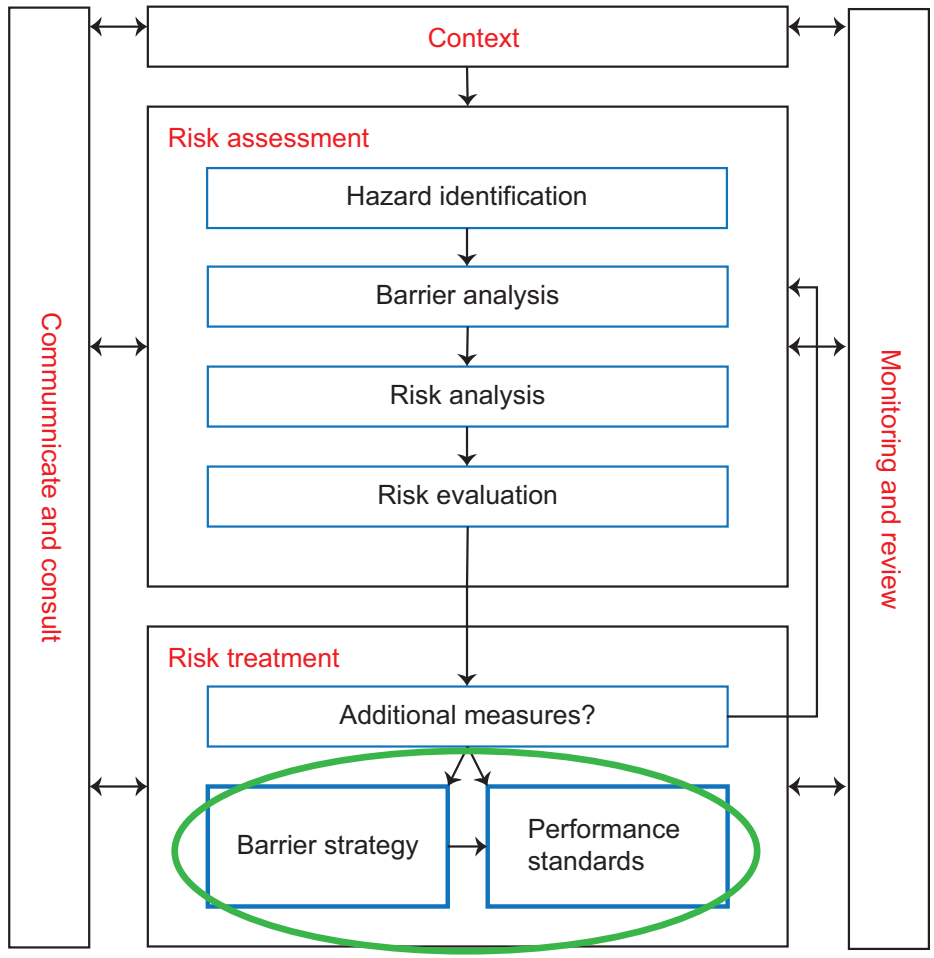
- Hazard-barrier matrix
- Barrier block diagram
  - Event tree and fault tree
- Bowtie-variants (not recommended!)
- BORA and Risk OMT
  - Risk influencing factors

Performance requirements

- For each barrier element
  - Qualitative and quantitative
- Basis
  - Semi-qualitative assessment, e.g. Layer of protection analysis (LOPA)
  - Risk analysis and risk acceptance criteria
  - Design and dimensioning loads
  - Generic performance standards
  - Task analysis
- For SIS (IEC 61508/61511):
  - Safety integrity level (SIL), e.g., SIL 3: $10^{-4} \leq \text{PFD} \leq 10^{-3}$
  - Architectural constraints
  - Treatment of systematic failures
- Iteration!

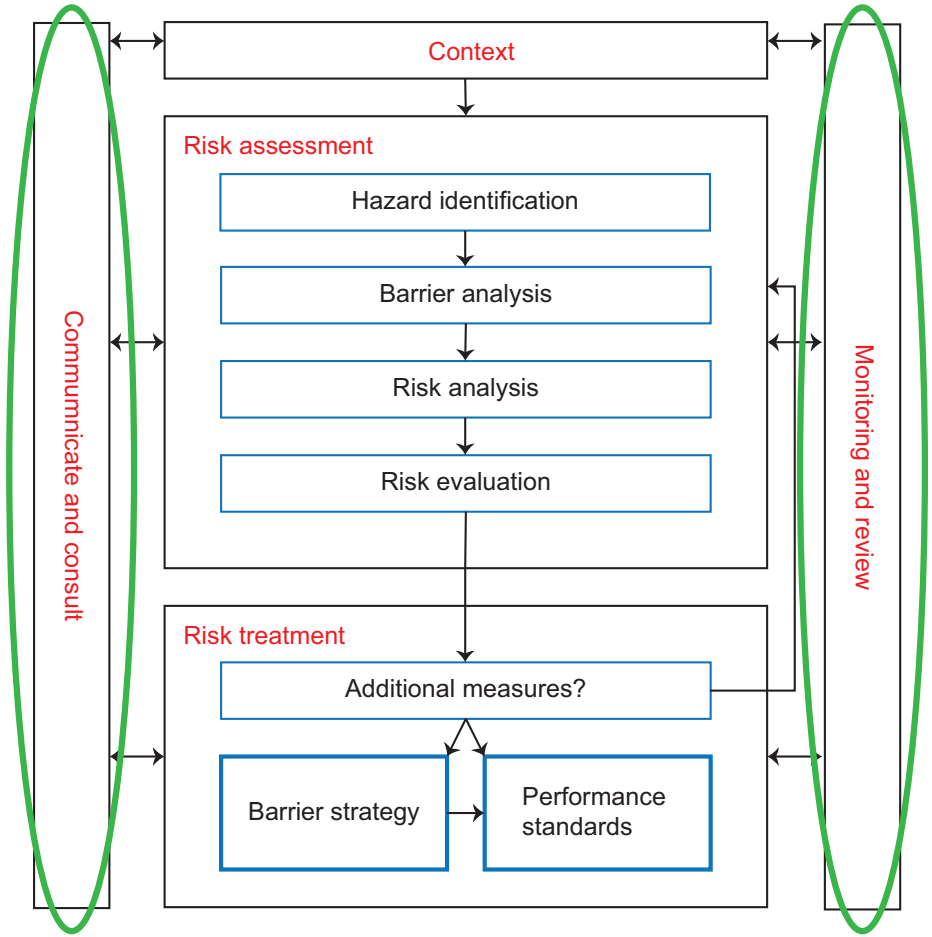
Output

- Specify performance standards
  - Group requirements for barrier elements
  - Clarify interphases with other barrier systems
- Define barrier strategy
  - Rationale for established barriers
  - Appropriate level (area, equipment)
  - Update to reflect actual condition



Integral processes

- Communication and consultation
  - Quality
  - Ownership
  - Shared understanding
- Monitoring and review
  - Operate in accordance with requirements
  - Ensure and maintain barrier performance
  - Control risk influencing factors



Barrier management in operation

- Operate in accordance with requirements
  - Operating procedures
  - Preconditions for start-up
  - Assumptions for use
  - Planning and execution of work and activities
- Assure and maintain barrier performance
  - Testing and inspection of barrier status
  - Preventive maintenance for preventing barrier degradation
  - Corrective maintenance for restoring barrier functionality

Monitoring barrier status

- Status
  - Failure/degradation of barriers
  - Risk influencing factors
- Data collection and integration
  - Maintenance reports
  - Audits
  - Incident investigations
  - indicators
- Assess and visualize
  - Barrier element and indicator status
  - Algoritm for barrier system status
- Commercial tools
  - E.g., Presight, WIMS, Intech

PSA regulations

- Framework (§11)
- Management (§5)
  - Reduce probability and limit harm
  - Independence
  - Strategies for design, use, and maintenance
  - Awareness of function, performance requirements, and status
  - Compensation for impaired barriers
- Facilities (e.g., §7)
- Activities (e.g., §45)

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Standards and guidelines

- Norsok S-001: Technical safety
- Norsok D-001: Drilling facilities
- Norsok D-010: Well integrity in drilling and well operations
- Norsok Z-008: Risk based maintenance and consequence classification
- Norsok Z-013: Risk and emergency preparedness assessment
- IEC 61511: Functional safety. Safety instrumented systems for the process industry
- ISO 13702: Petroleum and natural gas industries- Control and mitigation of fires and explosions on offshore production installations- Requirements and guidelines
- ISO 10418: Petroleum and natural gas industries. Offshore production installations. Basic surface process safety systems
- ISO 16530: Well integrity
- 070: Norwegian oil and gas. Application of IEC 61508 and IEC 61511 in the Norwegian Petroleum industry.
- API standards
- IMO codes and resolutions

Norsok S-001

- Technical safety systems at offshore installations for oil and gas production
  - Generic performance standard
- Functional requirements
  - E.g. coverage, voting, activation
- Survivability requirements
  - E.g., Independence, dimensioning accidental loads
- Utilities
- Interfaces with other safety systems

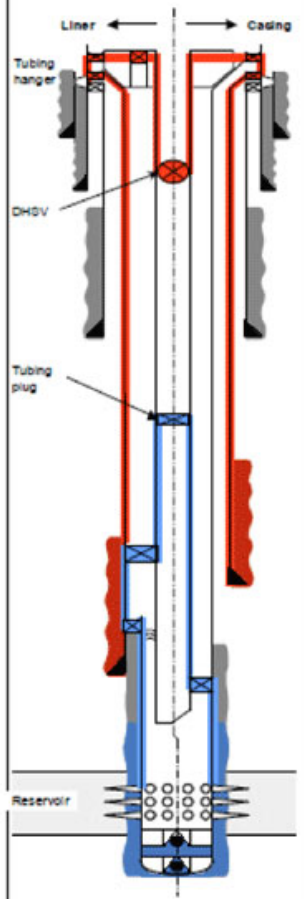
Norsok Z-013

- Risk and emergency preparedness assessment
  - Risk-based approach
  - Concept selection, design, and operation
- Hazardous events
  - E.g., process accidents, blowouts and well releases, external impact and environmental loads, loss of stability
- Barriers
  - E.g., for process accidents: Detection, emergency shutdown and blowdown, control of ignition, control of spills, emergency power system, fire and gas system, active fire protection, passive fire protection, explosion mitigation and protection system, evacuation, escape and rescue, segregation of main areas, structural integrity and stability

Norsok D-010

- Well integrity in drilling and well operations
- At least two independent and tested well barriers
- Element acceptance criteria table (EAC) for well barrier elements (WBEs)
- Well barrier schematics for each activity

9.8.2 Temporary abandonment – Perforated well with BOP or production tree removed

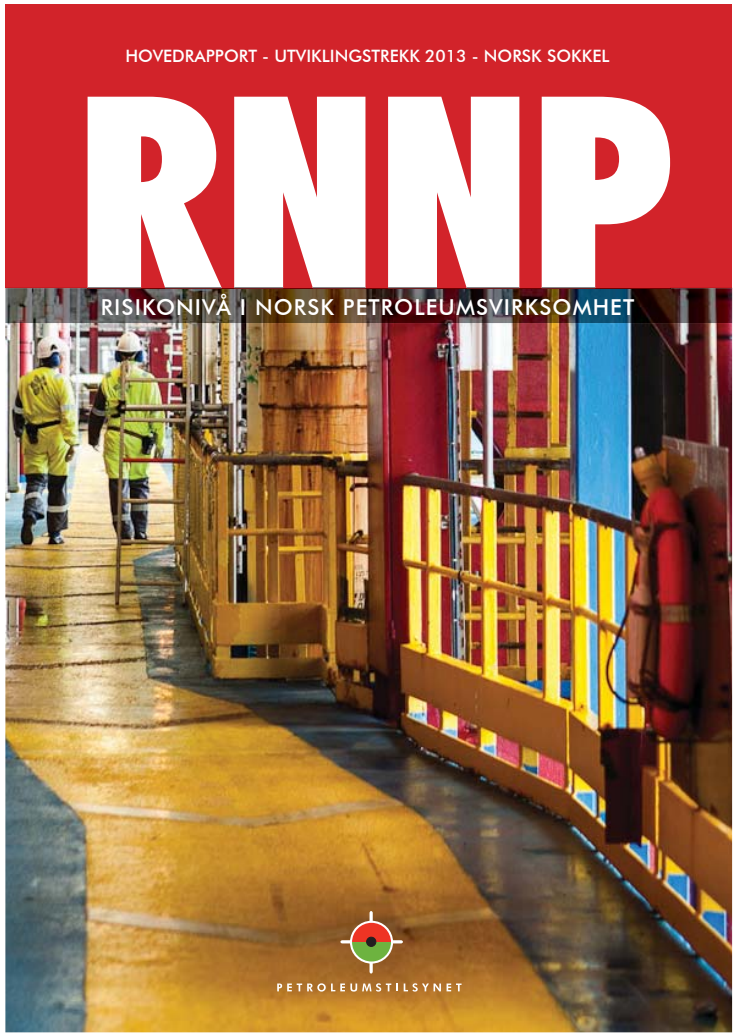


Well barrier elements	See Table	Comments
Primary well barrier		
1. Casing (liner) cement	22	
2. Casing (liner)	2	Liner above perforations.
3. Liner top packer	43	
4. Casing	2	Below production packer.
5. Production packer	7	50 m below TOC in casing annulus.
6. Completion string	25	
7. Deep set tubing plug	6	
or,		
1. Casing cement	22	
2. Casing	2	Above perforations.
3. Production packer	7	
4. Completion string	25	
5. Deep set tubing plug	6	
Secondary well barrier, reservoir		
1. Casing cement	22	Above production packer.
2. Casing	2	Common WBE, between liner top packer and production packer.
3. Wellhead	5	
4. Tubing hanger	10	
5. Tubing hanger plug	11	For SSWs.
6. Completion string	25	Down to SCSSV.
7. SCSSV	8	
or,		
1. Casing cement	22	Intermediate casing.
2. Casing	2	Intermediate casing.
3. Wellhead	5	
4. Tubing hanger	10	
5. Tubing hanger plug	11	For SSWs.
6. Completion string	25	Down to SCSSV.
7. SCSSV	8	

Note
None

Status

- Barrier failure data
  - Many installations below performance standards
  - Substantial variation
  - Lack of continuous improvement
- PSA audits
  - Lack of consistency
  - E.g., barrier strategy, performance requirements, and procedures
  - Industry experience
  - Good intentions, but difficult in practice
  - Challenge in the operational phase
  - Need for “good practices”



Unclarity

- Terminology
  - What is a barrier?
  - Barrier functions, systems, and elements
- Regulations and standards
  - Inconsistencies
  - Difficult to get overview
- Approach
  - The PSA (2013) note is very vague
  - Limited guidance for the operational phase

Operational and organizational elements

- Definition
  - What do they cover?
  - Do we need to distinguish between the two?
  - Performance shaping factors
- Technical focus
  - Standards
  - Performance requirements
- Inclusion in risk analysis
  - QRAs too coarse
  - Data

Integrating barrier and risk analysis

- Outsourcing of risk and barrier analysis
  - Separate activities
  - Limited coordination and consultation
- Modeling barriers in risk analysis
  - Model complexity
  - Operational and organizational barriers
  - Proactive vs. reactive barriers
- Establishing performance requirements
  - Level of resolution
  - Insensitivity to risk metrics
  - Risk-based vs. descriptive approach

Integrating maintenance and barrier management

- Separation from other disciplines
  - Assumptions and requirements
- Testing and verification
  - Imperfect testing
  - Other activities
- Priorities for handling deviations
  - Failure classification/ barrier element criticality
  - Causes vs. symptoms
  - Backlog

Monitoring barrier status

- Barrier status
  - Test frequency
  - Real time data
  - Costs
- Indicators
  - Leading vs. lagging
  - Incidents and minor accidents
  - Risk influencing factors
- Utilizing available information
  - Information is spread

Implementation and use in operation

- Implementing barrier management in operational phase
  - Conflict with existing systems
  - Lack of holistic overview and approach
  - Lack of experience with PSA audits and systems, e.g. drilling companies
- Using barrier and risk analysis in operational decision-making
  - Unmanageability
  - “Living” risk analysis

Awareness

- Communication and experience transfer
  - Interdisciplinary integration
  - Handover of information between phases and activities
  - Learning across installations and companies
- Social and psychological factors
  - Confirmation bias
  - Group think
- Competing objectives
  - Production vs. protection
  - Normalization of deviance

Competing perspectives

- Are barriers and barrier management the way to go?
- Normal accident theory (Perrow, 1984)
  - Barriers increase complexity
  - Adverse side effects
- Systemic view (Hollnagel, 2004)
  - Swiss cheese- an outdated accident model?
  - Dependencies and interactions
  - Control unwanted variability
- Support key point of PSA
  - Importance of a systematic and integrated approach!

Summary

- Barriers are important means for preventing and mitigating major accidents
  - Presupposes that they are systematically managed
  - Clarity and awareness of barrier functions and requirements
- PSA framework for barrier management
  - Systematic and holistic approach
- The industry has good intentions, but many challenges remain
  - Terminology
  - Integration across analyses and disciplines
  - Implementation in operation

Additional reading

- Sklet (2005): *Safety Barriers on Oil and Gas Platforms*, PhD Thesis NTNU.
- Rausand (2014): *Reliability of Safety-Critical Systems* , Wiley.
- Dekker (2011): *Drift Into Failure. From Hunting Broken Components to Understanding Complex Systems*, Ashgate
- Leveson (2012): *Engineering a Safer World: Systems Thinking Applied to Safety*, MIT Press
- Hopkins (2012): *Disastrous Decisions. The Human and Organizational Causes of the Gulf of Mexico Blowout*, CCH Australia limited.
- Størseth et al. (2014): Safety barriers: Organizational potential and forces of phycology, *Journal of Loss Prevention in the Process Industries*, 31, 50-55.