Comprehensive approach to ensuring the integrity of high-pressure gas pipeline DN 400

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There is **a change of gas flow** in Polish pipeline systems from east-to-west to opposite direction in the last few years.

This change requires to **increase the capacity of gas pipelines** at the pressure level **7.4 MPa** in some Polish regions.

This is achieved by

- construction of new high pressure pipelines
- integration of older revalidated pipelines operated in the past at the lower pressure into the high pressure level

A concrete example of this integration is revalidation of 55 km older gas pipeline DN 400 in south-western Poland

This revalidation was the joint work of **CEPS a. s.** and **T. D. Williamson Polska**

Revalidation included the following basic steps

- Cleaning the pipeline
- Performing of in-line inspection by MFL tool
- Material test of samples taken from the original pipeline
- Model integrity test of pipe body vessel from a pipe taken from the original pipeline
- Design of working procedures for integrity test
- Preparation the pipeline for testing
- Integrity test performance and drying by super dry air
- Final reports (together)

Basic data of pipeline

- Pipeline **DN 400**, **DP 6.3 MPa** was built 1991–1992 and 1997 for supplying of the area around Jelenia Gora by natural gas.
- Pipeline was **designed and built as a cleanable** with launching and receiving traps.

Pipe material

- Of 99% **helical welded pipes** 406 × 6.3 mm made of steel 18G2A
- Only **for bends** (R_{min} = 5D), **crossing and into protective pipes** were used **seamless pipes** 406 × 8.8 mm made of steel R45
- **Izolation**—PE (1997), bitumen (1991–1992)

Pipe documentation

- Part of the inspection documents of helical pipe from material 18G2A was preserved only.
- **No documentation of the pipe material R45 was found.**

Pipeline cleaning

- According to information from operator the **pipeline has never been cleaned**, neither in operation and probably even nor during construction.
- **Although there was big risk of pig stop** in the column of impurities or at the deformed pipe, **the operator required to carry out the cleaning during operation**.

Launching trap in the beginning of pipeline

1st cleaning run

- **The pig after about 40 km got stuck near the crossing railway line.**
- After digging work there was found sharp vertical segment bend.
- The found segment bend was cut out by using technology T. D. Williamson.

Repeated cleaning

- 2nd cleaning run took place without problem, but plenty of dust there was in receiving trap.
- After that **several cleaning runs were carried out due to removing dust from pipeline**.

ILI inspection of pipeline

- After cleaning the internal inspection of pipeline was performed using calibration and MFL tools of T. D. Williamson.
- **By passing MFL tool through pipeline there were detected many defects.**

Remediation of defects

- The largest of these defects were dug up after the shutdown (before integrity test).
- Depending on severity were cut out or covered by sleeve.

Samples for testing

- During the cutting out of segment bend during 1st cleaning run there was taken part of pipe 406 × 6.3 mm for testing.
- From this cut-out pipe were taken samples for **material tests** and for manufacturing of pipe body vessel for **model integrity test**.

Material tests

- Chemical analysis
- Tensile test
- Impact bending test
- Metallographic analysis
- Helical weld inspection

Result of material tests

Based on tests, the steel quality was evaluated as the **standard**, **without any major defects**.

Material tests of seamless pipe 406 × 8.8 mm from steel R45 **were not carried out**, because the operator did not provide possibility of sampling.

For the steel R45 is the guaranteed less yield point than for 18G2A.

Lower value of yield point, however, compensates the greater wall thickness and therefore the pressure value on the yield strength of both types of pipes (406 × 6.3 mm and 406 × 8.8 mm) is almost identical.

Based on the results the pressure values were determined for the model integrity test of pipe body vessel.

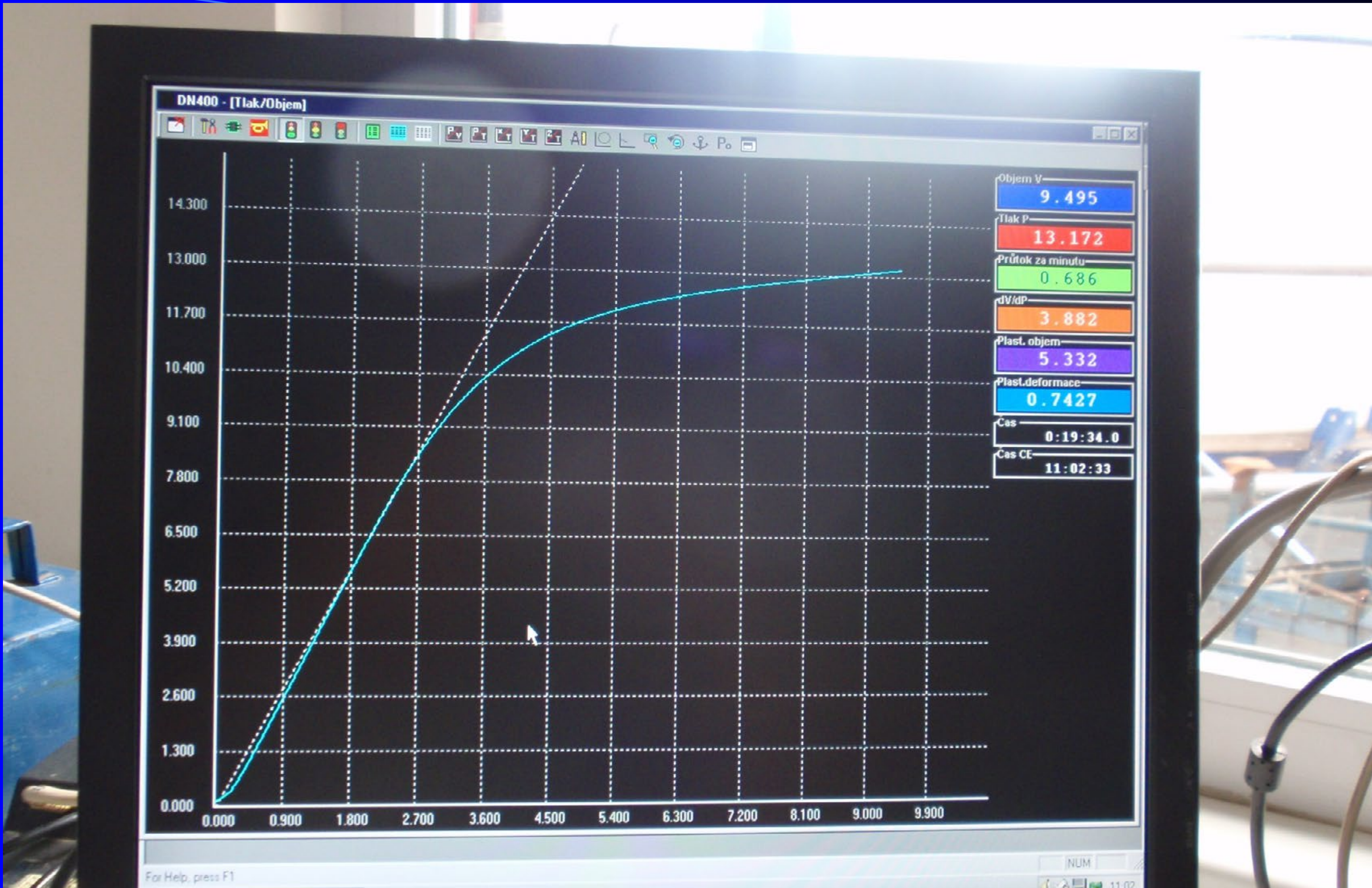
Pipe body vessel was at both ends closed and fitted with nipples and valves for connection of pressure sensors and high-pressure hoses for inlet and outlet of pressure water.

Pipe body vessel

The pipe body vessel was gradually pressurized to the yield strength to a value of permanent integral circumferential deformation **ε = 0.05%**

During model integrity test were on-line measured, monitored and recorded

- Dependence of p-V, p-t
- Flow of water pumped in
- Total volume of pumped water
- Size of pumped plastic volume
- Value of the permanent integral deformation ε

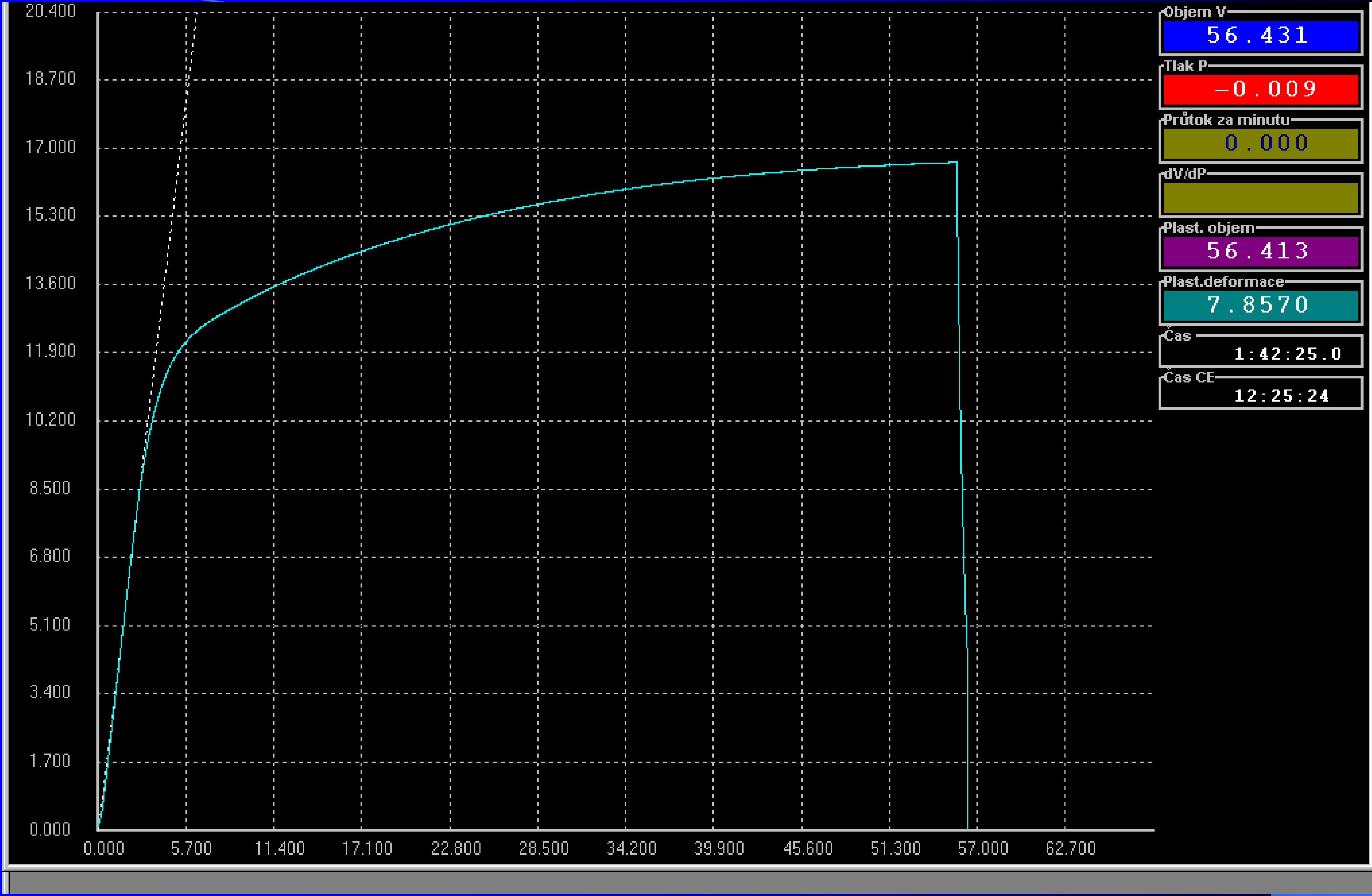


On-line measurement of dependence p-V

After **integrity test** the pipe body vessel was gradually **pressurized** to the ultimate strength limit **until destruction of the material**.

When pressure approached to calculated pressure of ultimate strength the **circumferential weld was destroyed**.

Destruction of circumferential weld



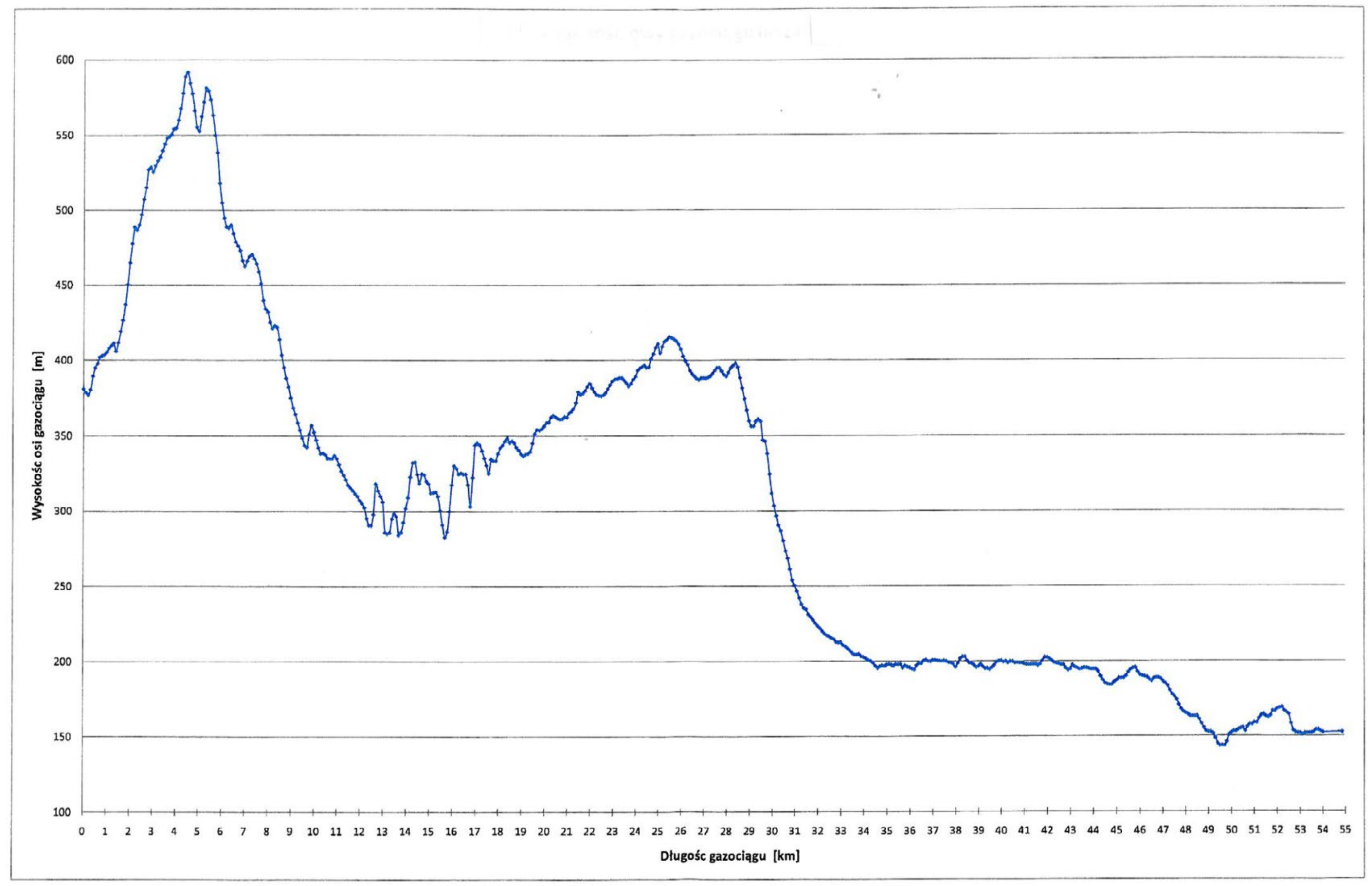
On-line measurement of dependence p-V shortly after the weld destruction

Based on results of these tests were determined maximum pressure P_{max} and maximum permanent integral deformation ε for performance of pipeline integrity test.

Pipeline DN 400 was divided into **four working units** that were step by step shutdown of operation and subsequently after execution of repairs, cut-outs of defects, integrity testing and drying, putting again into operation.

Each working unit was further divided into **working sections**, at which were performed integrity test.

Division of pipeline into working sections was **extremely difficult**, because territory which the pipeline leads is very **mountainous**.



Longitudinal profile of the pipeline

Time space for the performance of revalidation the operator defined as a maximum of 4 months, what was a very short term.

Before starting work **there was not rule or standard for carrying out the integrity test in Poland**.

For that reason **it was necessary to develop a technological procedure of integrity test performance**.

For the execution of integrity test were used two pieces of standard and made their combinations

Standard combination

- For carrying out the **strength test** (main part of integrity test) was applied *Technological procedure S05 CEPS*.

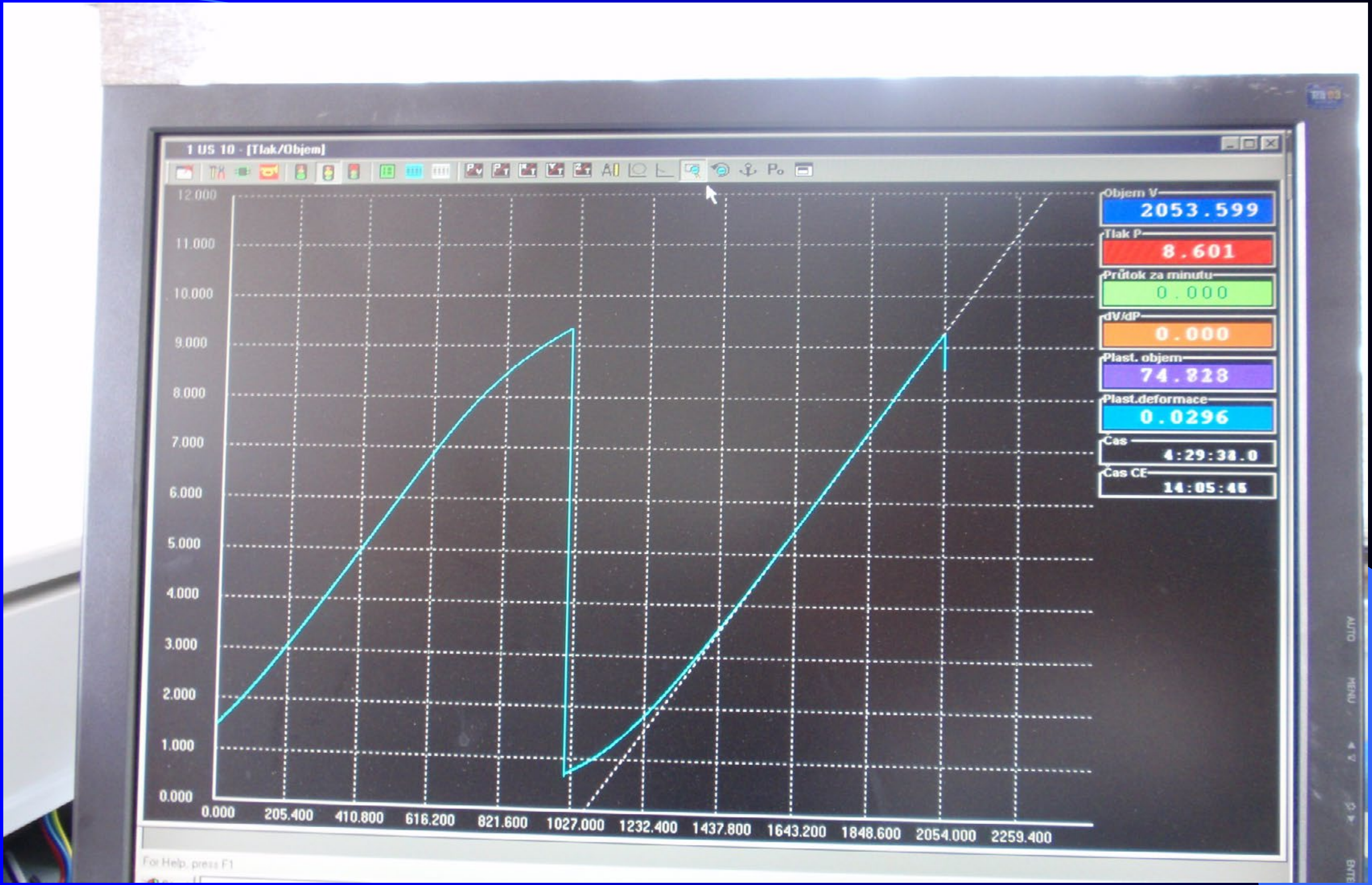
- For the subsequent **evaluation of tightness** was used Polish code for carrying out stresstest and subsequent pressure test of new pipelines, the standard ZN-G-3900 *Proby specjalne*.

That worked out technological procedure was approved by operator and the organization of the Polish state supervision UDT.

(The office of Technical inspection)

During integrity tests of each 16 sections were every on-line measured, monitored and recorded

- Dependence of p-V, p-t
- Flow of water pumped in
- Total volume of pumped water
- Size of pumped plastic volume
- Value of the permanent integral deformation **ε**



On-line measurement of p-V

During of integrity tests two destruction of the pipe occurred

- The first time on part of pipeline which was built 15 years ago in 1997.
- The second time a leak was detected in the section built in 1991–1992.

1^{st} destruction

- **During the strength test** of the integrity test was detected a significant drop of pressure.
- Based on calculation was set the **size of water leak in a amount of approx. 411 l/h**.
- After several days the leak was found during walking route along the pipeline.

Fountain in the rapeseed field

After reducing the pressure a very **impressive assembly circumferential weld** was found at position 12.

Assembly weld with defect

There was immediately carried out **back-checking of results of internal inspection of this site**, but this thorough checking **did not reveal any anomalies in record of the MFL tool**.

This finding again confirmed the long experience of CEPS, that **intelligent tool of the type MFL is not able to detect all pipeline defects of this type and scope**.

2nd destruction

- **During tightness of integrity test** a pressure drop of 2.7 bar during 24 hours occurred.
- This pressure drop was represented by the leakage of water 6 l/h.
- **By ILI there were many small detected defects in this pipeline section.**

This section was divided into three shorter sub-sections. After repeated tightness tests there was detected **leakage 2.5 l/h**.

This leaky section was again divided into three sub-sections.

After repeated tightness test all section were evaluated as tight, **no leakage was detected**.

Reducing the size of a water leak from a pipeline is a phenomenon that occurs almost very often after the division of the tested section into sub-sections.

The leaky place or places in the pipe wall are very small and during dewatering or re-filling using of high seal pig frequently occurs to “**clog or block**” of through space by particles of rust or sludge.

The pipeline after properly performed integrity test can be guaranteed as strength and secure.

However, it will be require that operator should carry out on the referred section the increased supervision.

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Pipeline drying

After the performed integrity test and after connection of the working sections of each working units was the pipeline **dried by superdry air up to dew point −20 °C of air leaving from pipeline**.

The mobile drying unit

Performing the integrity test culminated several years effort of operator to

- prove integrity of pipeline,
- ensure long-term safe operation,
- increase the maximum operation pressure in pipeline.

Summary

The combination of internal inspection, elimination of major found defects and following integrity test is **the most effective method of how to demonstrate reliability of high-pressure pipeline** and **ensure its long-term safe operation**.