Case study of challenging inspection of Offshore gas pipeline in the Black Sea

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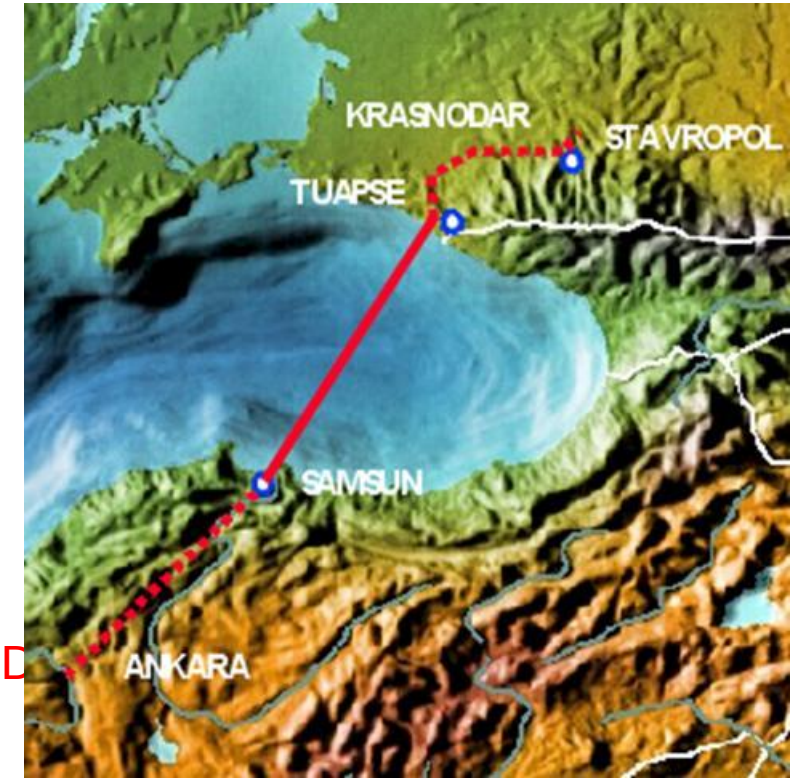
22nd November 2011

GE Oil & Gas
PII Pipeline Solutions

BSPC - Pipeline Details

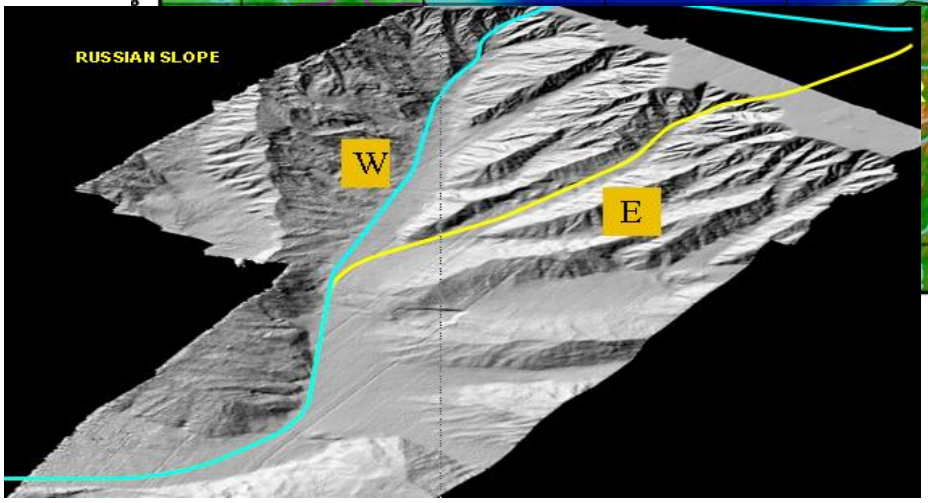
- 56” & 48”
- 24” Interconnector Pipelines 380 & 387 Km
- Depth max 2140m (7021’)
- Pressure 250 bar (3625psi)
- 7D bends
- 32mm wall thickness
- Ball Valves
- Barred Tees
- Reduced bore Tees – dia 505mm (83% of OD
- Buckle arrestors 47mm WT
- Internal epoxy coating
- Flow ~ 2.5m/s



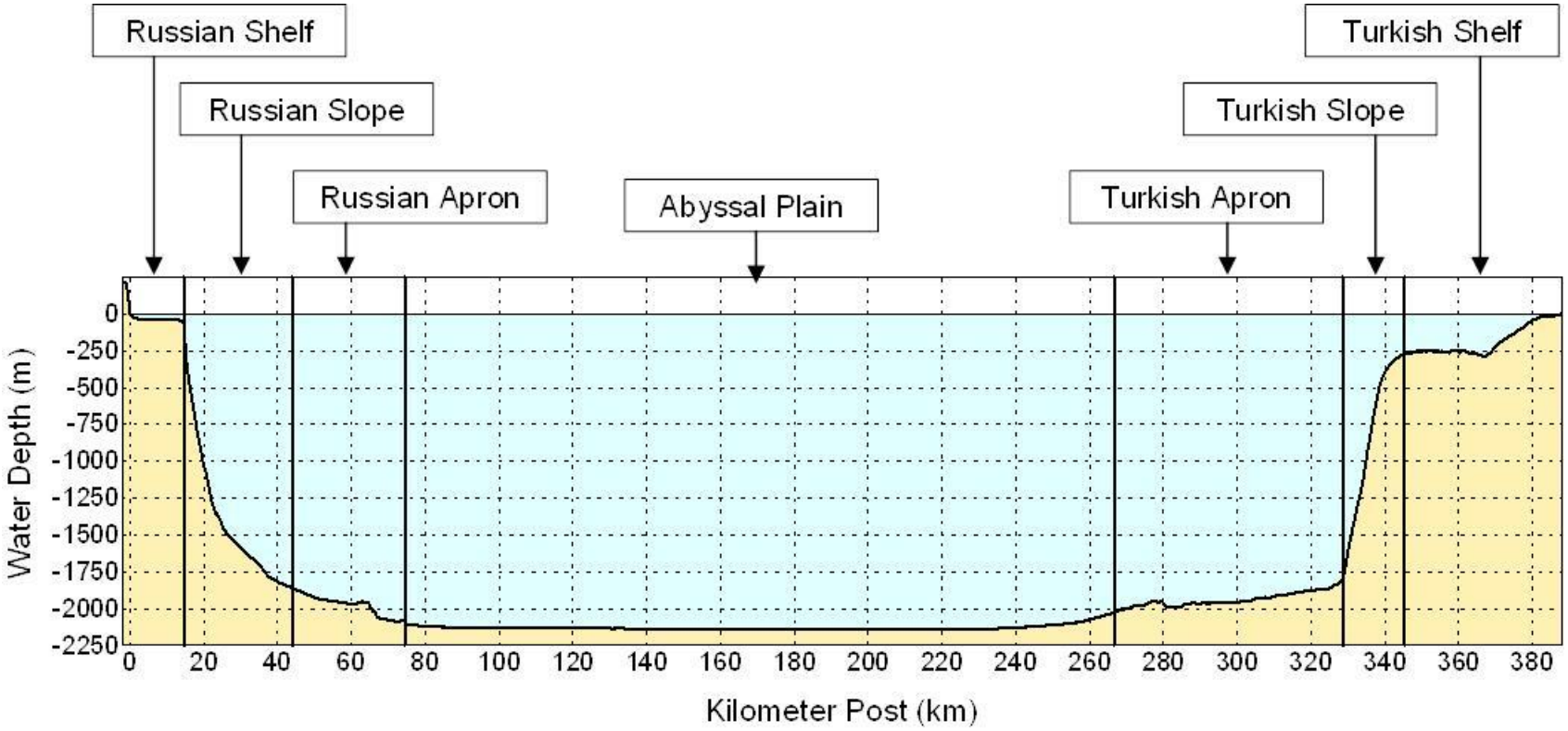
Blue Stream Pipelines Layout

Transportation System

- 2 Lines x 24” – Built 2001
- Overall Length 768 km
- Max Depth 2150 m



Blue Stream Pipelines Profiles



How the Key project issues were addressed

The BSPC Pipeline

Main challenges …

- Wall Thickness of 32mm
- Reduced bore passing – Flow Tee near receive (83% of OD)
- Pressures ~Pipeline Operating Pressure 250bar (Tool Design of 400Bar)

Client concerns …

- NO STUCK TOOLS!
- NO damage to internal coating
- Durability for >385Km

Project Scope of Work

- Cleaning
- Caliper
- Mapping/Strain
- MFL inspection
- Pig RECOVERY TOOL or Rescue Pig

Problem Statement

Snamprogetti S.p.A contracted as Lead Engineers responsible for engineering support for the IM programme by the Blue Stream Pipeline Company (BSPC)

Caliper

- Pressure
  - Pressure vessel integrity
  - Hall Effect sensors
- Data storage range
  - Capacity
- Power range
  - Capacity

Mapping

- Pressure
  - Pressure vessel integrity

Inspection System

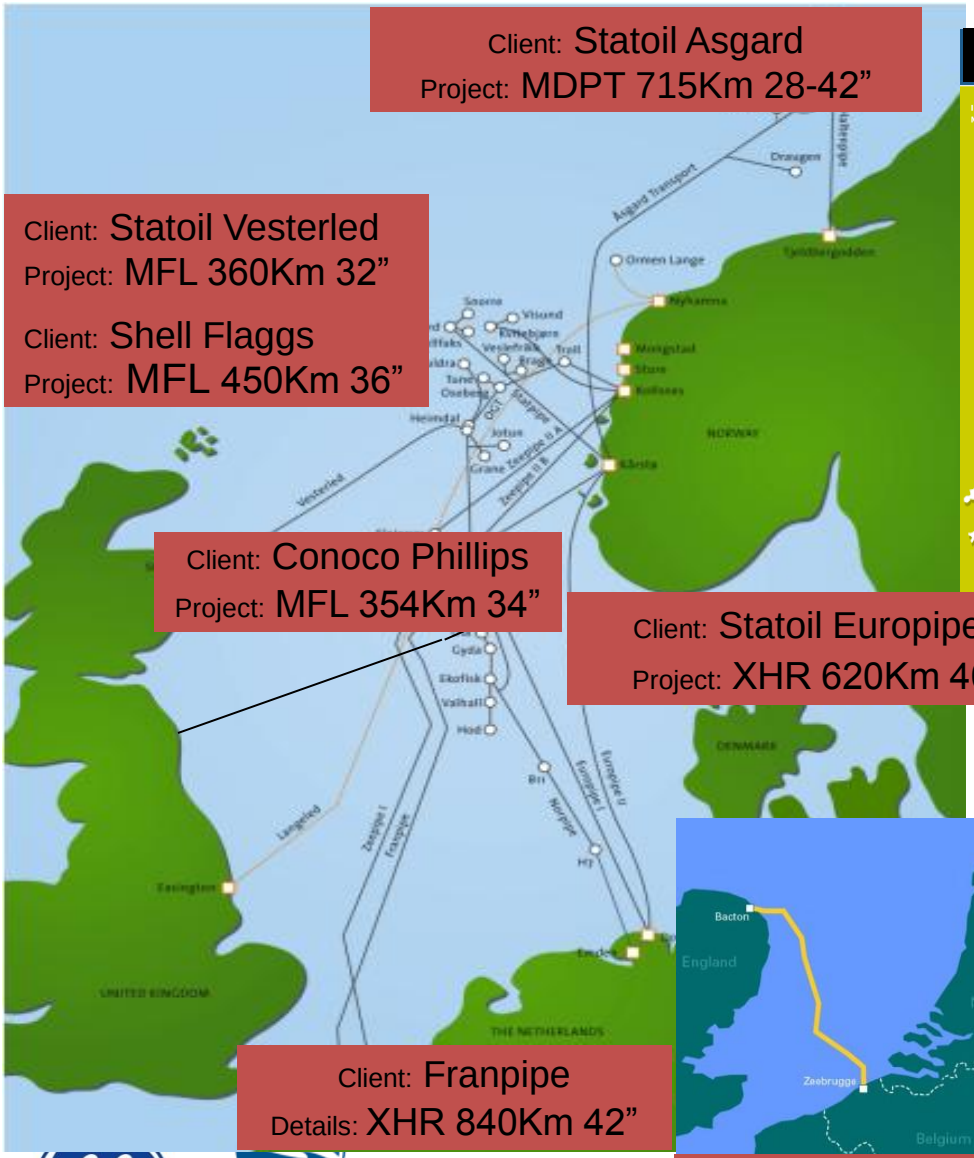
- Pressure
- Wall Thickness
- Buckle arrestors
- Range
- Bore passing
- Flow velocity
- Trap Dimensions

Experience from PII subsea projects.

Client: Statoil Asgard
Project: MDPT 715Km 28-42”

Client: Statoil Vesterled
Project: MFL 360Km 32”

Client: Shell Flaggs
Project: MFL 450Km 36”

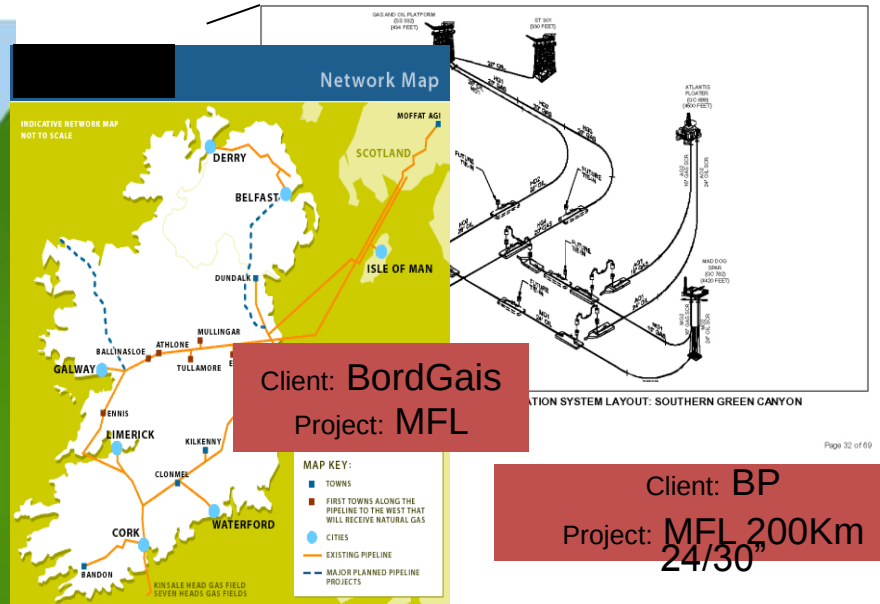


Client: Conoco Phillips
Project: MFL 354Km 34”

Client: Statoil Europipe1
Project: XHR 620Km 40”

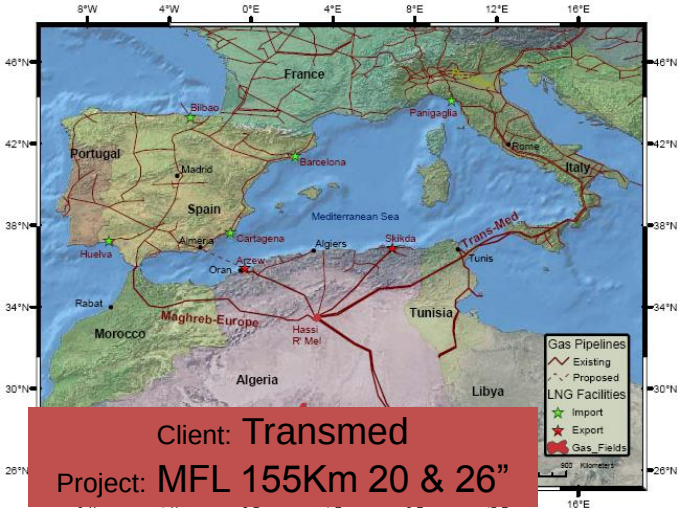
Client: Franpipe
Details: XHR 840Km 42”

Client: Interconnector
Project: MFL 238Km 40”



Client: BordGais
Project: MFL

Client: BP
Project: MFL 200Km 24/30”



Client: Transmed
Project: MFL 155Km 20 & 26”

Al Shaheen

Up Front Feasibility Study

- Identification of all pipeline data, plus any assumptions caused by missing data.
- Identification of proposed solutions
- Identification of predicted inspection specification, to be ratified by testing.
- Identification of pigging resources and any testing requirements.
- Identification of possible cleaning pigs/tools available.
- Suggested pigging methodology/schedule. Site Surveys completed in Russia & Turkey
- Identification of cost/timeline to undertake modifications and testing.
    - Cleaning
    - Geometry & Mapping (Strain or Out of Straightness assessment)
    - MFL Inspection
    - ALL above with Pig Recovery Strategy
- Costs and timescale for the BASELINE & subsequent INSPECTION

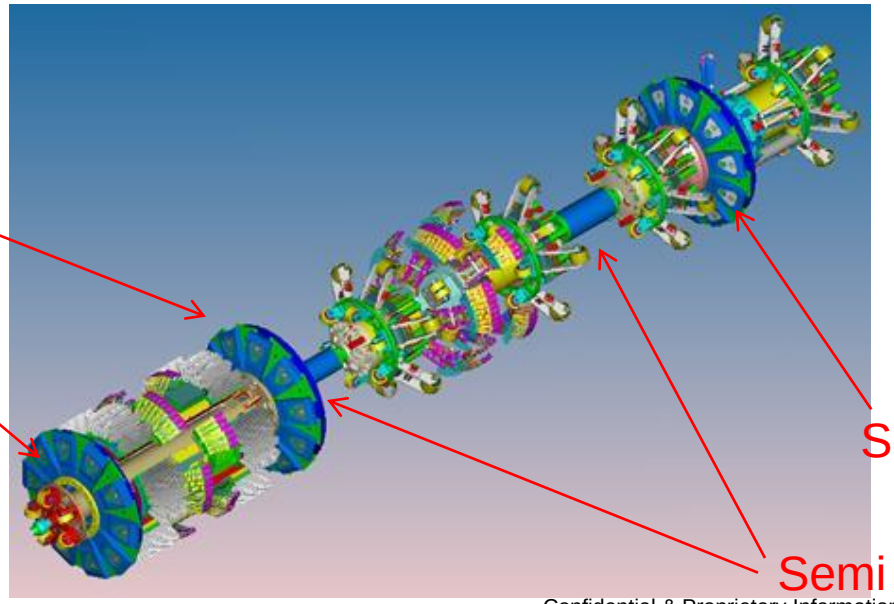
Engineering proof of Challenges

- Drive & Sealing
- CAD simulation and Magnetic Modelling
- Pig Recovery Strategy
- Location & Tracking (New Concern from the site survey)
- Pipeline Pressure
- Design Verification Testing
- Software & Pipeline Sentencing

Milestones with agreed testing criteria at every stage

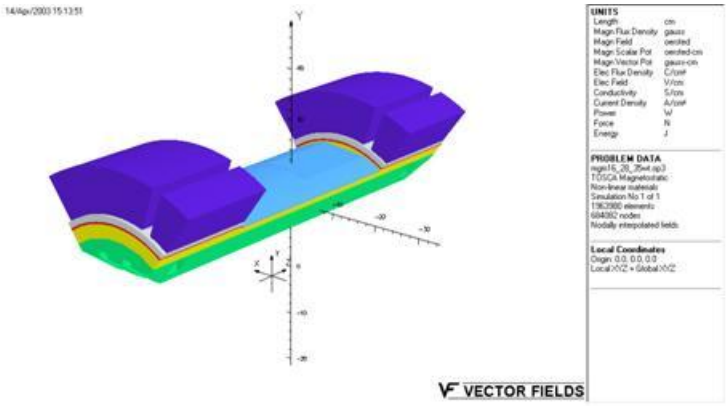
Drive & sealing

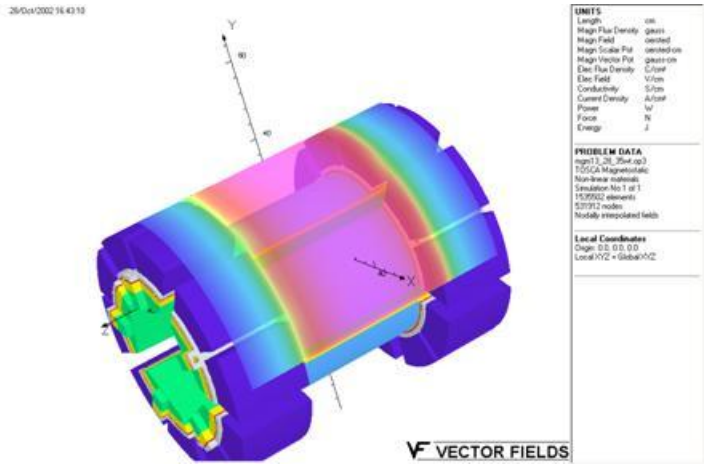
- Bypass & blow over tests required to ensure the multi diameter sealing arrangement is effective is all pipe sizes
- Designed in provision for a secondary drive element behind the MV on the BV to improve Drive Reliability
- Magnetiser locked down in 24” mode to suit BSPC application



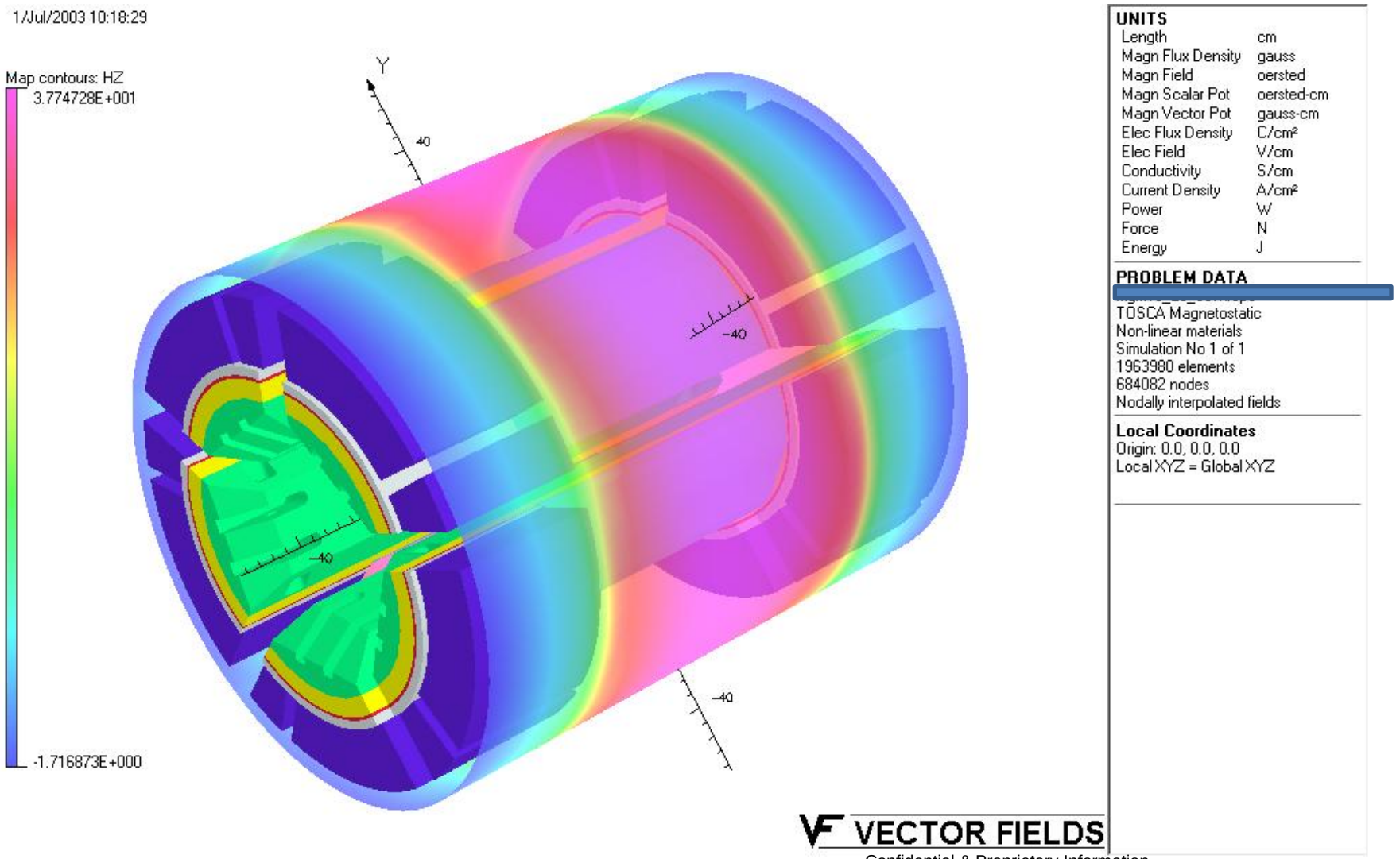
CAD simulation

- Skeleton modelling completed to allow flexible MV - quick change approach modelling & simulation through the bends & Tees
- Magnetic modelling of FLUXBLOCKER return path to optimise magnetic circuit

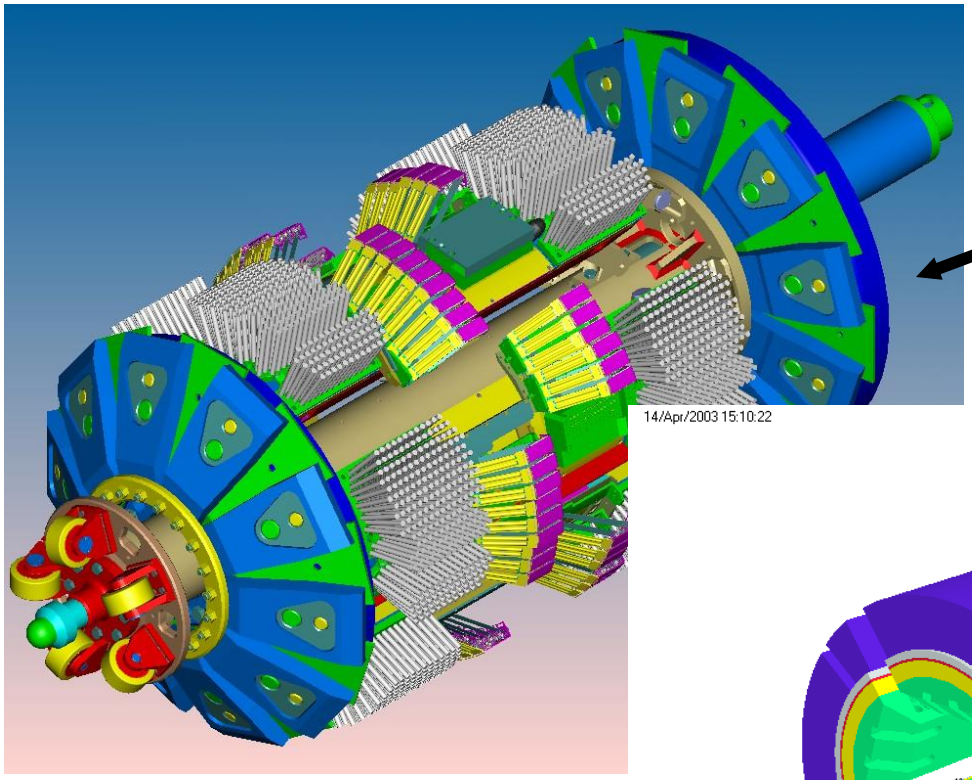




Blue Stream Modelling

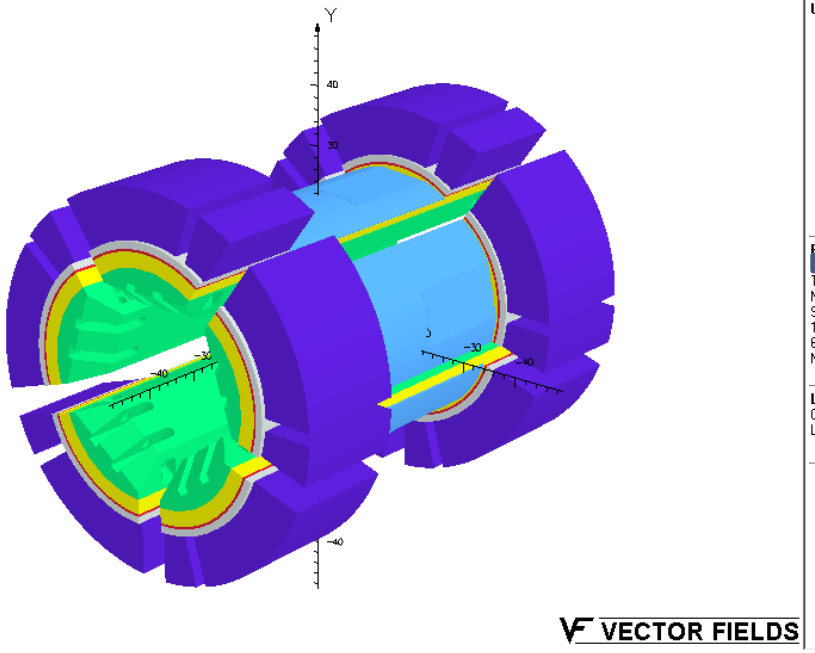


Blue Stream Magnetic Modelling



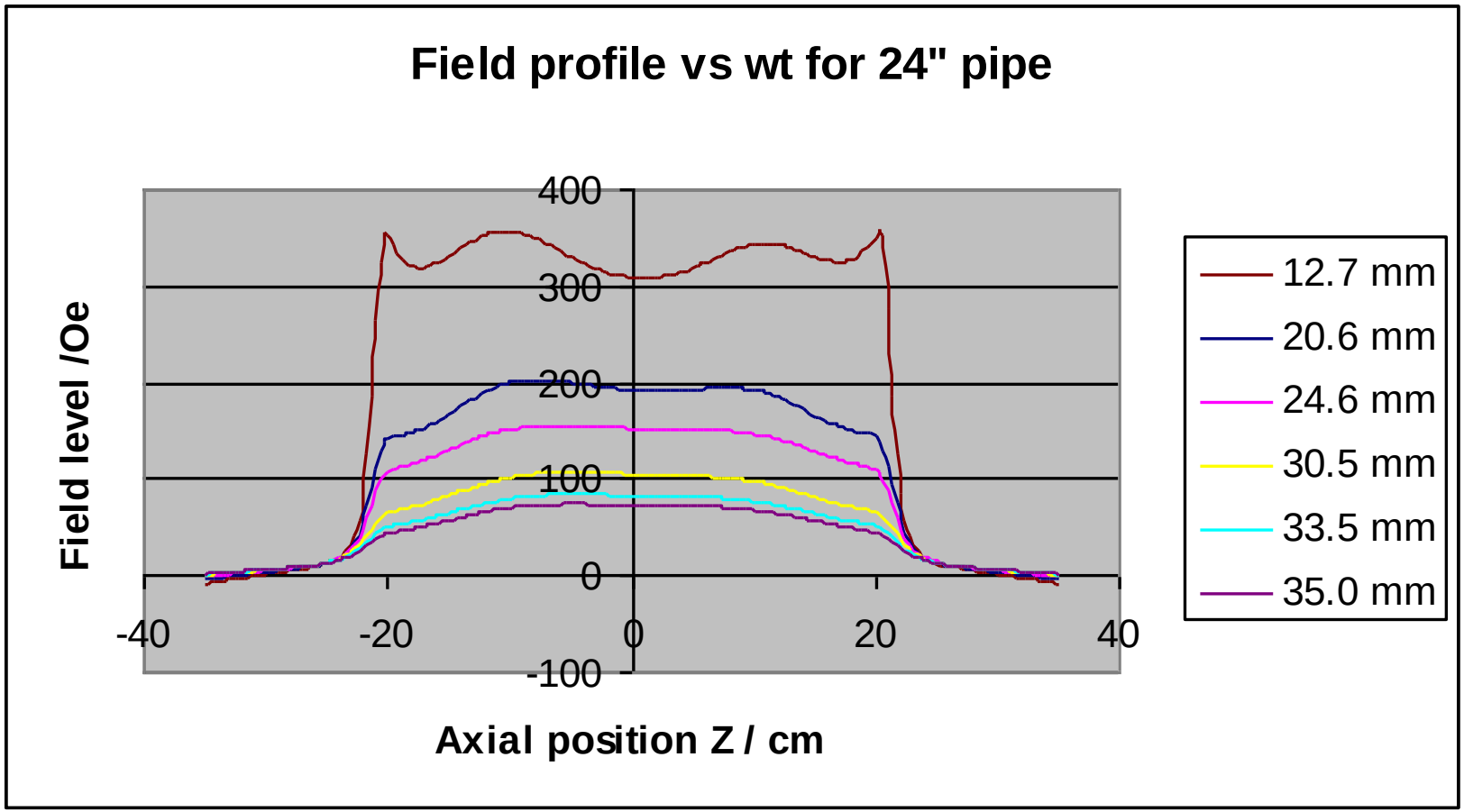
CAD 3D Model of BSPC Magnetic Vehicle

Model prepared for Finite Element meshing and analysis in 24” configuration



Detailed Magnetic Design

Axial Field profile versus Wall Thickness

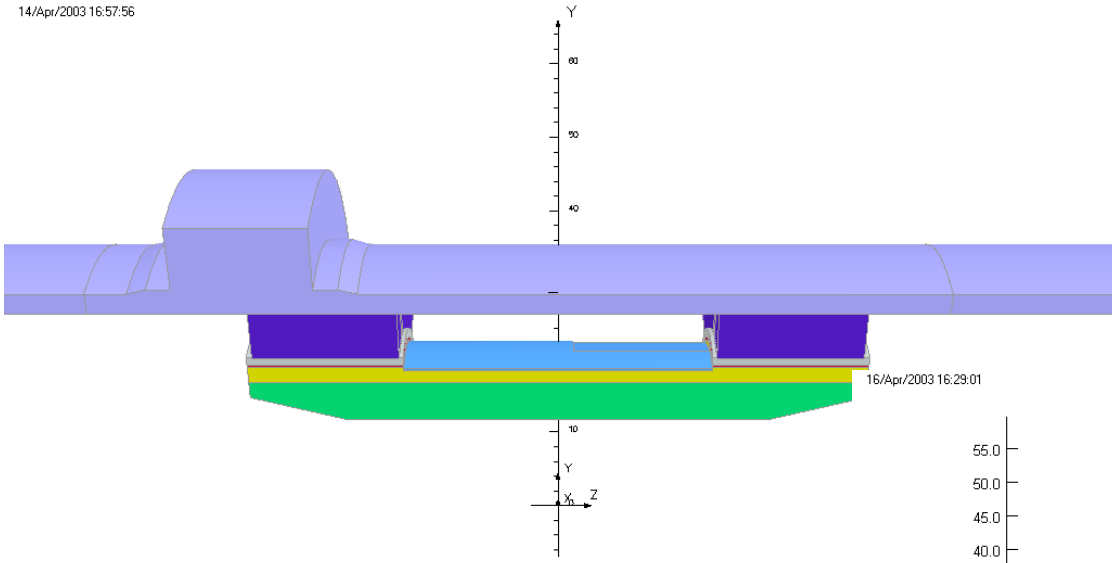


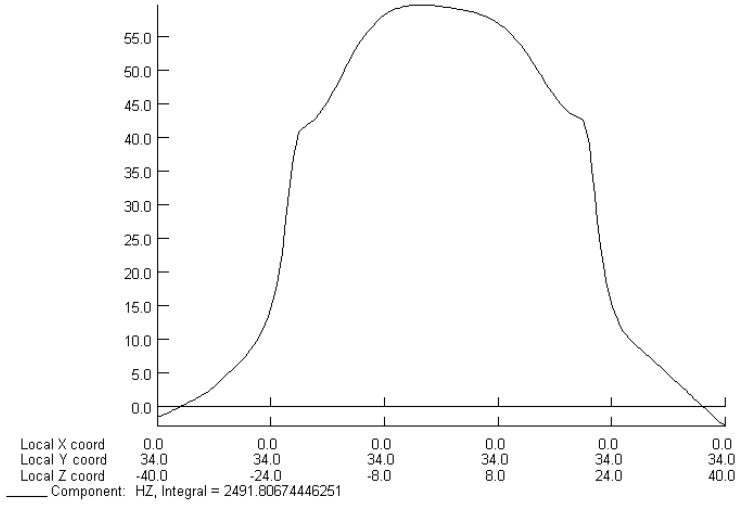
Wall Thickness Capabilities

Pipe Diameter	Predicted Min WT / mm (Inch)	BSPC Min WT / mm (Inch)	Predicted Max WT / mm (Inch)	BSPC Max WT / mm (Inch)
24Inch	13.70 (0.539)	25.4 (1.000)	38.10 (1.500)	32.0 (1.260)
* Pull Throughs required to verify top inspection speed for 32mm thickness inspection and static field measurements				

Test results demonstrated that the Magnetic Circuit was capable of inspecting 32mm WT @ 2m/s

Buckle Arrestor Static Modelling





UNITS

Length	cm
Magn Flux Density	gauss
Magn Field	oersted
Magn Scalar Pot	oersted-cm
Magn Vector Pot	gauss-cm
Elec Flux Density	C/cm²
Elec Field	V/cm
Conductivity	S/cm
Current Density	A/cm²
Power	W
Force	N
Energy	J

PROBLEM DATA

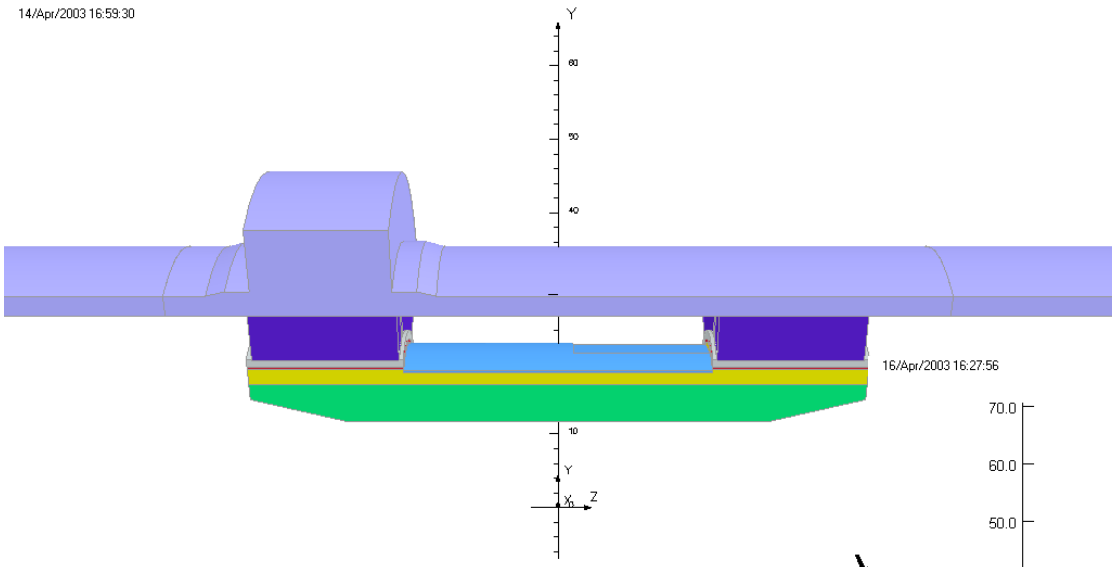
mgm15e_28_30wt_arrestord.op3
TOSCA Magnetostatic
Non-linear materials
Simulation No 1 of 1
3010499 elements
1049480 nodes
Nodally interpolated fields

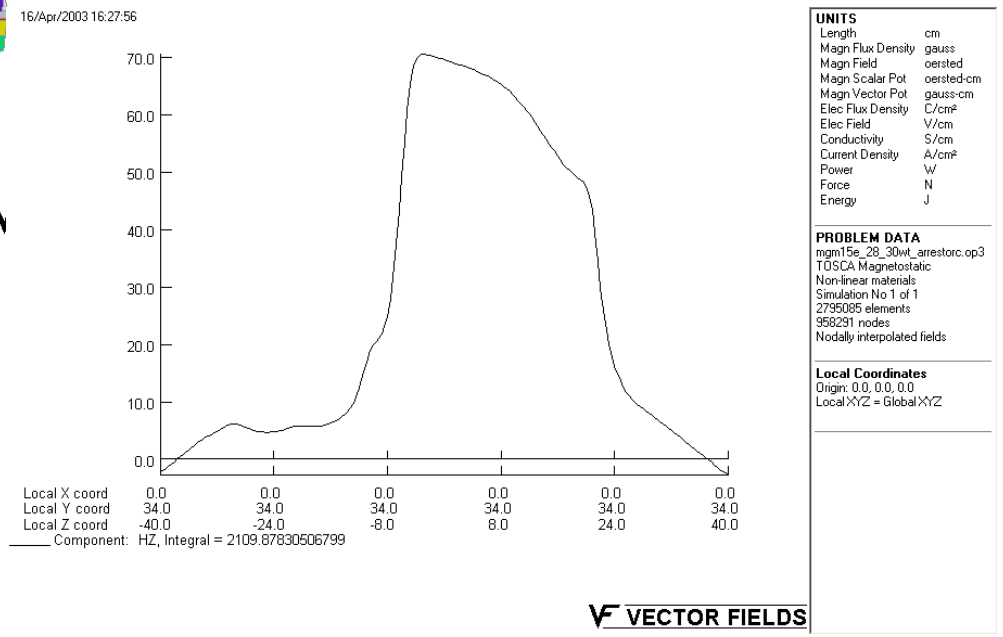
Local Coordinates

Origin: 0.0, 0.0, 0.0
Local XYZ = Global XYZ

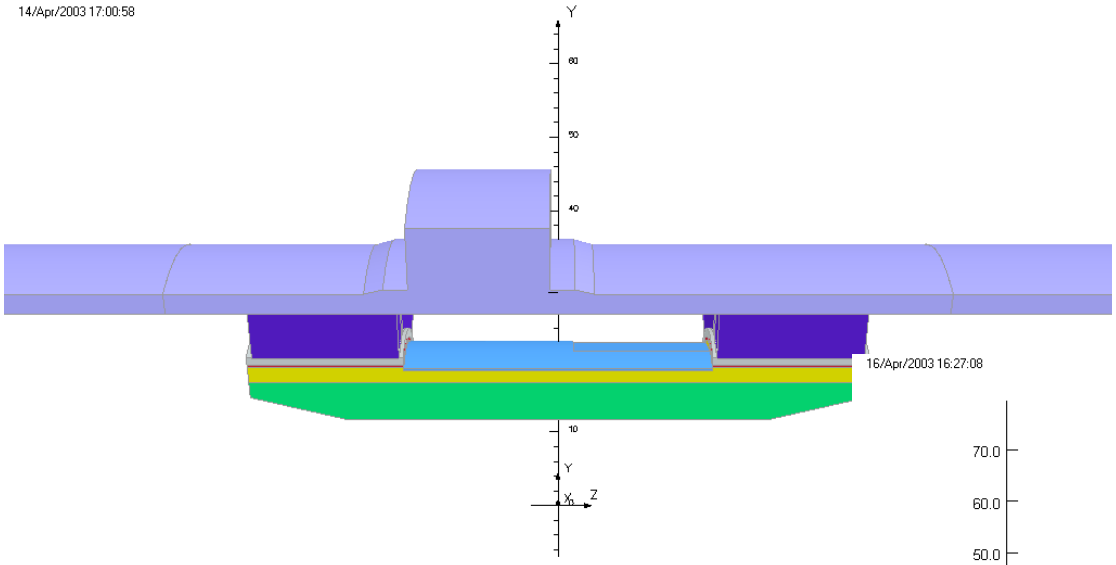
VECTOR FIELDS

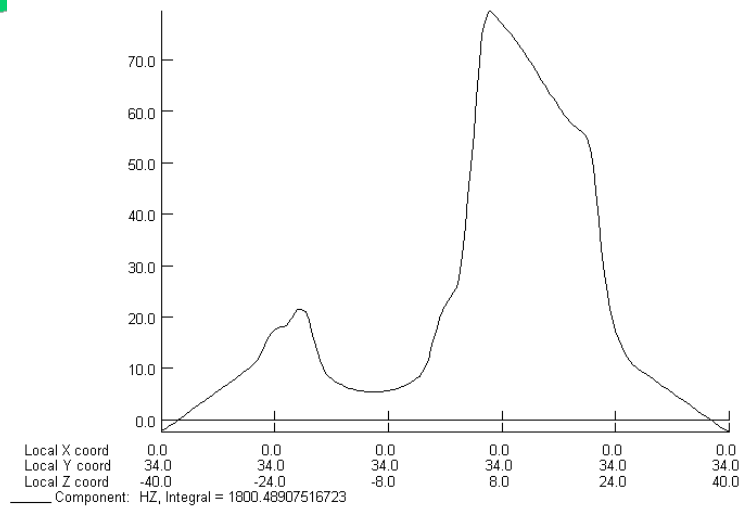
Buckle Arrestor Static Modelling





Buckle Arrestor Static Modelling





UNITS

Length	cm
Magn Flux Density	gauss
Magn Field	oersted
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Elec Flux Density	C/cm²
Elec Field	V/cm
Conductivity	S/cm
Current Density	A/cm²
Power	W
Force	N
Energy	J

PROBLEM DATA

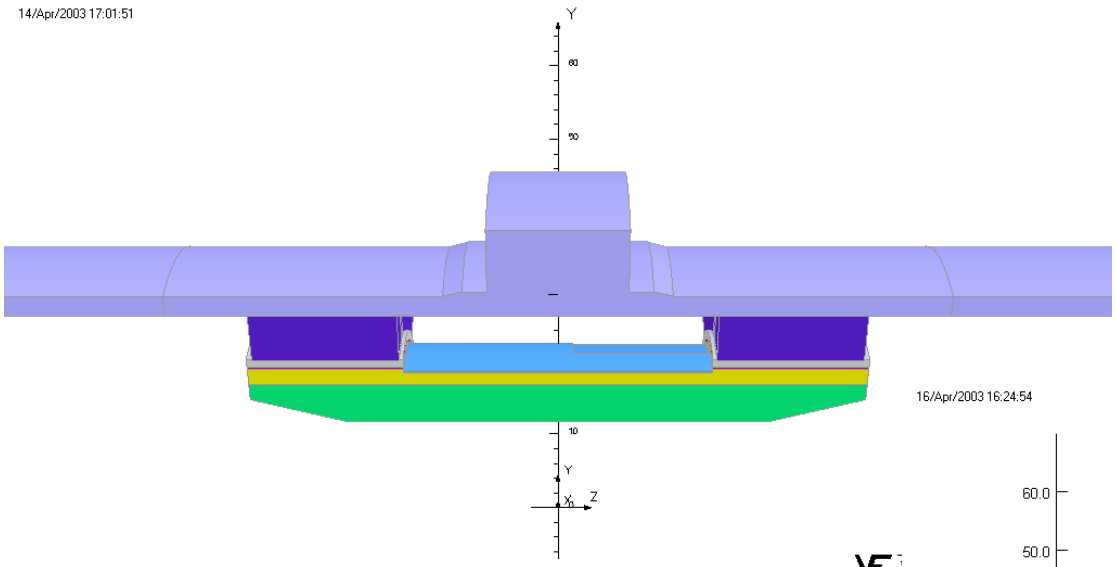
mgm15e_28_30wt_arrestorb.op3
TOSCA Magnetostatic
Non-linear materials
Simulation No 1 of 1
2785565 elements
959017 nodes
Nodally interpolated fields

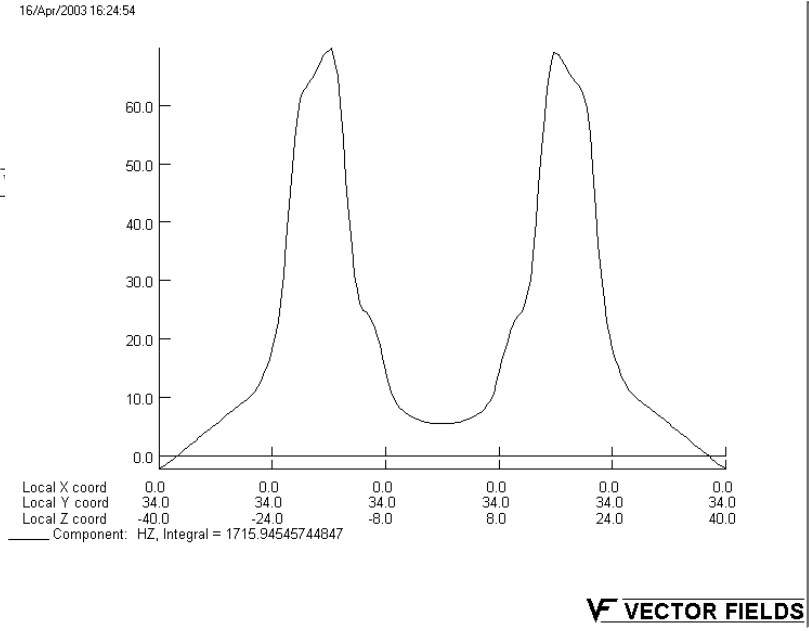
Local Coordinates

Origin: 0.0, 0.0, 0.0
Local XYZ = Global XYZ

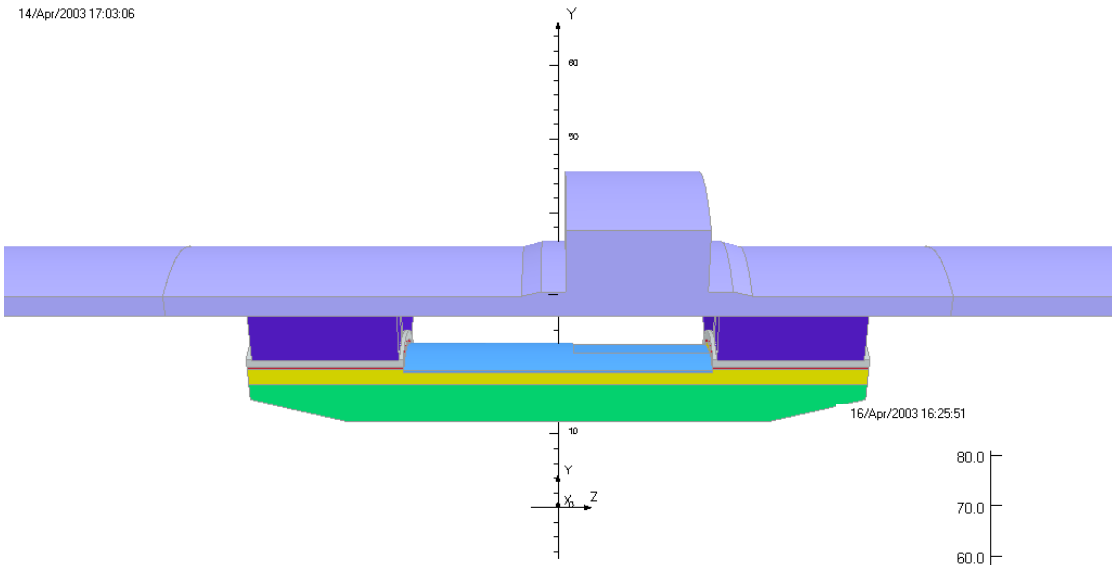
VECTOR FIELDS

Buckle Arrestor Static Modelling

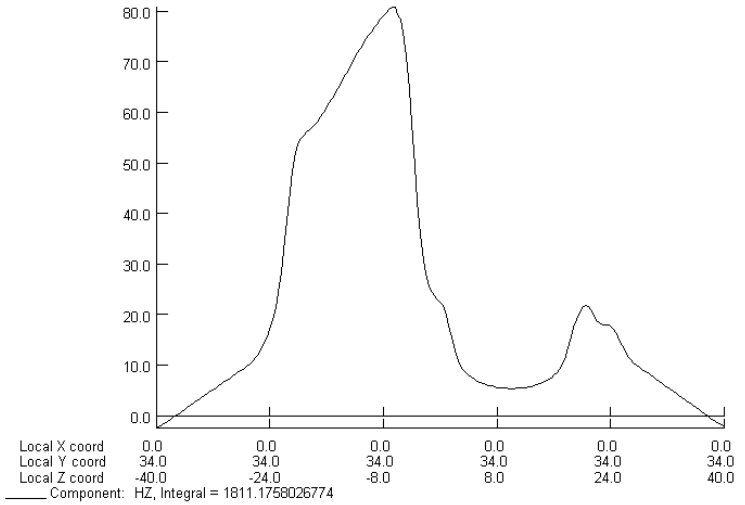




Buckle Arrestor Static Modelling



- Field level drops significantly in region of Buckle Arrestors
- Inspection not possible
- But … plan is to model and investigate as part of the project



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Power	W
Force	N
Energy	J

PROBLEM DATA

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TOSCA Magnetostatic
Non-linear materials
Simulation No 1 of 1
2782043 elements
957918 nodes
Nodally interpolated fields

Local Coordinates

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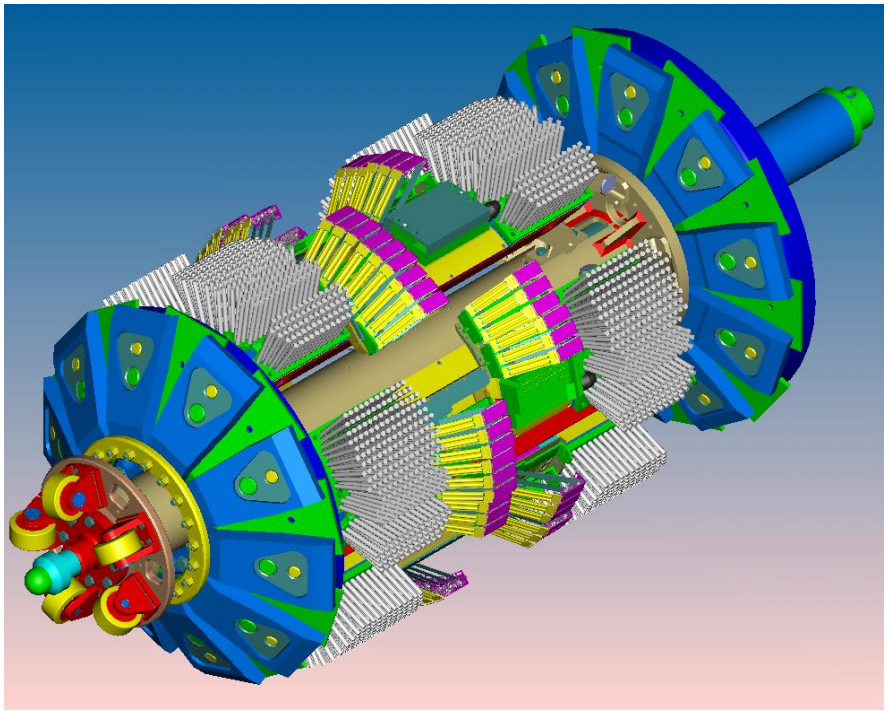
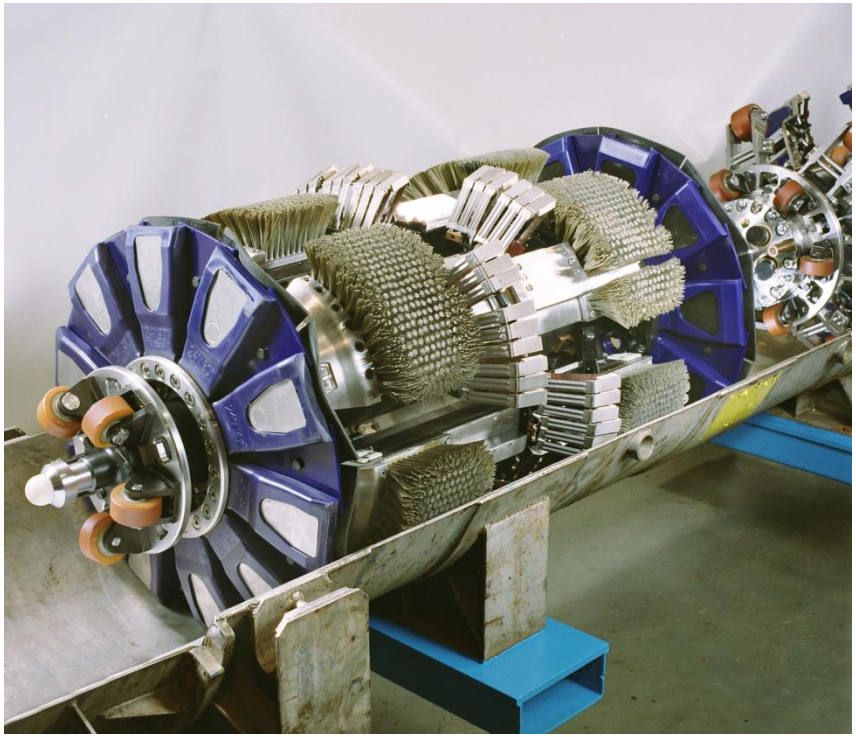
Local XYZ = Global XYZ

VECTOR FIELDS

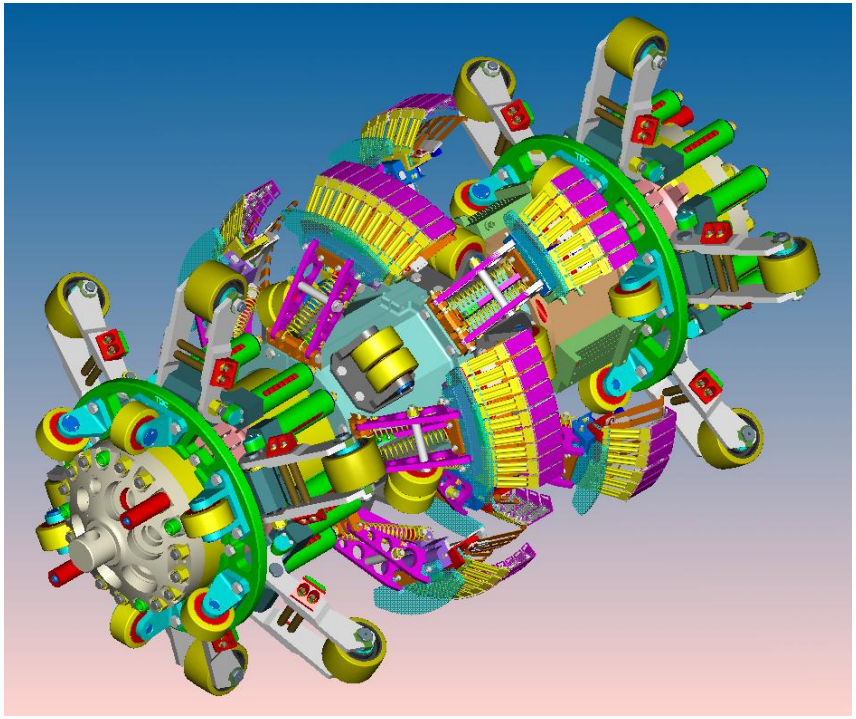
BSPC 24”Magnetic Vehicle

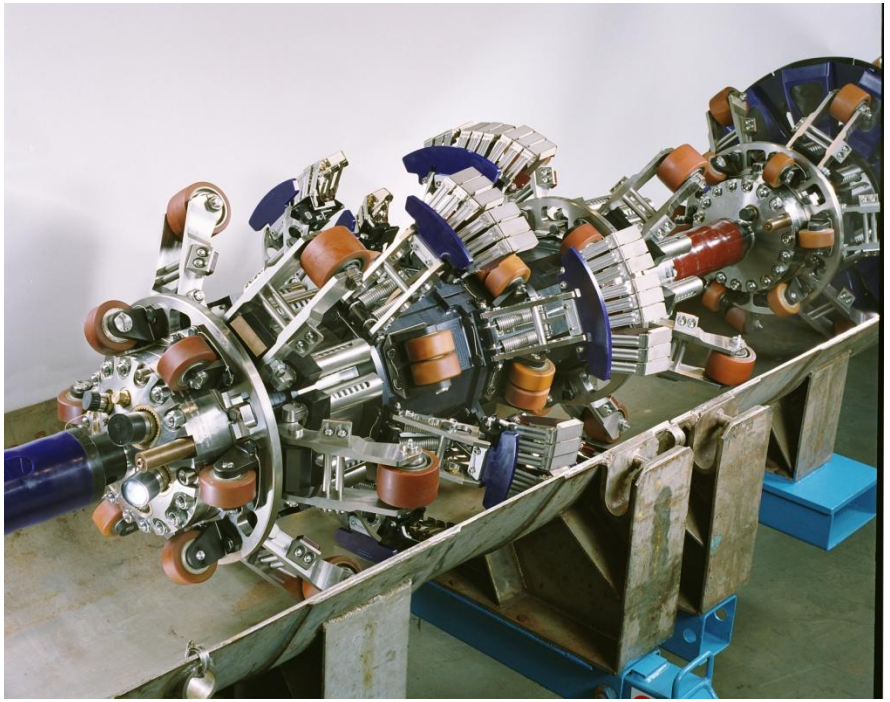




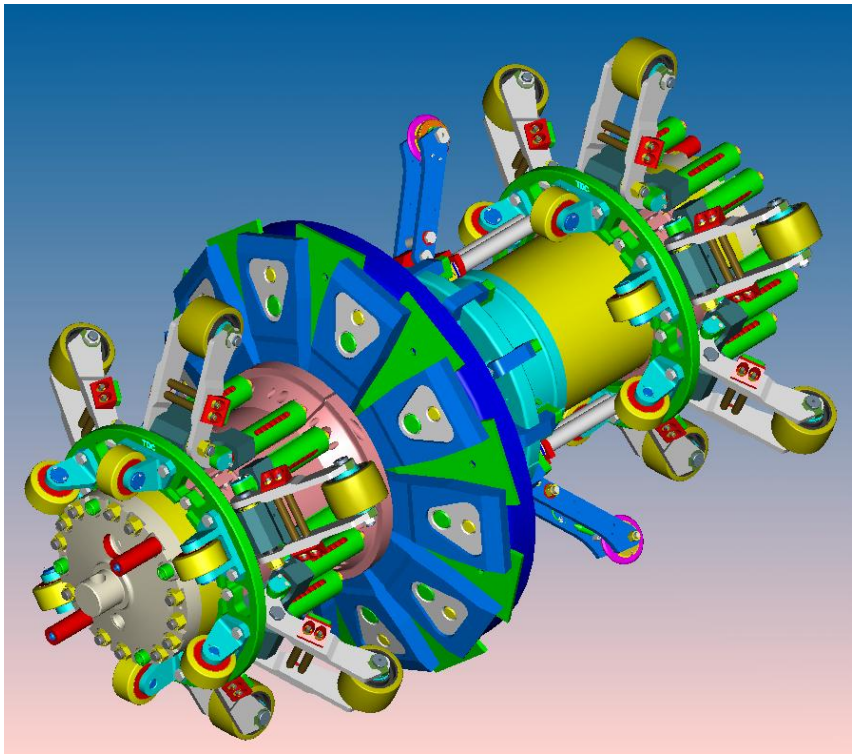
Design to Build…
Dual Diameter drive flaps
Strongest Commercial magnets

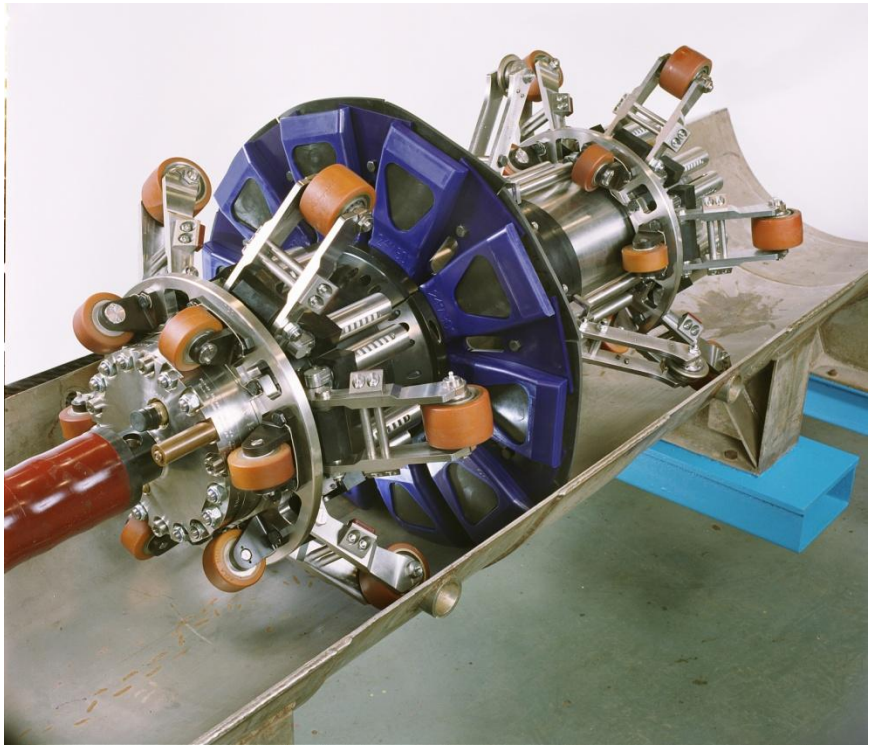
BSPC Instrument Vehicle Tool





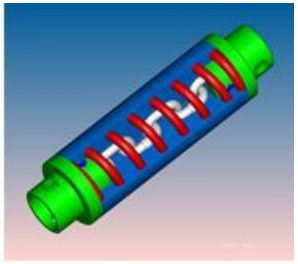
Battery Vehicle

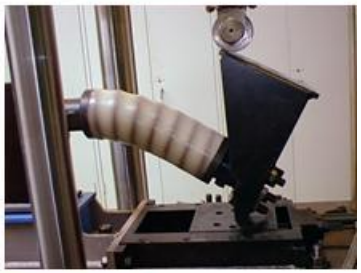


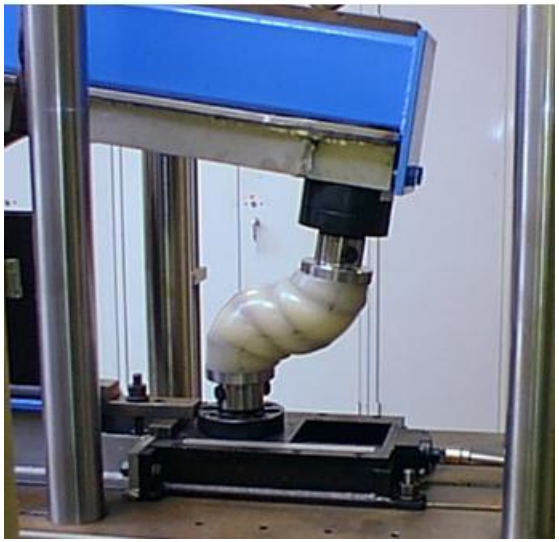


Pig recovery strategy

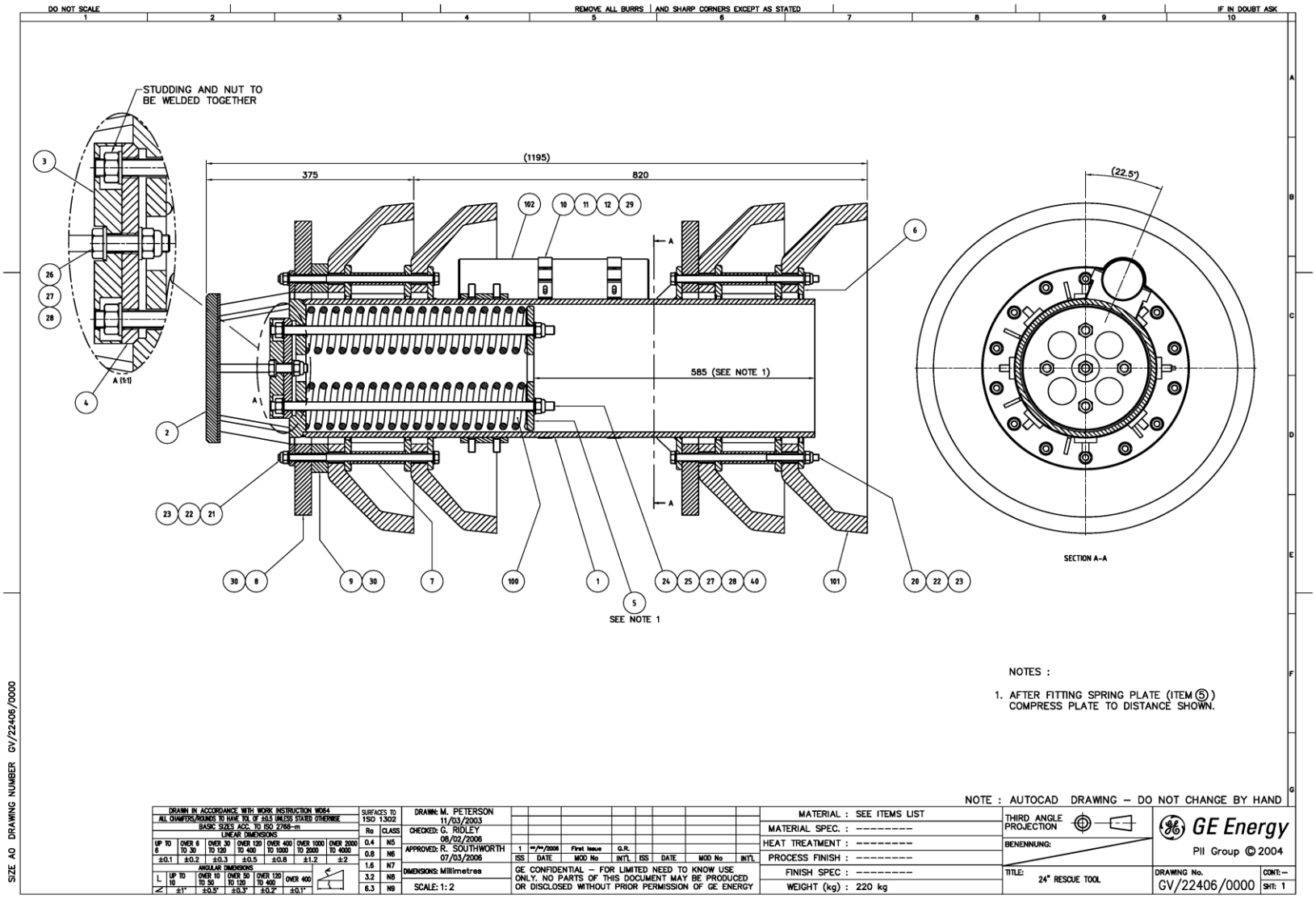
- Semi rigid towbars designed & developed to ensure that the 3rd module (rearmost) in the train could push the high drag MV through the bore reduction or in the unlikely event the main drive elements failed
- Provision to be able to drive the tool from the rear with a Recovery Pig should the main drive elements fail – **CRITICAL for successful pig recovery**







Rescue Pig

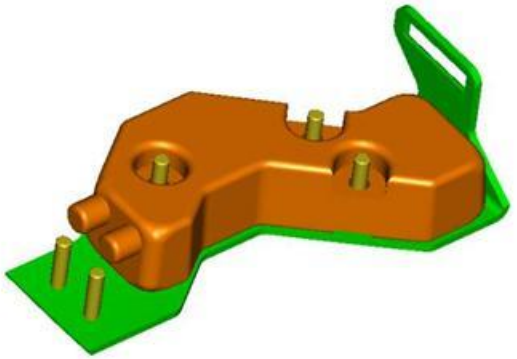


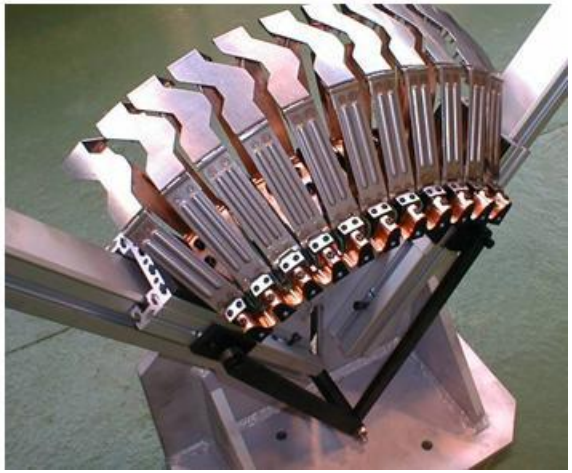
Location & Tracking

- Electromagnetic Transmitter (22Hz) fitted to the tool as standard
- Magnetic sensitive timer boxes used at strategic positions on the ONSHORE pipeline sections
- Acoustic monitors fitted to both the Launch & Receive sites to enable tracking of the pig position

Pipeline Pressure 250bar

- External harnesses & sensors tested to extremes of pressures & tested & rated to 400 Bar
- Overlapping sensors to optimise the sensor spacing in the various bores
- Magnetic modelling and simulation to ensure overlapping sensors (Circumferential & Axial) were optimised for the magnetic profile





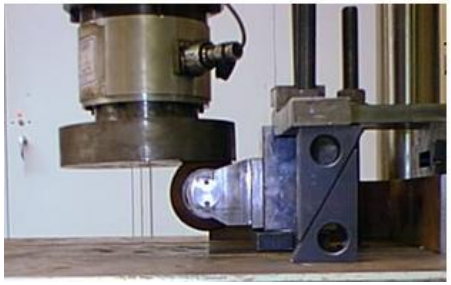
Design Verification Testing

Component & Sub Assembly Testing

- Pump through tests done to successfully demonstrate passage through simulated bore fitting
  - Would have been better performed with an actual flow tee but the mock ups were essential that these tests were done in advance of mobilising
  - Palladin Dock facility used for pump throughs
- Pressure & temperature tests completed on new sensor arrangements
- Sensor dynamics testing
  - Vibration

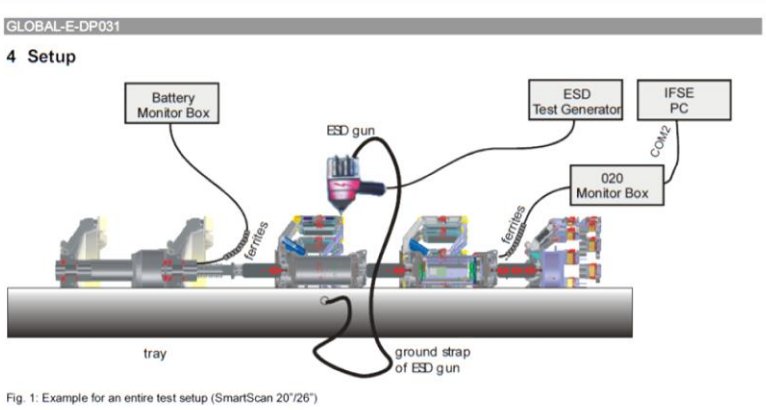


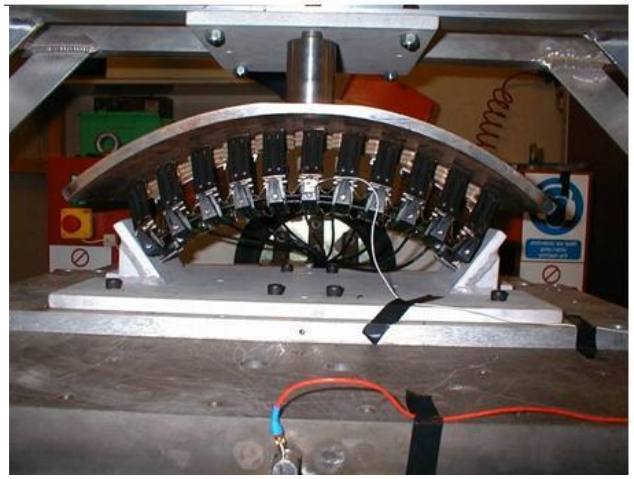





Reliability Testing

- Pressure testing of sensors and external electronics to ensure suitability
- Vibration & Bump
- Temperature
- ESD* 18Kv

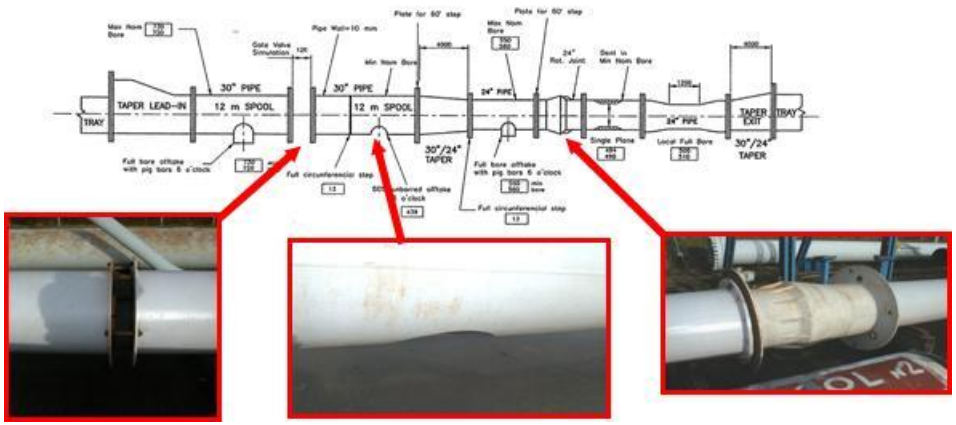




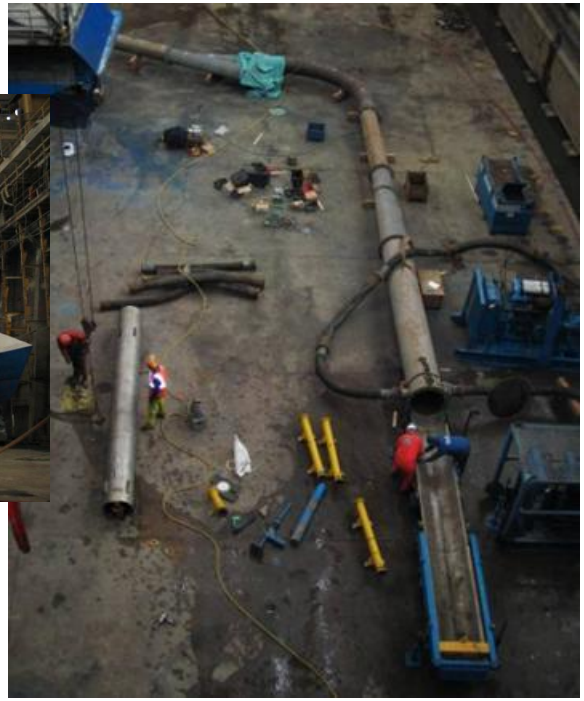
System Testing

Testing

- Initial testing done at PII
- FULL SCALE Testing using actual pipeline fittings
- Reliability Testing

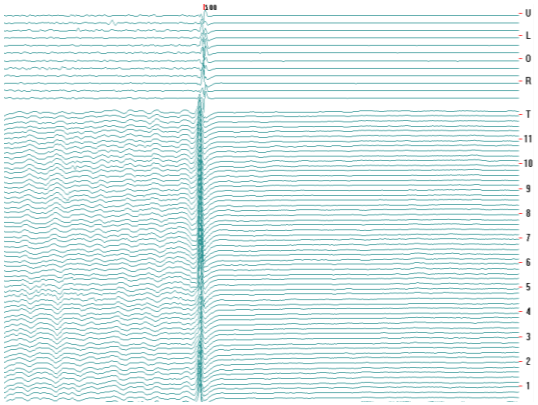


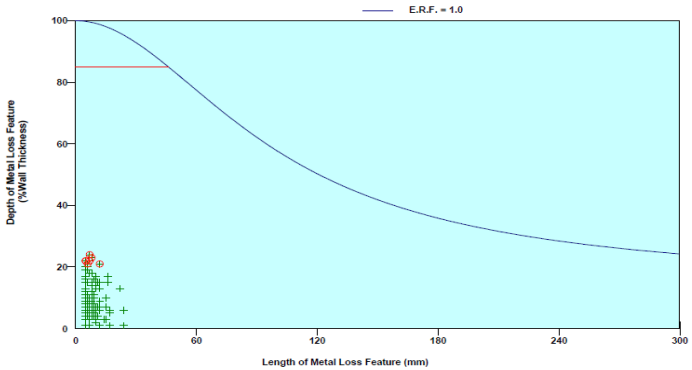
[Video]



Software & Pipeline Sentencing

- Dynamic sentencing, due to the varying forces on the pipeline.
- Internal Gas Pressure
- External Water Pressure
- Software & Calculations agreed with BSPC & Snamprogetti





Project Summary

- The two pipelines were successfully inspected & reported to BSPC
  - Tracking method using acoustic monitoring at Launch and Receive sites proved successful
    - Tools received on time as predicted
      - Credit to Saipem (Technical Project Consultants) for computation of run times
  - Recovery Pig was not required due to the successful running of the other tools
- Lessons Learnt - Licences, Permits, Import & Export time and complexity
- Setbacks - ESD, Sensor & MV Design
- Milestone & Feasibility/Engineering Proof Stages
- Project was successful, credit to the openness & cooperative approach by BSPC & their partners.

References & Many Thanks :

Massimo Volipini, Technical Manager BSPC

Claudio Monda, Project Manager SCS

Bill Herron Chief Engineer GE PII Pipeline Solutions