Arctic Tanker Design for Extreme Conditions
Key Considerations

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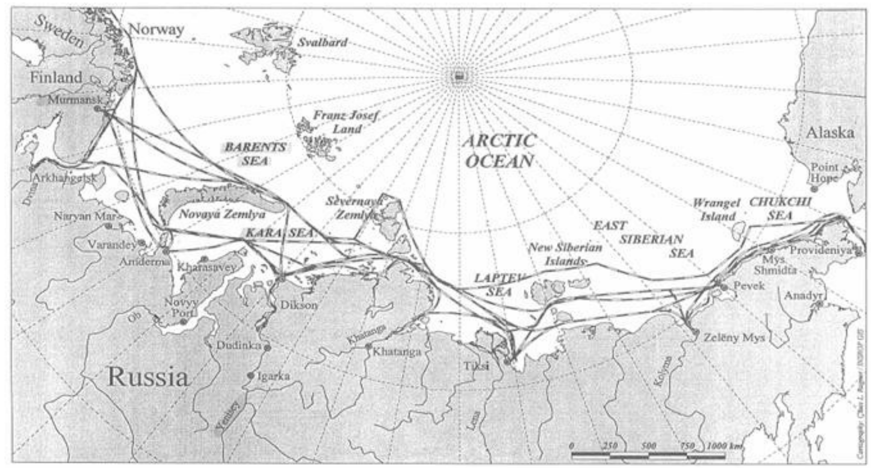
Drivers in Exploitation of Oil and Gas

- Political, social and economic changes
- Increased global energy demand driven by China and India
- Political instability in the Middle East
- Environmental protection

Challenges for Energy Transportation

Industry Response

- Suez Crisis: VLCC and ULCC
- Exxon Valdez accident: Mandatory double hull requirements
- Safety, Security and Environmental Protection: ISM, ISPS, TMSA
- Market for Natural Gas: Large LNG carriers
- Oil from Russia: Larger ice strengthened tankers



Arctic Challenge

Safety

- Loads on the hull and appendices
- First year and multiyear ice
- Design of equipment for low temperatures
  - Freezing conditions
  - Icing and ice blockage

- Lack of experience with larger vessels
- Remoteness and lack of infrastructure
- Impact on the crew
  - Cold temperatures
  - Lack of light and visibility
- Safety equipment fit for the conditions
- Lack of operational experience

Arctic Challenge

Environmental Conditions

- Temperature
- Ice Conditions
- Visibility
- Wind
- Waves

Winterization of an Arctic Tanker

Guidance for ship owners and shipyards on special considerations for harsh environments

- Hull construction and equipment
  - Material selection
  - Tank arrangement and heating
  - De-icing
- Systems and machinery
  - Reliability and redundancy
  - Deck machinery
  - Piping
- Safety systems
  - Life saving appliances
  - Navigational systems
- Ergonomic considerations
  - Enclosed work spaces
  - Protective gear
  - Insulation of accommodation spaces
- Training and manning
- Environmental protection

Winterization of an Arctic Tanker

Prevention of Ballast Tanks from Freezing

- Arrangement for preventing freezing in ballast tanks at higher service temperatures
- Heating calculations required for lower design service temperatures

Winterization of An Arctic Tanker

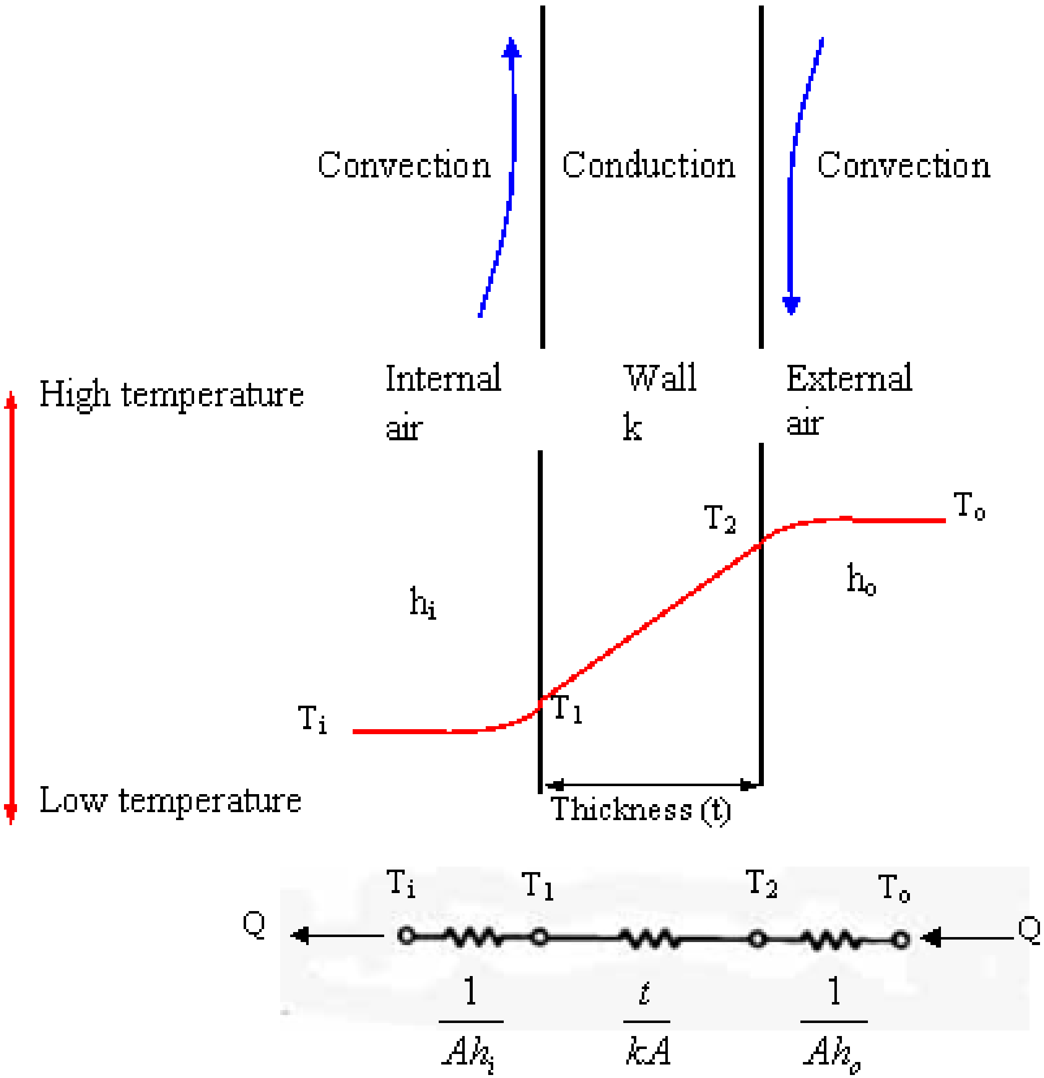
Procedure for Estimating Required Heating Capacity in Tanks

- General procedures based on overall heat transfer coefficients
  - Overly conservative
  - Lacks the information on surface temperatures

- New developed procedure based on the variable heat transfer coefficient representing variable convective coefficient related to temperature and wind conditions
  - Applied to the determination of heating capacity in a ballast tank for the arctic shuttle tanker.

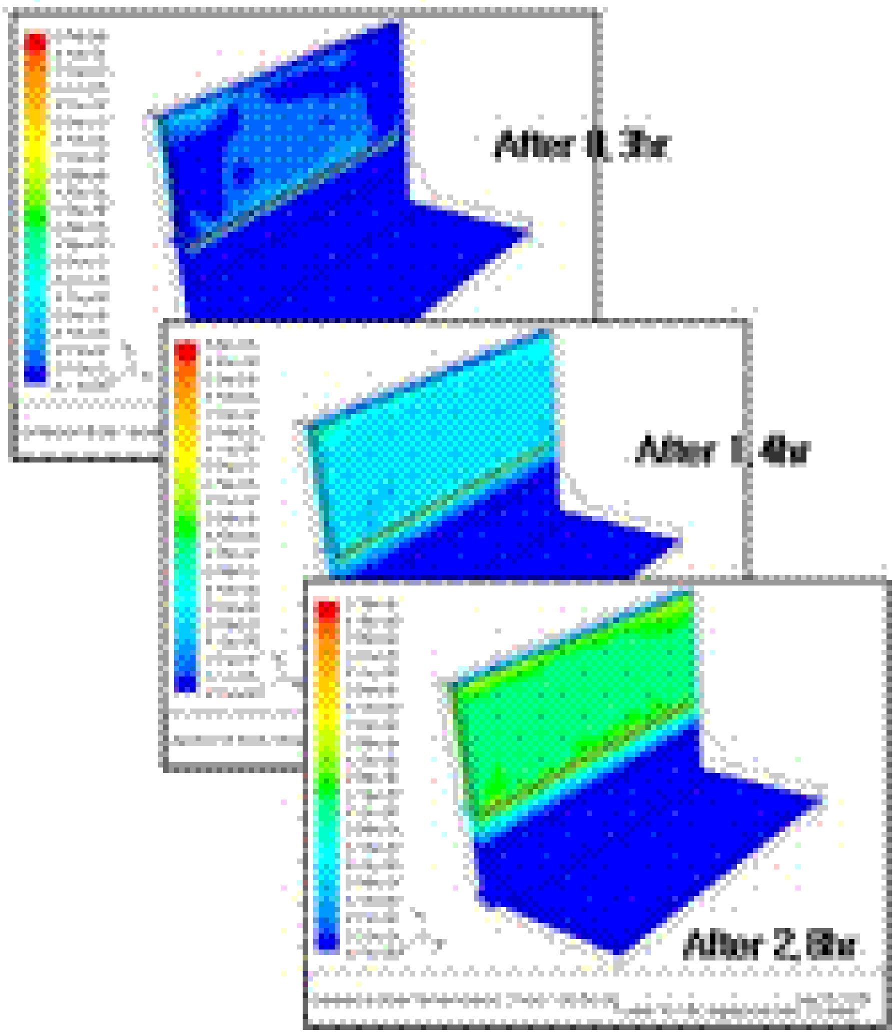
Winterization of An Arctic Tanker

Procedure for Estimating Required Heating Capacity in Tanks



Winterization of An Arctic Tanker

Procedure for Estimating Required Heating Capacity in Tanks



Winterization of An Arctic Tanker

Procedure for Estimating Required Heating Capacity in Tanks

Temperature

	Expected inside ballast tank temp. (℃)				Difference Original to CFD	Difference Developed to CFD
	Original		Developed			
	Design	CFD	Design	CFD		
Case1	2	8.37	2	2.14	↑6.37	↑0.14
Case2	2	8.28	2	2.12	↑6.28	↑0.12
Case3	2	8.05	2	2.08	↑6.05	↑0.08
Case4	2	8.21	2	2.13	↑6.21	↑0.13

Heater capacity

	Expected inside ballast tank heating capa. (W)			Difference Original to CFD	Difference Developed to CFD
	Design (Original)	Design (Developed)	CFD		
No. 2-4 W.B.TK.	282,808	194,572	178,880	58.2%	8.8%

Application of Ice Class Requirements

RS Ice Rules - Content

- Classification
- Ice Strengthening
- Main Engine Output
- Propulsion System

Application of Ice Class Requirements

RS Ice Rules – Design Principles

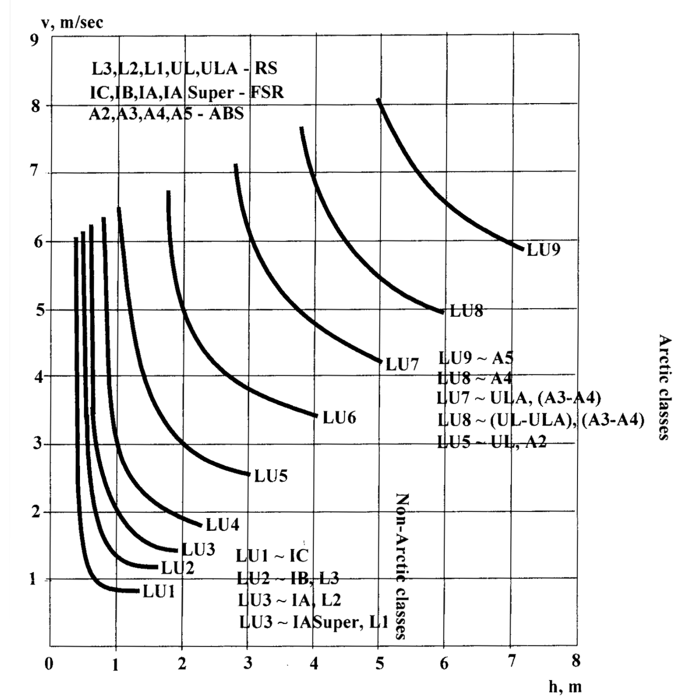
- Ice Strength Characteristics
- Ice thickness variable in Arctic – distribution law determination
- Design ice loads when operating under Base Dangerous Conditions
- Qualitative description – Permissible Service Conditions
- Quantitative description – Ice Classes

Application of Ice Class Requirements

Service Conditions – General Description

(i) When a ship is under permissible ice conditions, the hull–ice interaction should not lead to damages of the structures deteriorating the structural safety of a ship.

(ii) The required ship safety level in ice during various maneuvers and operations is provided by the requirements to the minimal engine output.



Application of Ice Class Requirements

Permissible Service Conditions

Ice Category	Operation Mode	Winter-spring navigation in seas					Summer-fall navigation in seas				
		Barents	**Kara**	**Laptev**	**East-Siberian**	**Chukchi**	**Barents**	**Kara**	**Laptev**	**East-Siberian**	**Chukchi**
		E H M Ea	E H M Ea	E H M Ea	E H M Ea	E H M Ea	E H M Ea	E H M Ea	E H M Ea	E H M Ea	E H M Ea
LU4	**IO**	- - - +	- - - -	- - - -	- - - -	- - - -	+ + + +	- - + +	- - - +	- - - +	- - + +
	IP	- * + +	- - - +	- - - -	- - - -	- - - *	+ + + +	* + + +	- - + +	- * + +	- * + +
LU5	**IO**	- - + +	- - - +	- - - -	- - - -	- - - -	+ + + +	- + + +	- - + +	- - + +	- - + +
	IP	* + + +	- - * +	- - - +	- - - +	- - * +	+ + + +	* + + +	* + + +	* + + +	* + + +
LU6	**IO**	* + + +	- - - +	- - - +	- - - +	- - - +	+ + + +	+ + + +	- + + +	- + + +	- + + +
	IP	+ + + +	* * + +	- * * +	- * * +	- * + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
LU7	**IO**	+ + + +	- - + +	- - - +	- - - +	- - + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	IP	+ + + +	+ + + +	* + + +	* + + +	* + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
LU8	**IO**	+ + + +	+ + + +	- * + +	* + + +	* + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	IP	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
LU9	**IO**	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	IP	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +

IO is independent operation
IP is icebreaker pilotage
+ – operation allowed
- – operation prohibited
* – operation with the higher risk of hull damage
E – extreme navigation (with mean reccourrence one time per 10 years)
H, M, Ea – heavy, medium, easy navigation (with mean reoccurrence one time per 3 years)

Permissible Service Conditions - Example

- LU 6
- Winter-Spring Navigation
- Independent Operation
- Barents Sea
  - Extreme navigation – high risk of hull damage
  - Heavy, Medium, Easy Navigation – operation allowed
- Kara Sea
  - Extreme, Heavy, Medium Navigation – operation prohibited
  - Easy Navigation – operation allowed

Application of Ice Class Requirements

Permissible Service Conditions - Example

- LU 6
- Winter-Spring Navigation
- Icebreaker Pilotage
- Barents Sea
  - Extreme, Heavy, Medium, Easy Navigation – operation allowed
- Kara Sea
  - Extreme, Heavy Navigation – high risk of hull damage
  - Medium, Easy Navigation – operation allowed

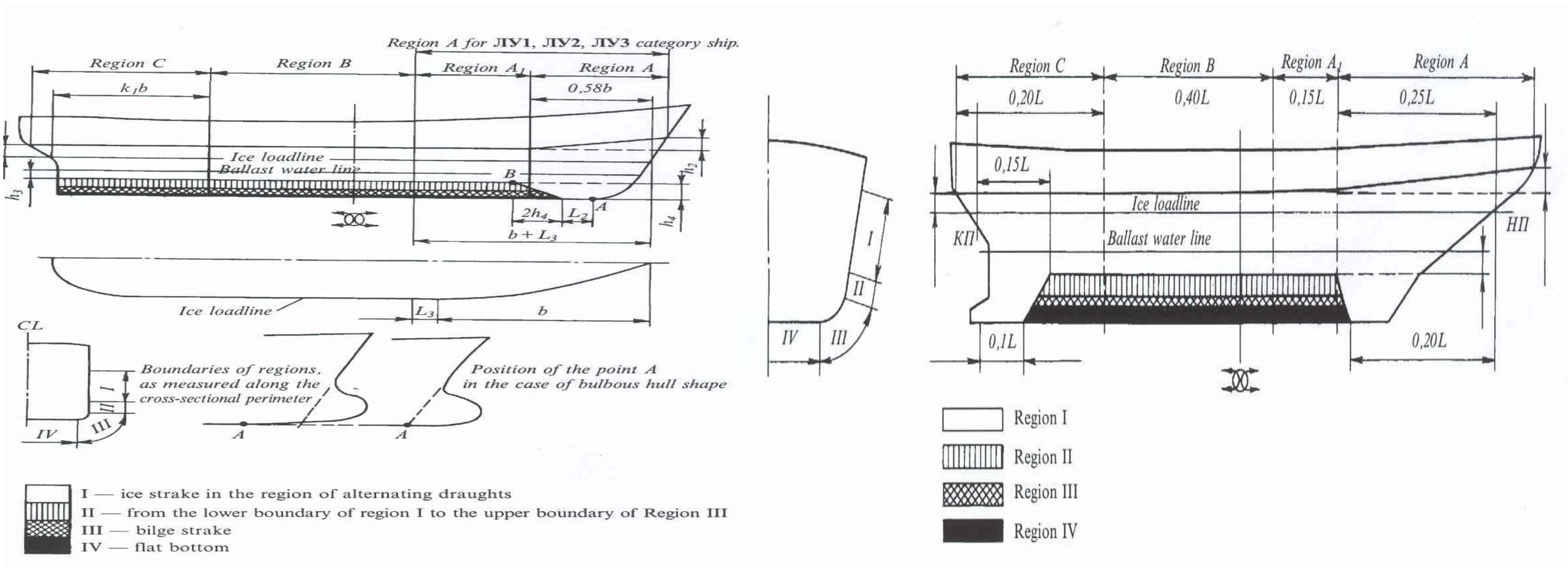
Application of Ice Class Requirements

Structural Strength Criteria

- Ice hull damage is to be considered as result of single action of ice load
- Design ice load corresponds to the ultimate hull structural strength at restricted plastic deformation
- A single ice damage with probability 7% is to be considered as normal operating practice
- The ice load is to be assigned based on an equal damage probability for different ice strengthening zones.
- Ultimate strength criterion - Design ice load not exceeding ultimate load on structure

Application of Ice Class Requirements

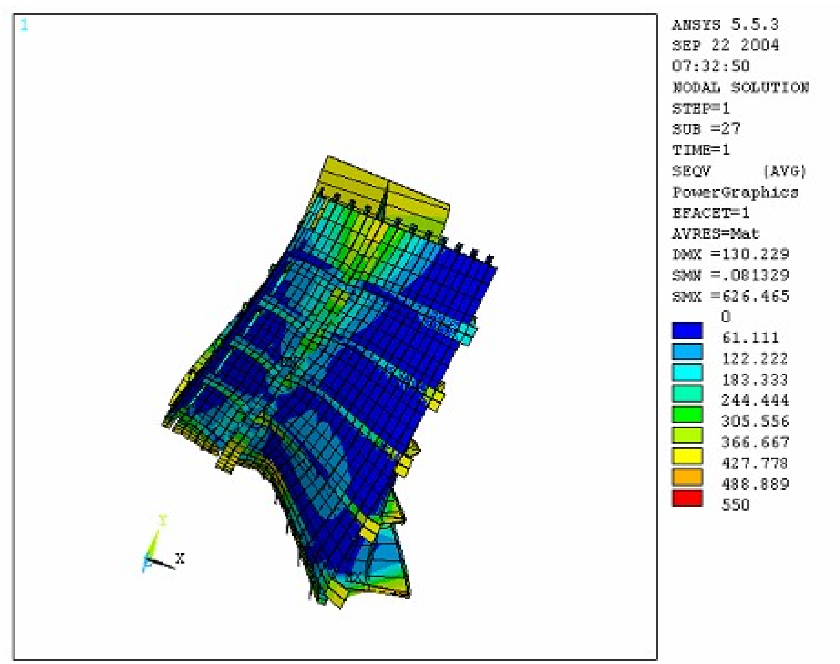
Hull form and ice belt area



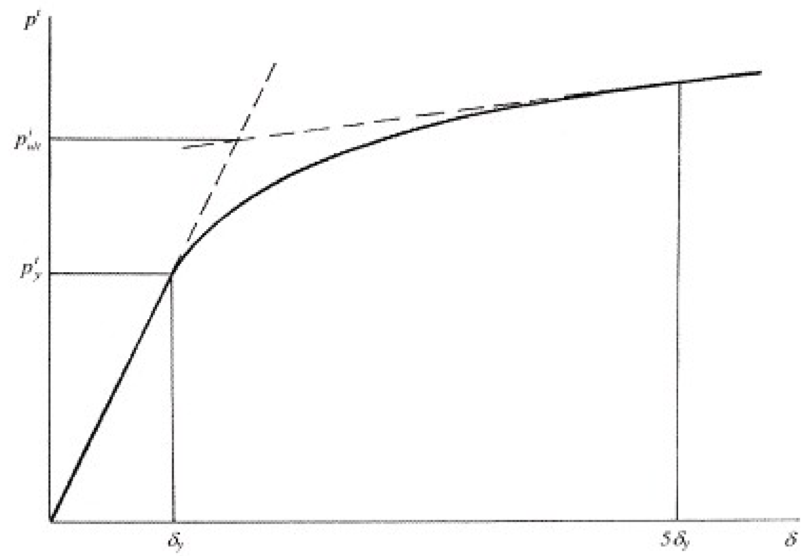
Application of Ice Class Requirements

Ultimate Limit State

Side Structure Grillage



Plastic deformation of side structure under ice load



Ultimate load curve

Application of Ice Class Requirements

Engine Output

Level ice capability for modern ice going vessels according to New RS Rules and Model and Full scale tests

	Norilsk-II, Double acting Ship. Ice category – LU7 Displacement –20000t Engine Power 1*13000 kW		Large capacity tanker "Varandey" Ice category LU6 Displacement ~90000t Engine Power 2*85000 kW	
Mode	*Traditional mode* *improved icebreaking bow*	*DAT mode* 	*Traditional mode*	 *Astern mode*
Model and full scaletest	~1.5m at V_S=2	~1.5m at V_S=3	~1.6m at V_S=2	~1.6m at V_S=2
RS Ice Rules	1.54m at V_S=2	1.55m at V_S=3	1.55m at V_S=2	1.5m at V_S=2

Application of Ice Class Requirements

Propulsion System

Propeller Blade

- Design ice loads
- Design stress
- Permissible stress
- Scantlings

Maneuverability of Large Tankers in Ice

- Hull shape for ice breaking in ahead and astern modes
- Podded propulsion
- Stopping ability
- Path stability
- Initial turning and yaw checking abilities
- Turning ability
- Importance of model test for checking maneuverability

Thank you for your attention