Effects of Water Depth Workshop

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A Rational Approach to Well Design

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What is the definition of risk?

RISK = Probability of Failure x Consequence (Cost)

The Good News

Only one basic design equation exists:

Strength (Resistance) > Load

The Bad News

- No standards for load calculations
- A great deal of uncertainty exists in wells
- No standard or consistent reliability

No Standards for Load Calculations

- No API or ISO standard details how loads will be calculated or even list important loads to be considered
- Load calculations and load definitions are left up to the Operator
- A Basis for Design (BOD) needs to be established before the design work can commence

Uncertainty in Well Design

- Pore Pressure / Fracture Gradient
- BHT / BHP
- SITP
- Flow Rates
- Gas / Oil Composition H_2S / CO_2
- Well Profile
- Abandonment Pressures
- . . .

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No Standard or Consistent Reliability

- What factor of safety to be used for burst?
- What factor of safety to be used for collapse?
- What factor of safety to be used for VME?
- What factor of safety to be used for tension?
- . . .
- . . .

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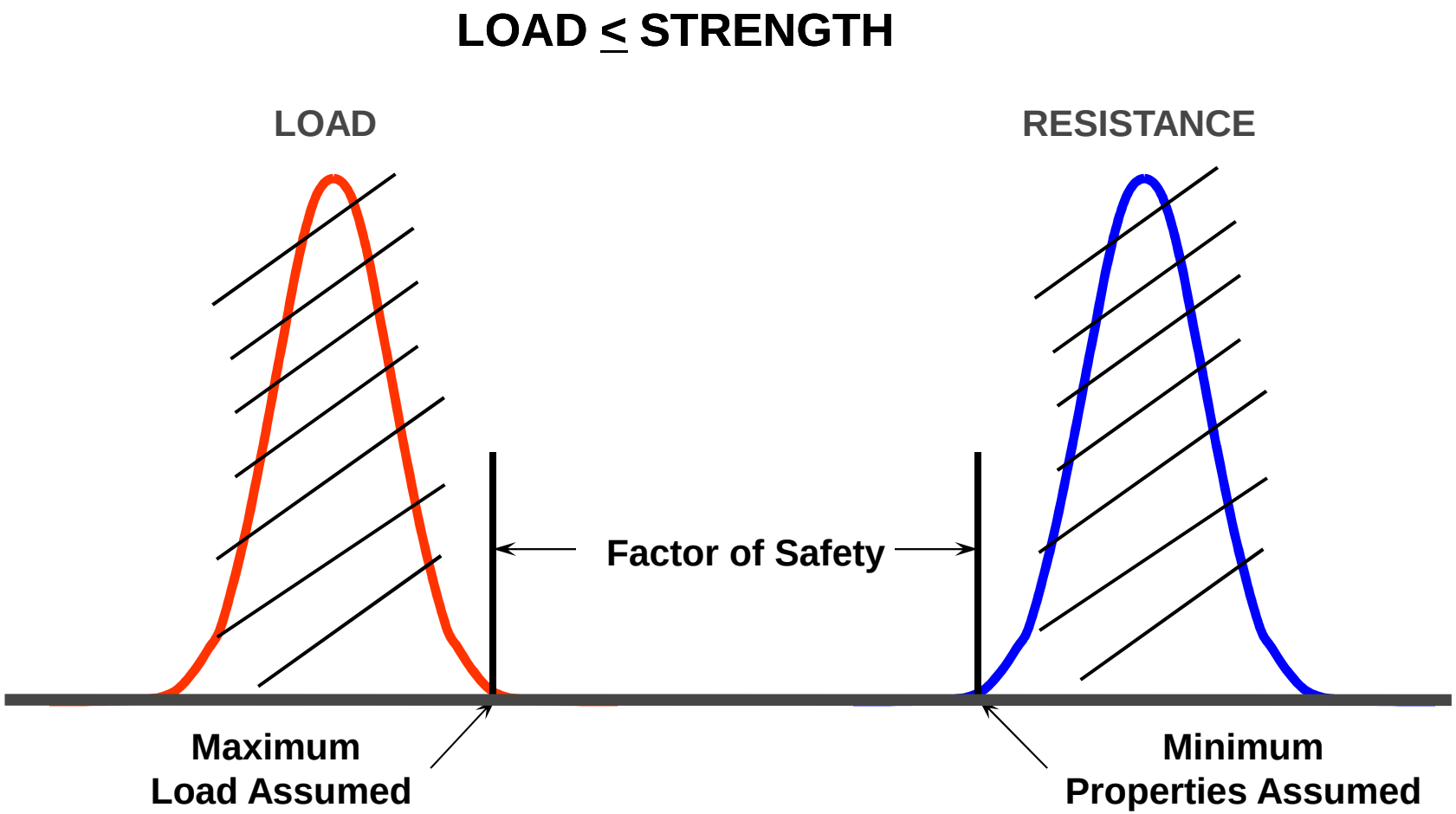
Design Philosophies

- Working Stress Design (WSD) also know as Allowable Stress Design (ASD)
- Reliability Based Design (RBD) using Limit State Theory

Deterministic Theory – WSD



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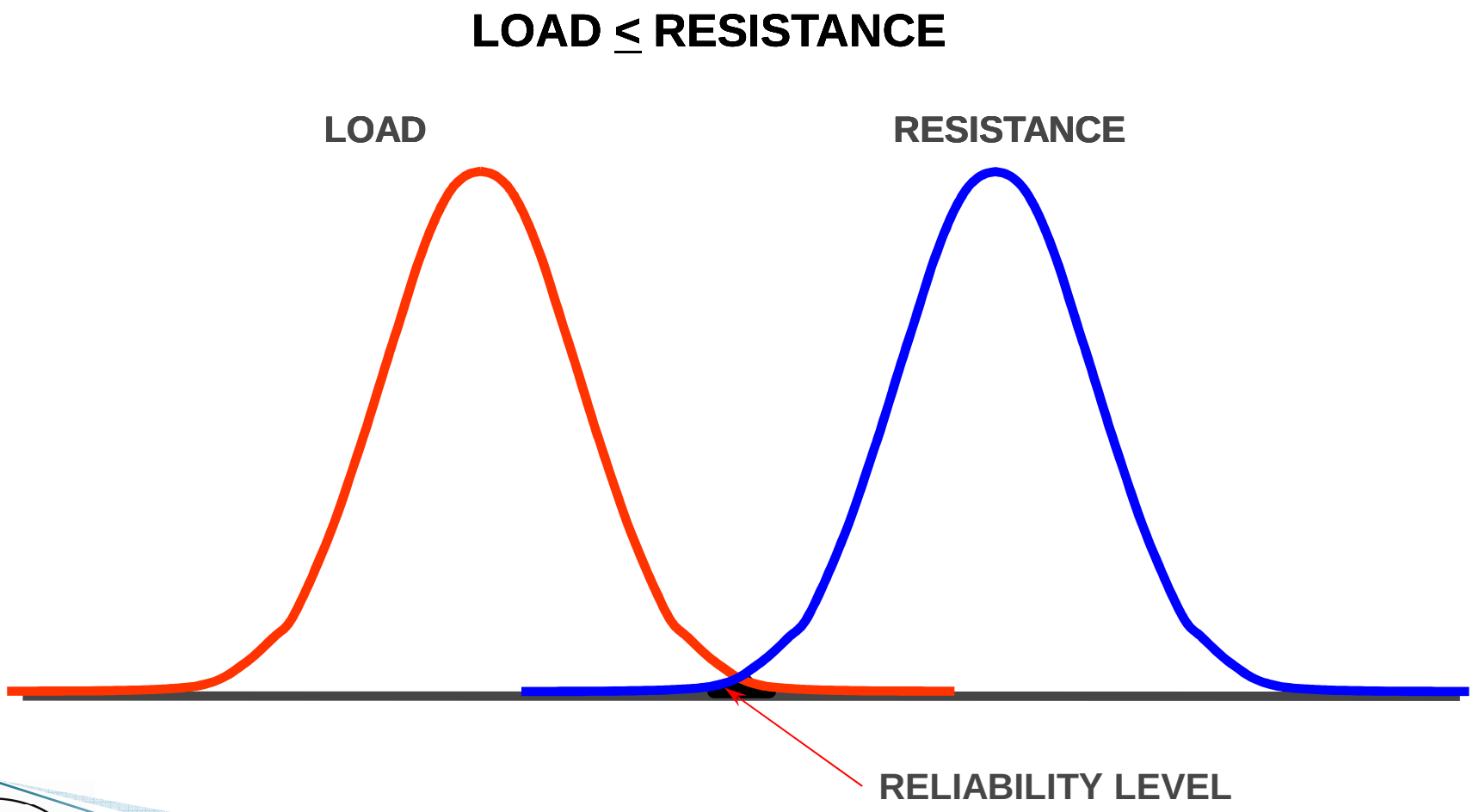
Probabilistic Theory – RBD



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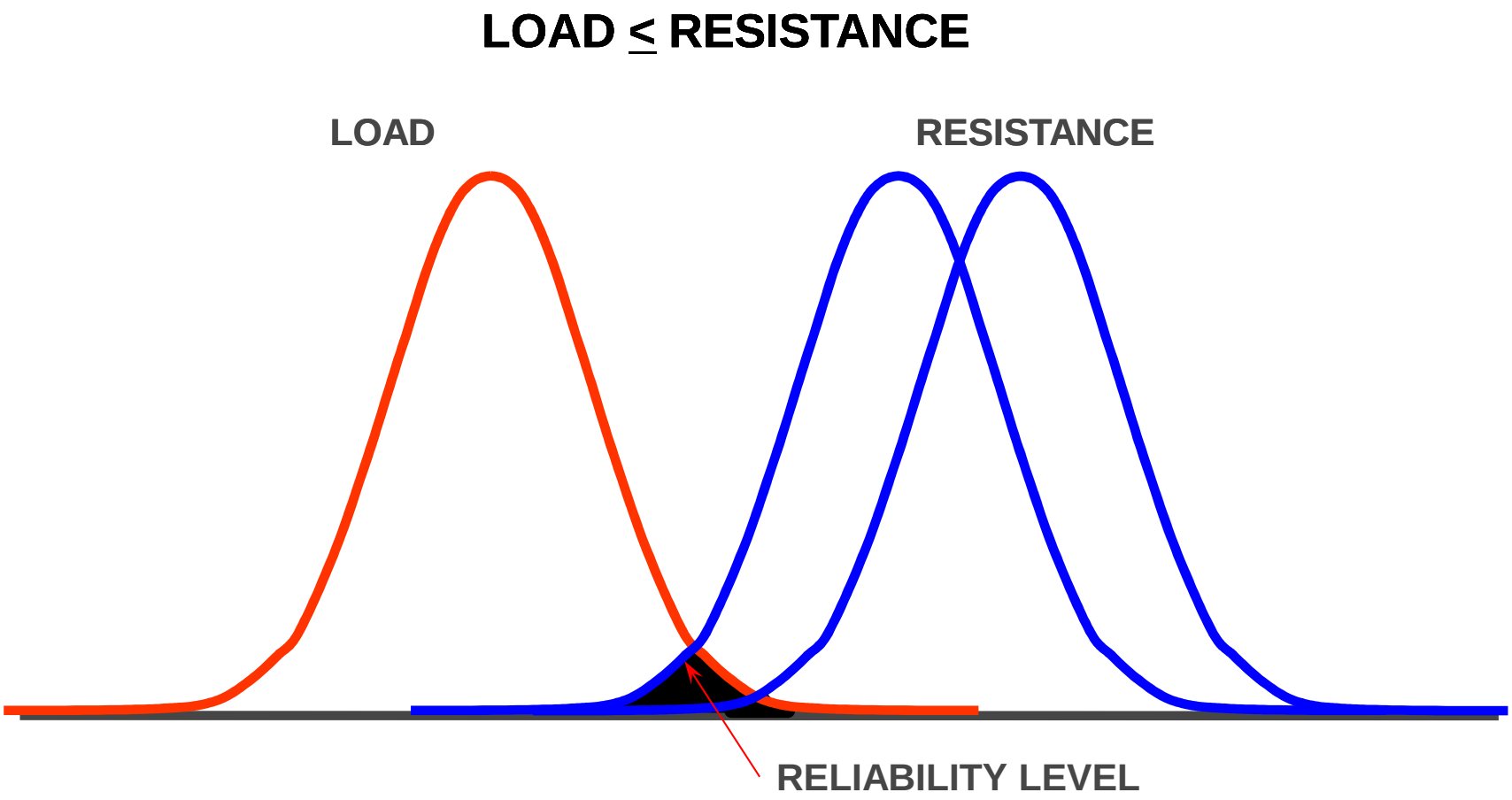
Probabilistic Theory – RBD



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Strength Uncertainty

- Controlled by Manufacturing Process
- Can Be Minimized But Not Eliminated
- Reflected in the distribution of strength-defining parameters (yield, OD, wall thickness, etc.)
- Can be measured and taken account of in design

Load Uncertainty

Load uncertainty is of two types

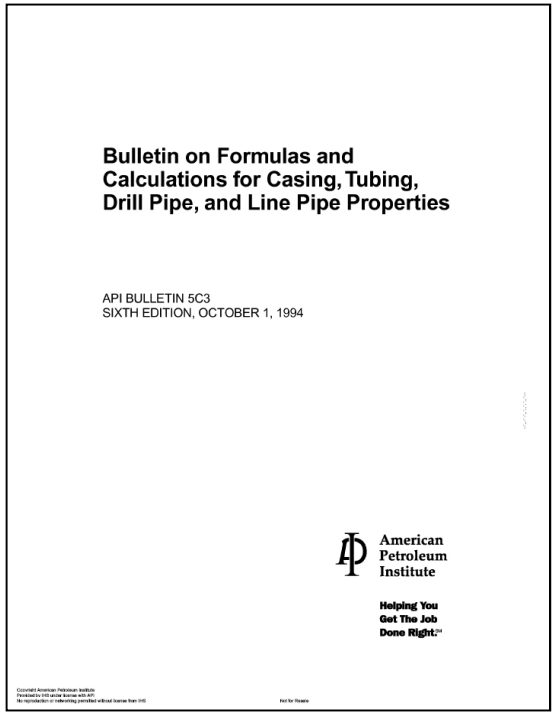
- Probability of occurrence of the load
- Variability in the magnitude of the load if it occurs

ISO TR 10400 – API TR 5C3

Has given the Industry Limit States which can be leveraged into RBD

History

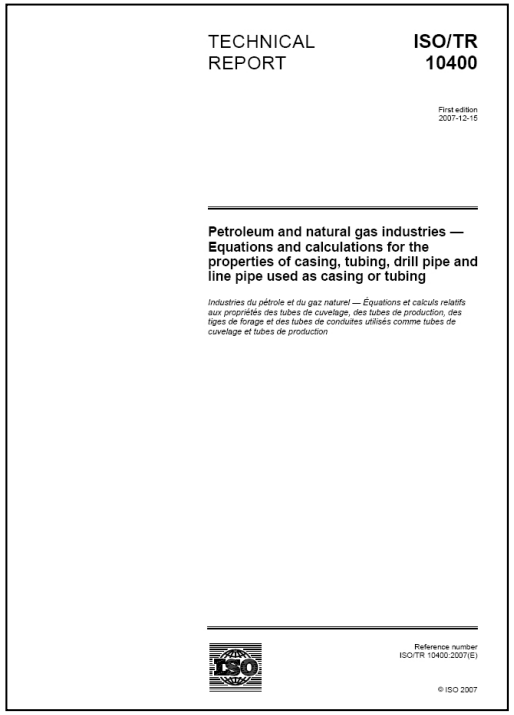
API 5C3



Your Old Friend

Developed in the 1960's
Revised multiple times
Retired in 2008

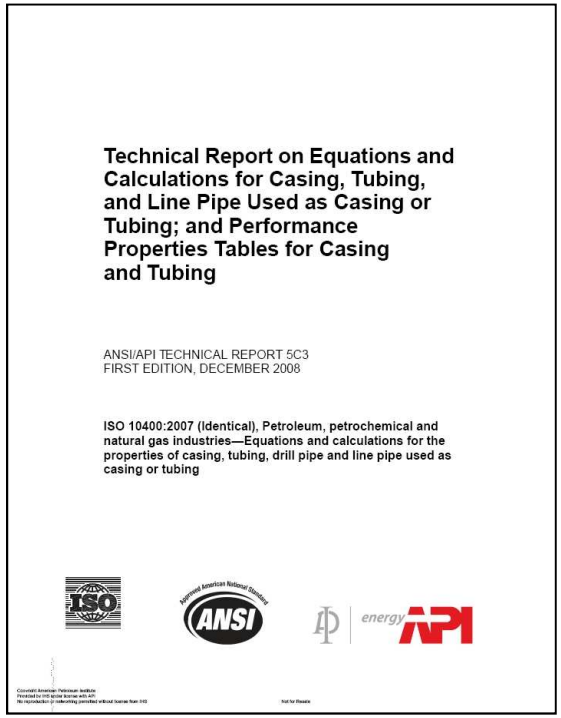
ISO TR 10400



Your New International Friend

Developed from 2000 – 2007

API TR 5C3



API Back Adopted ISO TR 10400 as API TR 5C3 in December 2008

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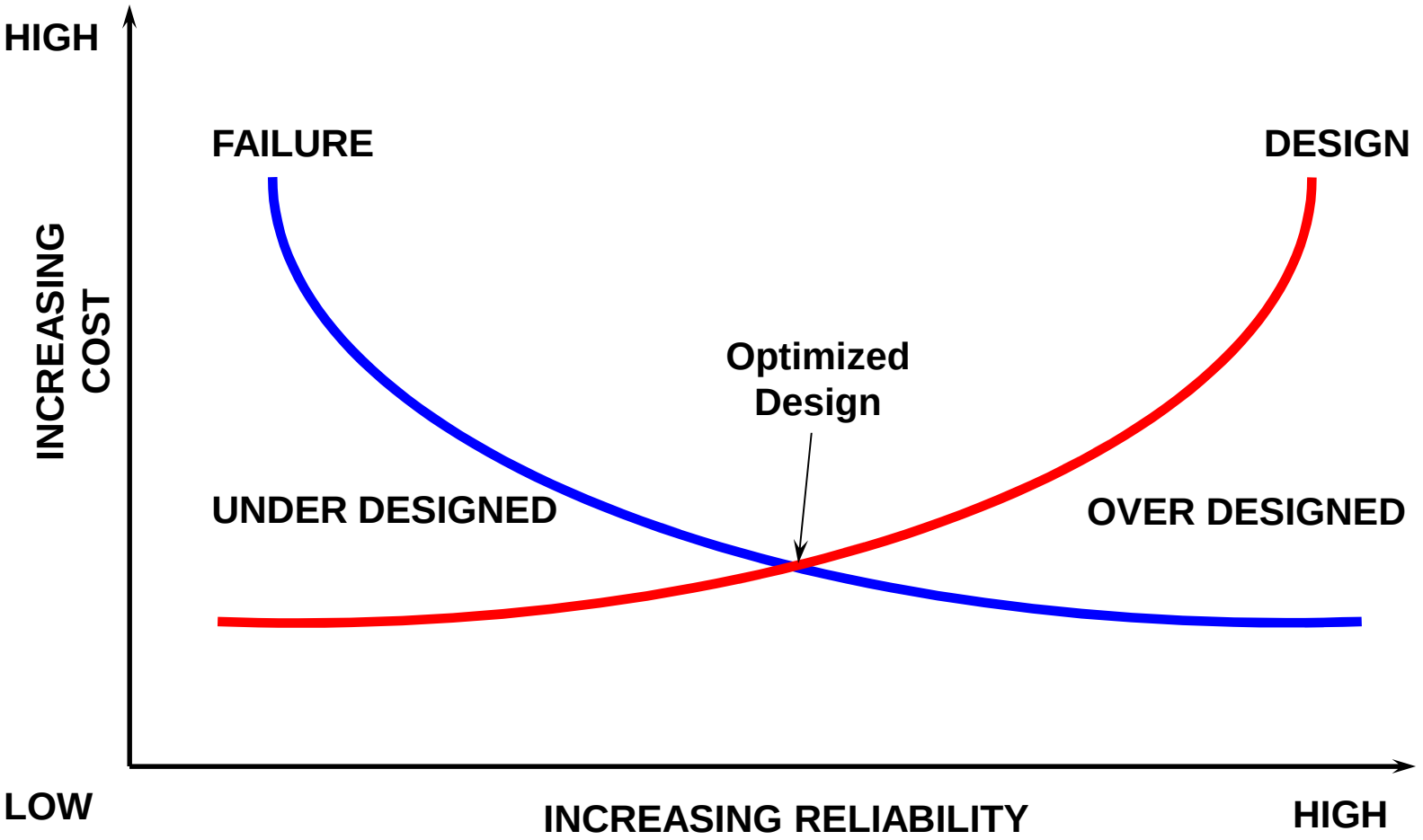
Optimization of Cost and Reliability



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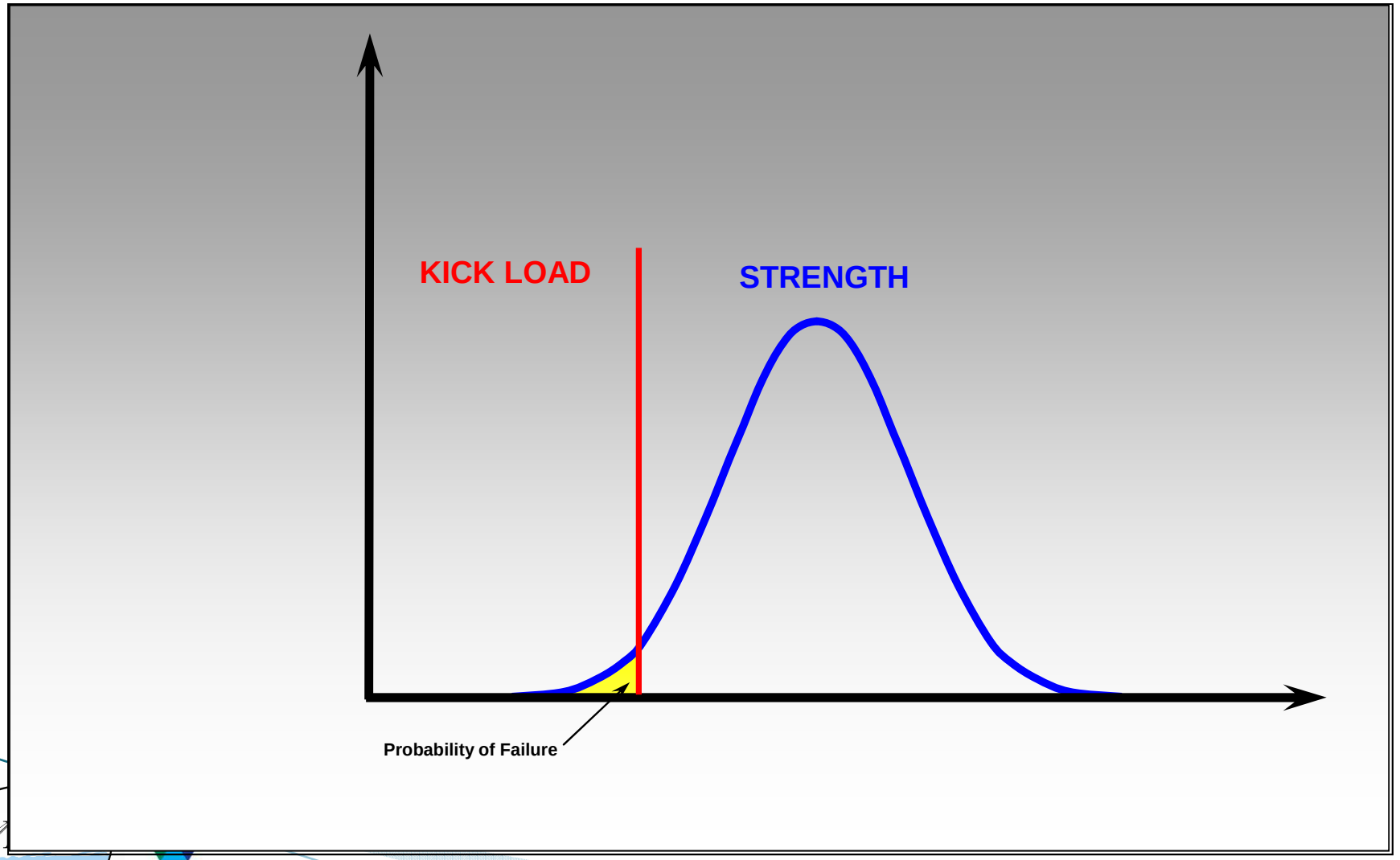
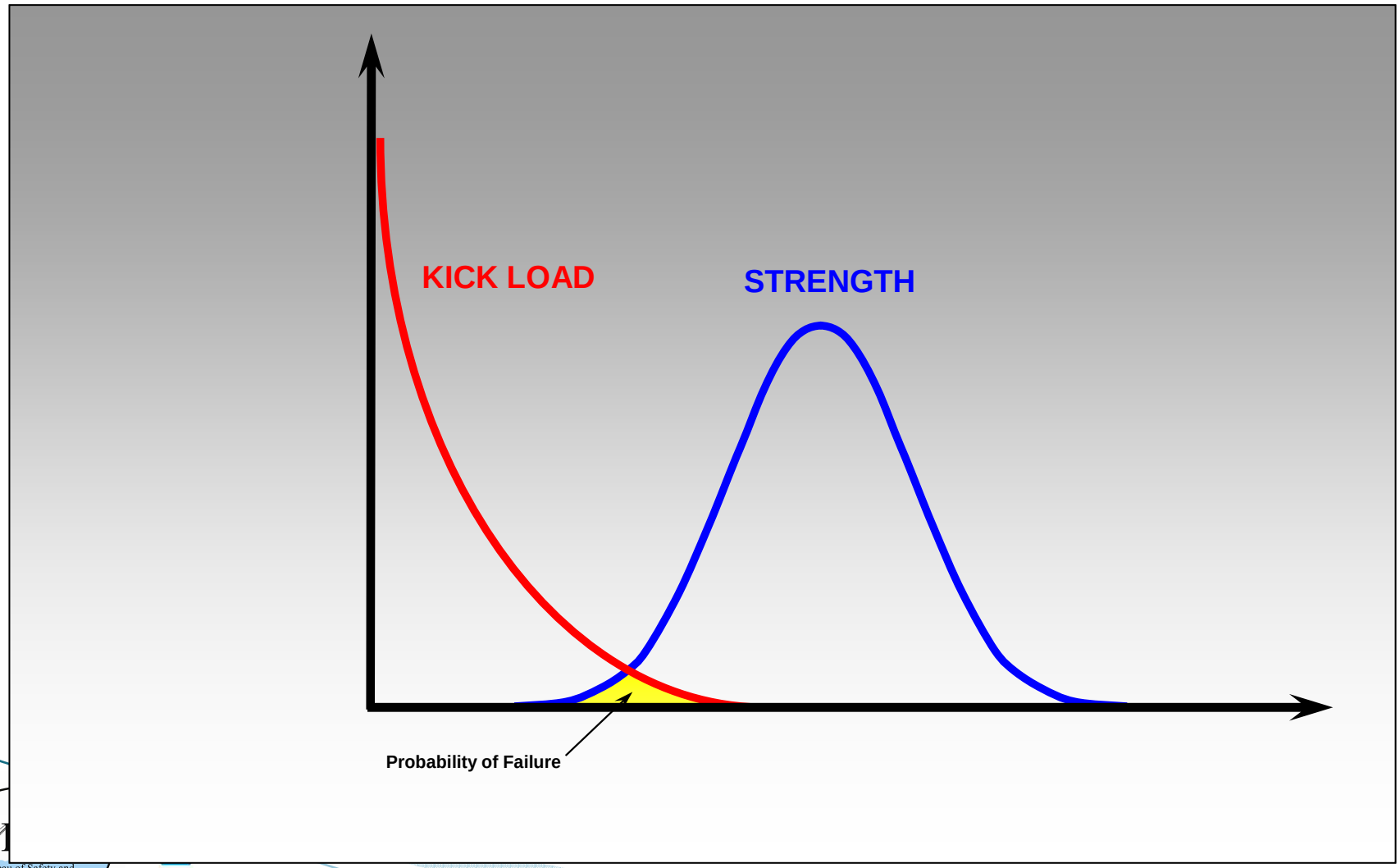
Design Levels

Design Level	Strength	Load
1	Deterministic Working Stress based on API Ratings	Deterministic
2	Deterministic Working Stress based on Advanced Engineering Mechanics	Deterministic
3	Deterministic Stress based on Limit State Design	Deterministic
4	Stochastic Stress based on Limit State Design	Deterministic
5	Stochastic Stress based on Limit State Design	Stochastic

RBD Level 4



RBD Level 5



Probability of Failures

Failure Consequence	Cost of Failure: High	Medium	Low
Severe	10^{-8}	$10^{-6.5}$	10^{-5}
Low	10^{-5}	$10^{-3.5}$	10^{-2}

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Concluding Notes

- Probabilistic design methods are standard in many structural design codes
- They may seem complex, but in reality they are more rational and appealing to our sense of risk-based decision making
- They are unavoidable in the modern design community, with more demanding wells and better understanding of performance properties
- Properly applied, they lead to the most risk-consistent, optimal designs

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