ISSUES IN DEVELOPING AND USING RISK TOLERANCE CRITERIA

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OVERVIEW

- Significance of risk tolerance criteria
- Development and use of risk tolerance criteria
- Issues

SIGNIFICANCE OF RISK TOLERANCE CRITERIA

- Decisions on process safety must be made with reference to risk tolerance criteria
- Increasingly, risk analysis methods and codes, standards, and regulations around the world are moving towards the use of numerical criteria, e.g.
  - Use of Layers of Protection Analysis (LOPA)
  - Standards for safety instrumented systems such as IEC 61511 / ISA 84

DEVELOPMENT AND USE OF RISK TOLERANCE CRITERIA

- Appears to be a straightforward task
  - Deceptive
- Pitfalls await the unwary
- Paper addresses about 20 issues in developing and using criteria
  - Selected issues are covered in this presentation

ISSUE - SOURCES OF RISK

- In process safety, the concern is with major hazards
  - Flammable, explosive, reactive and/or toxic hazards
- Facilities may pose risks to people from such other hazards as:
  - Working at height
  - Confined space entry
  - Asphyxiants
  - Corrosives
  - Hot gases and liquids
  - Cryogenics
  - Electricity
  - Pinch points
  - Vehicle accidents
  - Etc.

SOURCES OF RISK (CONTD.)

- Overall facility criteria are usually intended to address risks from all hazards at a facility
  - Should be offset to account for casualties from any sources excluded from a risk analysis

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EXAMPLE OF RISK OFFSET

- Individual annual fatality risk tolerance criterion for workers in a facility is set at 1×10^{-3}
- Existing annual fatality rate from occupational accidents is 0.9×10^{-3}
- Tolerable risk from process safety accidents is 1×10^{-4}
  - Order of magnitude lower than the overall facility individual fatality criterion
    - Will have a major impact on risk reduction measures needed

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ISSUE - RISK FROM DIFFERENT CASUALTY TYPES

- Exclusive use of fatality risk criteria for people is not completely satisfactory
- Process safety incidents can and do produce injuries as well
  - Often much more numerous than fatalities

IMPACTS OF CATASTROPHIC ACCIDENTS

Accident	Fatalities	Injuries	Ratio
Oppau, explosion, 1921	500 - 600	2,000	3 - 4
Feyzin, fire and explosion, 1966	18	81	5
Flixborough, vapor cloud explosion, 1974	28	36	1.3
Beek, explosion and fire, 1975	14	107	8
Mexico City, fire and explosions, 1984	500 - 600	5000–7000	10 - 12
Bhopal, toxic vapor cloud, 1984	4,000- 20,000	550,000	28 - 138
Norco, explosion, 1988	7	42	6
Pasadena, vapor cloud explosion, 1989	23	314	14
Sterlington, explosion, 1991	8	120	15
Toulouse, explosion, 2001	29	2,500	86
Skikda, explosion, 2004	30	70	2
Texas City, fire and explosion, 2005	15	170	11

Note: Data are from multiple sources on the internet.

RISK FROM DIFFERENT CASUALTY TYPES (CONTD.)

- Incorporate non-fatal health effects for people using the concept of equivalences
  - Allows a more inclusive definition of risk to be employed

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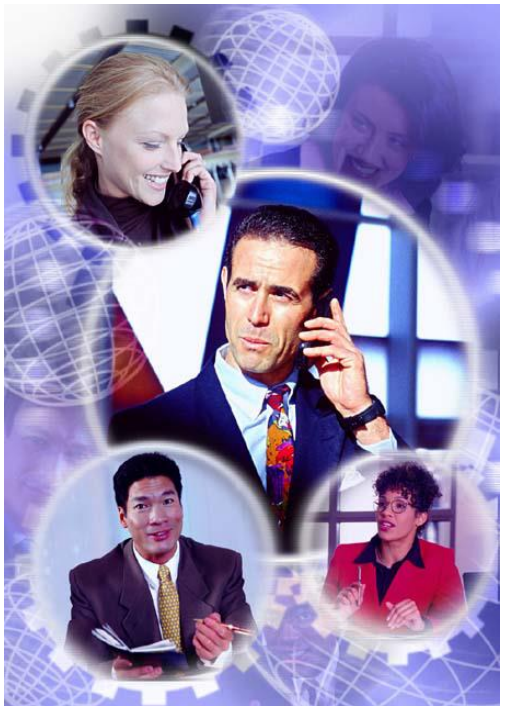
RISK FROM DIFFERENT CASUALTY TYPES (CONTD.)

- If average number of injuries that accompanies a single fatality is about 10
  - 10 injuries are equated with a fatality
    - Actual risk is doubled
- May not be of undue concern
  - Given uncertainties
- However, may be cases where the ratio of injuries to fatalities is much higher
  - Risk could be increased by an order of magnitude or more

ISSUE - PEOPLE AT RISK

- Different communities and countries accept different levels of risk
- Many companies operate in numerous countries and communities
  - Same criteria could be used for all
  - Likely that local adjustments will be desirable or necessary



PEOPLE AT RISK (CONTD.)

- Set criteria with reference to the risk levels from workplace and non-work-related accidents that are tolerated
- In the latter case with a reduction factor of as much as 1 percent
  - Account for the involuntary nature of the risk

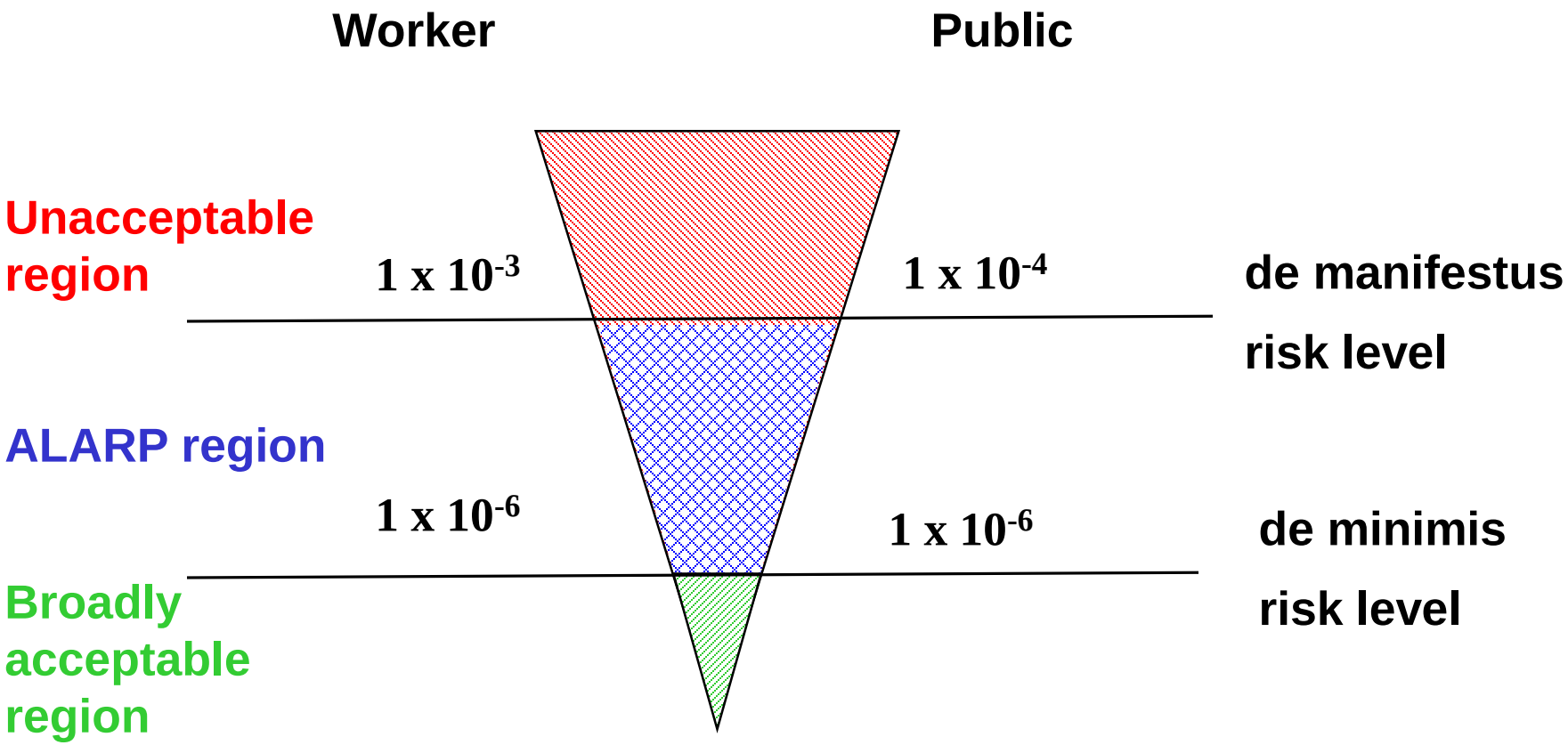
ISSUE - ALLOCATION OF CRITERIA

- Risk analysis evaluates the risk of individual hazard scenarios and hazardous events
  - Contribute to the overall risk of a hazardous facility
- Practitioners often use risk tolerance criteria for hazard scenarios or hazardous events
  - In the belief that it is easier to calculate their risk rather than the overall risk of a facility
- Such criteria have no meaning by themselves

ISSUE - ALLOCATION OF CRITERIA (CONTD.)

- Criteria must be derived by allocating or apportioning overall facility criteria to the scenarios or events
  - Facility criteria are divided by the estimated number of scenarios, events, etc
    - That can cause the casualty of one particular individual
- Estimating the number of events or scenarios is problematic
  - Guesstimates
  - No unique definitions

INDIVIDUAL RISK



Values are per person per facility per year for all hazards.

PITFALLS IN ALLOCATING CRITERIA

- Individual criteria must be allocated not only to single but also multiple fatality scenarios
- Resulting criteria must be applied to all fatality scenarios
  - Regardless of the number of fatalities

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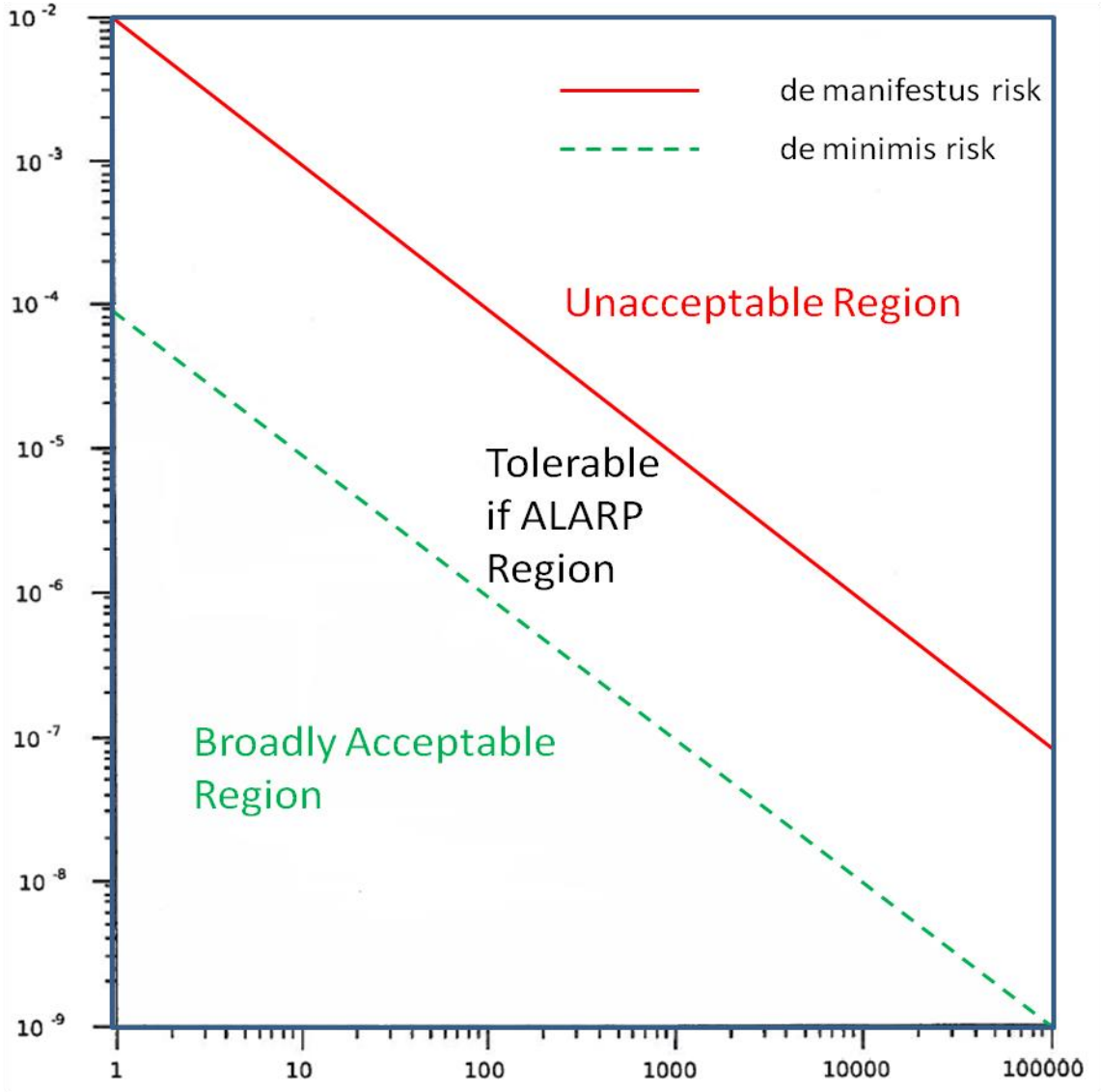
GROUP RISK - F-N LIMIT LINE



PITFALLS IN ALLOCATING CRITERIA (CONTD.)

- Group criteria must be allocated in frequency space
  - Not cumulative frequency space in which group criteria are expressed

ISSUE - ENTITY TO WHICH CRITERIA APPLY

- Facilities may contain multiple processes and units
- Risks can be evaluated for entities such as:
  - Processes
  - Units
  - Process modes and phases

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ENTITY TO WHICH CRITERIA APPLY (CONTD.)

- Facility personnel, and people living near a facility, will be concerned about the total risk to which they are exposed
  - From all hazards within the facility
    - Also, from different processes, units, and modes
  - Not just from one hazard scenario or hazardous event

ENTITY TO WHICH CRITERIA APPLY (CONTD.)

- Companies will be concerned about:
  - Risk to all employees and members of the public
    - From all hazards within the facility
  - Risk to individuals

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ENTITY TO WHICH CRITERIA APPLY (CONTD.)

- Cumulative risk estimates are needed for comparison with overall facility risk tolerance criteria
  - Type of criteria used by regulators
  - Only total facility risk has real meaning
- Must aggregate risk over all hazard types, processes, process units and process modes for the facility

ENTITY TO WHICH CRITERIA APPLY (CONTD.)

- Reliance solely on meeting overall risk tolerance criteria may result in the inequitable distribution of risk across a facility
- May be processes, areas, units, process modes, etc. that bear the brunt of the risk
  - Resulting from the disproportionate allocation of risk across the facility

ENTITY TO WHICH CRITERIA APPLY (CONTD.)

- Overall risk determination should be accompanied by the allocation of the overall risk tolerance across a facility
  - Particularly to receptors as ultimately that is what matters

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ISSUE - MATCHING CALCULATED RISK WITH CRITERIA

- Type and form of risk estimates must be the same as those of the risk criteria used, e.g.
  - Type of individual risk
  - Form of expression of group risk
- Entity to which they apply must be defined
  - E.g. scenario, event, process, facility

PITFALLS IN MATCHING CALCULATED RISK WITH CRITERIA

- Overall facility criteria are incorrectly applied to individual scenarios or events
  - Underestimates risk
- Individual risk criteria are used but group risk is calculated
  - Leads to unnecessary risk reduction measures
- Group risks are calculated in f-N space but are compared with tolerable criteria from F-N space
  - Underestimates risk

ISSUE - UNCERTAINTIES IN RISK ESTIMATES

- Factors influencing the situation are known but their effects cannot be described precisely
  - Modeling
  - Data
- Significant for high-consequence, low-frequency events
  - Particularly important when risk estimates are close to risk tolerance criteria

UNCERTAINTIES IN RISK ESTIMATES (CONTD.)

- Often addressed by making conservative assumptions throughout the analysis
  - Produces unknown conservatism in the results
- Preferred treatment is to conduct uncertainty analysis
- Calculate risk distribution
  - Use high percentiles for comparison with risk tolerance criteria

SIGNIFICANCE OF UNCERTAINTIES

- Consequence severities
  - Calculated: within a factor of 2
  - Estimated qualitatively: within a factor of 5
- Frequencies
  - Calculated: within a factor of 10
  - Estimated qualitatively: within a factor of 50
- Risk
  - Modeling uncertainties
  - Factor of 10

SIGNIFICANCE OF UNCERTAINTIES (CONTD.)

- Overall uncertainty factor of at least 200
- Typical range between intolerable and broadly acceptable risk tolerance values is 1,000
  - Uncertainties are a major issue

CONCLUSIONS

- Development and use of risk tolerance criteria should be approached with care
  - Numerous pitfalls must be avoided
- Risk tolerance criteria help to determine the extent of harm that is viewed as tolerable
  - Influence:
    - Allocation of resources
    - Technologies used in facilities