Energiegase:
Methan, Biogas, Wasserstoff, Synthesegase.

TEIL 7 – Pipelines: Maintenance, Operation & Dispatching

WS 2023/24
Ruhruniversität Bochum
Lehrstuhl für Energieanlagen und Energieprozesstechnik

Prof Dr Gerald Linke, CEO DVGW, German Gas and Water Association

DVGW

Teil 7 – Pipelines

Maintenance

Operation & Dispatching

1. Risks pipelines are exposed to
2. Inspection and repair methods
3. PIMS
4. Dispatching and emergency response
5. Valves and valve spacing

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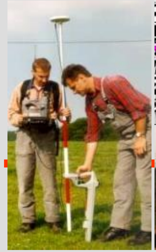
Operation of Pipelines

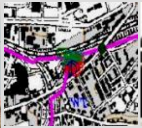
Safety devices, monitoring (grid control), maintenance, patrolling

Quality control

Operation → Monitoring → Maintenance



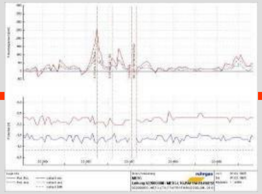
Surveillance by walking



... by car

... by helicopter

Tracing of observations



Intelligent piging

Repair/ rehabilitation

Operation of Pipelines

Safety devices, monitoring (grid control), maintenance, patrolling

Quality control

Planing **Constr.** **Operation** **Surveillance**

Grid control &
Central Emergency Office

Geographic
Information System

Fleet Management

Navigation System

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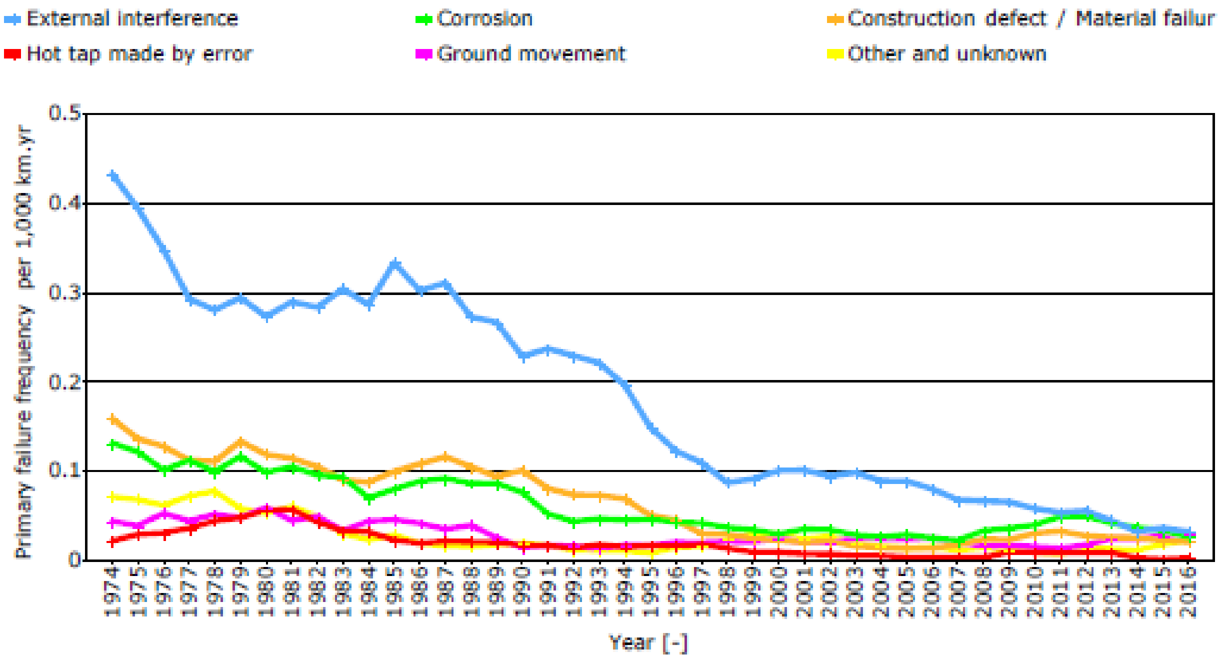
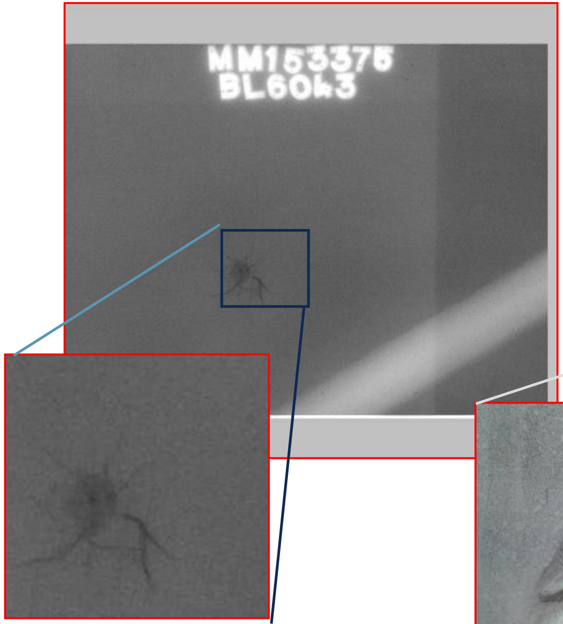
Pipelines are exposed to threats

See EGIG statistics and findings from the 2018 report:



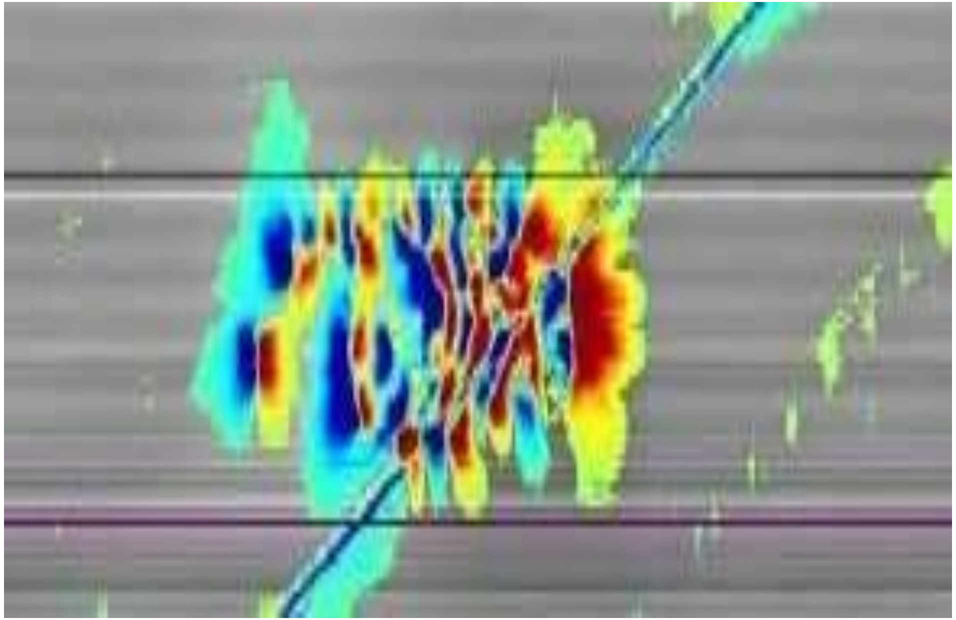
Defects from external interference

Internal crack



Gouges due to TPI

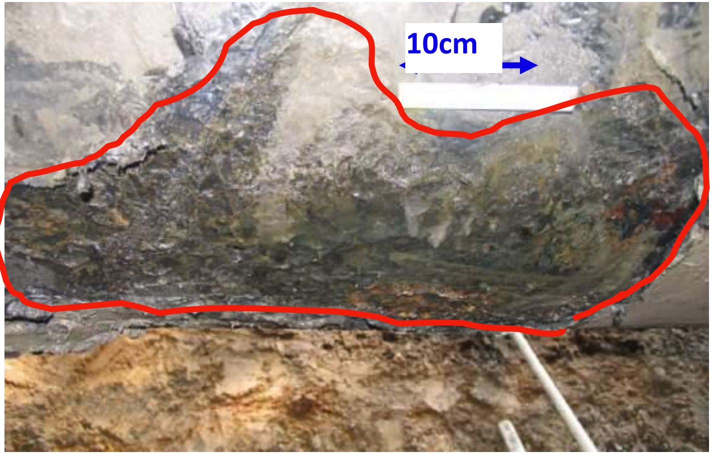
Corrosion defects



Disbonding defects

Wrapped double layer

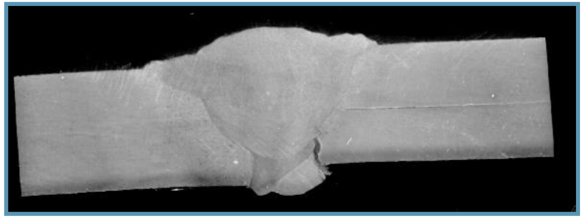
Mud in between layers

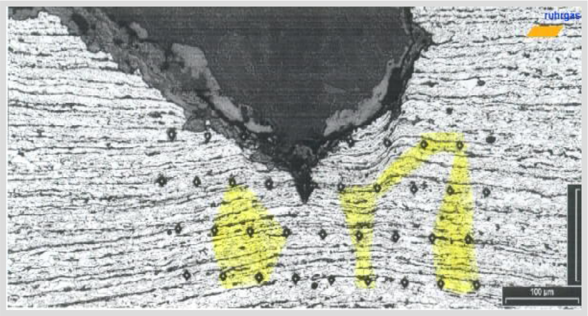


Corrosion due to disbonding

Material defects

Failure Analysis





Analysis of failure of important components to find defects with

- Microstructure

  (here: crack in girth weld with lamination in base material)

- Hardness testing

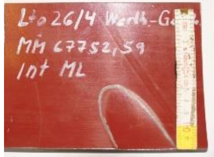
  (here: crack tip after stress test)

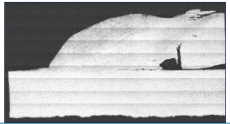
Typical mill defects

- Inclusions
- Laminations
- Rolling Defects
- Surface Defects
- Grindings
- Indentations
- Hard Spots / Cracks
- Welds Defects



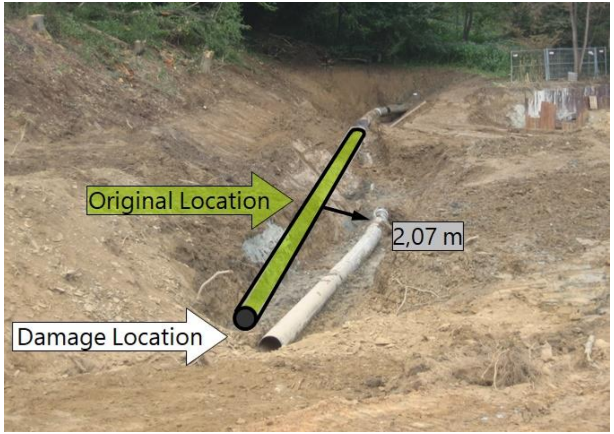


Other damages

Landslide



Lightning strike

Eccentricity in casings

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Teil 7 – Pipelines

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1 Risks pipelines are exposed to

2 **Inspection and repair methods**

3 PIMS

4 Dispatching and emergency response

5 Valves and valve spacing

Operation of Pipelines: Inspections Methods

Inline inspection with intelligent “pig”

Cleaning Pig

Calipper Pig (inst. of Dummy)

MFL Pig

Operation of Pipelines: Inspections Methods

Type of Inspection	Baseline	Operation	Integrity Aspects
Geometry (Callipper)	✓	✓	▪ Dents ▪ Ovalities ▪ Expansions
MFL	✓	✓	▪ Corrosion ▪ External damage ▪ (Weld Anomalies) ▪ (Mill Defects)
IMU (Mapping)	✓	✓	▪ Position
IMU (Strain)	✓	✓	▪ Displacements ▪ Additional Stress/Strain
Interval	1 x	15 – 25 Years	

Operation of Pipelines: Inspections Methods

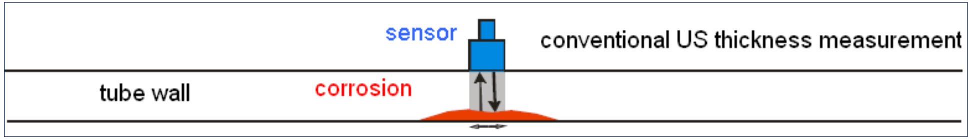
Non-destructive Testing on Pipeline on site

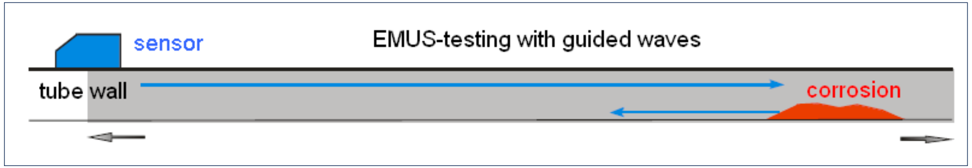
Non-destructive testing of girth welds – especially welding under operating conditions:

- Ultrasonic testing
- X-ray testing
- Magnetic inspection
- Liquid sustain testing
- Eddy current testing
- Visual testing

Operation of Pipelines: Inspections Methods

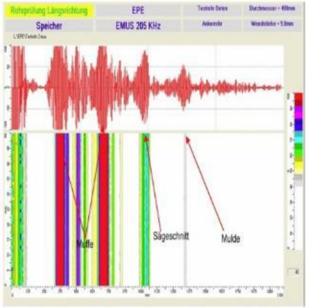
EMUS electro magnetic induced ultra sound



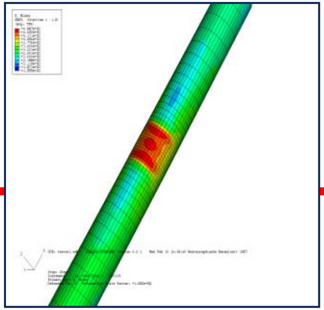


1. System test EON ruhrgas

2. Measurement



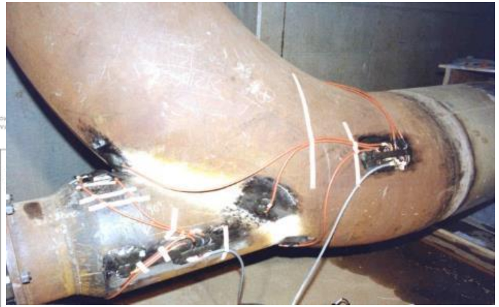
3. Results

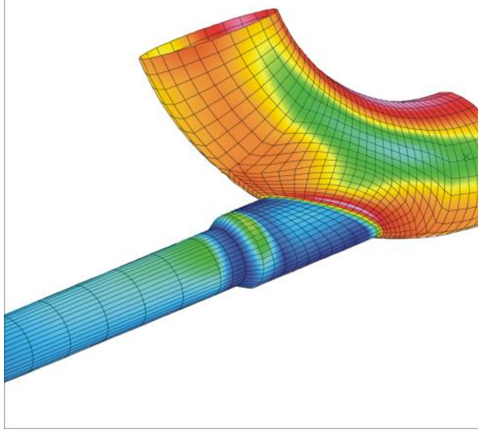


4. Assessment- FE-analysis

Integrity

Estimation of Stress/Strain of Component under Operation





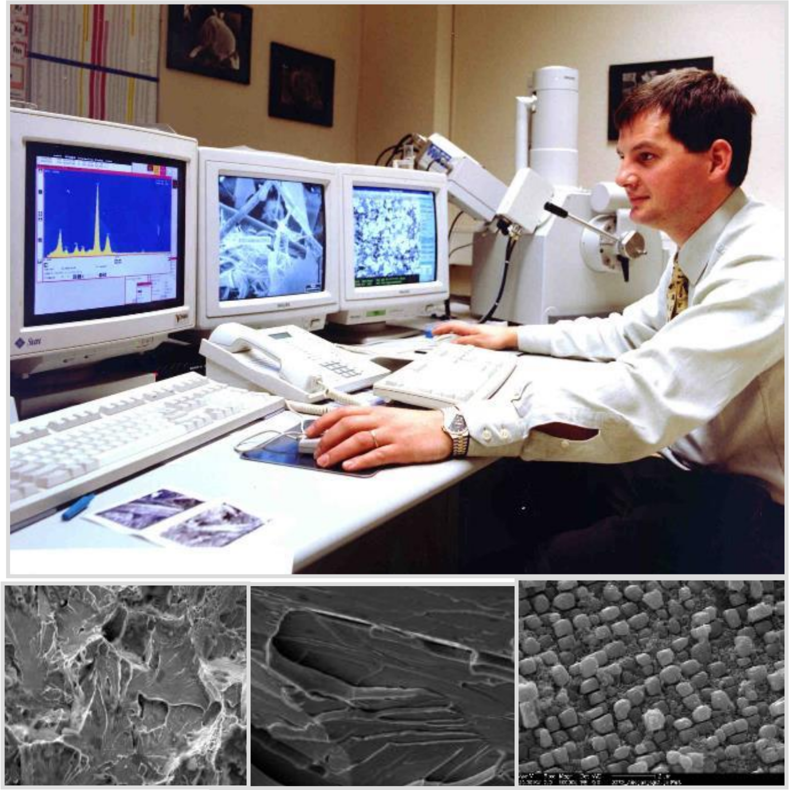
Numerical simulation to calculate stress/strain of components

Measuring stress/strain by strain gauges

Example:

Bend with Support under Operation

Operation of Pipelines: Investigation Methods defect colonies and failure analysis



Analysis of failure of important components to find defects with

- Scanning electron microscope

  (fracture surface)

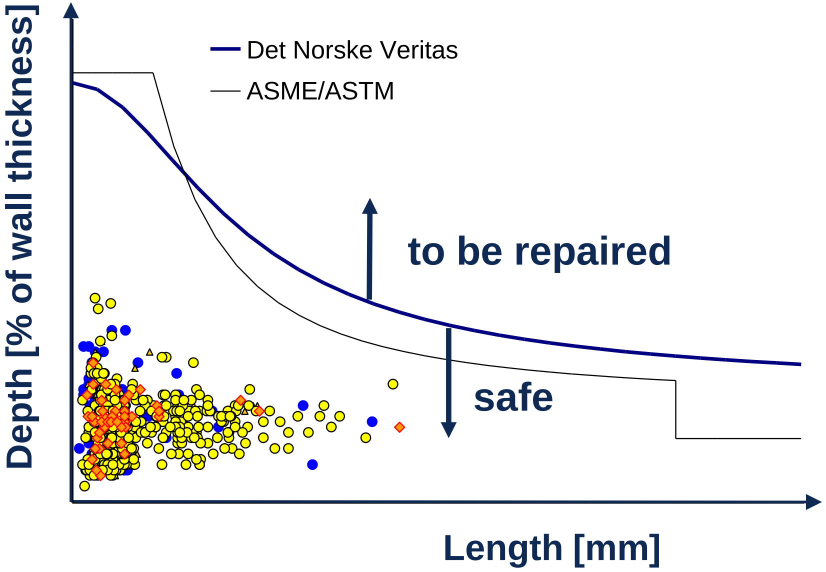
- EDX

  (chemical analysis)

Operation of Pipelines: Investigation Methods defect colonies

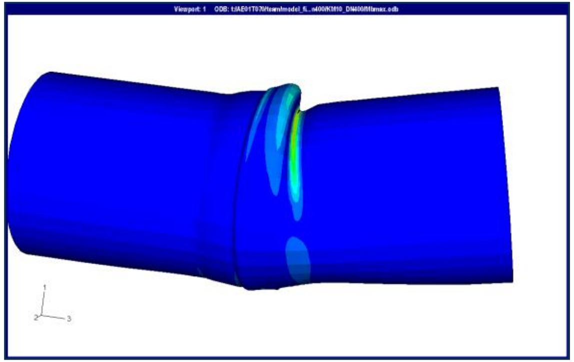
Assessment Methods – Metal Loss with DNV-RP 101

Result of assessing integrity of Pipe with metal loss caused by external corrosion



Operation of Pipelines: Investigation methods for joints

Simulation by FEM of complex loading



Numerical simulation of complex components to assess the behaviour under special conditions:

Example:

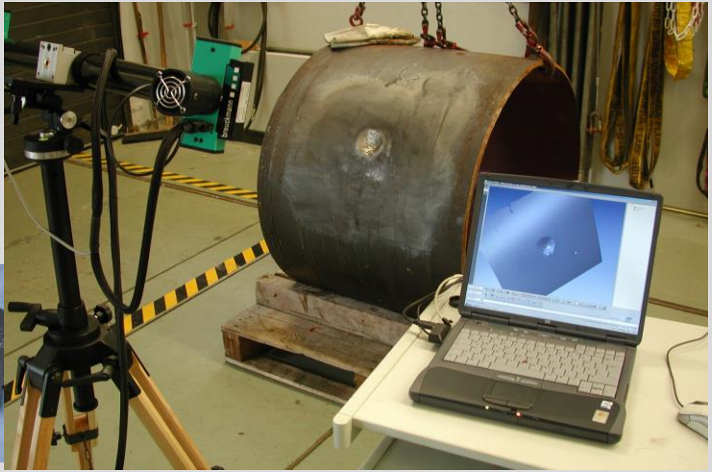
Special old joints with gas welded seam under operating pressure and bending

Operation of Pipelines: Investigation Method Finite Element Analysis

Step 1

Scanning the surface of the defect
- direct scan
- scan of a cast model
- (negative shape)

The cast consists of plastics moulding material and can be easily moulded by the NDT-personnel on site



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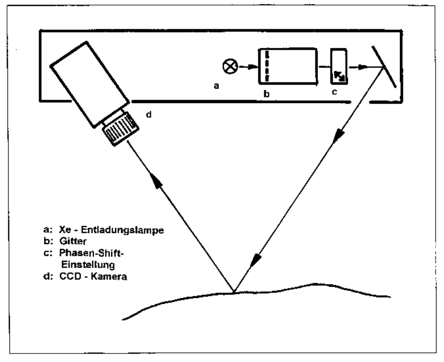
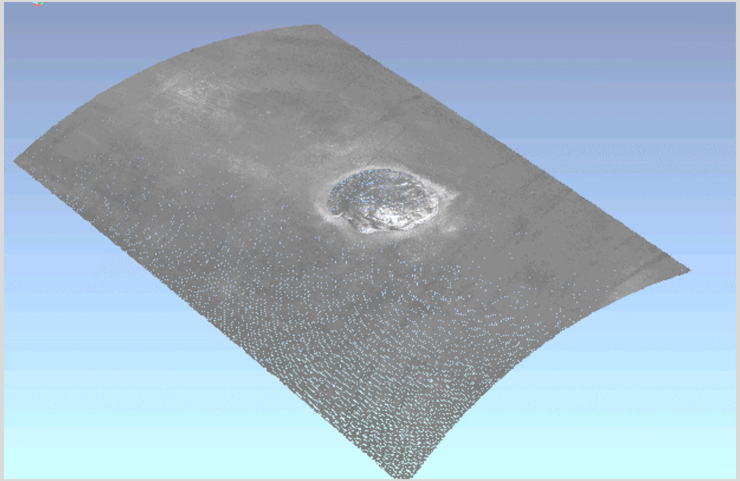
Operation of Pipelines: Investigation Method Finite Element Analysis

Step 1

The result of the measurement is
a 3-dimensional cloud
of up to 1,3 Mio. points
with the coordinates x, y, z





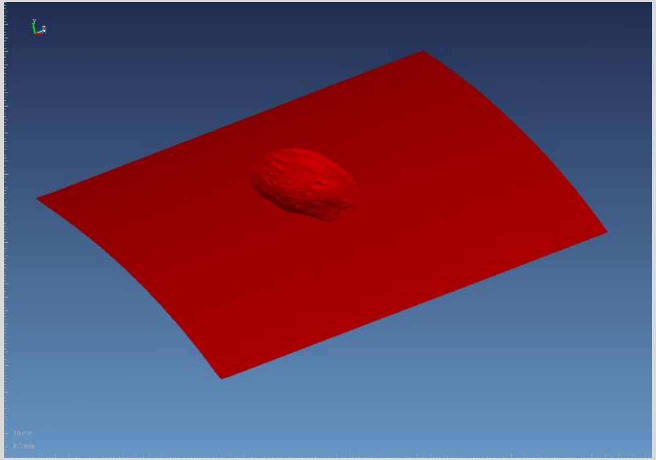
Point cloud generated by optoCAM

Operation of Pipelines: Investigation Method Finite Element Analysis

<u>Step 2</u>

Computing the Surface

All geometric details
of the surface
are taken into account
for the evaluation

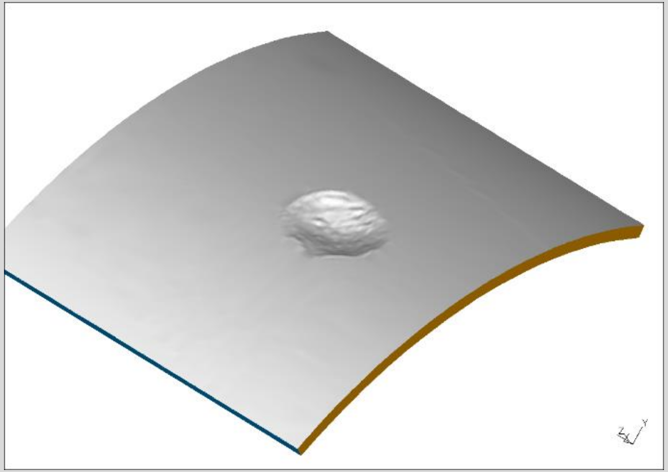


Surface computed and mathematically defined using Freeform Modeller

Operation of Pipelines: Investigation Method Finite Element Analysis

<u>Step 3</u>

The interface transfers the surface to the CAD system which generates a volume model



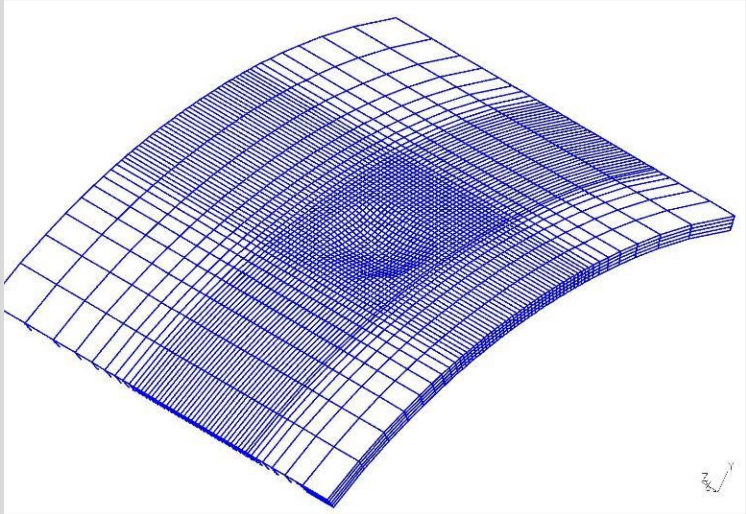
CAD model – Volume model

Operation of Pipelines: Investigation Method Finite Element Analysis

<u>Step 4</u>

Generating the
Finite-Element-Model

Using the FEM software
I-DEAS & ABAQUS,
a computation model
is developed from
the pipe surface



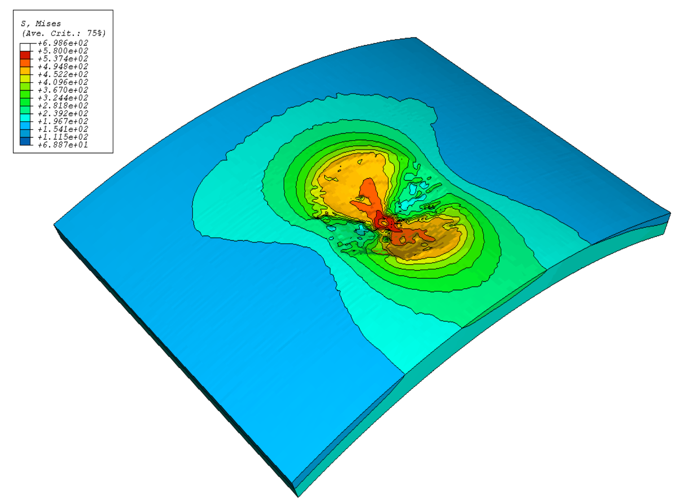
Finite element computation model

Operation of Pipelines: Investigation Method Finite Element Analysis

Step 5

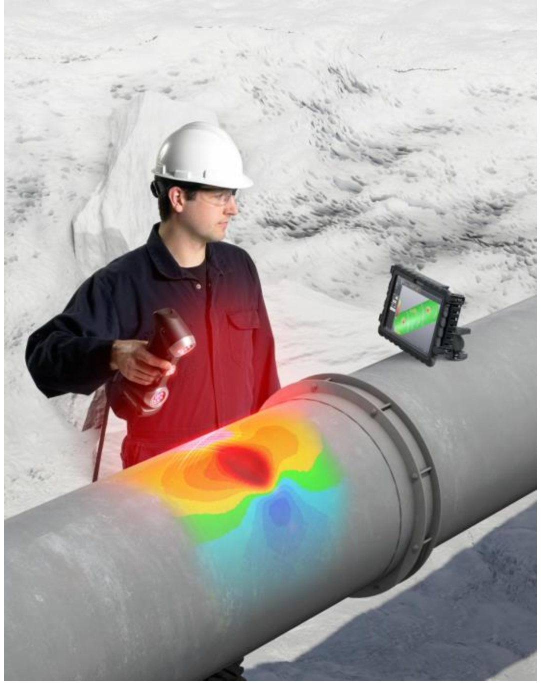
Compute Stress & Strains

Result of finite element analysis:
The maximum stresses occurring in the pipe have been determined and can be analysed in terms of reliability



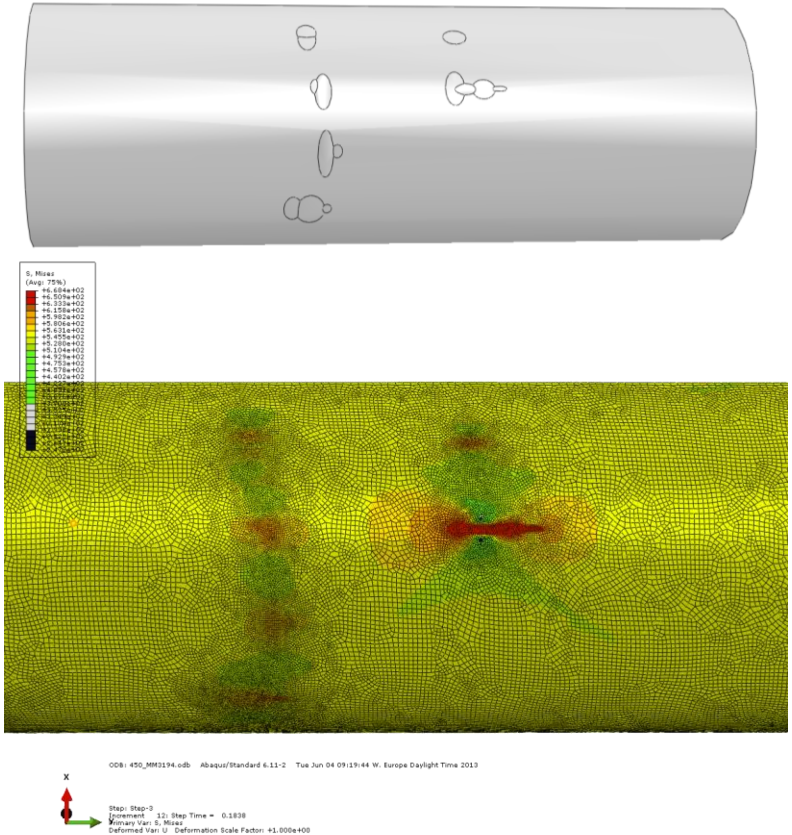
Equivalent stresses according to von Mises

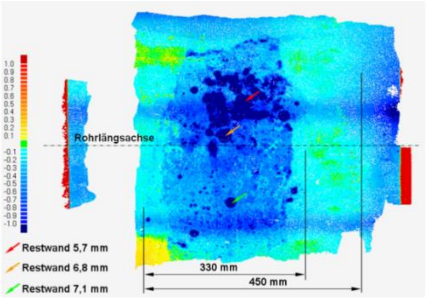
Today, the whole measurement process is done with modern applications like “HandySCAN” that sends the data to the FEM computer

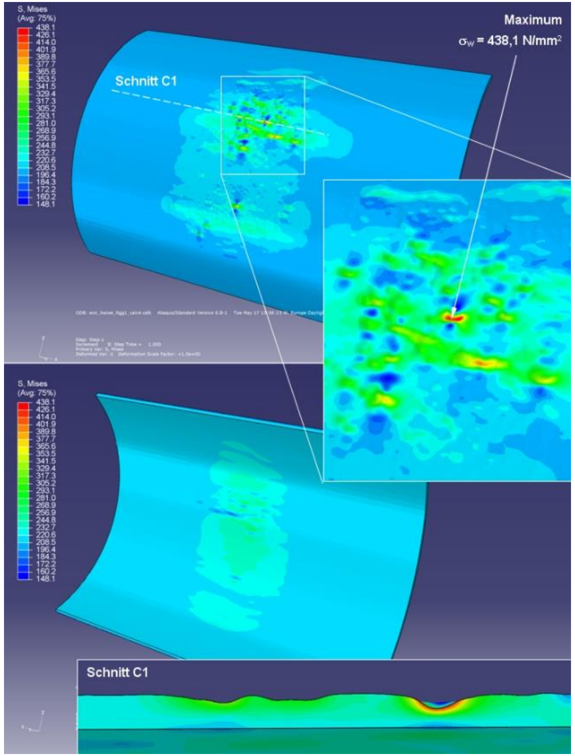


HandySCAN 3D professional scanner

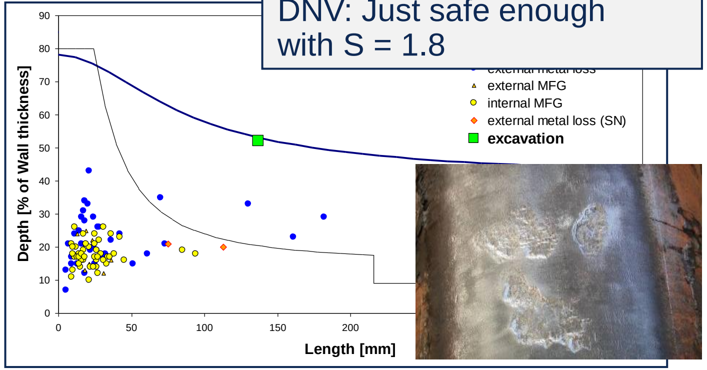
Operation of Pipelines: Investigation Method Finite Element Analysis



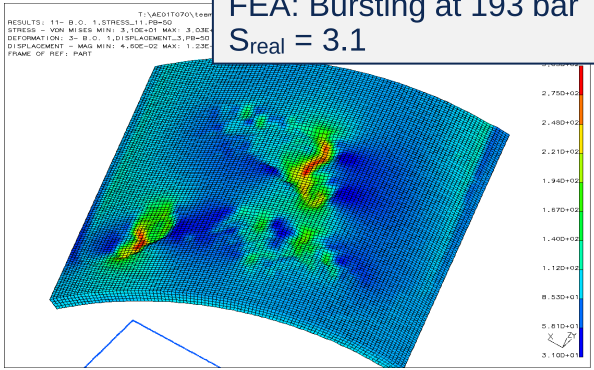




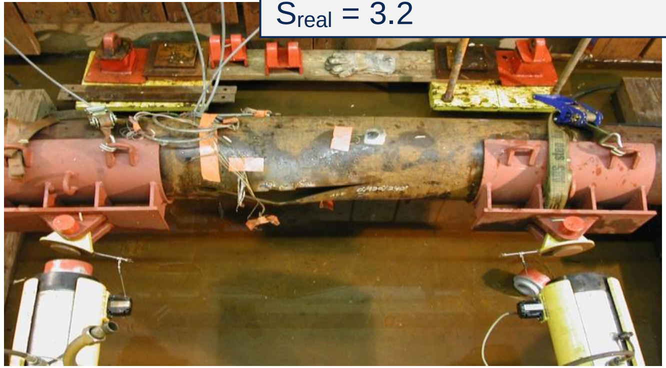
Comparison of simple integrity formula, of FEA and of burst tests



DNV: Just safe enough with S = 1.8



FEA: Bursting at 193 bar
S_{real} = 3.1



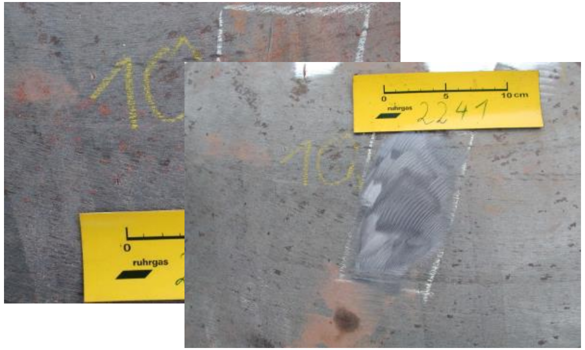
Test: Bursting at 199 bar
S_{real} = 3.2

Pig	52%, 137 mm long
Excavation	69%, 150 mm long

Calculation is conservative

compared to real pipe behaviour

Pipelines: Repair Methods



Smooth Grinding of Corrosion or Gouge

Welding Patches at small Pittings/Leaks caused by Corrosion (only soft steel)

Split Sleeves with Hot Formed Ends for Repairing Large Metal Loss, Dents, Gouges

Knuckle Joints for Protection of Old Joints

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Pipelines: Repair Methods: Different sleeves

Repair of severe defects

- Split sleeve
- Temporary sleeve
- Replacement
- Non-Metallic Composite Repair Systems (no standard method for OGE)

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Pipelines: Repair Methods

Temporary Repairing Methods

- for Low Pressure

- Plidco for High Pressure

- Manibs for Coated Pipe

Cutting Pipeline resulting in Decreasing of Stress/Strain in Area of Coal Mining

Inliner inside the Original Pipeline

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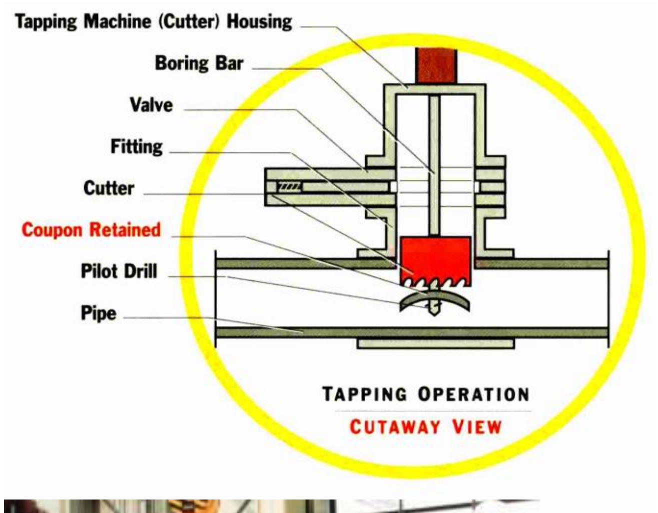
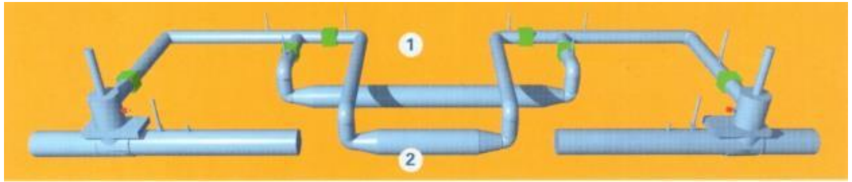
Pipelines: Repair Methods

Hot tapping & plugging:

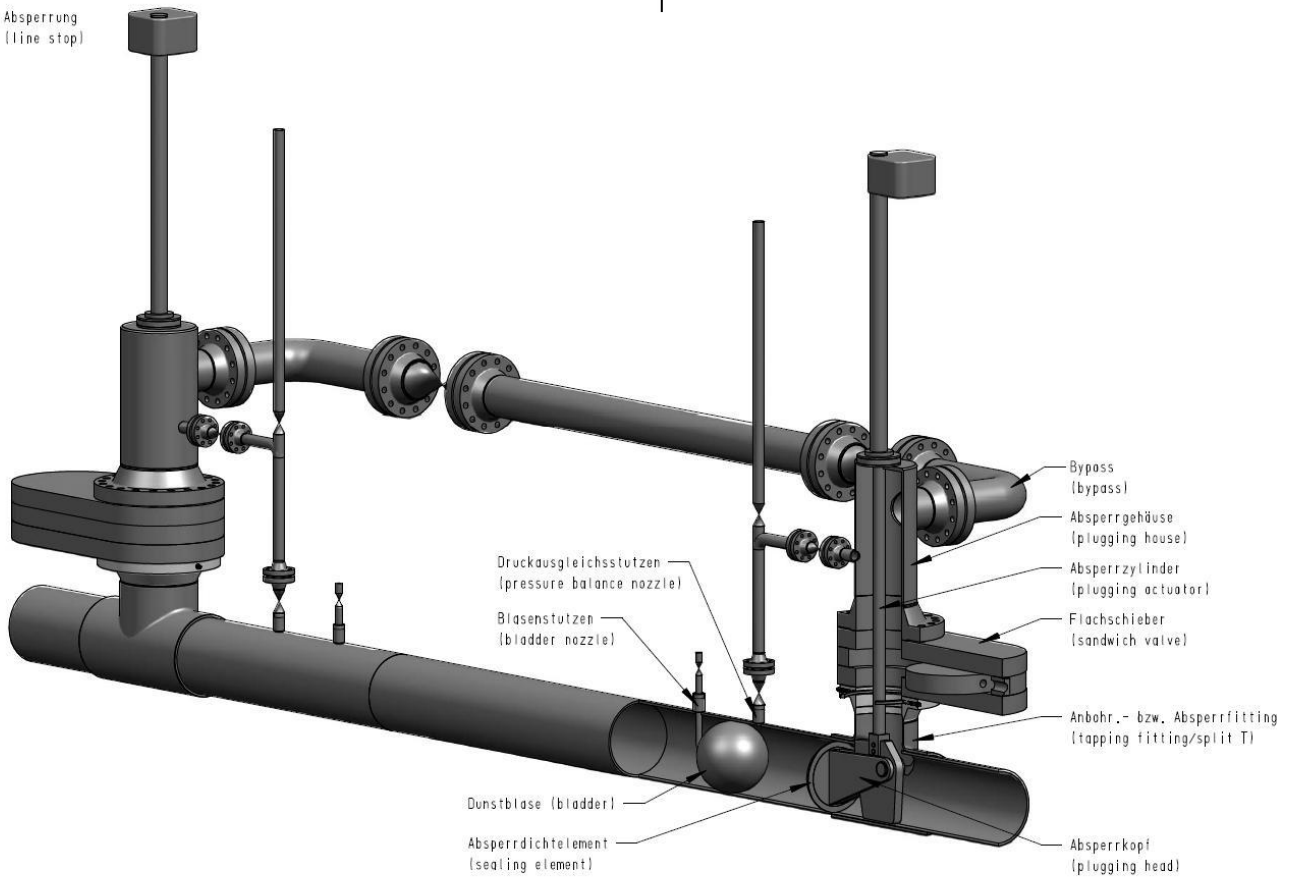
Hot tapping is a method for accessing the inside of an operating pipeline, using either a drill or a circular cutter to remove a coupon from the pipeline.

Plugging it consists of hot tapping the live pipeline, bypassing the product and replacing the defect pipe session with new material





Pipelines: Creating a bypass (principle)



Pipelines: hot tapping of a DN 800 pipeline




Photos of a construction site
(Source: Open Grid Europe, 2020)

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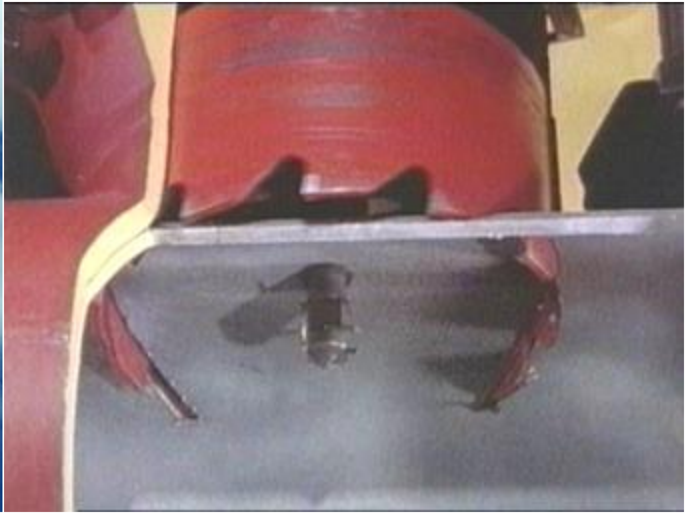
Pipelines: hot tapping of a DN 800 pipeline

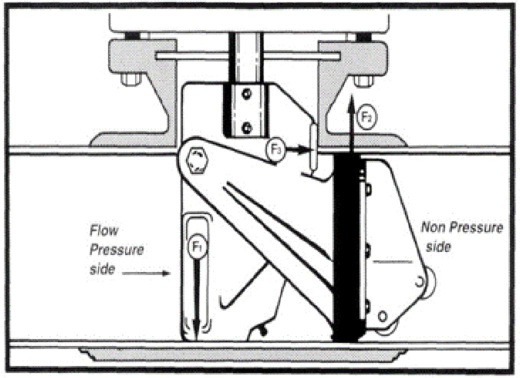


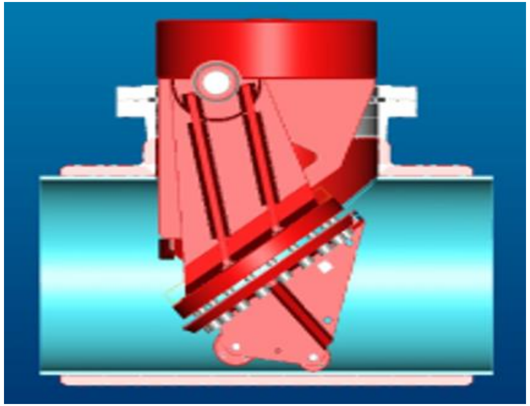
Drilling machine and drilled plate (Source: Open Grid Europe, 2020)

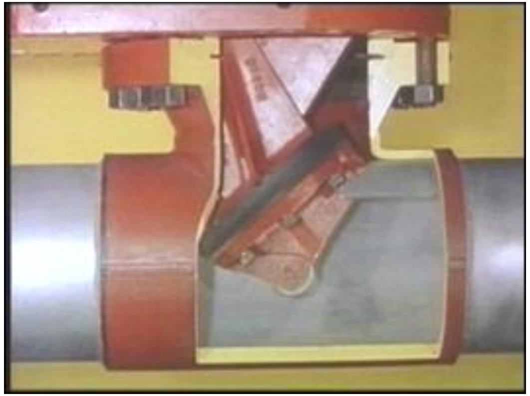
Pipelines: Plugging (big calliper equipment and principle)

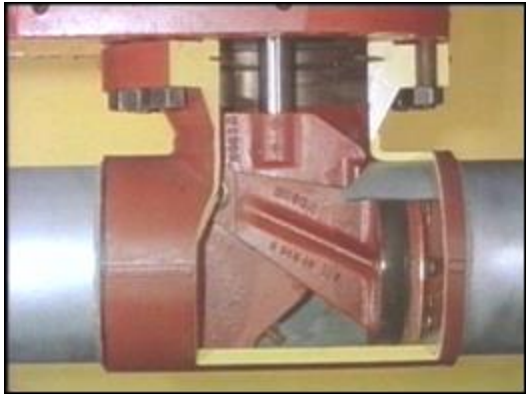
Photos Open Grid Europe, 2020

STOPPLE PLUGGING HEAD FORCES









Decompression of a pipeline section using a mobile compressor unit

Mobile compressor (Source: Open Grid Europe, 2020)

Decompression of a pipeline section using a mobile flaring system

Mobile flaring unit (Source: Open Grid Europe, 2020)

Teil 7 – Pipelines

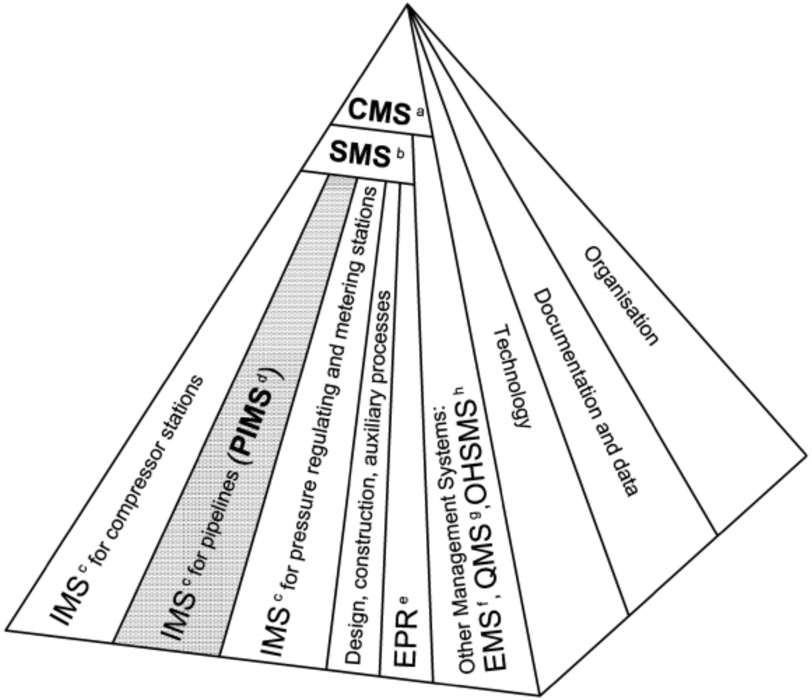
Maintenance

Operation & Dispatching

PIMS

Pipeline Integrity Management System – a decisive part of a company management system

see DIN EN 16384



Key

a – CMS - Company Management System
b – SMS - Safety Management System (for gas transmission infrastructure
c – IMS - Integrity Management System
d – PIMS - Pipeline Integrity Management System
e – EPR – Emergency Preparedness and Response Procedure
f – EMS - Environment Management System
g – QMS - Quality Management System
h – OHSMS - Occupational Health and Safety Management System

PIMS

Objective:

- Technical infrastructure safety and asset preservation

How to reach the objective:

- Systematic, quality-controlled as-built documentation; access to primary data
- Standardised methods and procedures for condition assessments, evaluation criteria and action to be taken
- Quality-assured procedures based on specific deadlines
- High level of information about the technical integrity of the pipeline systems
- Support for decision-makers when it comes to deciding on repair or replacement measures

disbonded coating

coating crack

bent pipe joint with a lip

corrosion damage

dents and gouges

pitting corrosion

PIMS

- PIMS contains methods, criteria and procedures for the integrity assessment of pipelines
- PIMS specifies, describes, organises and documents the whole assessment and restauration process
- PIMS provides full transparency about …

1. **Technical Integrity**
2. **Data- and Informational Integrity**
3. **Organisational Integrity**

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PIMS Technical integrity is based on a sound and uniform assessment of components, defects,..

PIMS standard:

- Defines the rules for providing evidence on technical pipeline integrity
- Describes the methods for condition assessment incl. acceptance criteria
- Describes the type, scope and frequency of assessments
- Lists possible remedial actions
- Is created and maintained by the PIMS group of experts

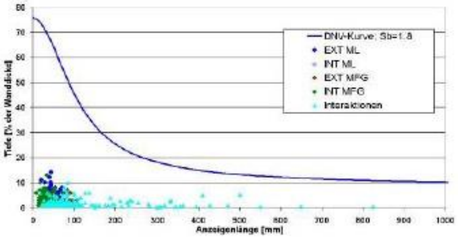

Open Grid Europe
The Gas Wheel

Diese Werknorm ist ein Teil des Konzeptes für ein neues Integritätsmanagementsystem für Verdichterstationen (CIMS)

RN 210-001

Grundlagen der Leitungsintegrität;
Regeln und Verfahren zum Nachweis der technischen Leitungsintegrität

Version, Stand: 1, 06.01.2015



PIMS More details what is fixed in a Pipeline Integrity System Catalogue

- Fundamentals of Pipeline Integrity: Design, Construction, Additional / External Loads, Operation, Supervision, CP
- Integrity Assessment Fundamentals
- Assessment Process, Follow-Up and Documentation
- Assessment of Piggable Pipelines:
  - Time of Inspection and Assessment, First Assessment, Inspection Interval
  - Mechanical Assessment of Defects
    - **Manufacturing Defects, Construction Defects, Third Party Damage, Bending Strain, Corrosion Related Metal Loss, Dents, Expansions, Ovalities, Seam Weld Anomalies, Cracks, Other Defects**
  - Corrosion Assessment of Defects
    - Integrity Assessment based on the Safety Factor / Load Factor
    - Metal Loss Features in Casing Pipes
    - **AC Corrosion Assessment**
    - **Corrosion Progress and Prognosis of Defect Depth**
- Assessment of Non-Piggable Pipelines


Open Grid Europe
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Version, Stand: 1, 06.01.2015

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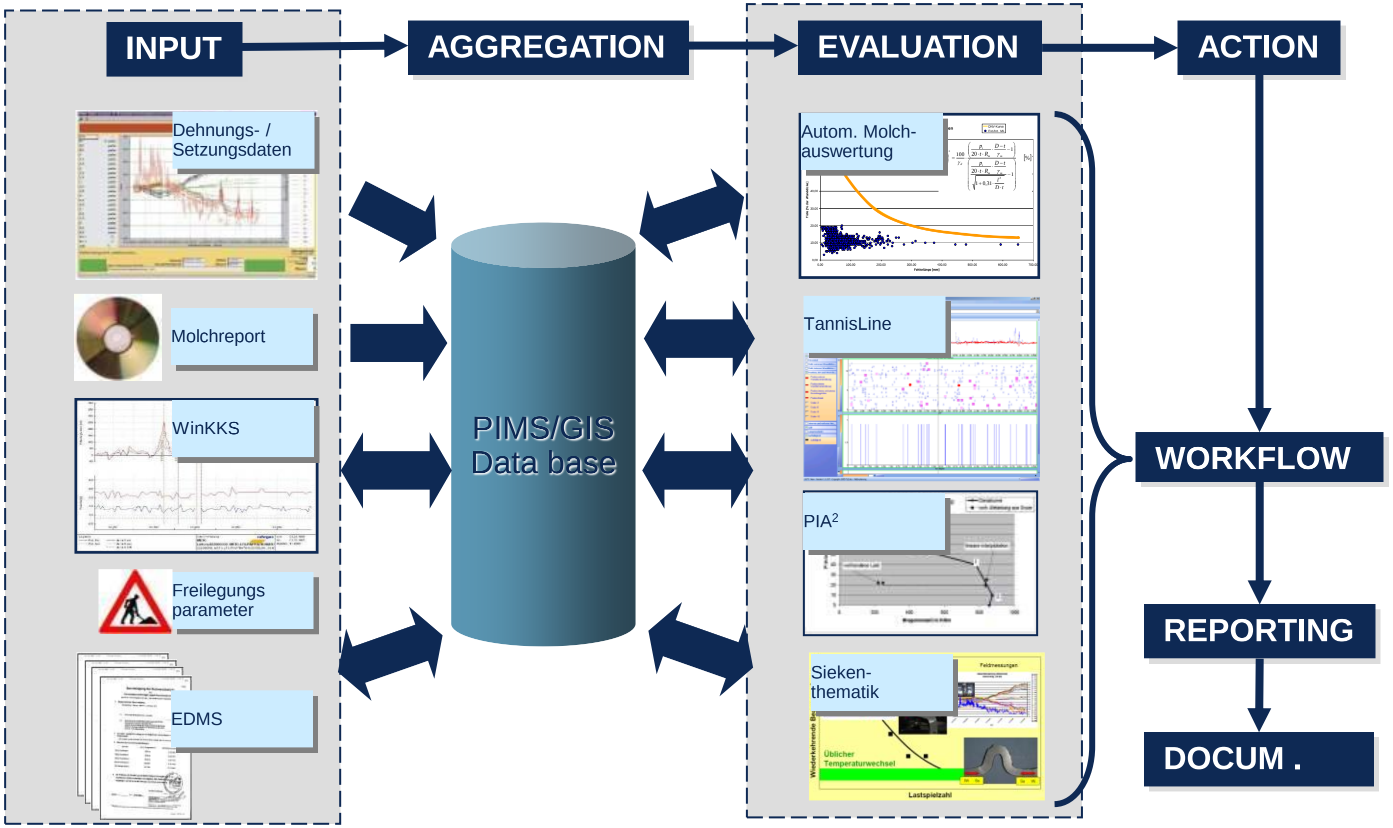
Which formulas are applied?

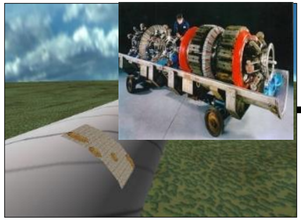
- **Metal Loss Features** due to corrosion or grinding repair of other features (corrosion, manufacturing, cracks, …) acc. to DNV RP-F101 with a safety factor against failure of S = 1,8 min.
- **Weld Defects** acc. to DVGW GW 350 and DIN EN 12732 App. G2
- **Dents** in base material (not near seam weld) acc. to DVGW G 473
- **Cracks** without grinding repair acc. to ASTM STD 536 or BS 7910
  (cracks repaired by grinding are treated as metal loss features)
- **Expansions** acc. to internal standards
- **Bending Strain** e.g. due to dislocations acc. to DIN EN 1594 – App. B to F,
  verification against max. strain and denting, limits acc. to DIN EN 1594: 2000 – App. G
- **Defects near Seam Welds or Combination of Multiple Defects** – Individual Assessment

PIMS – how a IT-based PIMS system should look like

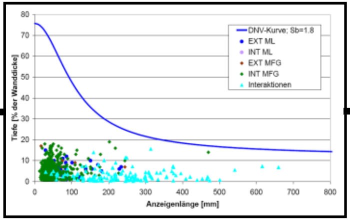


PIMS – running the process

ILI



Assessment DNV RP-F 101 Part A



Excavation and NDT

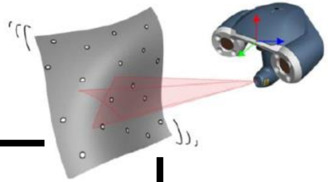
EN 1594 or DNV RP-F101 Part B

Errechnung der Mindestwanddicke nach DIN EN1594
(Sicherheitsbeiwerte entsprechend DVGW G463)
Berechnung für gerade Rohre

Nenndruck	PN	67,5	bar
Außendurchmesser	Da	914,4	mm
Streckgrenze	Rt0,5	415,00	Mpa
Sicherheitsbeiwert	S	1,60	
Mindestwanddicke	**Tmin**	**11,9**	**mm**

Bewertung nach DNV RP-F101 (Part B)

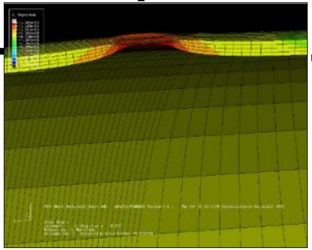
Nenndruck	PN	67,5	bar
Außendurchmesser	Da	914,4	mm
Wanddicke (Nom. oder Meßwert)	t	12,60	mm
Fehlertiefe	a	3,00	mm
Fehlerlänge	L	60,00	mm
Zugfestigkeit	Rm	550	Mpa
Verhältnis	d/t	0,24	-
Berstdruck, nominal	P0	153,69	bar
Berstdruck, lokal	Pb	151,55	bar
Faktor d. Schwächung	Rs	0,99	-
Modellfaktor	F1	0,90	
Sicherheit (Bersten)	**S**	**2,02**	



Handyscan

(if needed)

Grinding



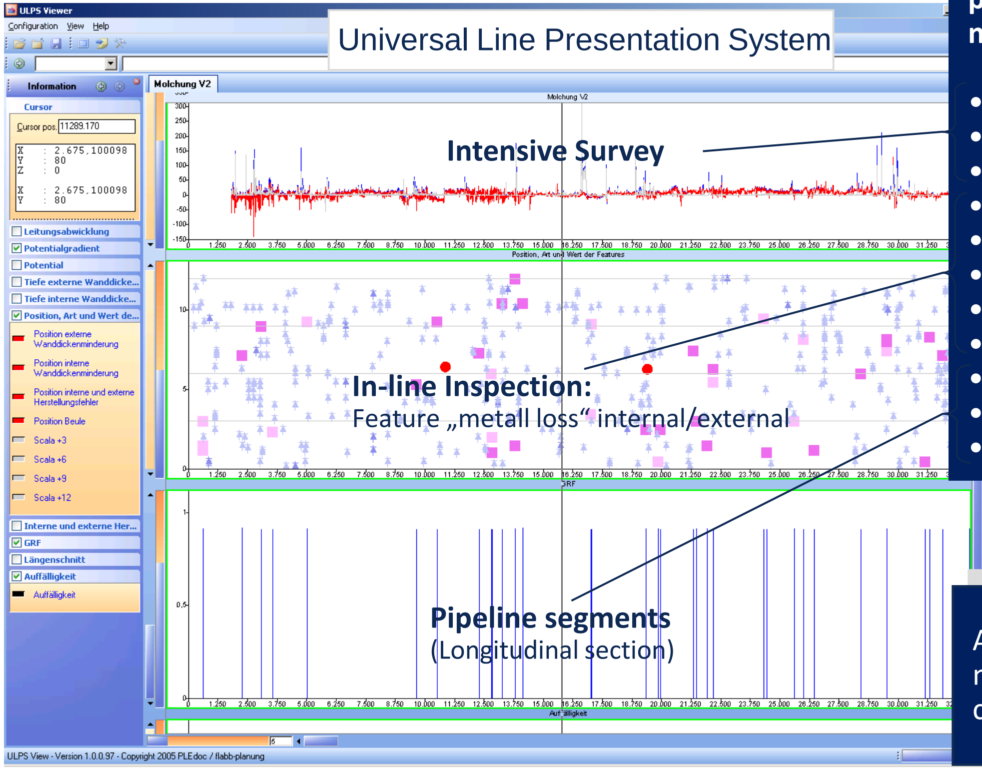
Modelling CAD and FE-Calculation

Repair (if needed)

Assessment, certified experts statement and documentation

DVGW

PIMS – Visualisation of data



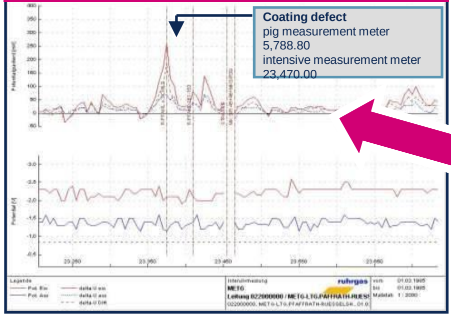
Compilation and presentation of different measurement data

- pipeline
- potential gradient
- potential
- depth of ext. wall defect
- depth of int. wall defect
- position and type
- manufacturing defect
- ERF
- longitudinal section
- other distinctive feature
- ...

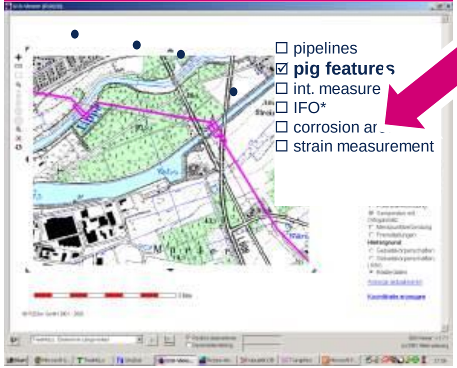
Assessment by material and corrosion experts

PIMS – data access and administration

Intensive measurement data



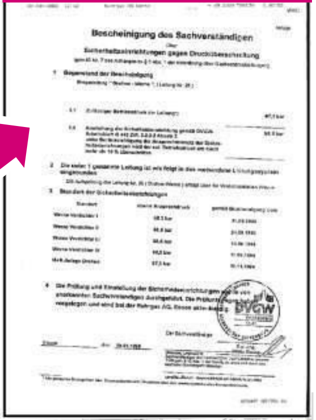
Location: GIS data



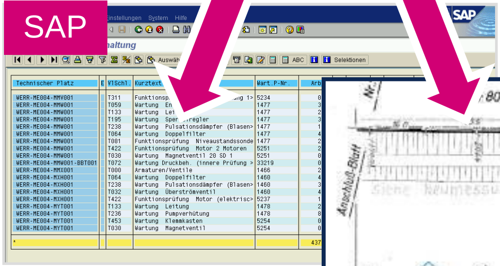
Access to measurement data (operational data)

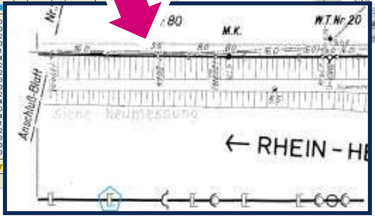
Access to pipeline documentation (design data)

Commissioning file

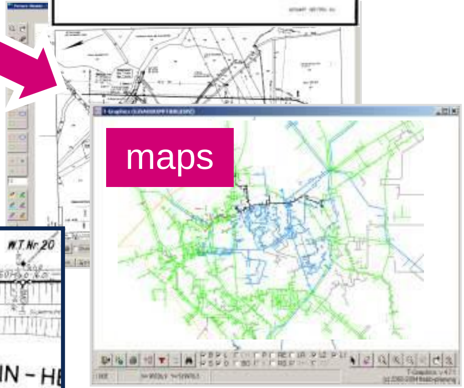


SAP





maps

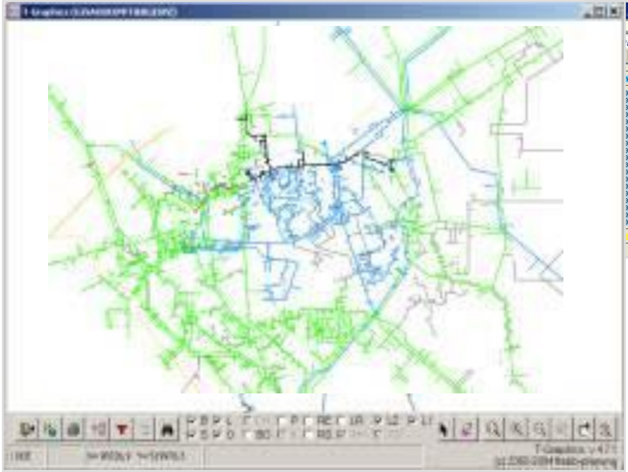


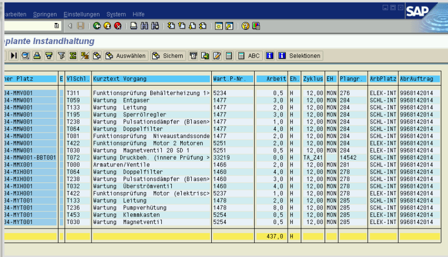
PIMS – data access and administration

PIMS is used to document and/or systematically track pipeline-specific data:

- Pipe book
- Certifications and technical approvals
- Graphs and drawings
- Maps and plans
- SAP PM (Plant Maintenance)


Bescheinigung des Sachverständigen





Teil 7 – Pipelines

Maintenance

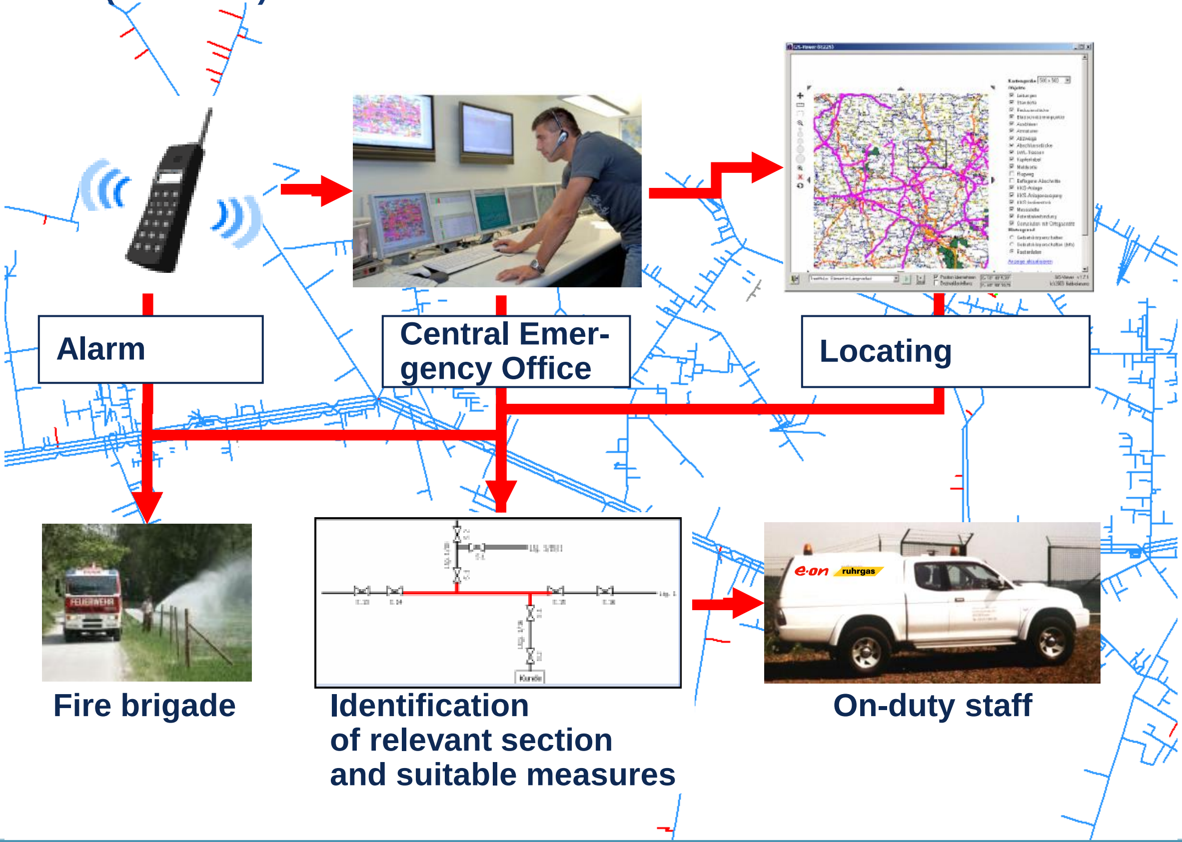
Operation & Dispatching

Pipelines: Dispatching, grid control (and emergency preparedness) centre

Work space in a dispatching centre

Pipelines: Emergency preparedness

Emergency preparedness (Kasuistik)



Emergency preparedness (Kasuistik)

Questions in connection with a reported pipeline failure

- Where exactly is the failure ?
- Which pipeline is affected ?
- Between which valves is the failure ?
- How does the failure affect the supply ?
- Is it possible to close the adjacent valves ?
- How can the supply be continued ?
- Which customers are in the section to be closed ?
- Can the customer stop his supply at the specific point ?
- What is the contractual situation ?
- What is the relevant partners address ?

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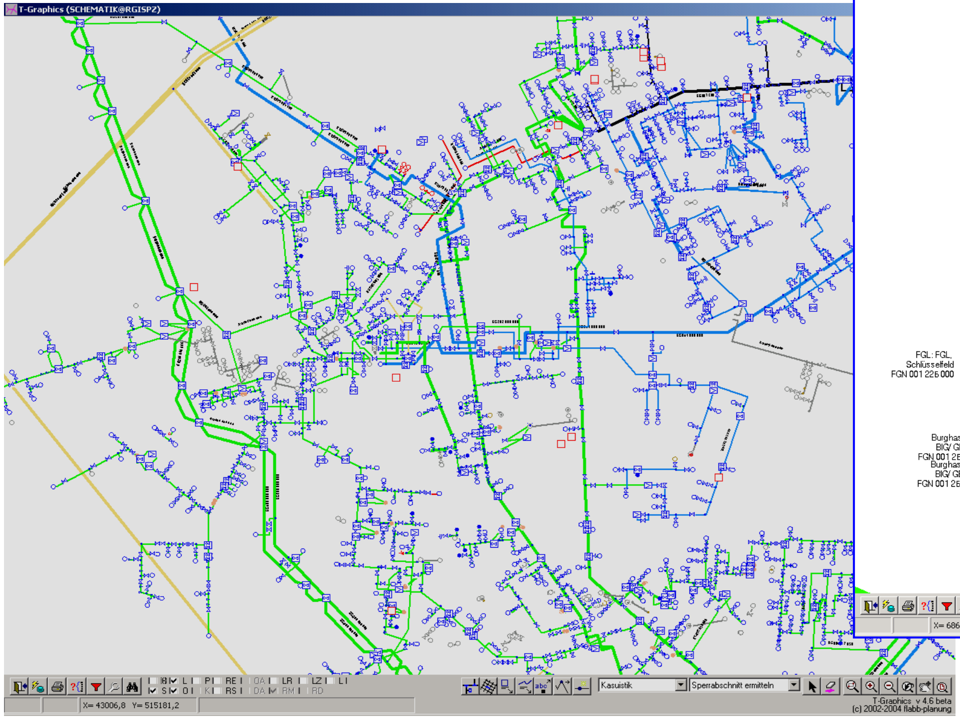
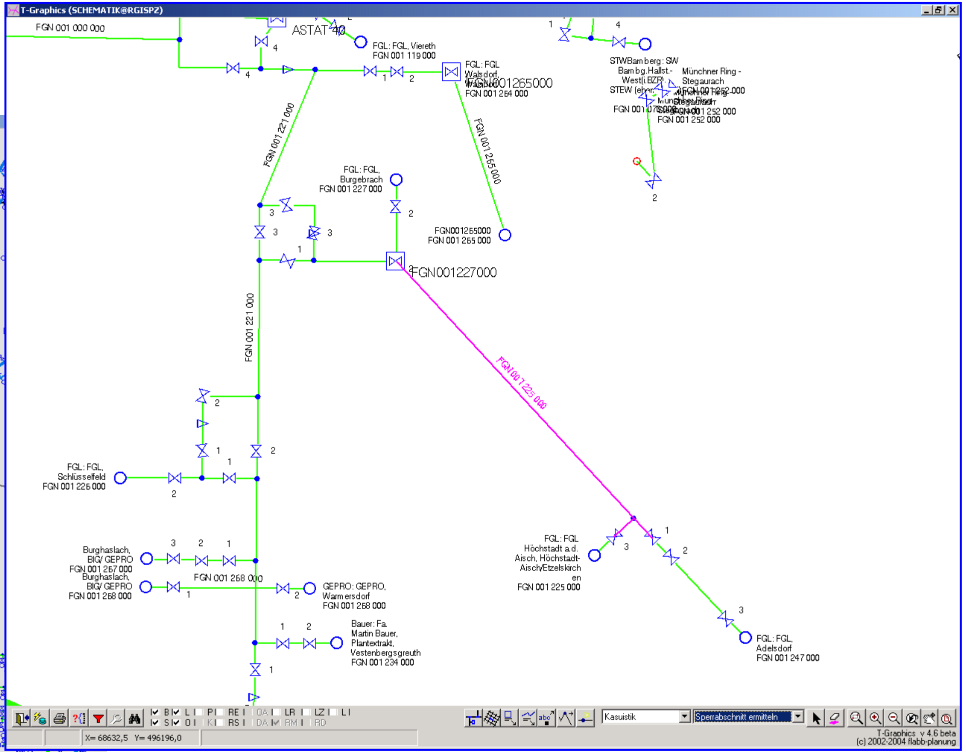
Pipelines: Features of a Kasuistik

Emergency preparedness (Kasuistik)

Tools and Instruments





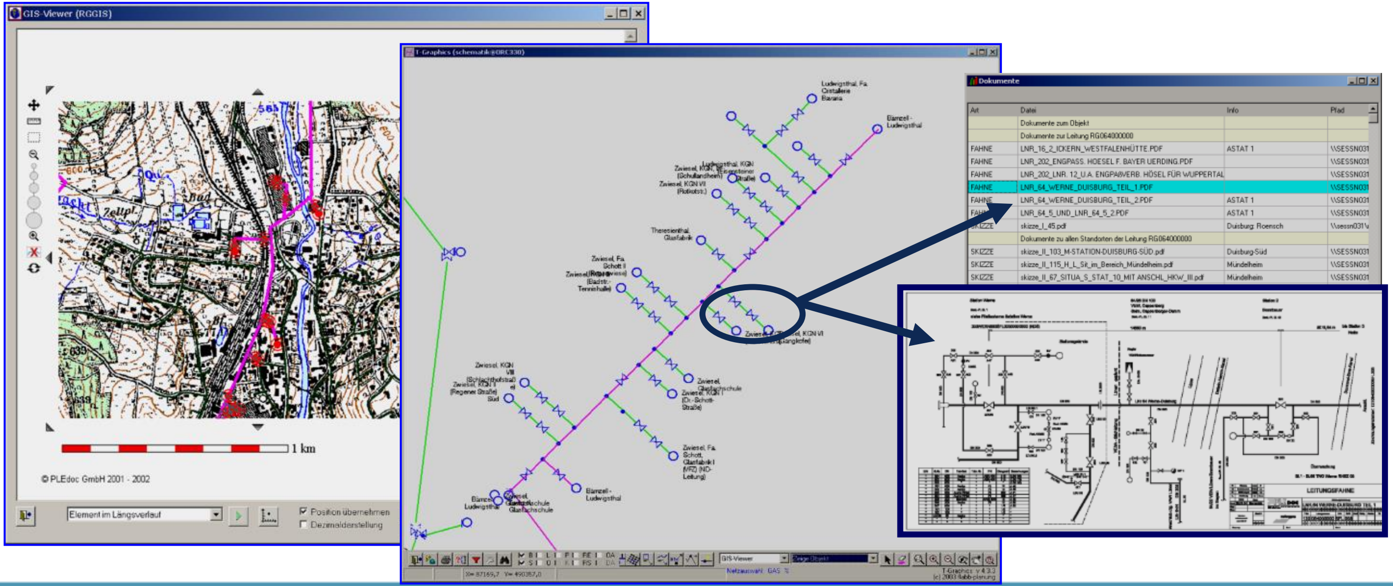
Pipelines: Features of a Kasuistik

Emergency preparedness (Kasuistik)

Tools and Instruments

From GIS to Schematic View

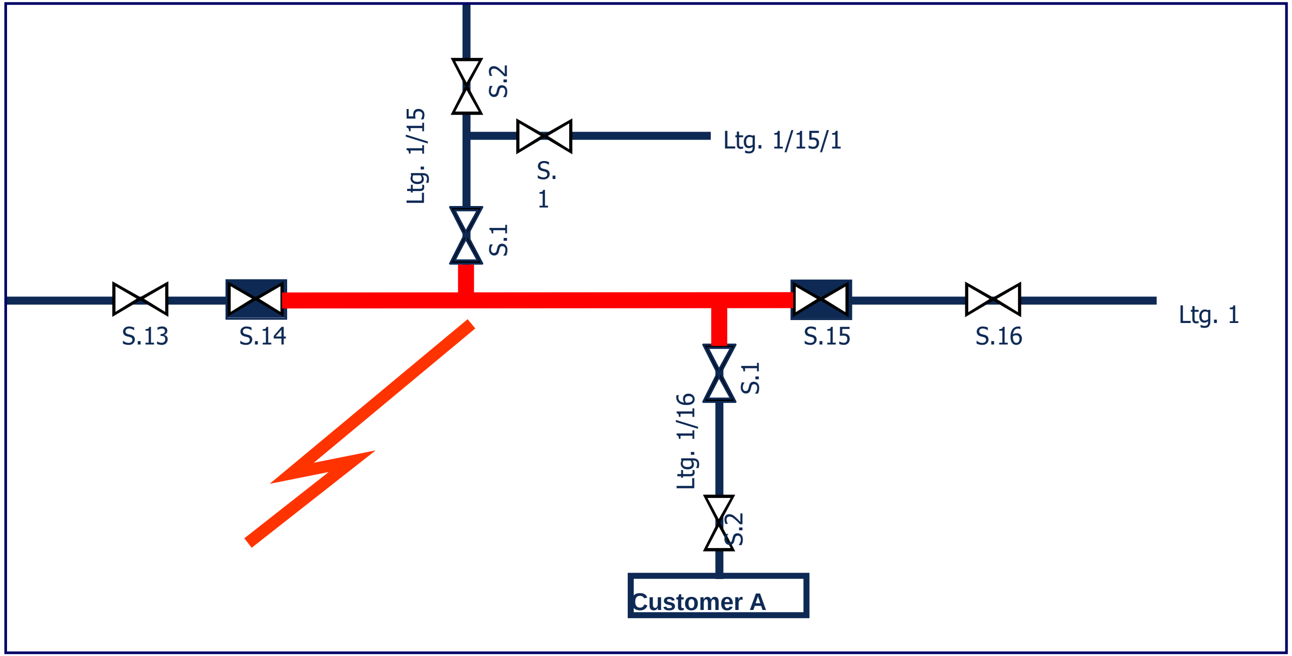
- Schematic grid visualisation to enable the user to observe and assess the entire supply situation
- Simple switch between geographic and schematic view
- Fast access to documentation: detailed listings and maps



Pipelines: Kasuistik - a method to react within minutes by shutting down the right values

Emergency preparedness (Kasuistik)

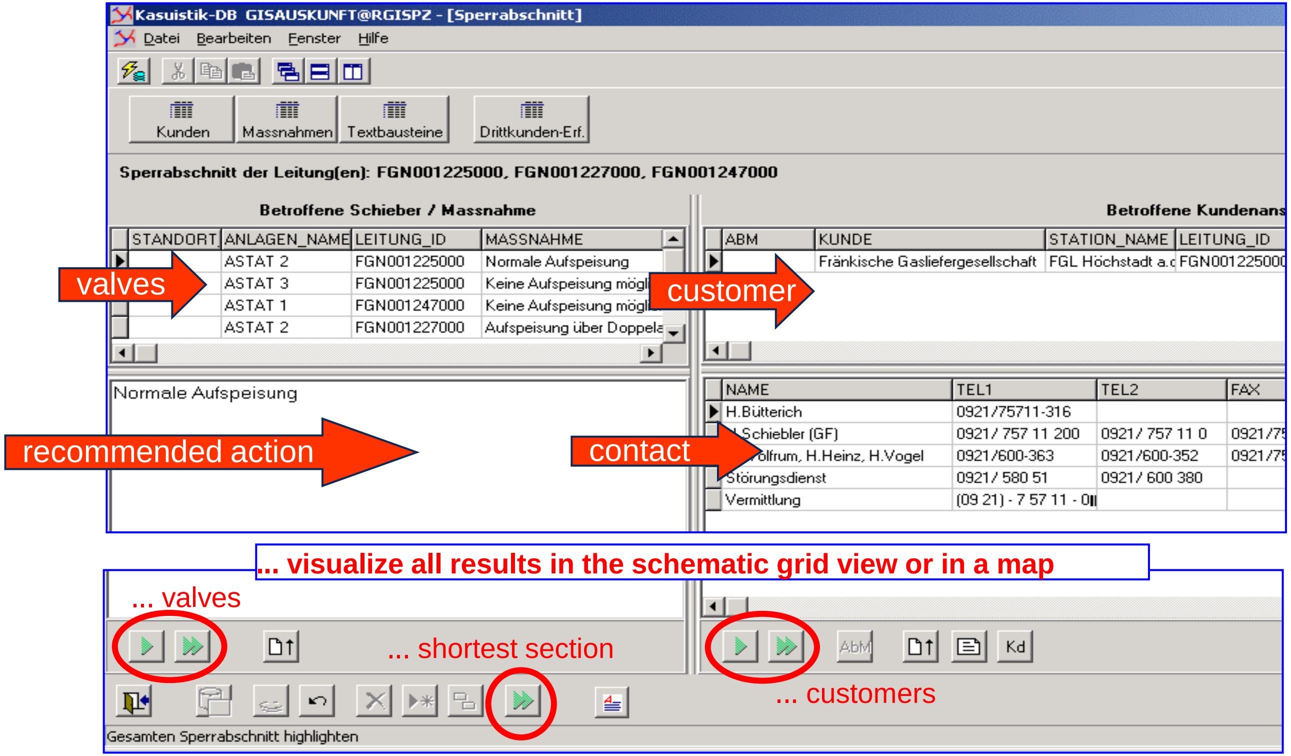
Tools and Instruments



Pipelines: Kasuistik - a method to react within minutes by informing customers and staff on duty

Emergency preparedness (Kasuistik)

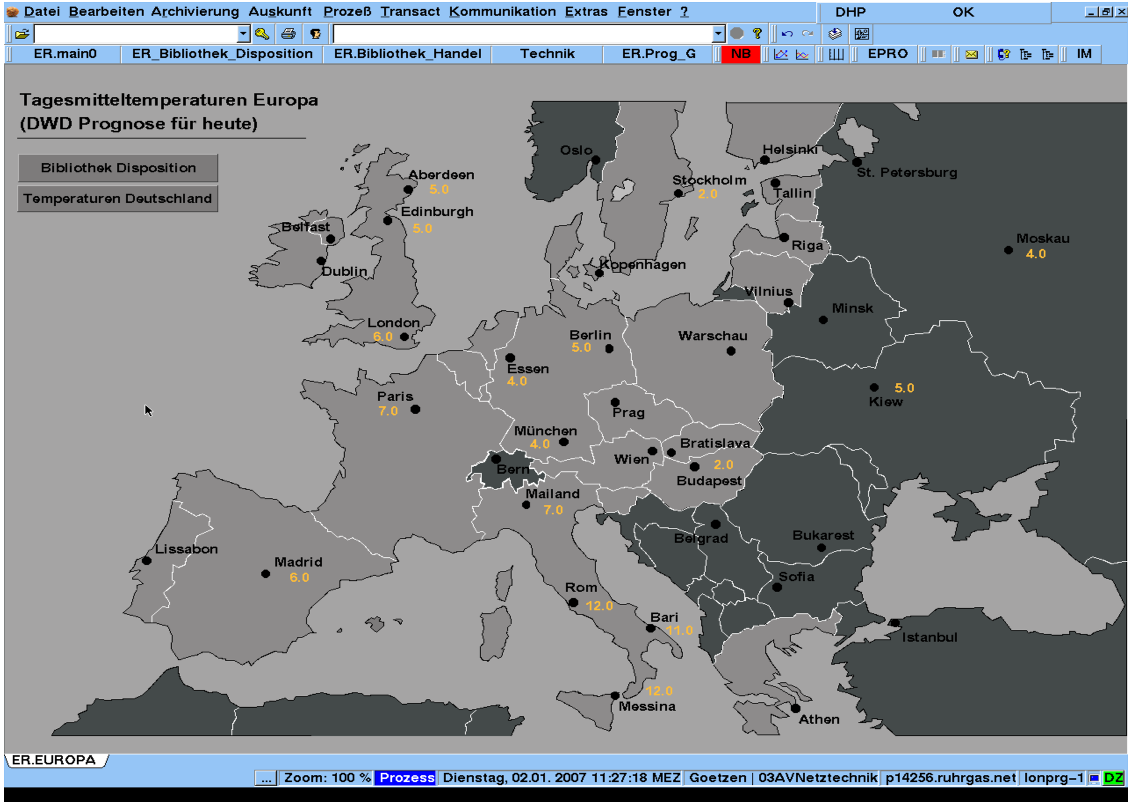
Tools and Instruments



Pipelines: Grid Control and Network Operation

SCADA systems and GIS applications

The SCADA system is used to monitor and control the gas grid. Flows, quantities, gas qualities and pressures are visualised.
In addition, commands can be send out to start or stop a compressor, to close valves and to operation other technical equipment.



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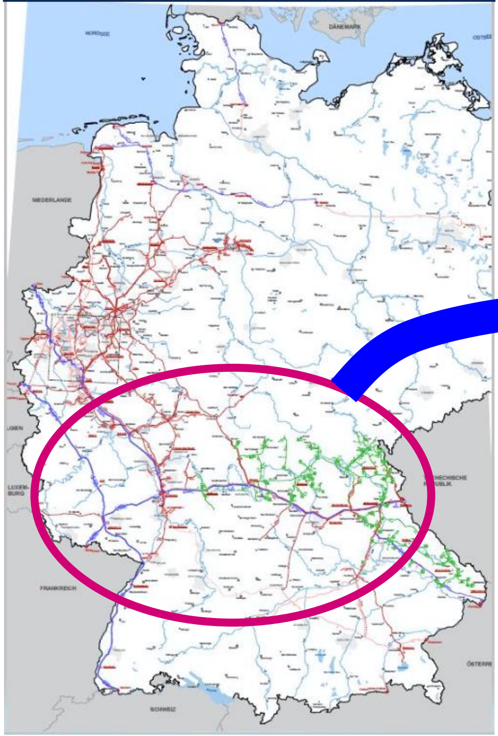
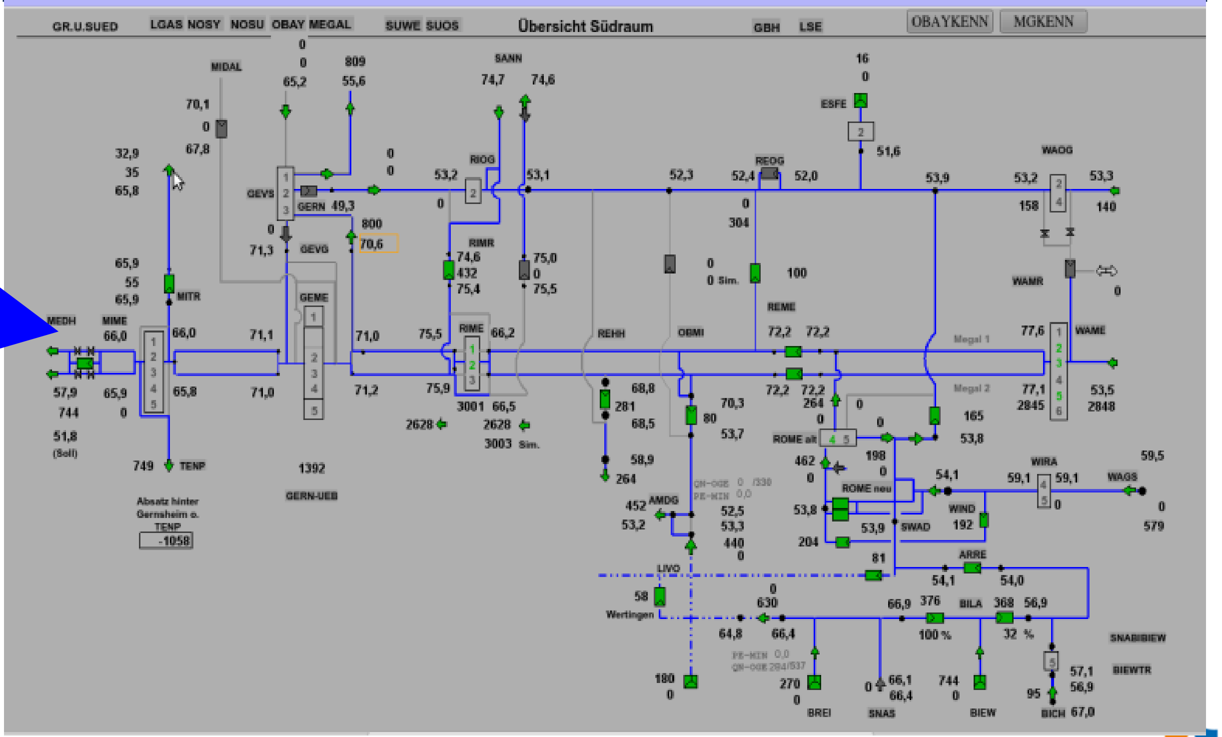
A SCADA System monitors and controls a pipeline grid

Topographic view



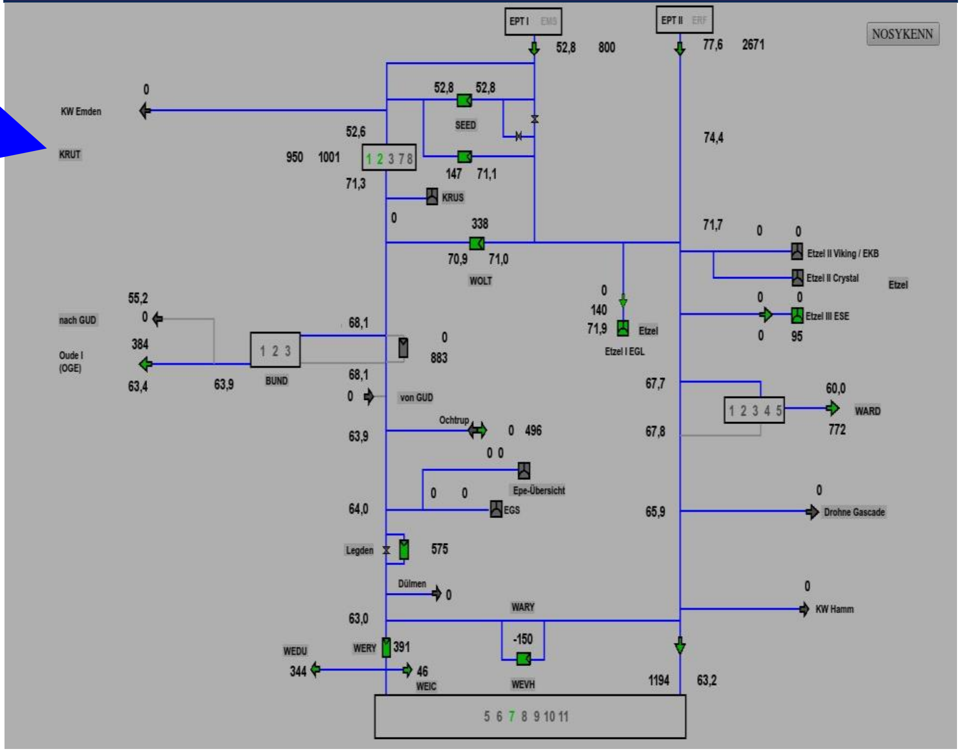
Schematic view



A SCADA System monitors and controls a pipeline grid

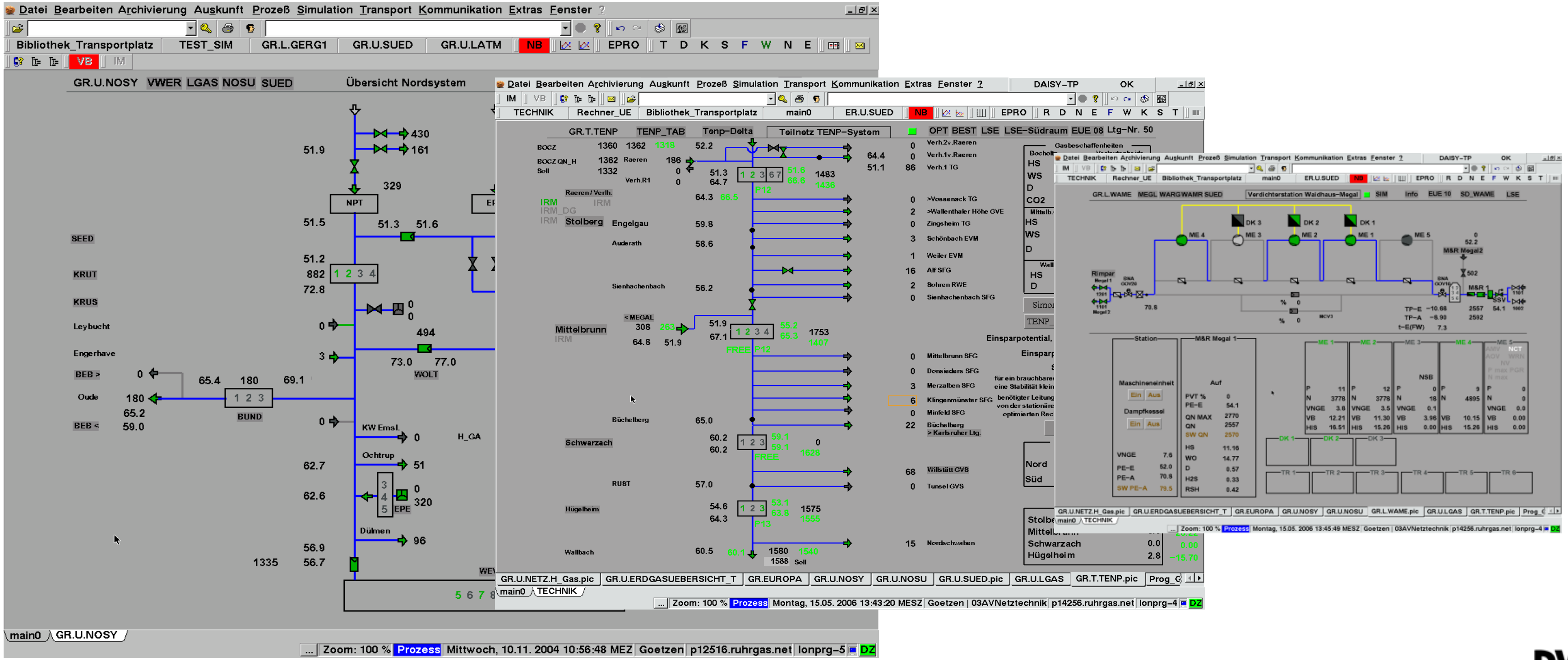
Topographic view

Schematic view



A SCADA System monitors and controls a pipeline grid

The operator can zoom into a frame with more details and down to each individual engine.
It is possible to start and stop compressors and shut down values.



Teil 7 – Pipelines

Maintenance

Operation & Dispatching

1. Risks pipelines are exposed to
2. Inspection and repair methods
3. PIMS
4. Dispatching and emergency response
5. **Valves and valve spacing**

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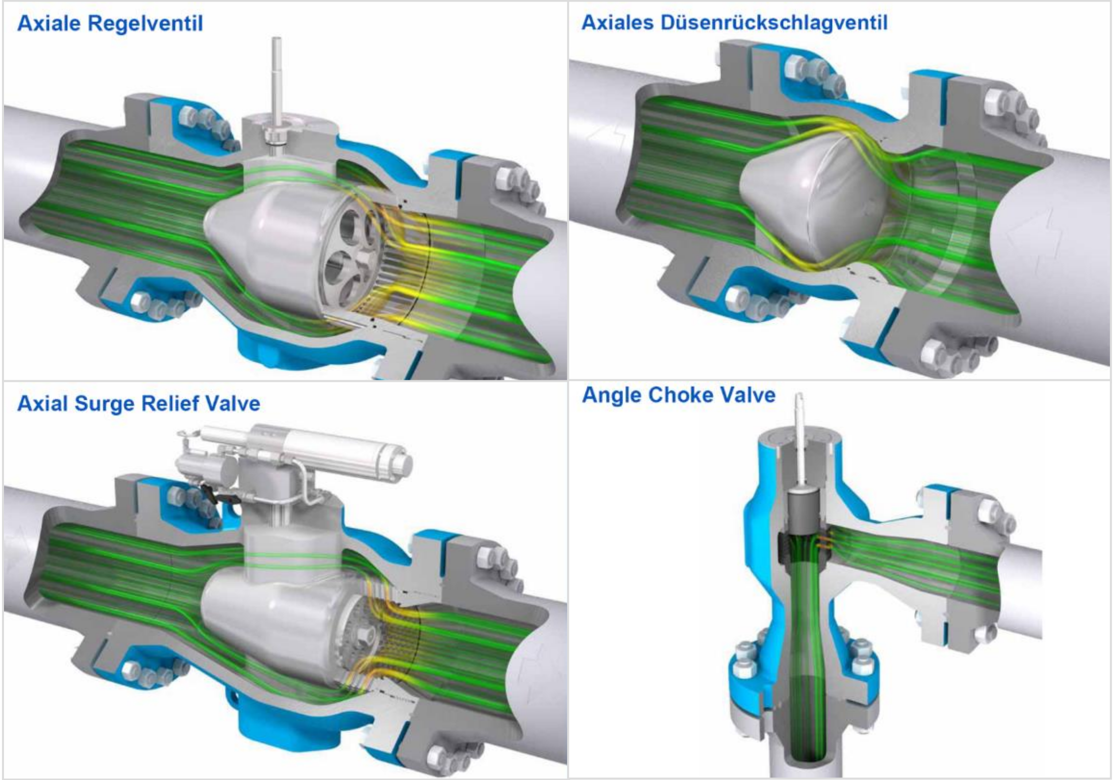
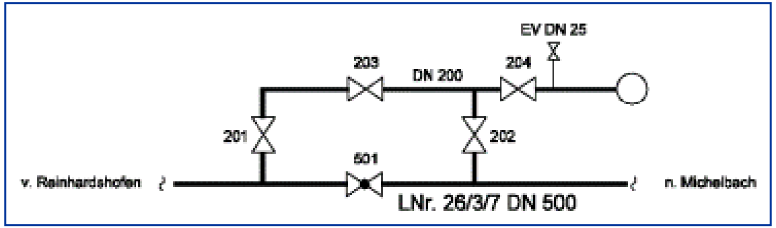
Valve stations



The high-quality shut-off valves installed in the pipelines are usually ball valves

Thanks to the ball valve shut-off principle repair and welding work on modern transportation pipelines can be performed in a gas-free atmosphere.

Tightness test via block-and-bleed shut-off function in open and closed positions!



Spacing distances of valves: Comparison of spacing distances in different countries

Germany		France		Danmark			
				D_{max} = 4 km	D_{max} = 6.4 km	D_{max} =12 km	D_{max} =16 km
D_{min} = 10 km	D_{max} = 18 km	D_{min} = 10 km	D_{max} = 20 km	Class 4	Class 3	Class 2	Class 1

Swissgas	Norway	Italy		Netherlands
D_{max} = 20 km	not explicitely given	D_{min} = 2 km	D_{max} = 10. km	Distance is derived from volume of gas enclosed between two valves = 700.000 normal m3.
sitespecific but remote control	Distance is determined on the basis of safety studies	pressure-dependent		

Spain				Canada			
D_{max} =5 km	D_{max} = 10 km	D_{max} =20 km	D_{max} =30 km	D_{max} = 8 km	D_{max} = 13 km	D_{max} =25 km	D_{max} =not req.
Class 4	Class 3	Class 2	Class 1	Class 4	Class 3	Class 2	Class 1