

Long term ageing of polypropylene foam. The results of testing performed after 18 years of exposure in a subsea environment

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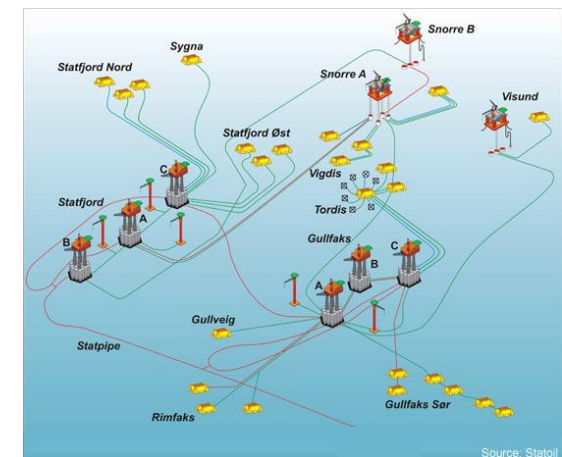
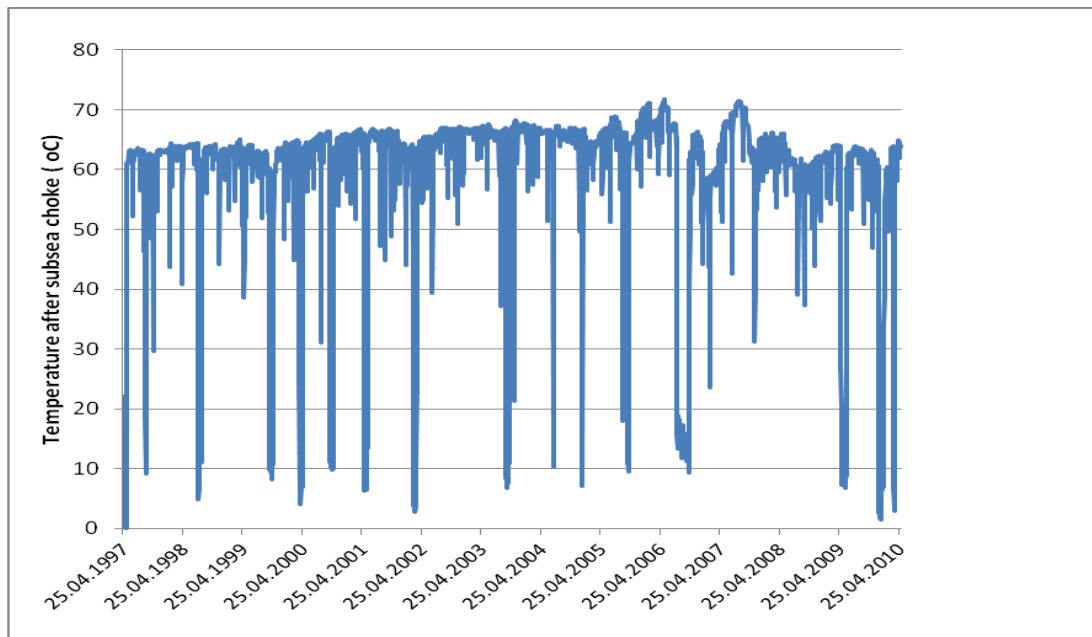
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Introduction

- Tordis field decommissioned after 18 years
- Pipe samples retrieved for ID corrosion study
- Samples of Field Joint and Line Pipe insulation made available for testing
- Chemical and mechanical testing performed

Tordis Field

- This oil field lies in block 34/7 in the Tampen area of the Norwegian North Sea, and came on stream in 1994
- 200 m water, operation 70°C



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Insulation system

- 275 mm OD pipe, 15.9 mm wall
- Line pipe
 - Cross head applied 4-layer PPF insulation
 - Spray applied FBE and extruded adhesive
 - Cross head layer 3 (PPF)& 4 onto cold pipe
 - Induction heat to fuse layer 2 to layer 3
 - Total thickness 50 mm
- Field Joint
 - IMPP

Samples for testing

- Start of life sample
 - Section of line pipe with field joint that had been used as a demonstration / show pipece.
 - Kept in office environment
- End of life sample
 - Section of line pipe and field joint retrieved from sea bed after 18 years of operation.

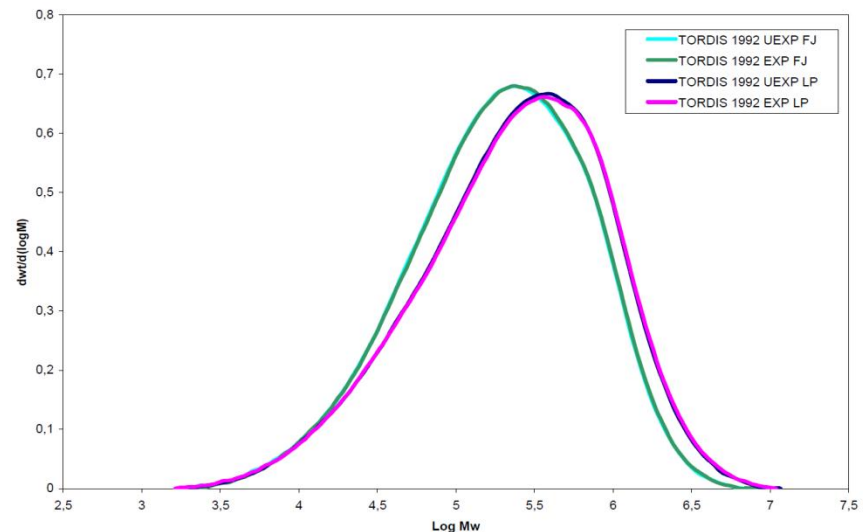
Testing performed

- Gel Permeation chromatography
- Melt flow index measurements
- Oxygen induction time
- 3-point flexural testing
- Uni-axial tensile testing
- Density
- Thermal conductivity

Testing performed

- Gel Permeation chromatography
 - Provides an indication of degradation of the polymer through a movement of the average molecular weight to lower values and a narrowing of the molecular weight envelope.

Sample	Mw	Mn	PDI
Unexposed field joint	380000	73000	5,2
Exposed field joint	385000	75000	5,1
Unexposed foam	505000	81000	6,2
Exposed foam	520000	80000	6,5



Testing performed

- Melt flow index measurements
 - Provides a point value relating to melt viscosity and is generally used as a quick means of detecting degradation of the polymer.

Sample	MFR (g/10 min)
Unexposed field joint	0.559
Exposed field joint	0.560
Unexposed foam	0.713
Exposed foam	0.759

Testing performed

- Oxygen Induction Time
 - Reflects the residual level of anti-oxidant present in the material after exposure. Residual anti-oxidant indicates that the polymer remains oxidatively protected.

Sample	OIT /min.
Unexposed field joint	49
Exposed field joint	54
Unexposed foam	20
Exposed foam	17

Testing performed

- 3-point flexural measurements
 - Used to compare the mechanical properties of the materials in flexure before and after exposure.

		Exposed foam	Typical raw material	Exposed field joint	Typical raw material
FLEXURAL MODULUS	MPa	1010,8	1000*	754,8	800
FLEXURAL STRENGTH	MPa	27,5	26*	21,3	21,5
FLEXURAL STRAIN AT FLEXURAL STRENGTH	%	6,9	6,6	6,8	6,5
FLEXURAL STRESS AT 3,5% STRAIN	MPa	23,1	21*	17,6	18
FLEXURAL STRESS AT BREAK	MPa	27,1	-	21,5	-
FLEXURAL STRAIN AT BREAK	%	7,9	-	7,7	-

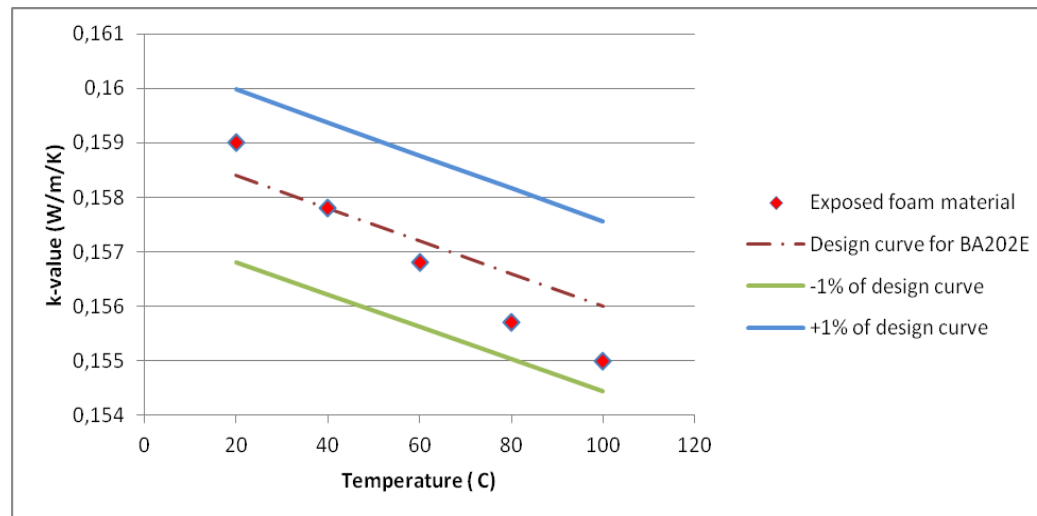
Testing performed

- Uni-axial tensile testing
 - Used to compare the mechanical properties of the materials in tension before and after exposure.

Specimen		Stress at Yield (MPa)	Elongation at Yield (%)	Stress at Break (MPa)	Elongation at Break (%)
Exposed FJ	Average	15,96	15,0	14,86	50,41
	StDev	1,57	3,28	0,97	7,53
Unexposed FJ	Average	17,14	18,24	19,42	47,70
	StDev	0,35	1,11	1,18	20,62
Exposed foam	Average	16,32	12,8	15,48	27,24
	StDev	3,14	7,85	2,99	11,28
Unexposed foam	Average	12,30	12,3	12,48	31,67
	StDev	1,74	1,65	1,61	11,02

Testing performed

- Thermal conductivity measurements
 - The design case includes assumptions on change in k-value.
 - Material remains within the design envelope



Conclusions

- GPC data indicates no significant change in molecular weight
 - Supported by MFR and OIT measurements
- Mechanical testing in flexure and tension show only small changes
- Thermal conductivity testing shows that the design curve is still valid
- Insulation system has behaved as expected during the life of the field.
- No indication of degradation of the PP material.