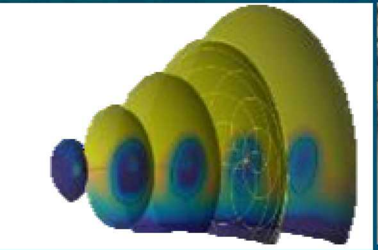
SAND2020-1297C

# Outcomes of IEA TEM #91: *Durability and Damage Tolerant Design of Wind Blades*



*PRESENTED BY*

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SAND2018-9430 PE

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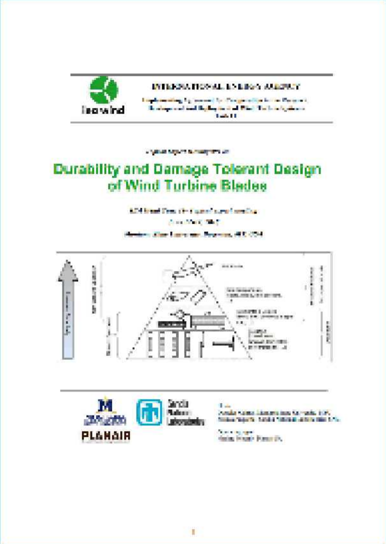
# IEA Wind Technical Experts Meeting #91:
## *Durability and Damage Tolerant Design of Wind Blades*

Bring together wind and aerospace communities

Develop a vision for how durability and damage tolerant design can be implemented for wind blades

Topics:

- Aerospace Experience and Wind Standards
- Manufacturing & Inspection
- Modeling & Testing
- Operations


INTERNATIONAL ENERGY AGENCY

Durability and Damage Tolerant Design of Wind Turbine Blades

PLANAIR


IEA TEM #91 Participants, Bozeman, MT, June, 2018

# Background: Durability and Damage Tolerant Design

Large amount of existing design experience and standards from aerospace

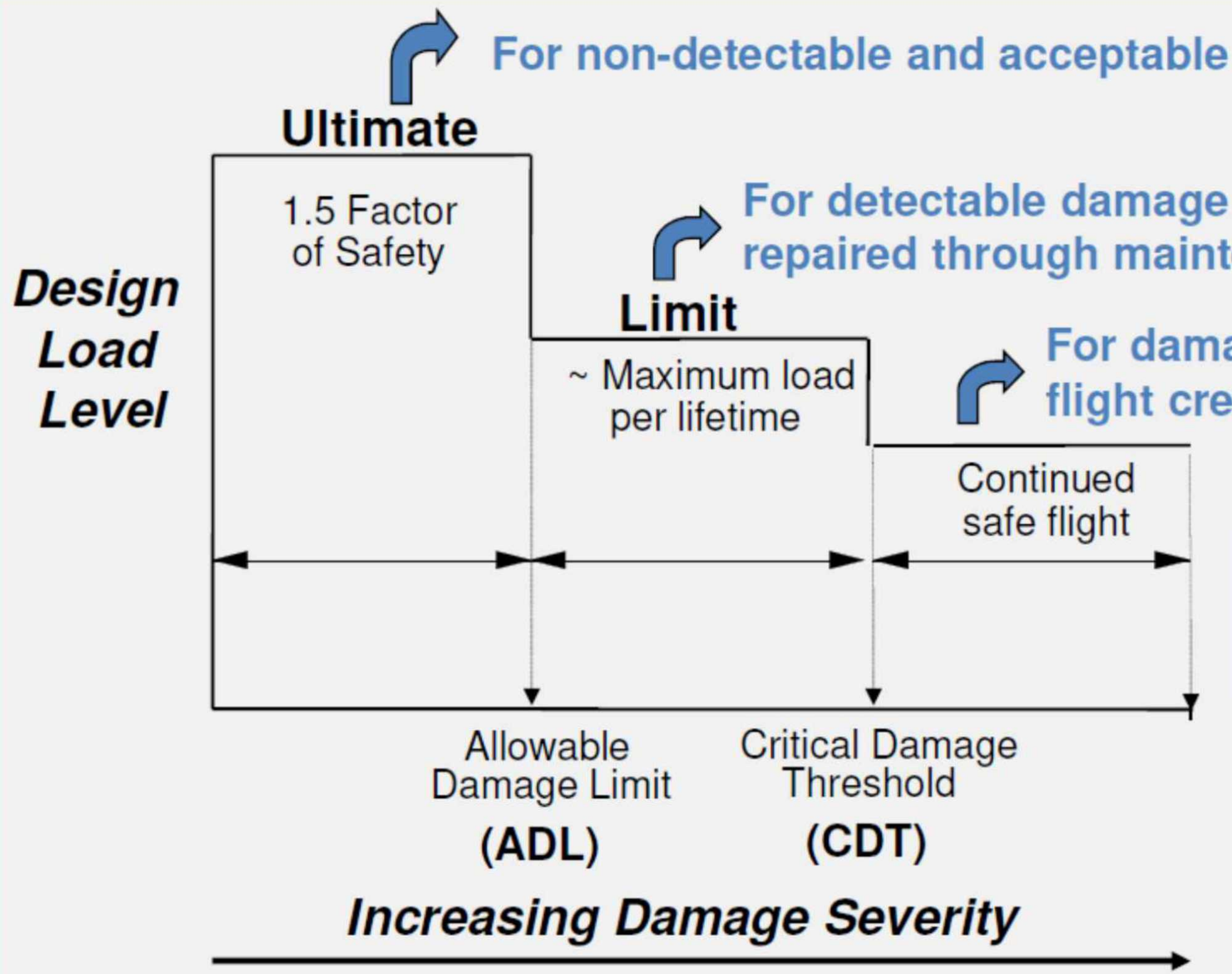
- CMH-17 Composite Material Handbook, Chapter 12 “Damage Resistance, Durability, and Damage Tolerance

Difference between Safe-Life and Durability and Damage Tolerant design[1]

- Safe Life – Operational life is limited to ensure adequate fatigue resistance
- Durability – Structural resistance is maintained throughout component lifetime, with repairs as necessary
- Damage Tolerance – Structure retains the required strength for a period of time after sustaining damage.

[1] “Application of Aerospace Durability and Damage Tolerance Approaches to Wind Blade Design”, Graesser & Hoyt, 2018 Sandia Blade Workshop

# Aerospace Approach



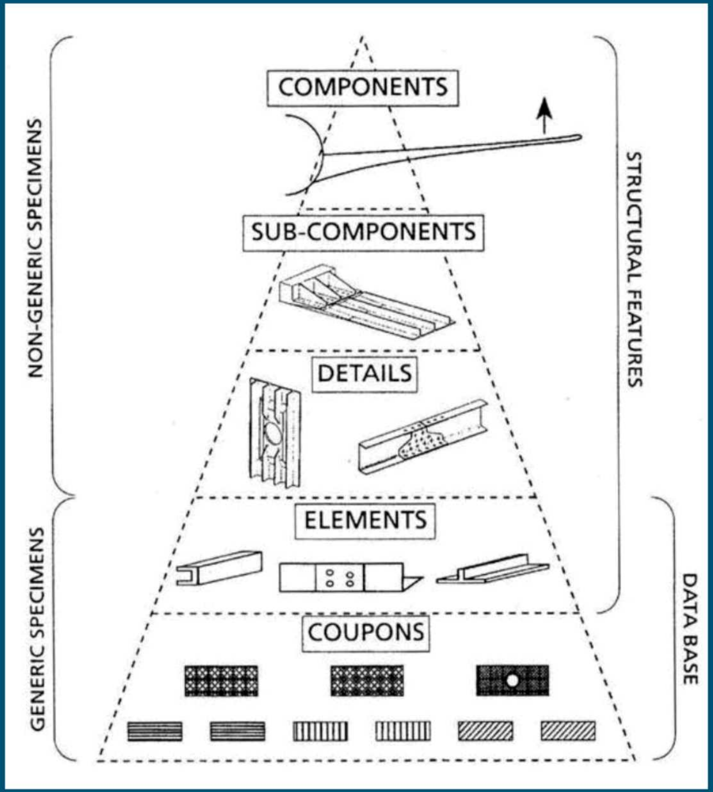

Is there an equivalent to Ultimate and Limit load levels in the wind industry?

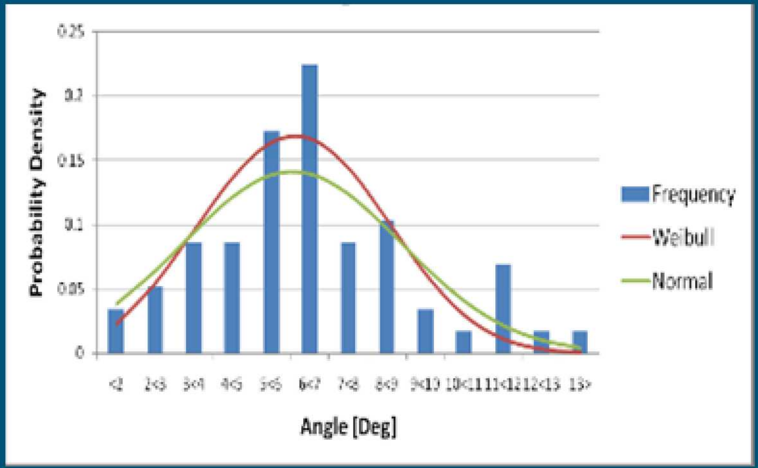
Figure from CSET – Composite Structural Engineering Technology Course[1]

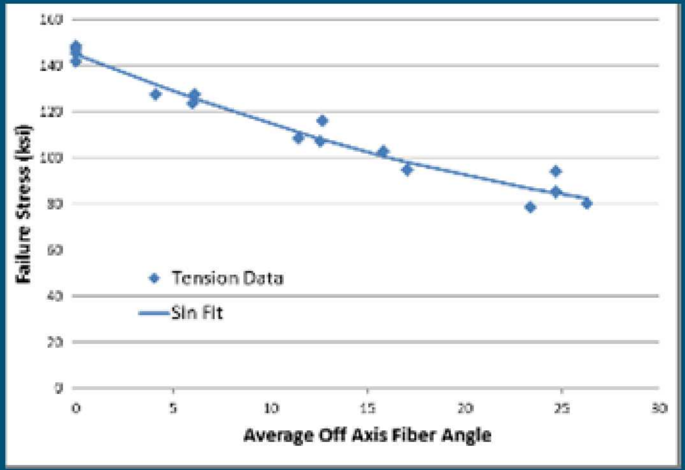
# Requirements

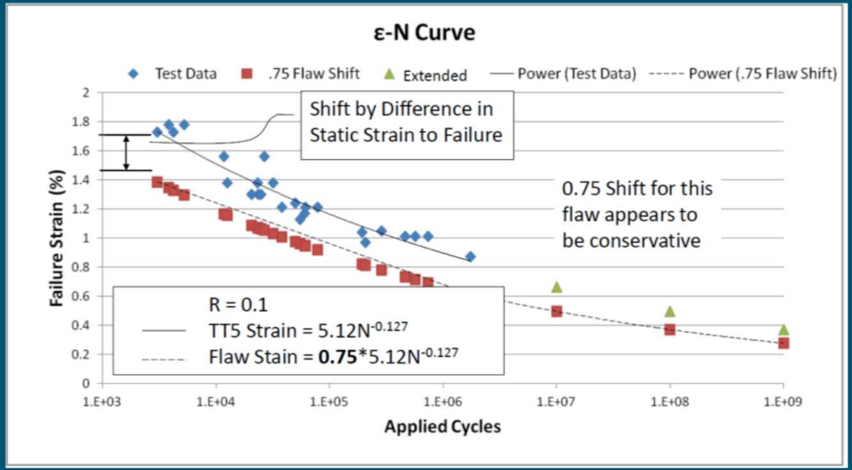
Testing

- Multiple levels from coupon through full structure, with the inclusion of possible defects



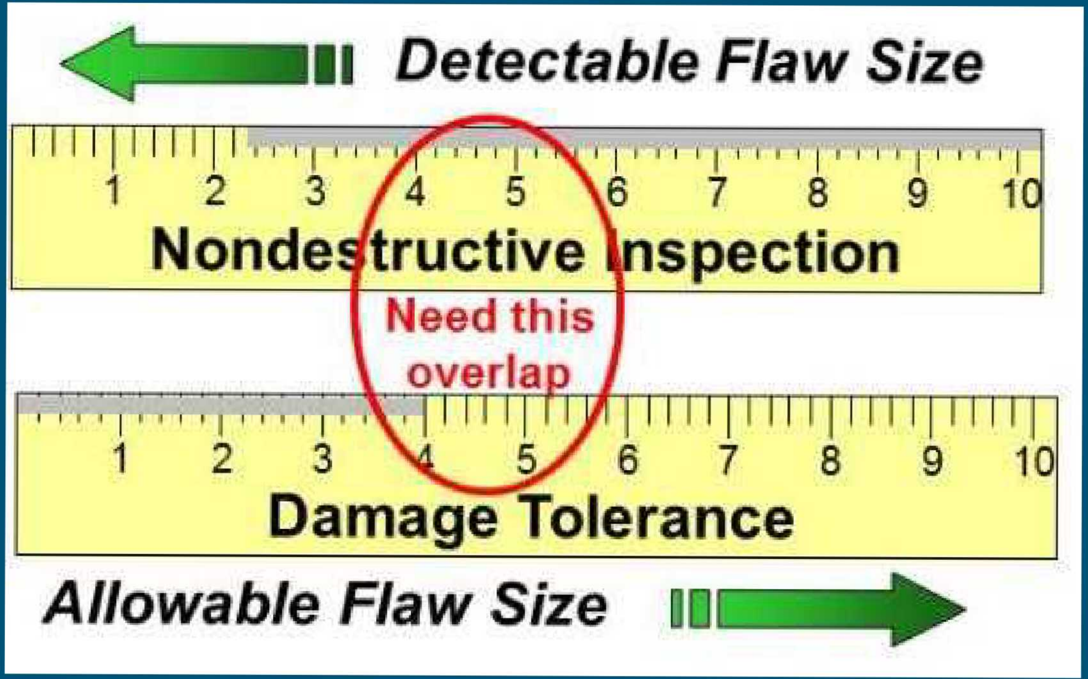



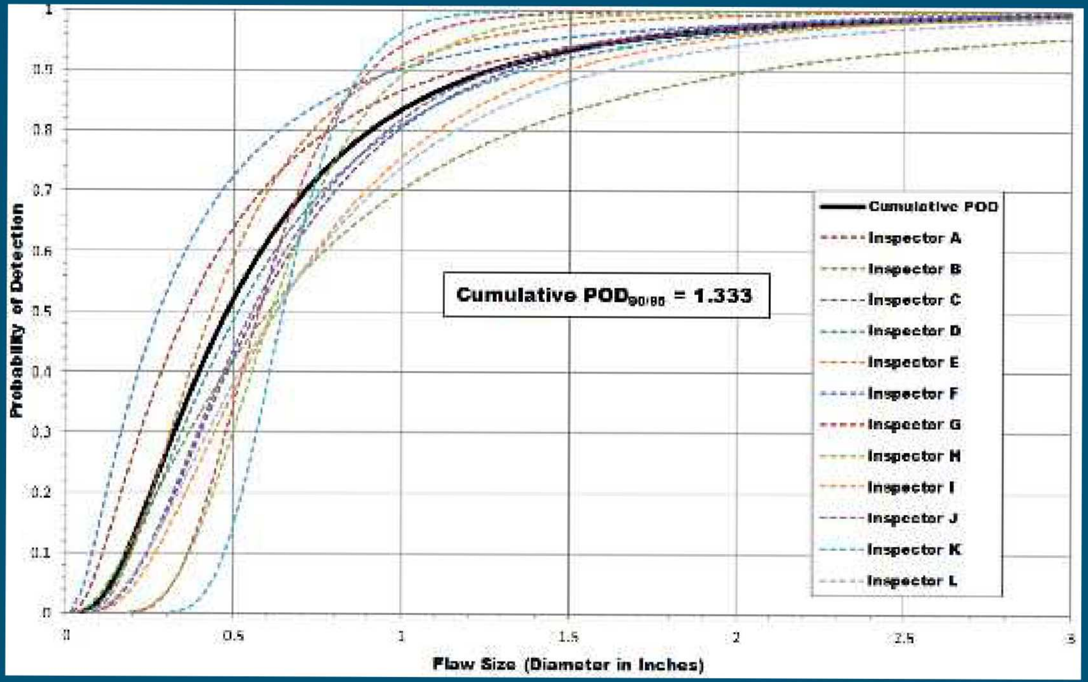



# Requirements

## Inspection Methods

- Probability of detection data for plant and field inspection methods

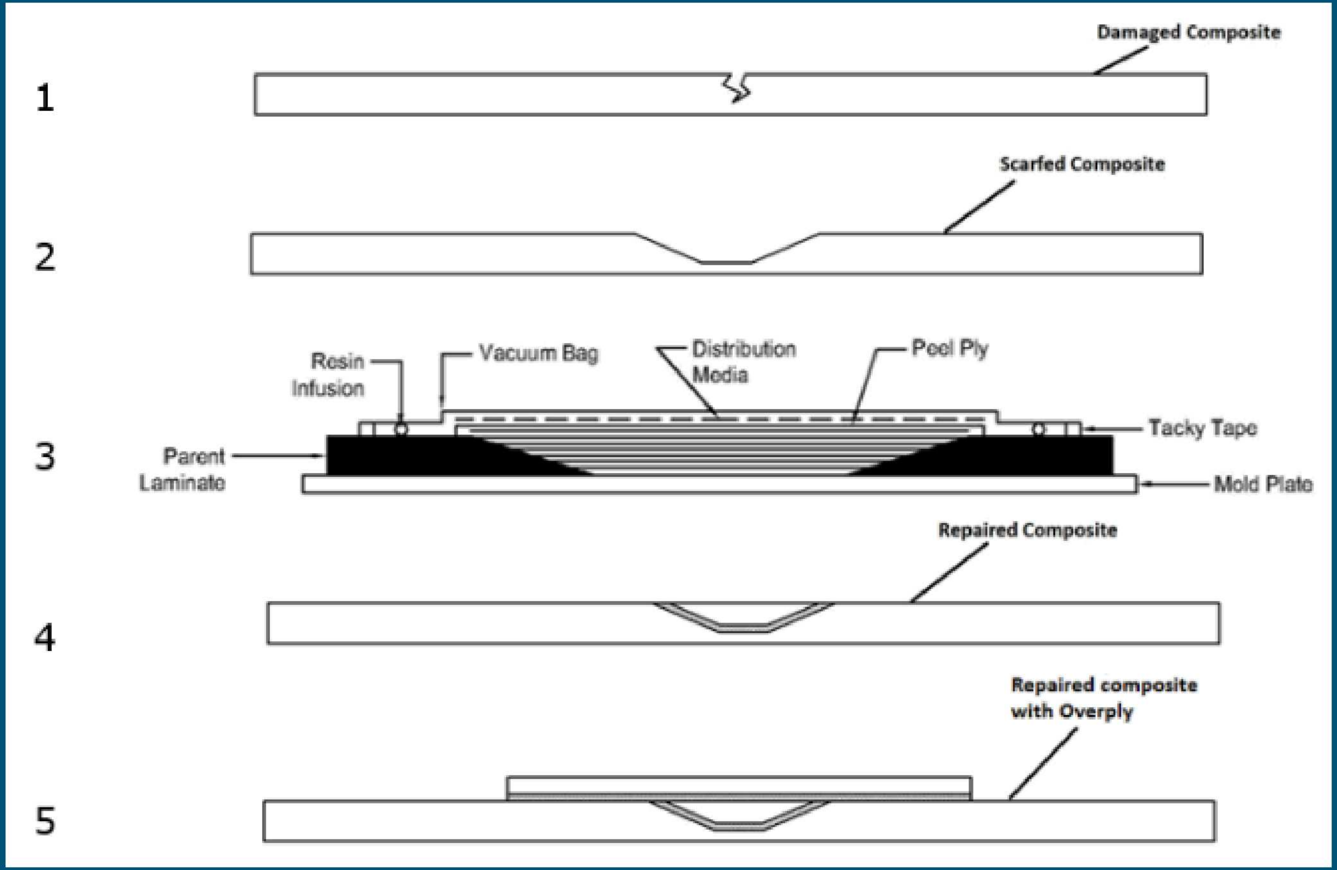


# Requirements

## Repairs

- Tested and validated, including in field conditions. May not be able to fully recover original strength.



# Differences with Wind Blades

Design, testing and maintenance budgets

Frequency and ease of inspection

Repair conditions

Consequence of failure

# Recommended Future Activities

**Development of a leading edge erosion standard including test methods and defined erosion classes**

**Repair standards for wind blades**

A formal IEA Task should be developed that focuses specifically on the development of durability and damage tolerant design for wind blades

Research into the development of test methods for wind blade laminates and sub-structures with simulated damage, along with accompanying validated models

Further development of filed inspection technology and improved monitoring of turbine loads

Addition of durability and damage tolerant design to IEC 61400-5

# Multi-Scale Modeling and Testing

**Develop a model of leading edge erosion that includes the effects of both rain and environmental exposure**

**Repairs should be based on analysis or pre-approved and defined methods from the OEM**

**Include the effects of manufacturing variances in tests and models of blades**

**Further develop damage progression models and utilize high-performance computing for probabilistic analysis of operational failure**

More detailed sub-structure test methods should be developed to add to or possibly replace full-scale structural blade tests

Certification by analysis should be explored after design methods are validated for blades that are similar to previous designs, including the allowance for adjustments to already certified designs

Blades that have been removed from service should be subsequently inspected and tested to validate damage growth models

Focus on known problematic areas in developing test methods such as spar-web interface, trailing edge bonds, and sandwich panels

Investigate damage tolerant materials, material forms, and structural designs that optimize mass and reliability

# Manufacturing and Inspection

**Damage tolerance includes designing and manufacturing for the possibility of damage caused by lightning and erosion**

**Formation of an operator group devoted specifically to wind blade damage, inspection techniques, and repair methods**

**The use of digital twins should be explored as a method of prognostics for both**

**Improve standards to drive industry**

Flaws must be considered during the design process if they cannot be shown to not exist in a certain manufacturing process, or found with inspection and adequately repaired

Wind plant owners should receive a manufacturing report on every blade that includes the results of inspections and repairs that are performed in the factory

Non-destructive inspection methods for wind blades will need to be faster, easier, and cheaper than what exists in the aerospace industry

Owner operators will need to improve their technology base to more fully understand wind blade design and composite structures

A comprehensive maintenance approach should be developed which engages OEM's and owner/operators in a collaborative relationship to share information

Actionable findings should be defined by turbine OEM's so that damage can be classified and dispositioned

Updates like airworthiness directives should be issues so that owner/operators can direct inspections

Wind blades should have more frequent inspections early in operation to detect premature failures and less frequent thereafter

# Operations

**Develop repair methods standards or recommended best practices specific to wind blades which consider both the original design standards requirements and applicability to field installation.**

**Understand other environmental effects like icing, hail, and dust.**

**Improve standards to require evaluation of and design for erosion effects.**

**Define erosion classes based on rain occurrence, droplet size, UV exposure, temperature extremes, and other important operational and environmental metrics.**

Establish training requirements for wind blade inspectors and repair technicians.

Develop inspection procedures for repairs and recommended re-inspect schedules to verify quality.

Investigate other methods besides scarf repairs, such as the use of doublers.

Develop test methods for determining allowables for erosion protection and other repairs.

Modify standards to allow designers to take advantage of inspection and repair in the operational life of a blade.

Preform load accumulation monitoring through the use of existing turbine sensors to understand differences between turbines in a plant, inform inspections, and possibly modify operation.

Define allowable damage size based on testing of coupons, details, and substructures with simulated damage.

# Relevant Standards

**6.6.6.2 Erosion**

Wind turbine blades are vulnerable to erosion, in particular at the leading edge and tip. This erosion can be caused by such environmental exposure as rain, dust, and sand.

Relevant surface finishes should be evaluated for expected erosion, and the basis for erosion protection is to be specified for the blade.

If the blade utilizes anti-icing functions, the surface finishes should be evaluated against erosion for the maximum expected surface temperatures.

IEC 61400-5 (to be published)

DNV·GL

**RECOMMENDED PRACTICE**

DNVGL-RP-0171 Edition February 2018

**Testing of rotor blade erosion protection systems**

The electronic pdf version of this document, available free of charge from http://www.dnvgl.com, is the officially binding version.

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