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PROVIDING RELIABILITY OF TRUNK GAS PIPELINES OPERATION ON THE BASIS OF IN-LINE INSPECTION RESULTS

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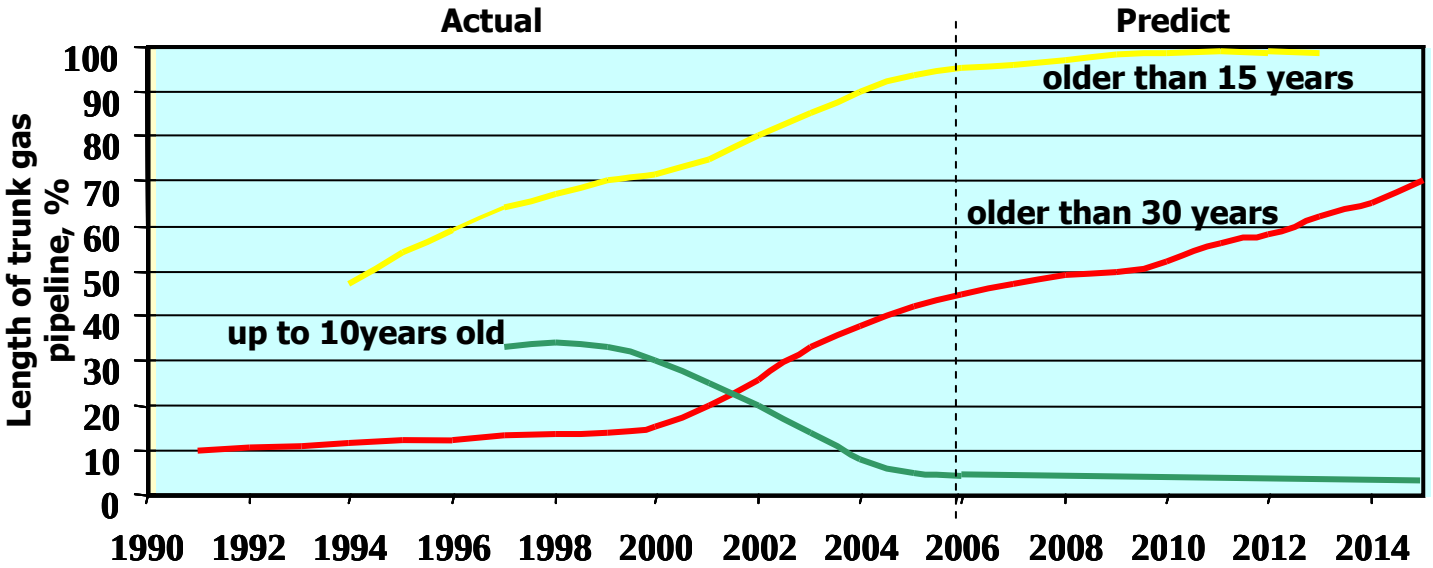
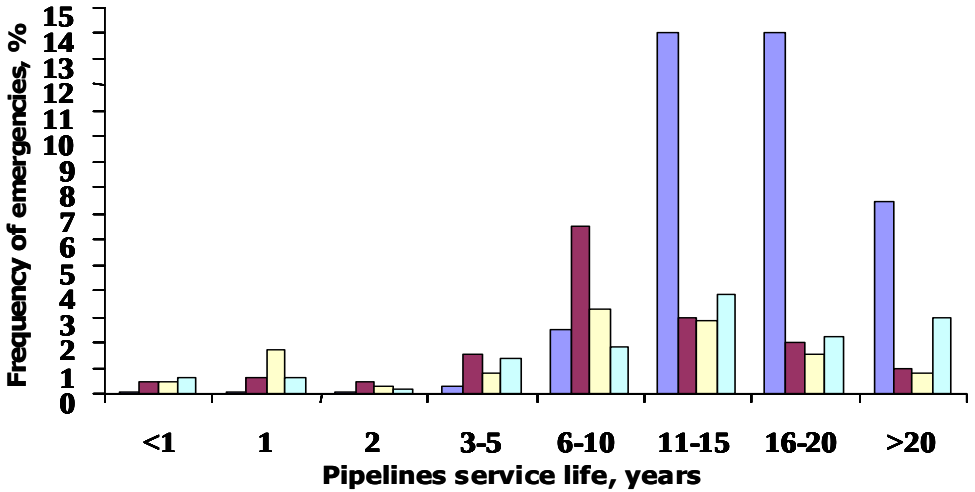
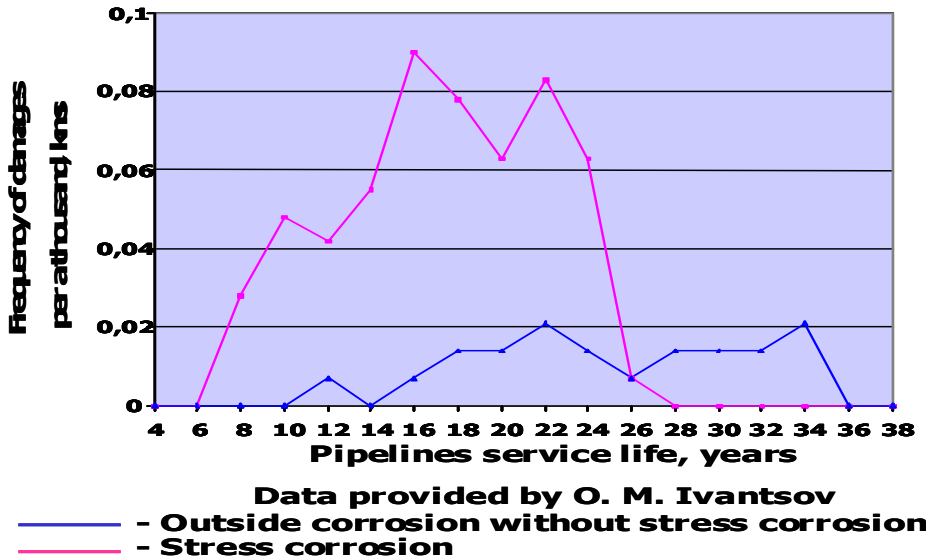
DYNAMICS OF AGEING & EMERGENCIES OF TRUNK GAS PIPELINE SYSTEM

Mean age of trunk gas pipelines



Frequency of emergencies of trunk gas pipelines depending on their service life

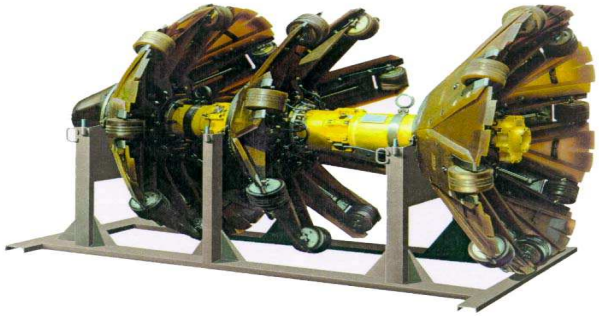


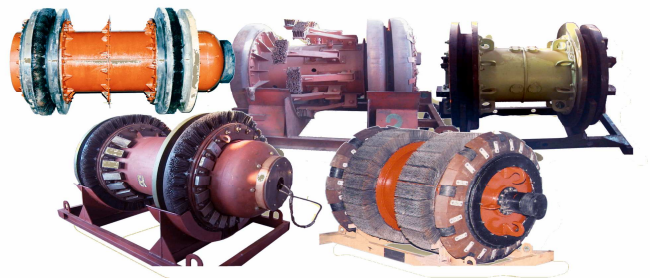


COMPLETE SET OF IN-LINE INSPECTION TOOLS FOR TRUNK GAS & OIL PIPELINES DIAMETERS FROM 20” TO 56“

Gauge cleaning pigs,
Rough and fine cleaning pigs
Magnetic cleaning pigs

- *Checkup of pipeline inner passage (gauging)*
- *Efficient inner cleaning of polluted pipelines*
- *Efficient inner cleaning of finely dispersed debris*
- *Removal of ferromagnetic sediments*
- *Magnetizing pipe metal for magnetic ILI*





Electronic caliper logging tools of “PRT” type

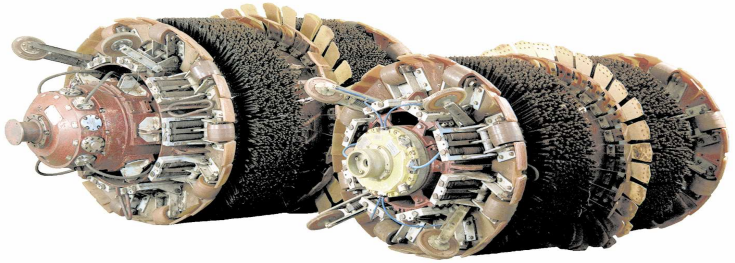
- *Checkup of pipeline geometry*
- *Positioning of pipe imperfections & pipeline geometry defects (ovalities, gouges, dents) with assessment of their sizes*

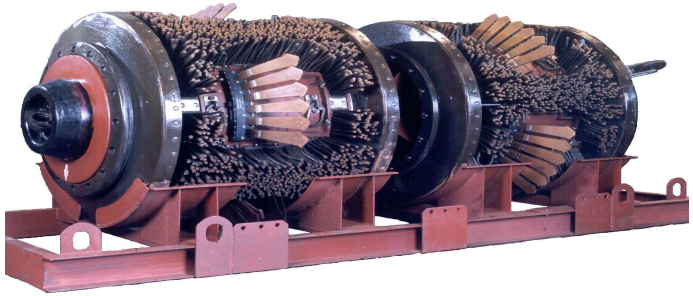
Maximum speed: 7 m/s
Minimum passage bore:0.7 DN
Minimum pipeline bend radius: 1.5 DN
Maximum section length per run: 250 km

High resolution MFL tools

- *Detection, identification & sizing of general & pitting corrosion defects, transverse cracks, mechanical damages, girth weld defects, other circumferential pipe wall defects.*

Maximum run speed: 4 m/s
Minimum passage bore: 0.85 DN
Minimum bend radius: 2.5 DN
Maximum pressure: 12 MPa
Maximum section length per run: 250 km





High resolution TFI tools

- *Detection, identification & sizing of longitudinal cracks, including stress-corrosion cracks, defects of longitudinal weld seams & other longitudinal pipe wall defects.*

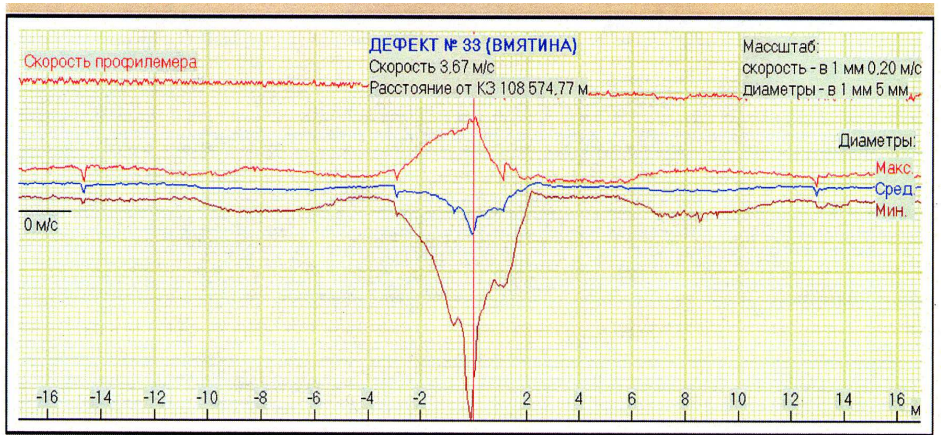
Maximum run speed: 4 m/s
Minimum passage bore: 0.90 DN
Minimum bend radius: 2.5 DN
Maximum pressure: 12 MPa
Maximum section length per run: 250 km

ELECTRONIC IN-LINE PROFILE TOOL

Operation principle: measurement of pipeline inner diameter by rollers on lever supports.
Diameter: from 20” to 56”.
Sensitivity of pipeline profile measurement: 1 mm.
Detectable pipeline features:

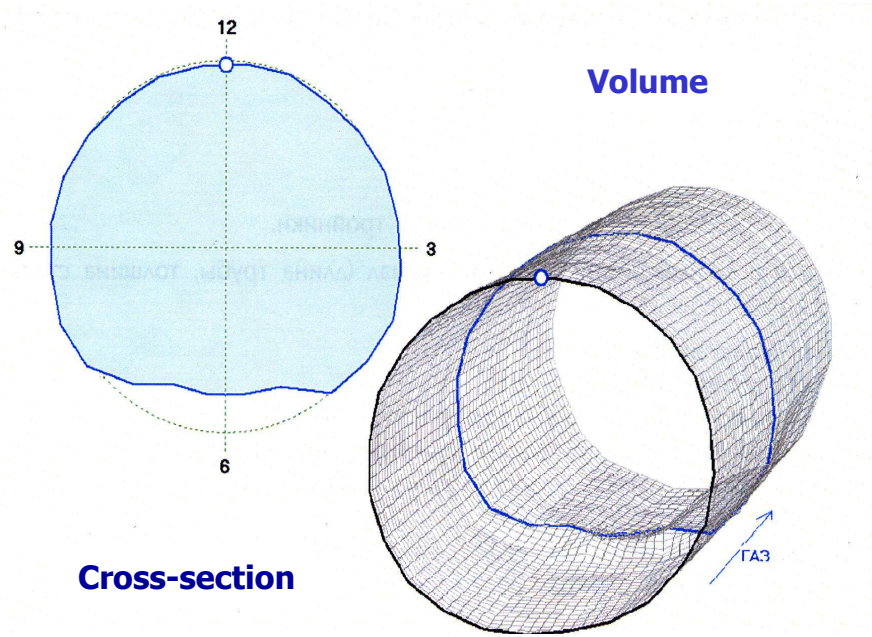
- Dents
- Gouges
- Ovalities
- Pipeline design elements: valves, outlets, tees.

Software

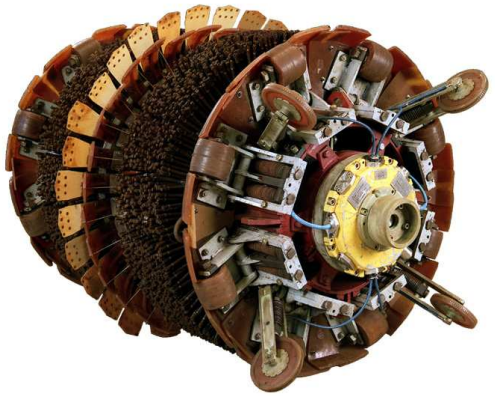


PARAMETERS OF DEFECT NO.33 (DENT)

•Distance from launcher	108574.77 m
•Tie-up to reference points	M39+1580.81/M40-2948.11m
•Maximum deviation from nominal diameter	157 mm
•Length	3.7 m
•Width	726 mm
•Position of defect in pipe circumference	5.5 hrs



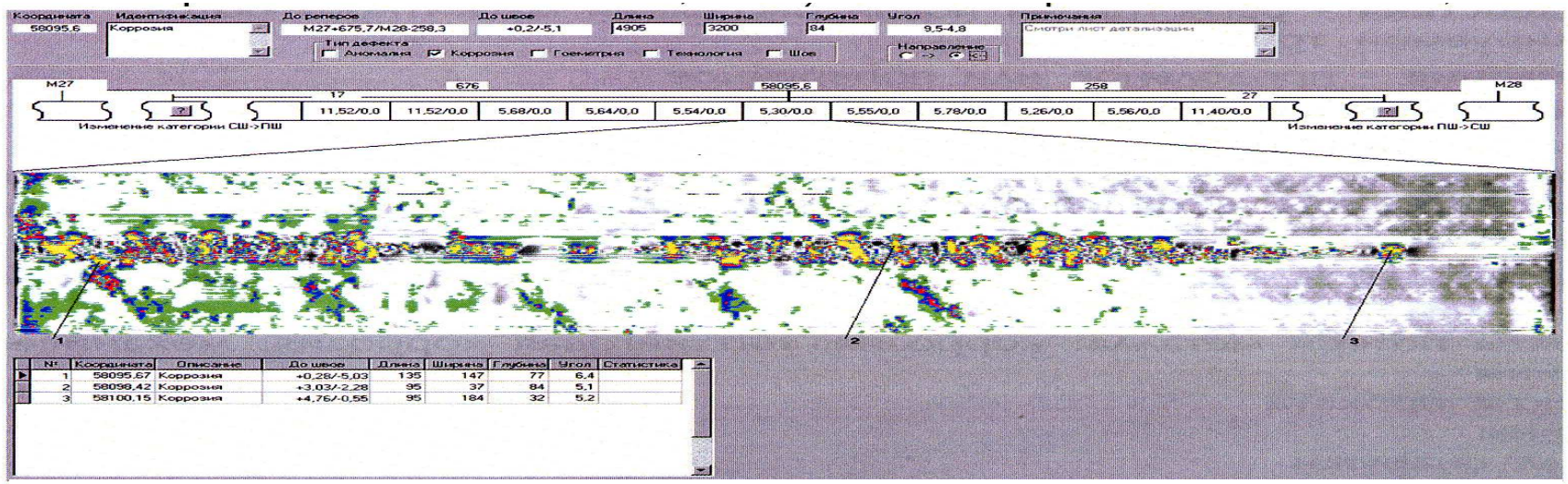
MFL IN-LINE INSPECTION TOOL OF "DMT" TYPE

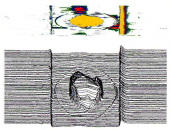


Technical specifications:

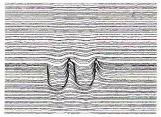
Diameter: from 20" to 56".
Maximum run speed: 5 m/sec.,
Optimum run speed: 2 – 3 m/sec.
Maximum length of inspected section per one run: 250 km
Maximum passage bore: 0.85D
Minimum curvature radius: 2.5 DN
Maximum pressure: 12 MPa
Transported products: gas, oil, water, etc.
Continuous operation period: 100 hours.

Software

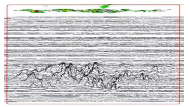




Tee



Installed marker



Corrosion caverns

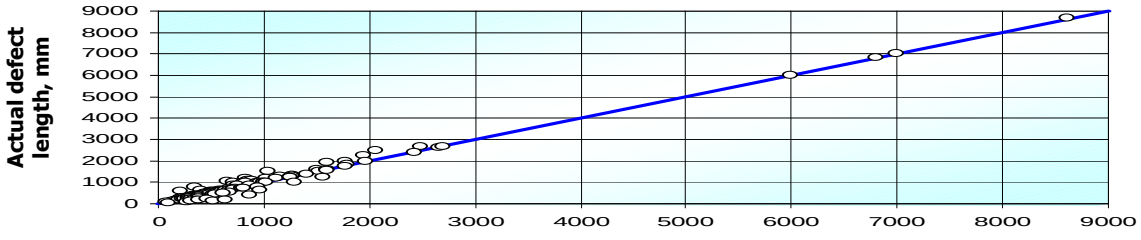
TFI IN-LINE INSPECTION TOOL OF "DMTP" TYPE

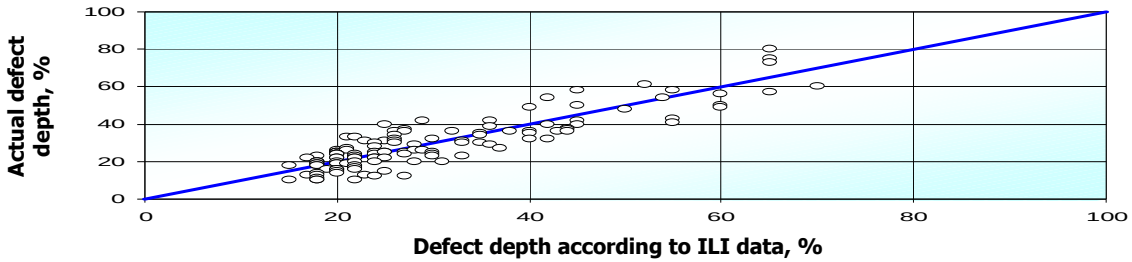
Technical specifications:

Diameter: from 20" to 56".
Maximum run speed: 5 m/sec.,
Optimum run speed: 2 – 3 m/sec.
Maximum length of inspected section per one run: 250 km
Maximum passage bore: 0.85D
Minimum curvature radius: 2.5 DN
Maximum pressure: 12 MPa
Transported products: gas, oil, water, etc.
Continuous operation period: 100 hours.

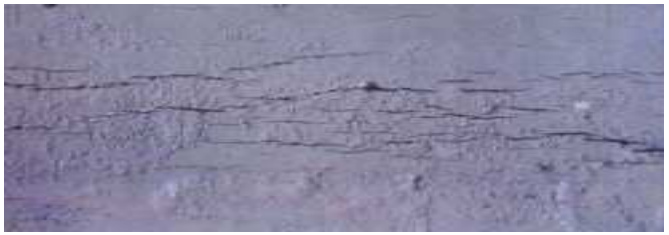
Software

Reliability of ILI results



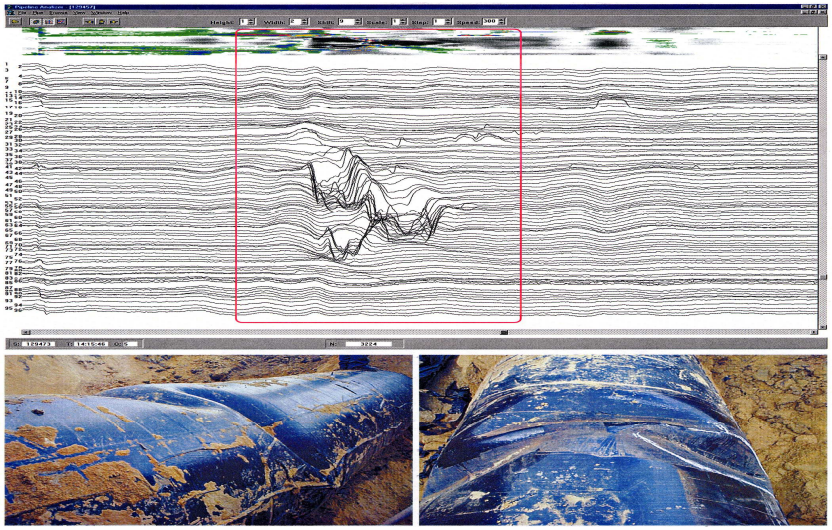


Samples of detected cracks

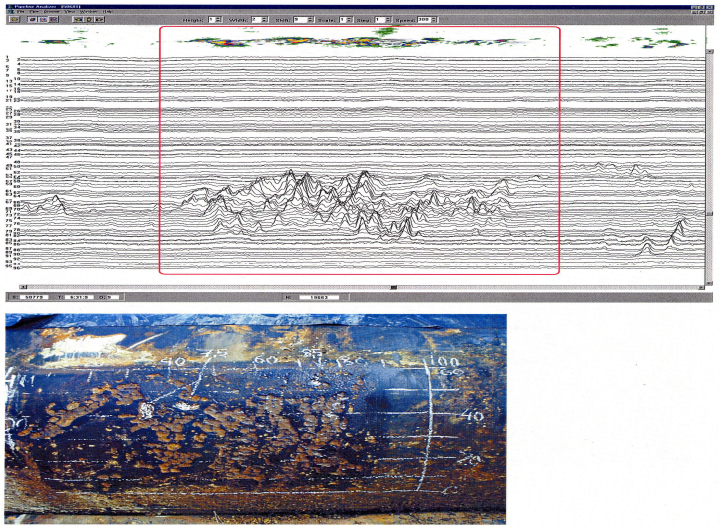


IDENTIFICATION OF PIPELINE DEFECTS DETECTED BY MAGNETIC IN-LINE INSPECTION TOOLS

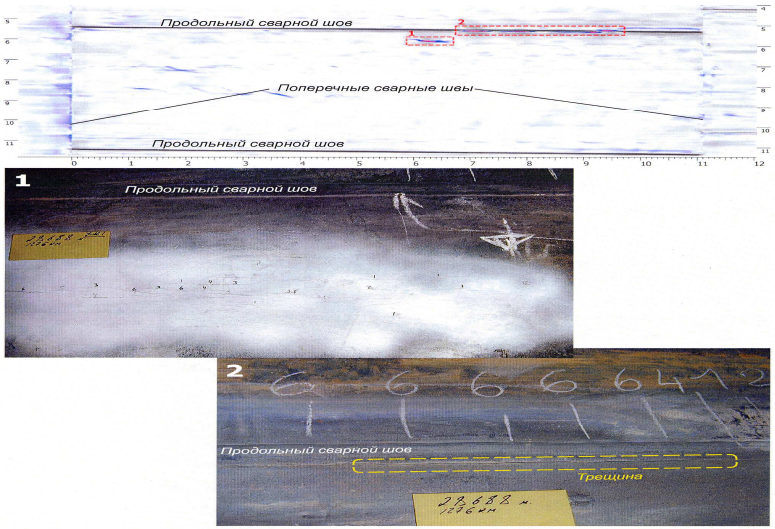
Geometry defect



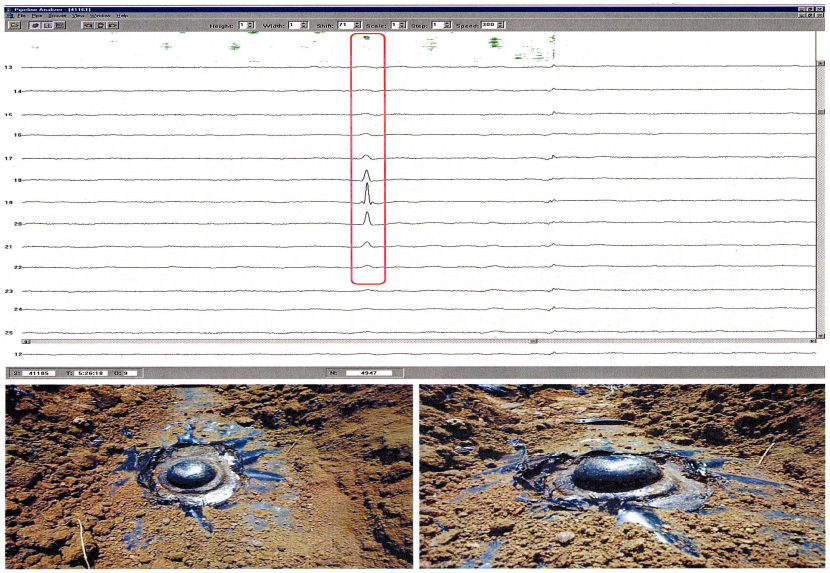
Corrosion



Stress corrosion cracking in longitudinal weld seam zone



Welded patch

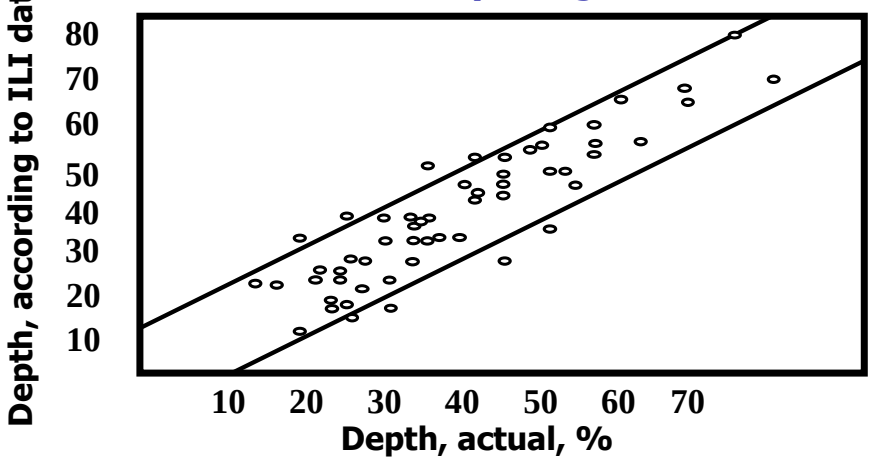


RELIABILITY ANALYSIS OF MAGNETIC IN-LINE INSPECTION RESULTS

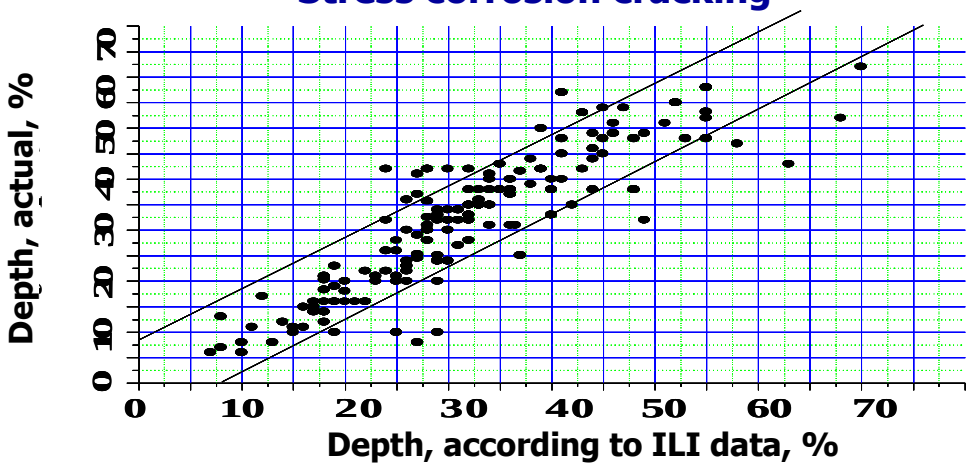
Defects detected by MFL (DMT type) and TFI (DMTP type) tools	Minimum sizes of defects
Single caverns	t x t x 0.6t
Pitting corrosion	2t x 2t x 0.2t
General corrosion	3t x 3t x 0.1t
Penetrating defects	0.25t (diameter)
Longitudinal cracks	3t x 0.03t x 0.2t
Longitudinal grooves	3t x 0.5t x 0.2t

Comparison of magnetic in-line inspection data and direct measurements of defects during pipeline excavations

General and pitting corrosion



Stress corrosion cracking



Tolerance of defect depth assessments:

Stress corrosion cracking

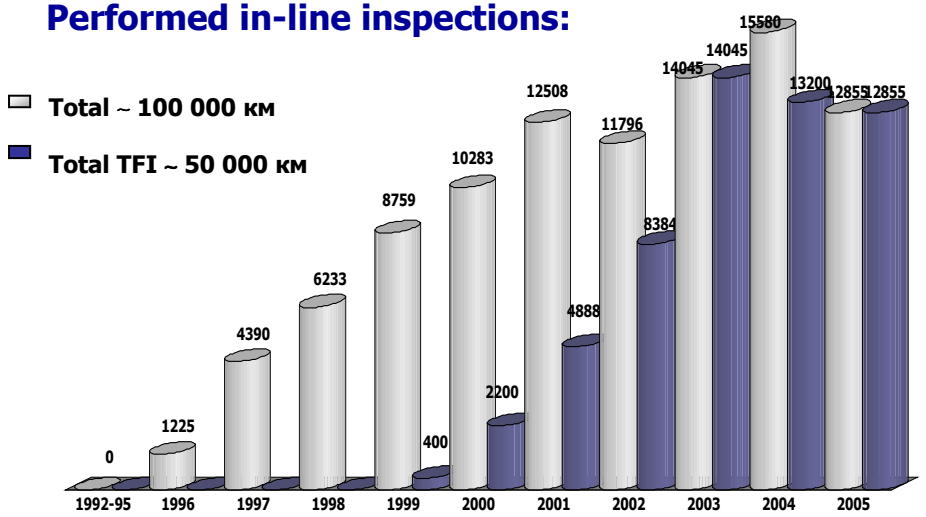
- 90% cases ± 7.5%

General and pitting corrosion

- 90% cases ± 7.5%
- 80% cases + 5%

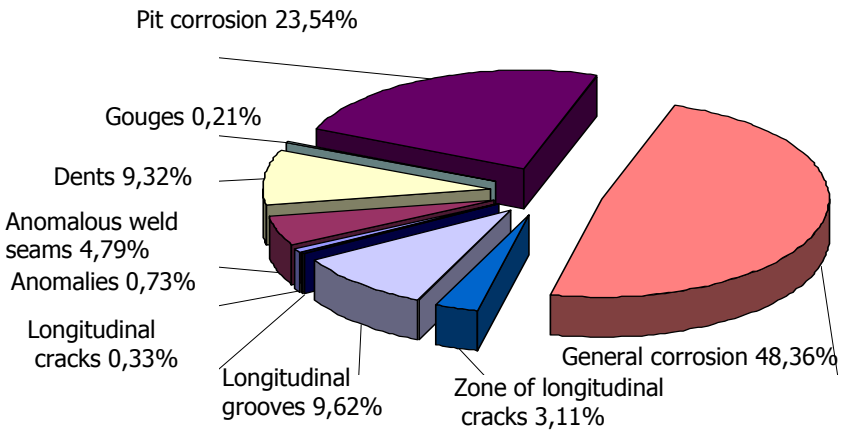
IN-LINE INSPECTIONS OF TRUNK GAS PIPELINES IN PRACTICE

Performed in-line inspections:



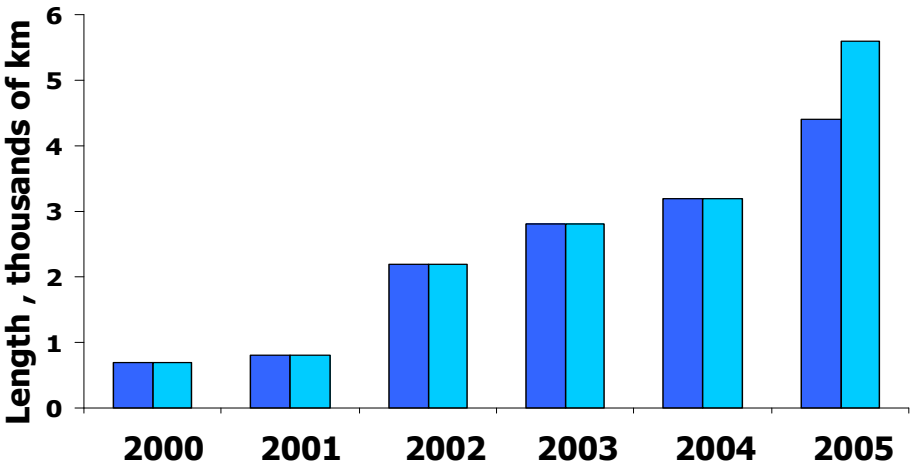
Total number of detected defects ~ 500 000,
Including stress-corrosion cracks ~ 4 200

Distribution of types of detected defects



Severe defects ~ 4 500,
including SCC ~ 1 500

Diagnostics of Trunk Gas Pipelines Outside Russia



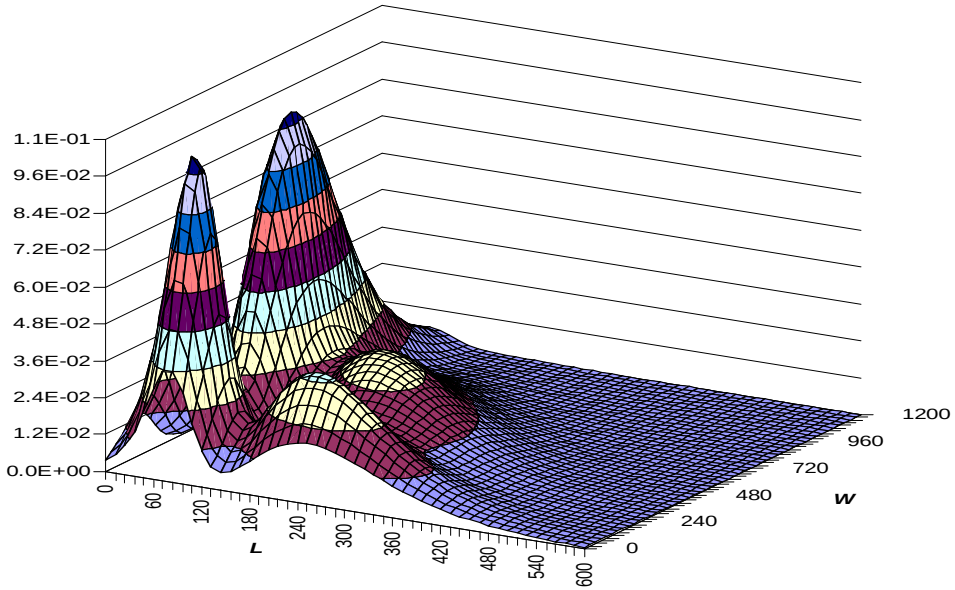
Customers: 12 countries:

Argentina, Iran, Czechia, India,Germany, Poland, Uzbekistan,Kazakhstan ,Ukraine, Byelorus, Latvia Estonia

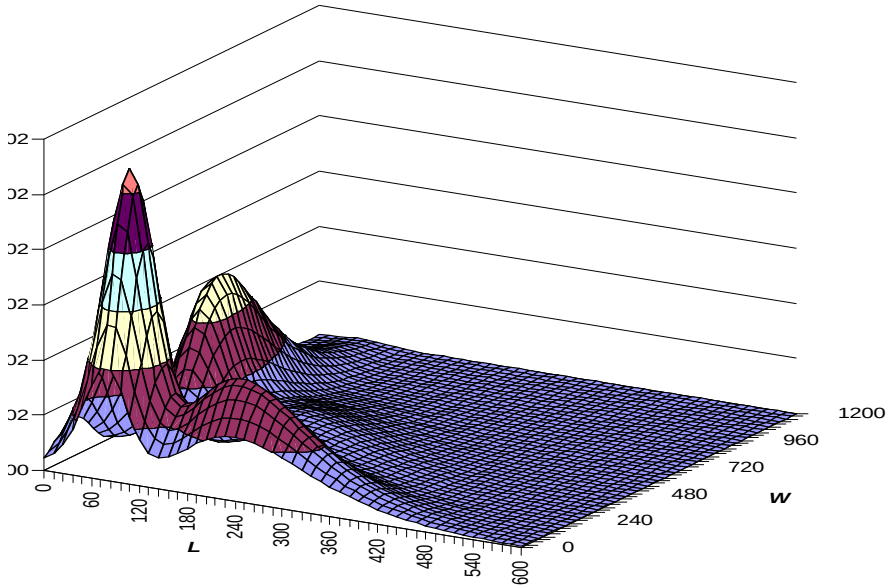
- Diagnosed since 2000.

- Total number of contracts since 2000.

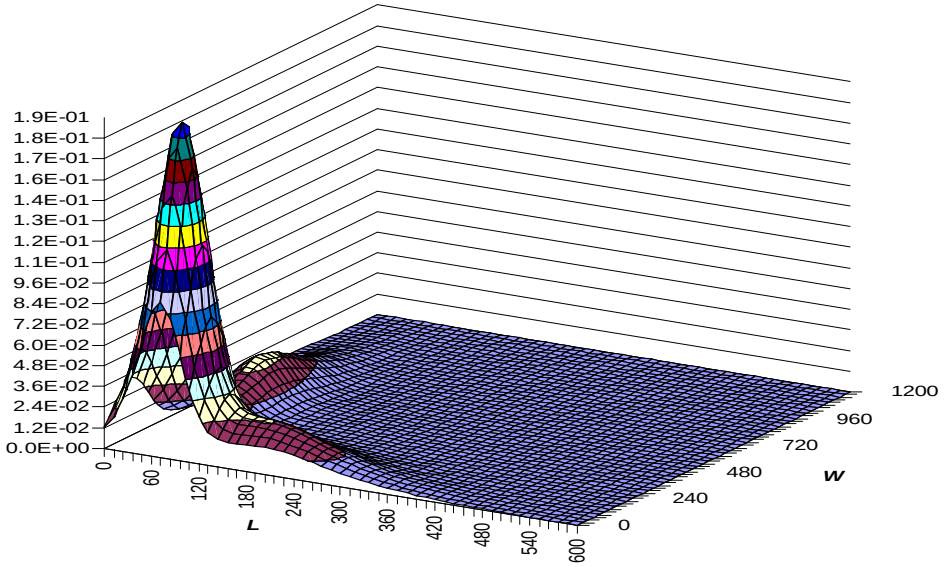
CONVENTIONAL DENSITY OF DISTRIBUTION OF LENGTH (L), WIDTH (W), AND RELATIVE HEIGHT (H) OF CORROSION DEFECTS IN TRUNK GAS PIPELINES



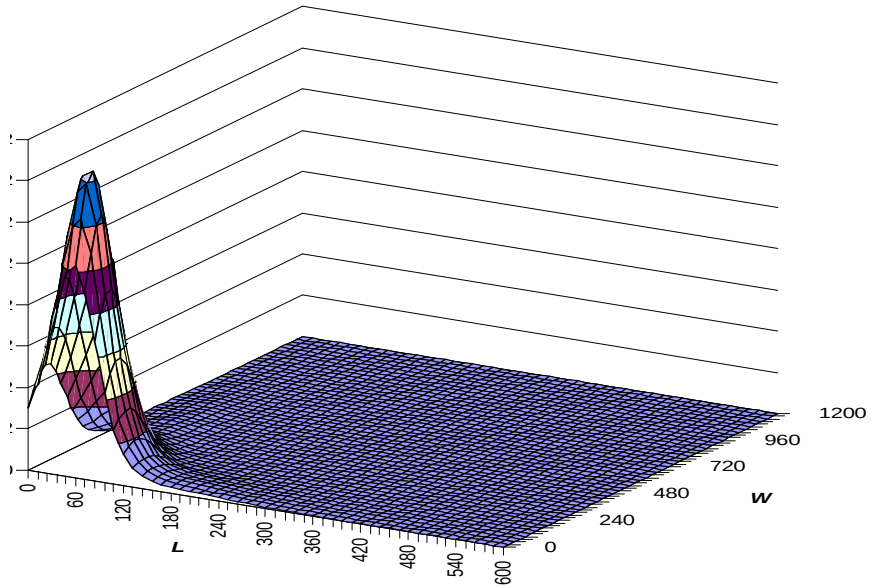
H = 10%



H = 20%



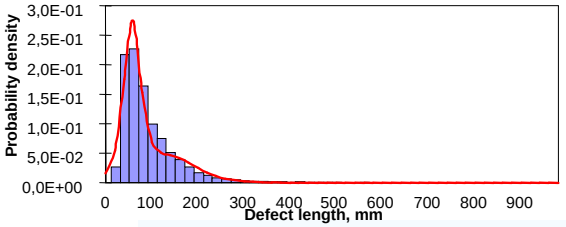
H = 30%

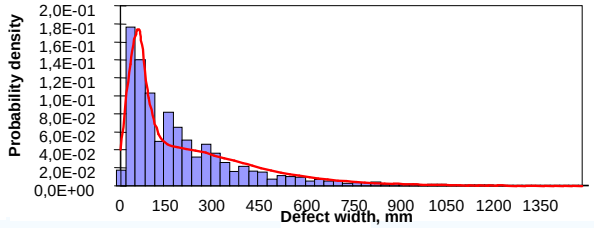


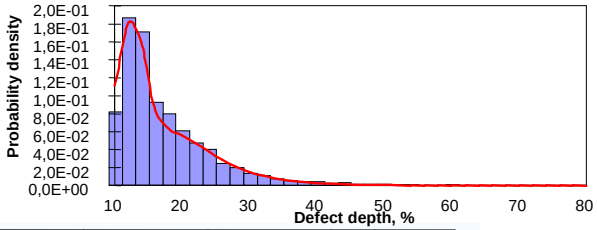
H = 50%

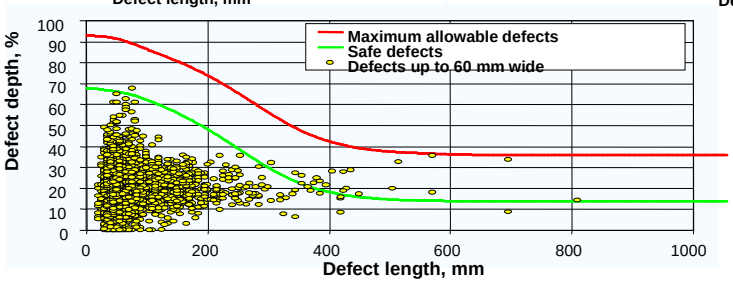
PARAMETERS OF CORROSION DAMAGES AND ASSESSMENT OF GAS PIPELINE STRENGTH

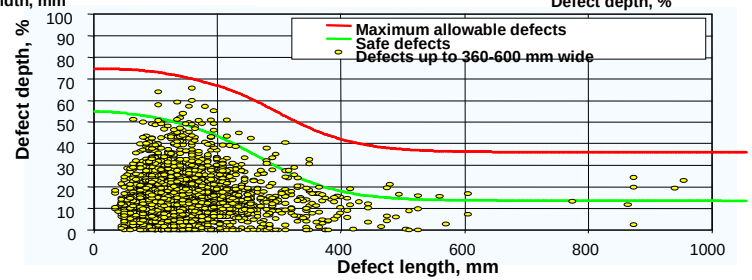
Corrosion metal loss



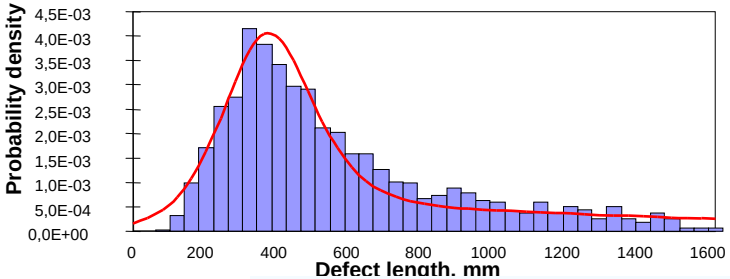


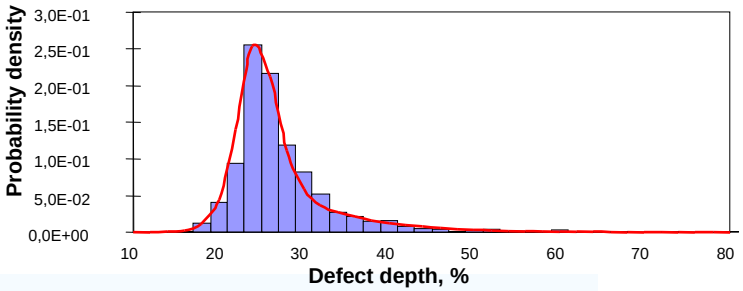


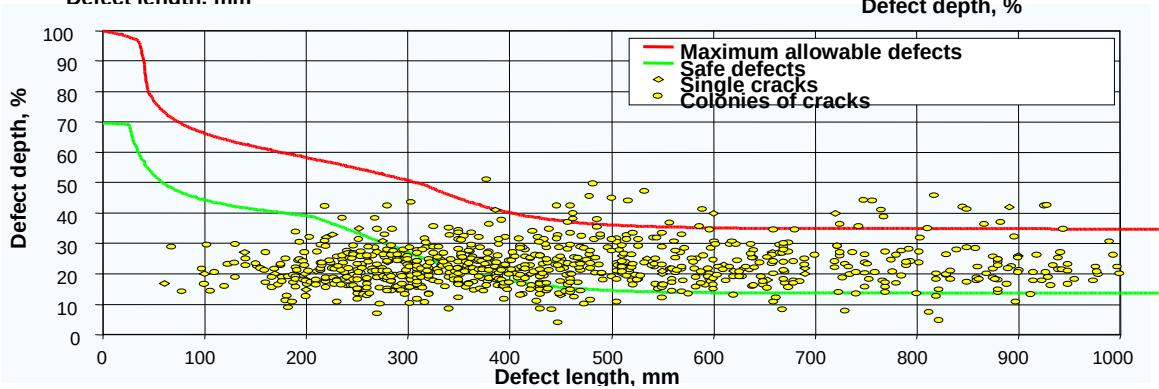




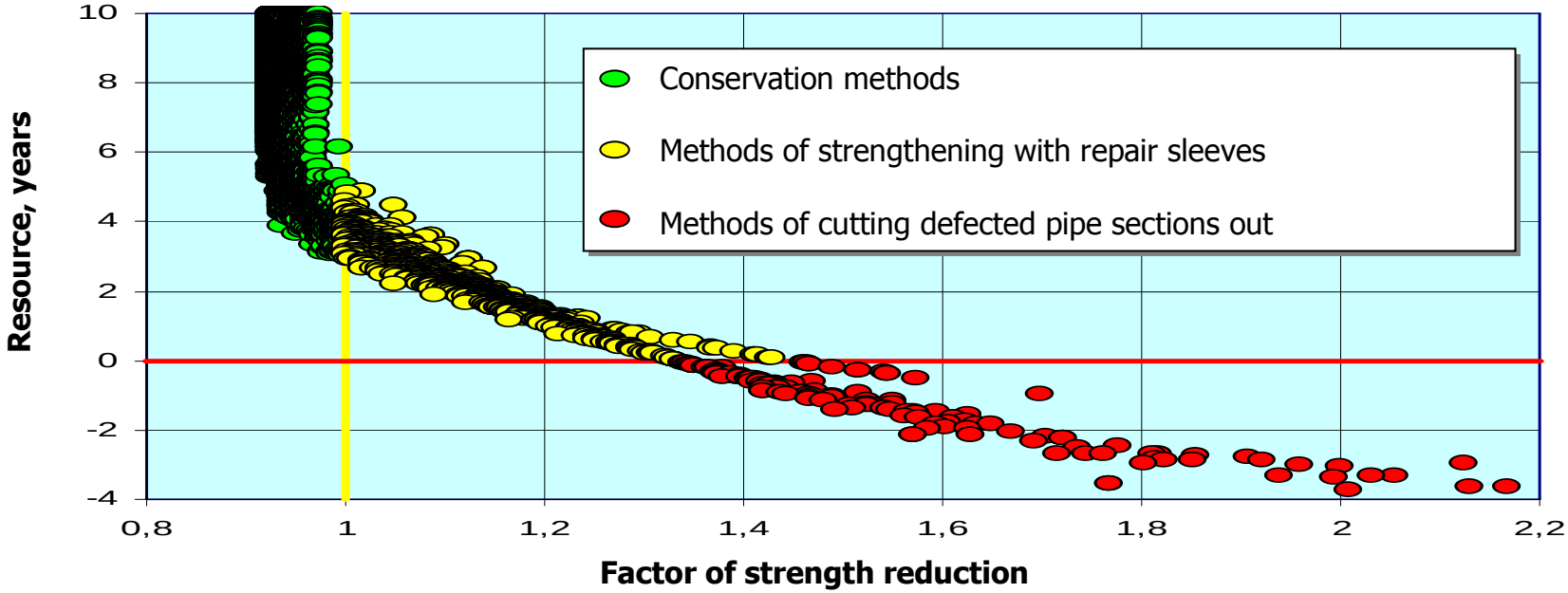
Stress corrosion cracks and colonies of cracks



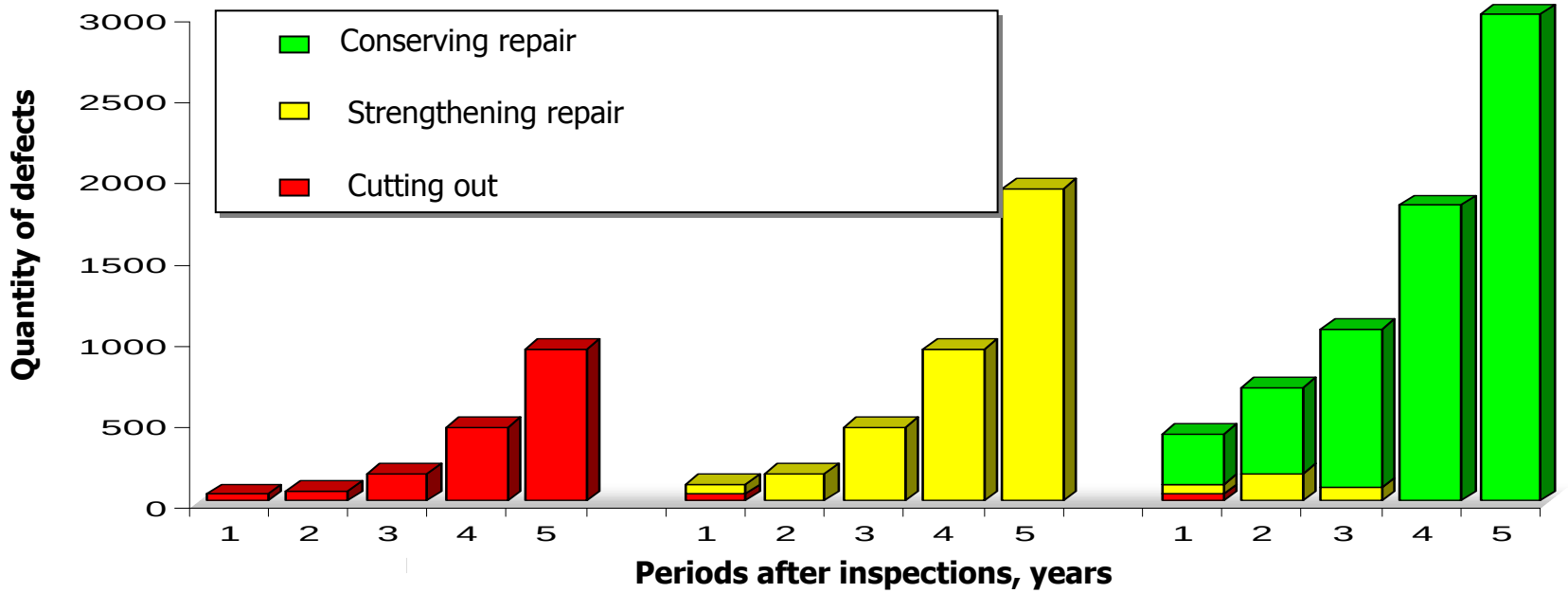




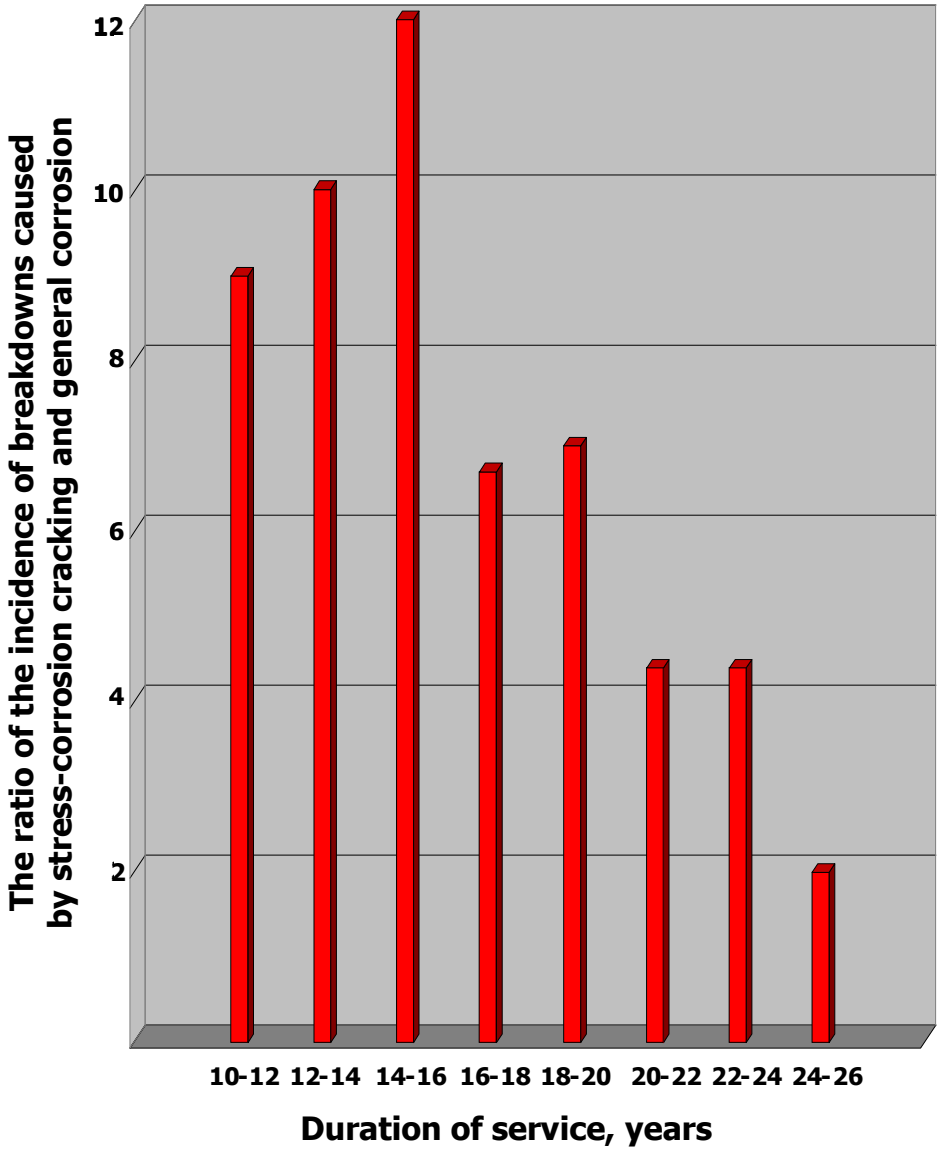
REPAIR METHODS OF CORROSION DEFECTS DEPENDING ON PIPE STRENGTH AND RESOURCE



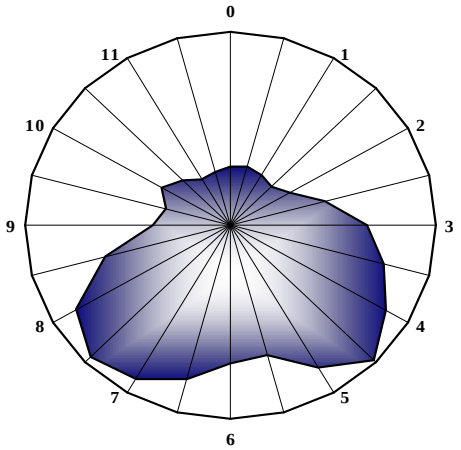
POSSIBLE VERSIONS OF REPAIR SEQUENCE



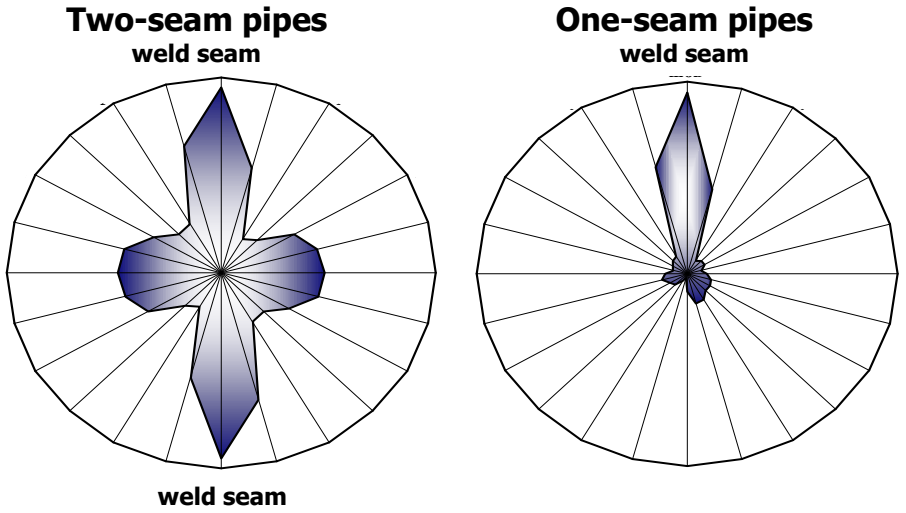
RELATIVE INCIDENCE OF PIPELINE FAILURES CAUSED BY STRESS CORROSION. LOCATIONS OF FAILURE NUCLEI.



Statistic distribution of SCC defects in pipe circumference

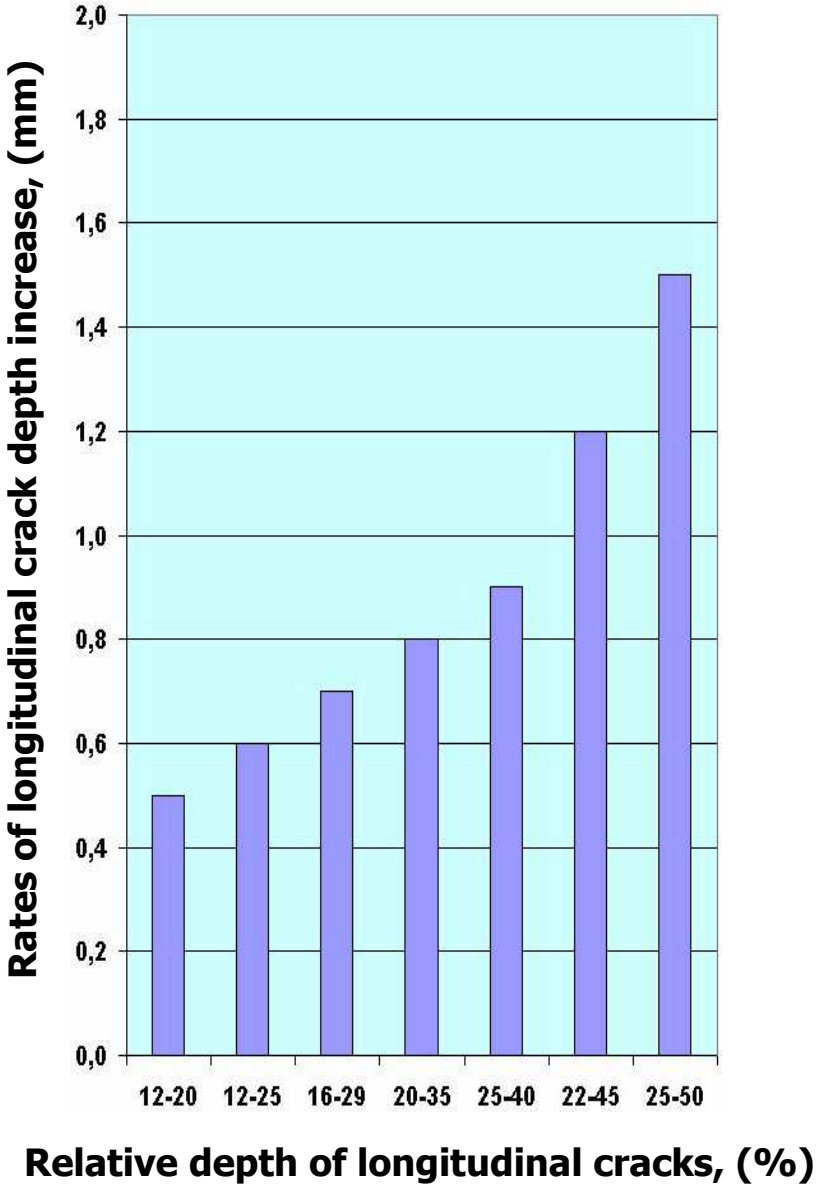


Statistic distribution of SCC defects relative to longitudinal weld seams

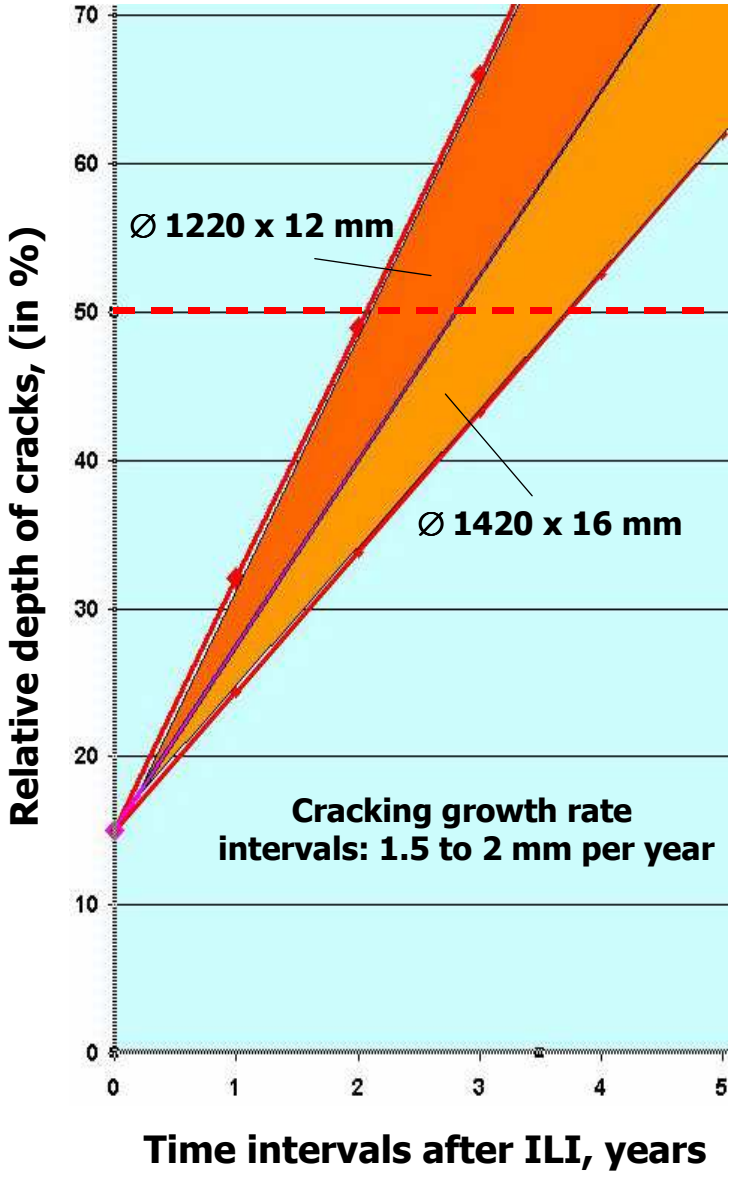


THE DYNAMICS OF THE STRESS-CORROSION CRACKING GROWTH

Range of cracking growth rates

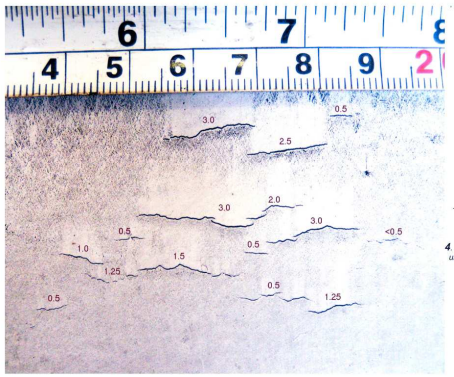


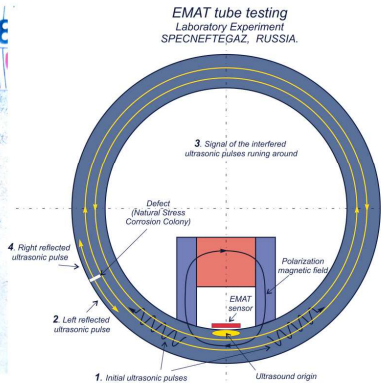
Sub-critical crack growth rate

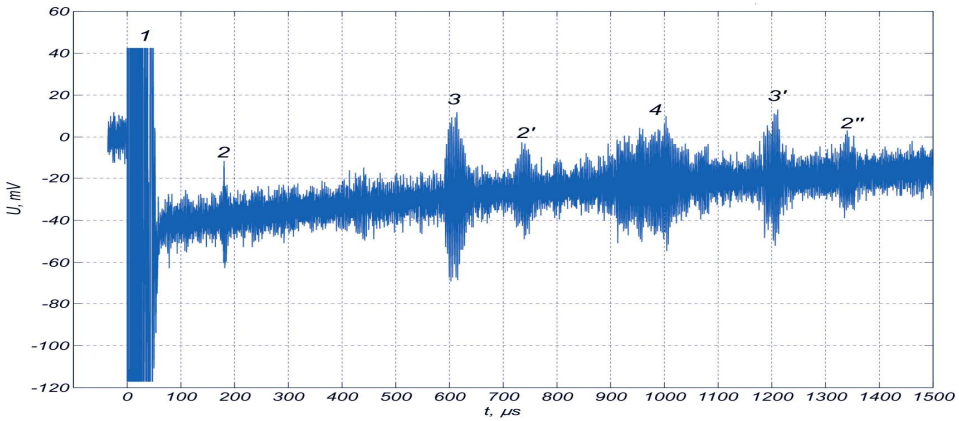


DETECTION OF SCC ZONES AT EARLIER STAGES OF CRACK FORMATION

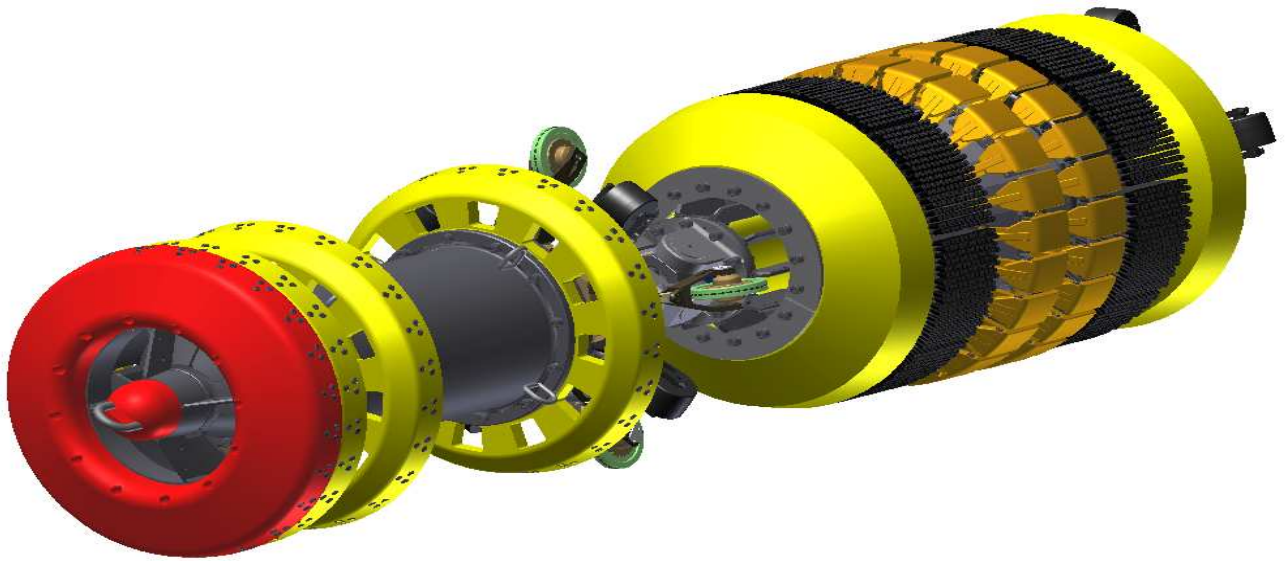
Signals of EMA converter obtained from a ∅610 pipe segment with a colony of small stress-corrosion cracks (Argentina)







Defectoscope ДЭМАТ26-24" for detecting SCC zones at earlier stages of crack formation

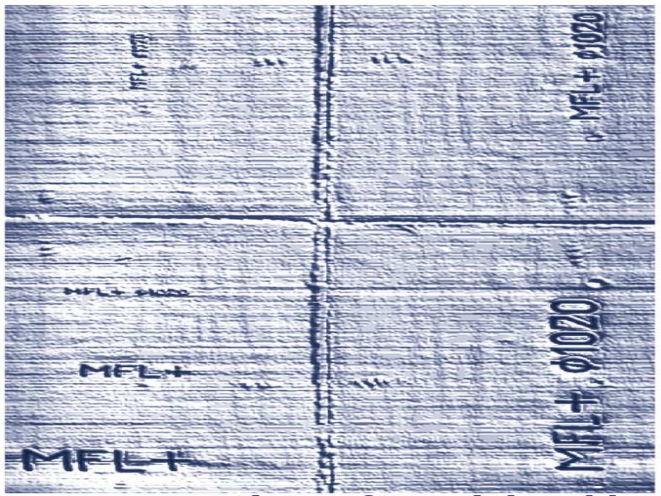


DETECTING DEFECTS OF THE INNER SURFACE OF A ∅ 1220 MM PIPE WITH THE MFL-PLUS DEFECTOSCOPE

The MFL-plus Defectoscope

View of the pipe inner surface

Diagram of the pipe inner surface



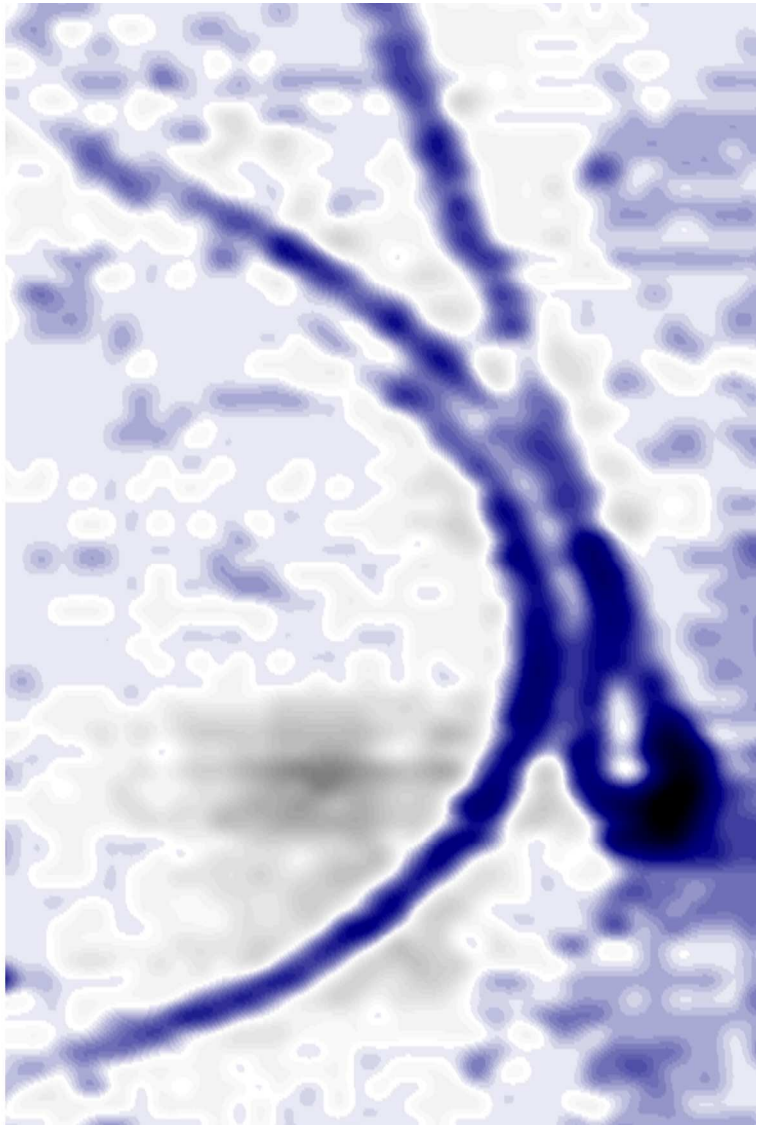
Longitudinal weld

Circumferential weld

A DEFECT (DEPTH < 0.5 MM) ON A PIPE'S INSIDE SURFACE

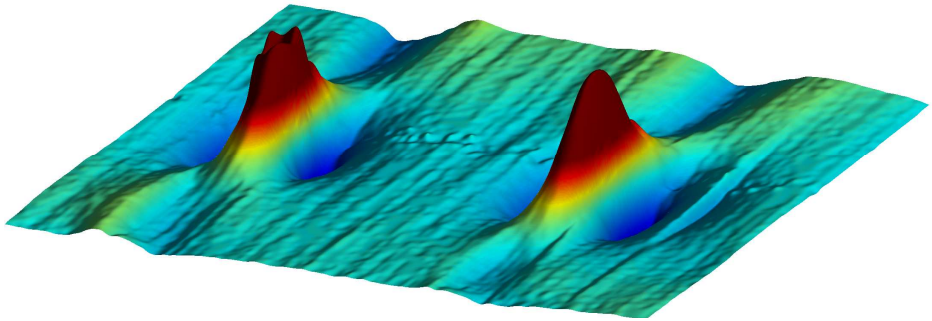
A photograph

Recorded diagram

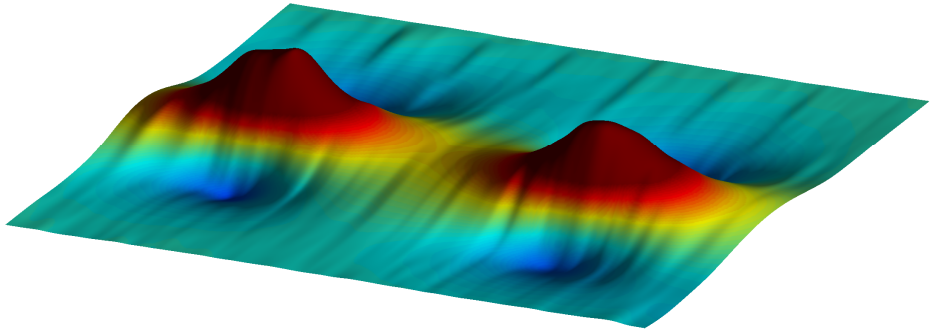


SORTING OUT DEFECTS ON THE PIPE'S INSIDE AND OUTSIDE SURFACES WITH THE INTROSCOPE MFL+

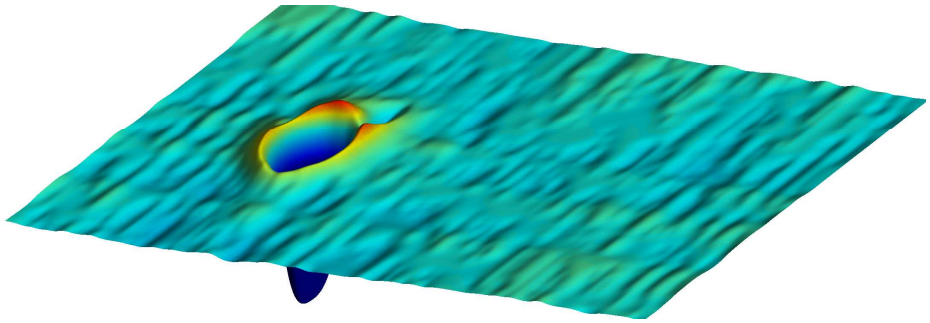
TFI



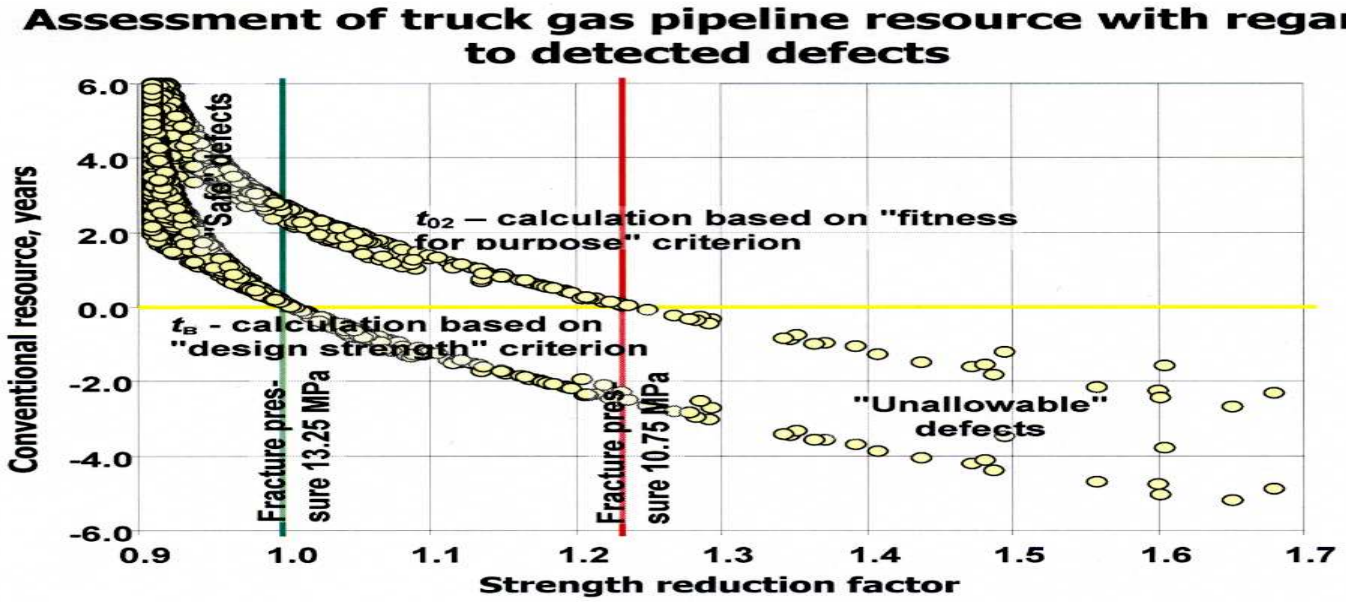
MFL

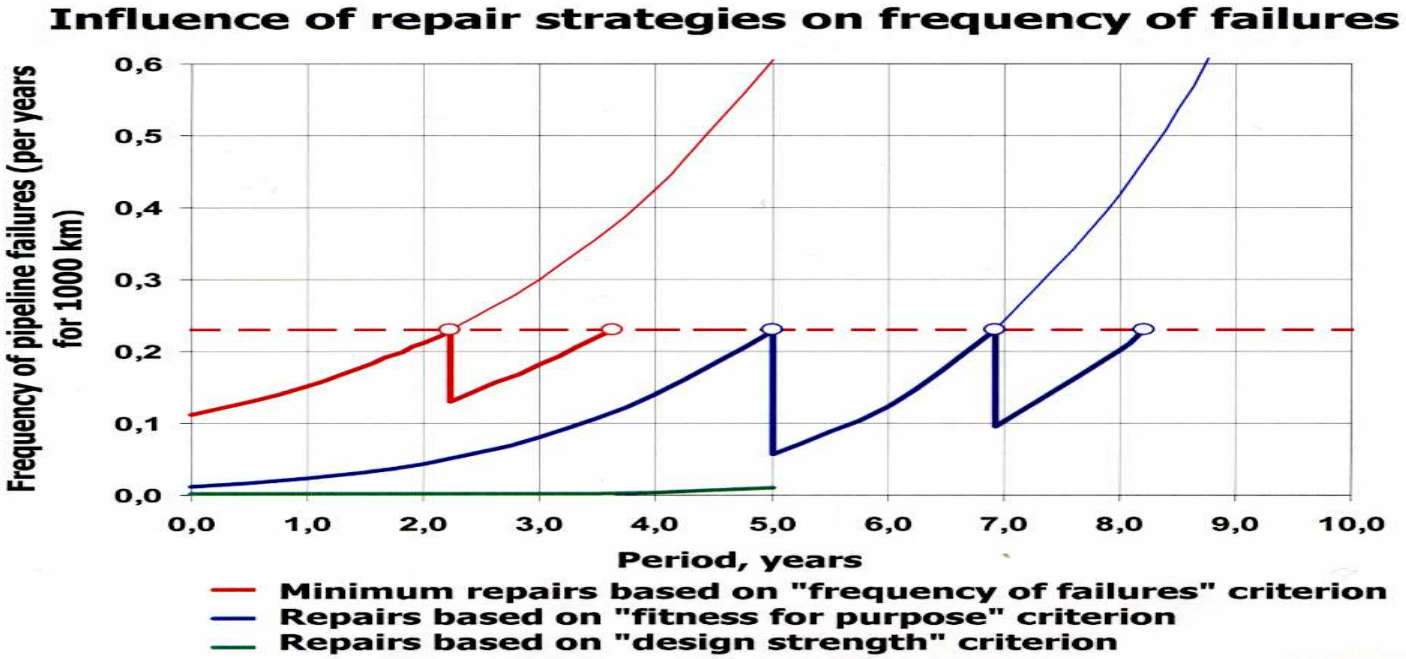


Introscope MFL+



COLCULATION OF PIPELINE RESOURCE & STRENGTH PARAMETERS, CHOICE OF REPAIR STRATEGIES BASED ON ILI RESULTS





MODEL OF OPTIMIZING ILI PERIODS & PIPELINE REPAIR SCOPES

Optimization of defects growth (h^*) depending on ILI periods

$$1-\frac{(C_A-C_Д)}{C_A}\times\frac{\nu_m\tau}{h_{пр}}=F_\nu\left(\frac{h_{пр}-h^*}{\tau}\right)$$

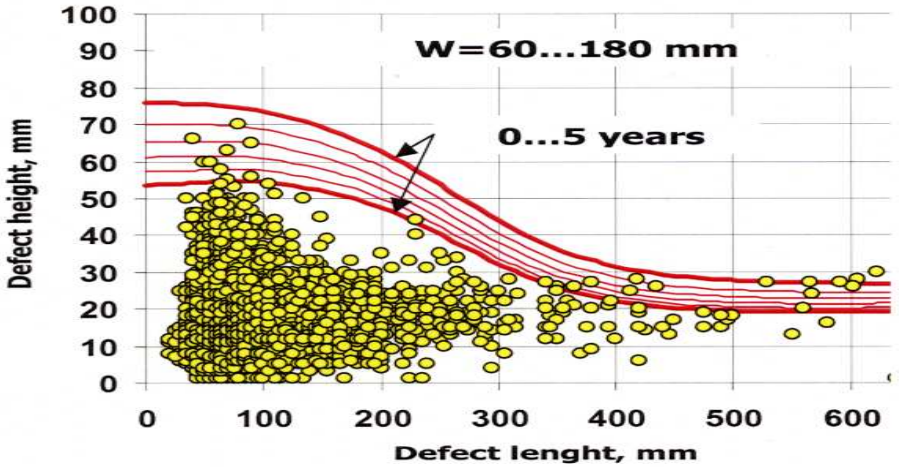
Optimization of ILI periods ($\tau_{опт}$) depending on defect sizes

$$1-\frac{(C_A-C_Д)}{C_A}\times\frac{\nu_m\tau_{опт}}{h_{пр}}=F_\nu\left(\frac{h_{пр}-h_0}{\tau_{опт}}-\nu_m\right)$$

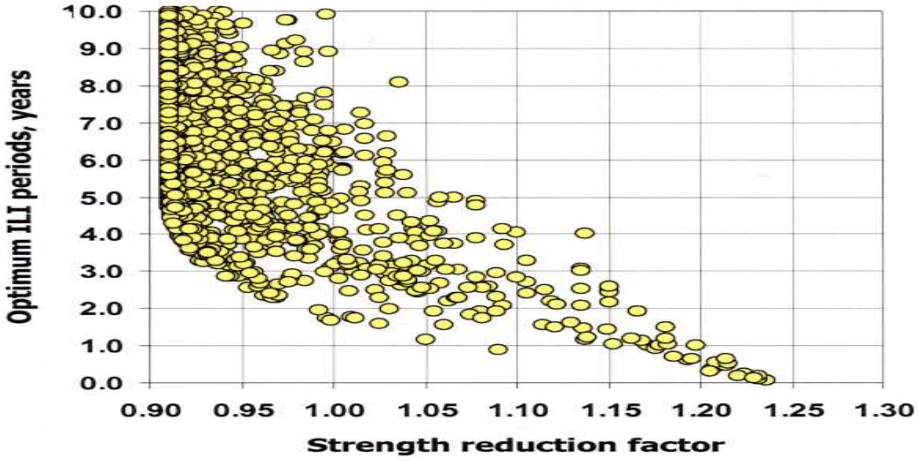
$C_Д$ – expenditures for ILI/repair
$F_\nu(\nu)$ – function of corrosion rate distribution

C_A – emergency costs
ν_m – mean corrosion growth rate

Limit levels of defects growth



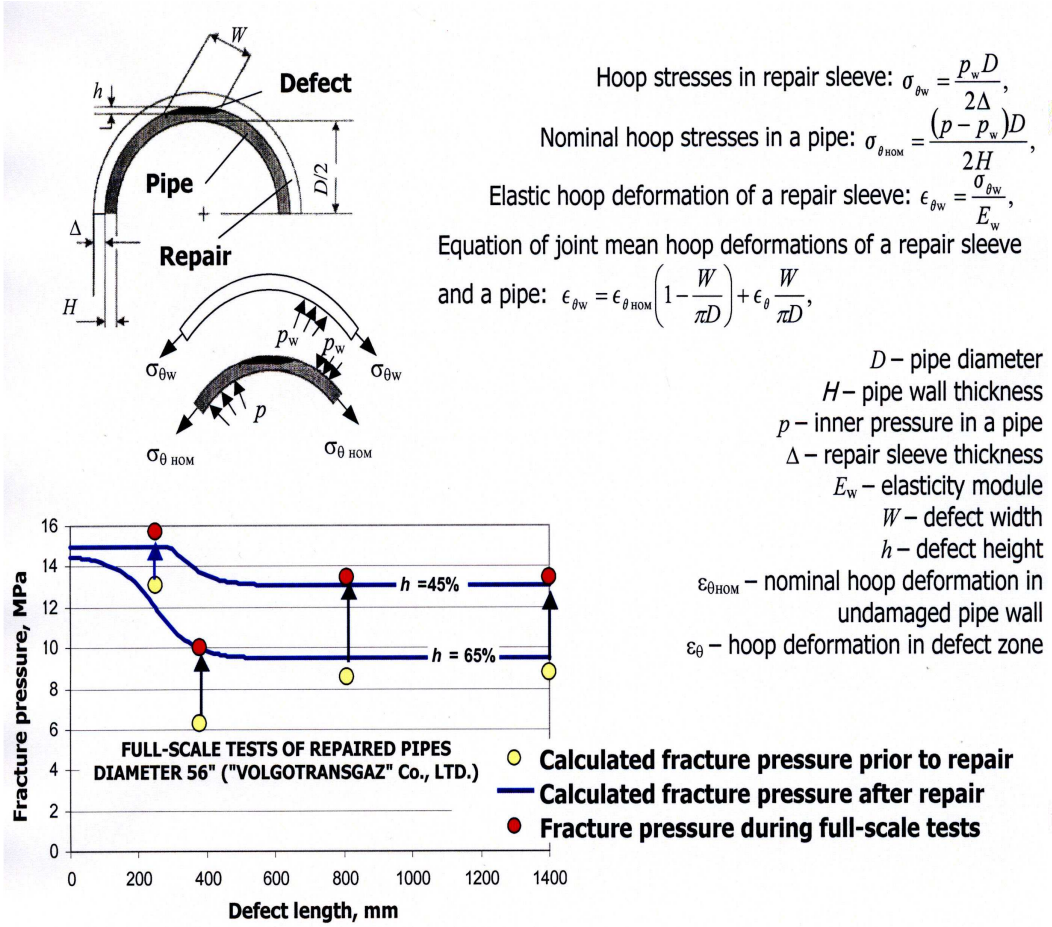
Optimum period for repeated ILI



Planning of repair scopes (% of detected defects) until the next ILI

MODEL OF JOINT DEFORMATION OF A REPAIR SLEEVE & PIPE IN THE PLACE OF CORROSION DAMAGE REPAIR

Comprehensive software for calculation of optimum parameters to repair corroded pipes of trunk gas pipelines, using composite materials



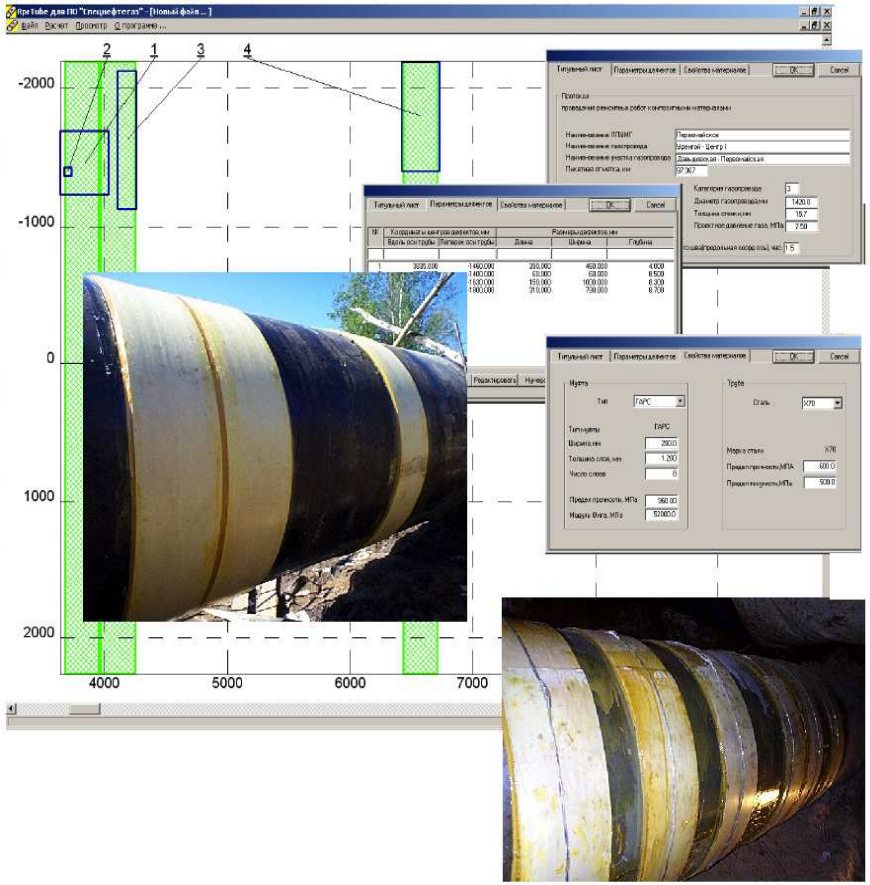
Hoop stresses in repair sleeve: $\sigma_{\theta w} = \frac{p_w D}{2\Delta}$,

Nominal hoop stresses in a pipe: $\sigma_{\theta ном} = \frac{(p - p_w)D}{2H}$,

Elastic hoop deformation of a repair sleeve: $\epsilon_{\theta w} = \frac{\sigma_{\theta w}}{E_w}$,

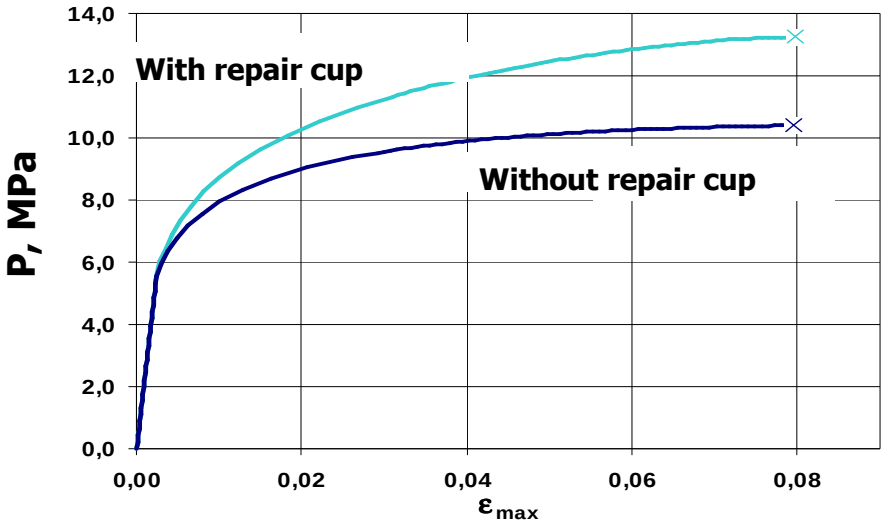
Equation of joint mean hoop deformations of a repair sleeve and a pipe: $\epsilon_{\theta w} = \epsilon_{\theta ном}\left(1 - \frac{W}{\pi D}\right) + \epsilon_{\theta}\frac{W}{\pi D}$,

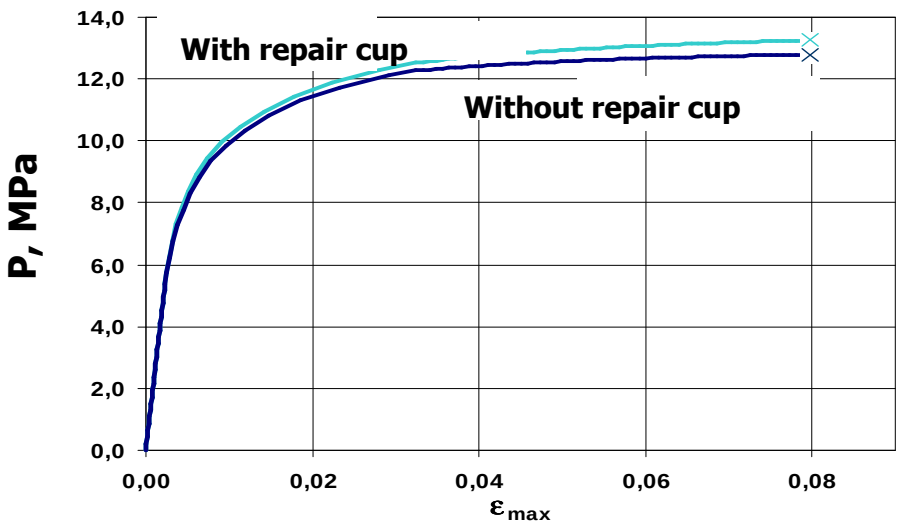
D – pipe diameter
H – pipe wall thickness
p – inner pressure in a pipe
Δ – repair sleeve thickness
E_w – elasticity module
W – defect width
h – defect height
$\varepsilon_{\theta ном}$ – nominal hoop deformation in undamaged pipe wall
ε_{θ} – hoop deformation in defect zone

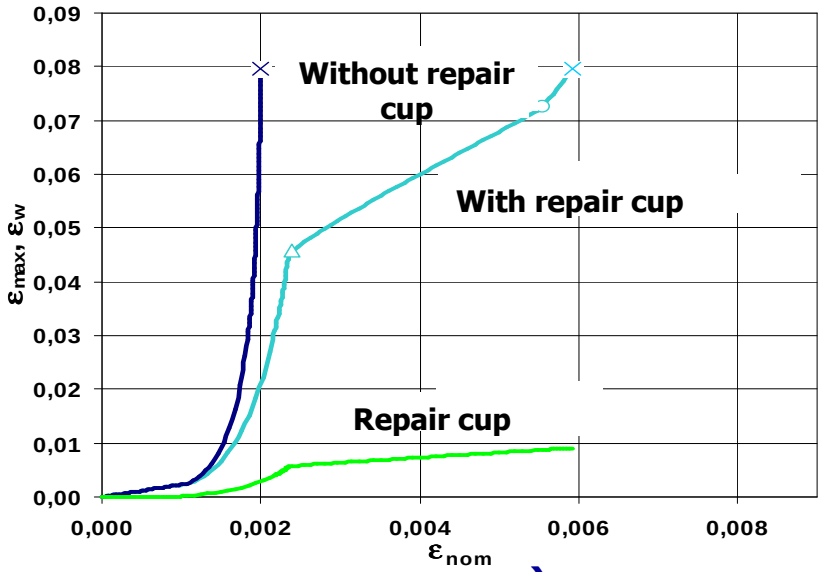


Recommended for usage by the "GAZPROM" JSC Standard

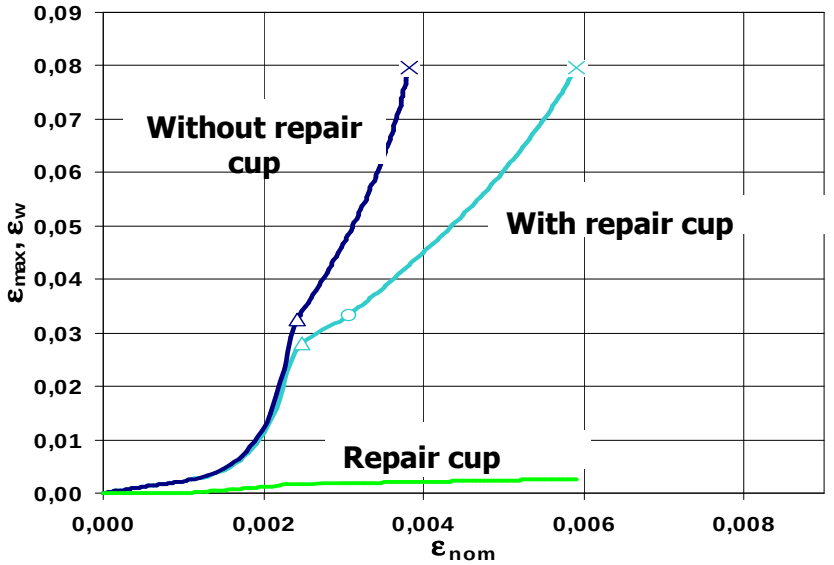
SPECIFICATION OF LOAD-CARRYING CAPACITY OF A PIPELINE SECTION IN REPAIRED GENERAL (A) & PITTING (B) CORROSION SITES







a)



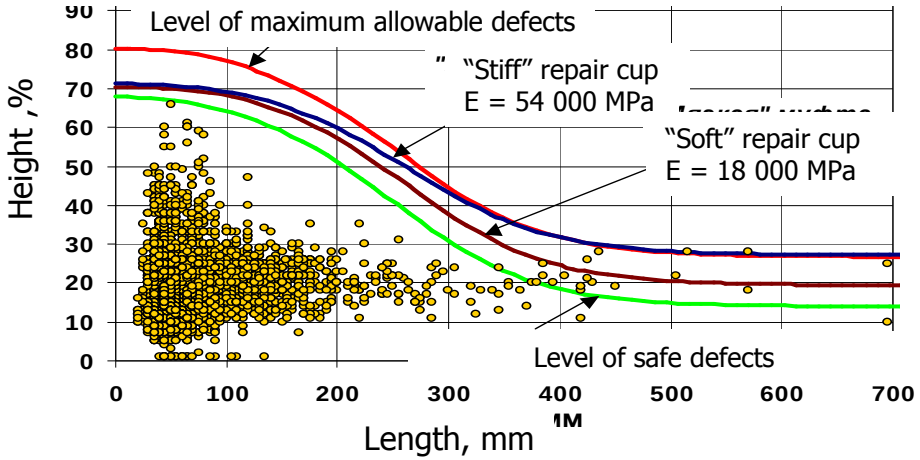
b)

elasticity modulus 36000 MPa,
tensile strength 600 MPa

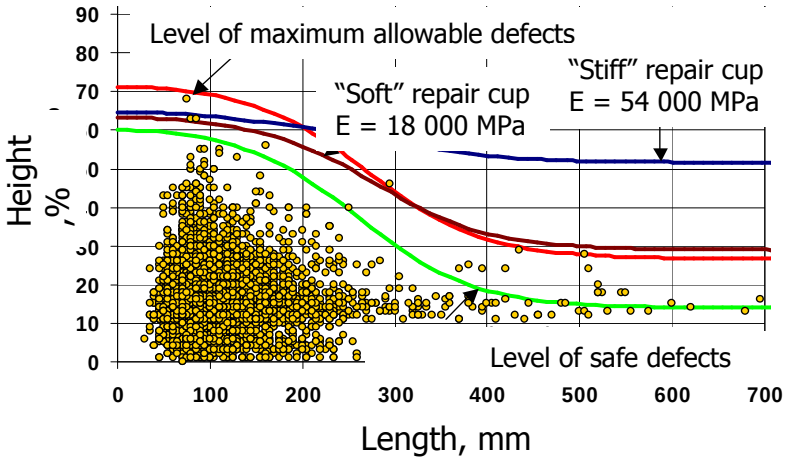
× – fracturing; Δ – start of plastic deformation of an undamaged; O –transition from longitudinal to circumferential rupture

INFLUENCE OF COMPOSITE REPAIR SLEEVES ELASTICITY MODULUS ON RESTORATION OF LOAD-CARRYING CAPACITY IN REPAIRED CORRODED PIPES

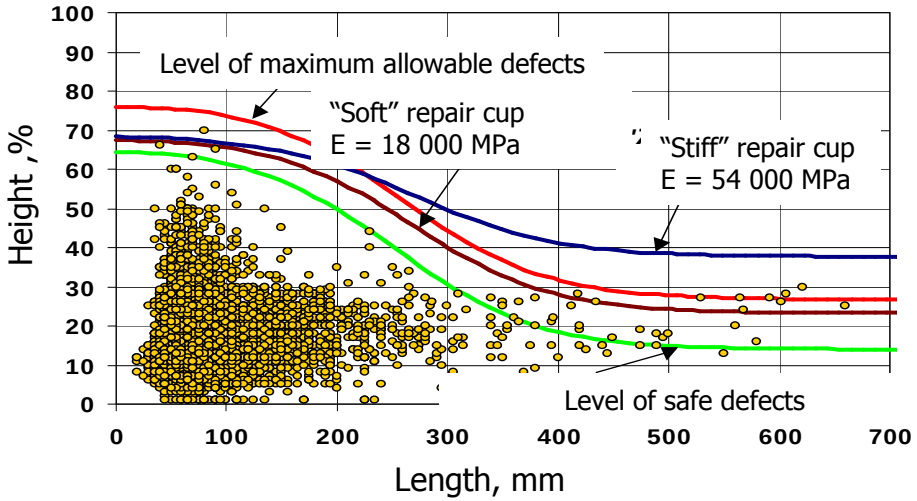
Maximum allowable sizes of corrosion defects (W < 60 mm)



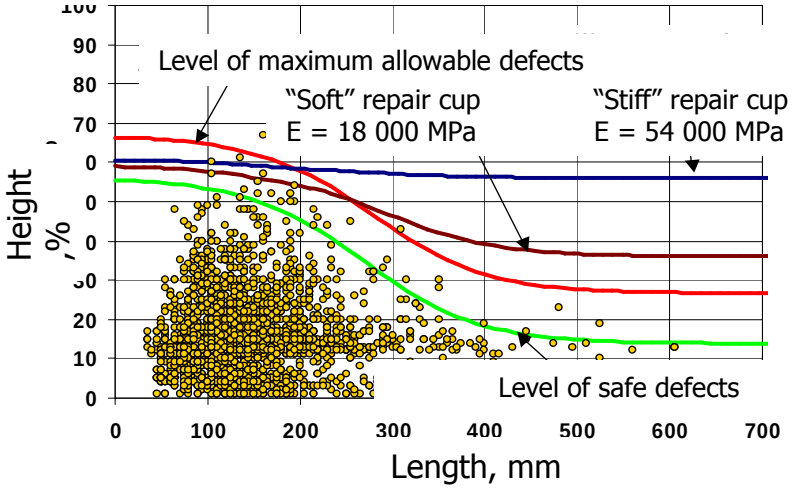
Maximum allowable sizes of corrosion defects (W = 180…360 mm)



Maximum allowable sizes of corrosion defects (W = 60…180 mm)

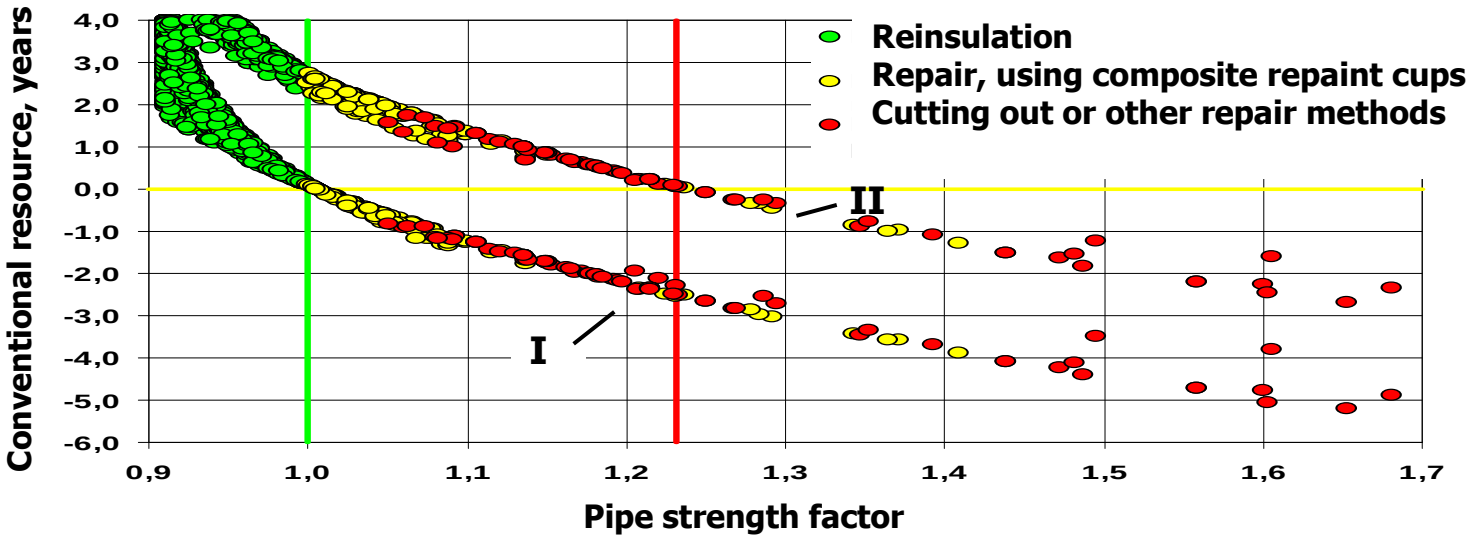


Maximum allowable sizes of corrosion defects (W = 360…600 mm)

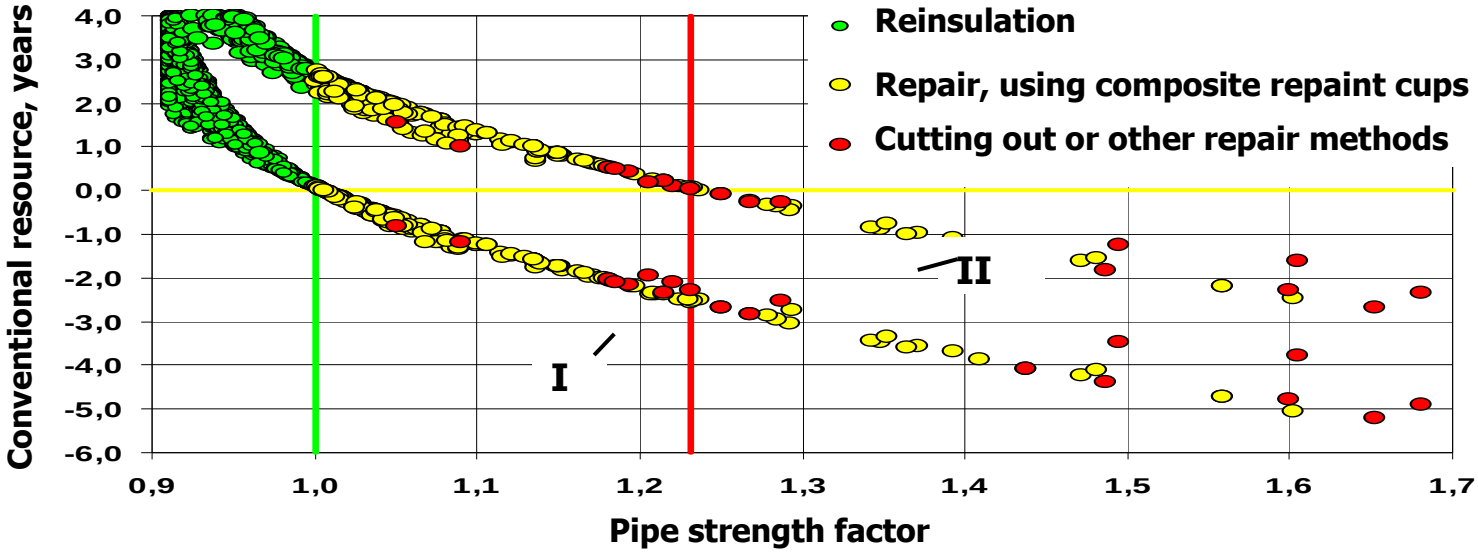


Tensile strength of repair is 600 MPa

SELECTION OF TECHNOLOGIES FOR REPAIR OF CORROSION DAMAGES IN TRUNK GAS PIPELINES



elasticity modulus of repair cups is 18000 MPa



Elasticity modulus of repair cups is 54000 MPa

I - calculation according to "design strength" criterion

II - calculation according to "fitness for purpose" criterion

DYNAMICS OF SCC DIAGNOSTICS AND TRUNK GAS PIPELINES IMERGENCY INCIDENCE