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Long term experience with DENSOLEN-Tapes

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Long term experience with DENSOLEN-Tapes

Excavation of 27 year old pipeline segments protected with DENSOLEN-Tape S40

Previous investigations on long term performance of polyethylene butyl-rubber composite tapes are based on tape samples, which as the longest period yet reported had been buried for 17 years. Beside high insulation resistance values and extremely low undermining corrosion [1] reports a very high peel strength for DENSOLEN-Tape S40 after 17 years of operation. A current pipeline project now offered the opportunity to confirm these results on long term performance of DENSOLEN plastics tapes for an even longer ageing period.

In autumn 2003 segments of a 27 year old pipeline ("Isarschiene", running from Moosburg (G) to Straubing (G)) owned by Erdgas Südbayern (ESB) had to be excavated for bypassing, which offered the opportunity for assessment of the coating performance (**Figure 1** and **Figure 2**).

The field joints of the polyethylene factory coated pipeline had been wrapped with four layers of DENSOLEN-Tape S40, which is a 0,75 mm thick, symmetrically structured three-ply tape with polyethylene carrier film and plies from butyl rubber on both sides (**Figure 3**). At the moment of construction the four layer coating system was in accordance with the DVGW-leaflet GW 7 [2], which was the valid technical specification for field coatings at that time. Although today's corrosion protection standards [3], [4] and stress-classes had not yet been developed in 1976, the DENSOLEN S40 tape system would even fulfil today's requirements of stress-class C-50. Correspondingly the observations made on S40 can also be transferred to currently produced DENSOLEN tapes, which despite further developments and modifications in the last 25 years are nevertheless comparable with DENSOLEN-Tape S40 regarding general function and composition. The most important functional feature of such three-ply DENSOLEN tapes is their ability to self amalgamate in the overlap areas, forming a sleeve type coating, which is impermeable for water vapour and oxygen.

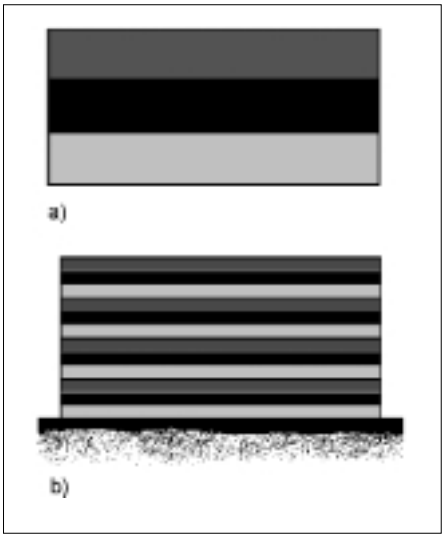

Fig. 3: a) Cross Section of DENSOLEN-Tape S40, b) Cross section of DENSOLEN S40 tape system

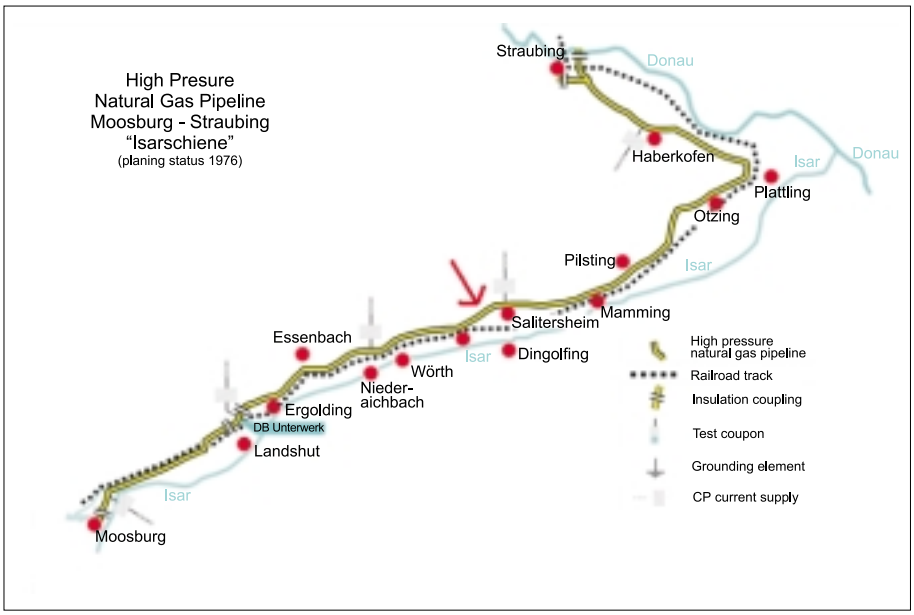

Fig. 1: Dismounting location of pipe segments

Fig. 2: Dismounted pipe segments DN 300

Concerning operating conditions of the "Isarschiene" it has to be mentioned, that starting 1990 the cathodic protection

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Fig. 4: Partly peeled off welded joint DN 300 with DENSOLEN-System S40

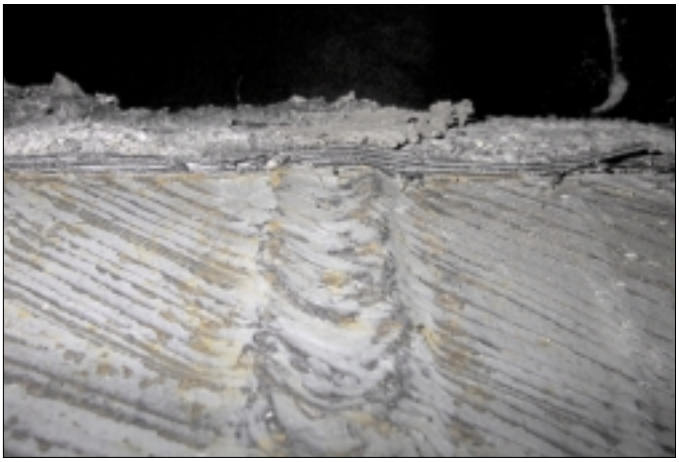


Fig. 6: Close-up view of weld bead. Rust originates from outdoor storage of pipe with partly peeled off tape wrapping

system was run with partly severe cut-in potentials of up to -15 V. In contrast up to 1990 the cut-in potential showed typical values of app. -2000 mV and the cut-off potential typical values of app. -1100 mV. According to current information by the pipeline owner, the presently determined cut-in potentials range between -4 and -11 V. The dramatic change of the protective potentials was caused by constructive measures to avoid alternating current interference by two railroad tracks running parallel to the pipeline. As a part of this constructive measures, two insulating couplings and several grounding units had been incorporated into the pipeline, which originally was built without electrically separated segments [5]. A hydrogen embrittlement, which could have taken place due to the very negative potentials, has not been observed [5]. Also a possible cathodic disbonding of the tape coating could not be observed by the present investigation on the excavated pipe segments.

The outstanding long term behaviour of DENSOLEN-Tape S40 is now being demonstrated by peel strength tests carried out on the dismounted pipe segments, which is exemplarily shown in **Figure 4** to **Figure 7** exemplarily.

Regarding the welded joint in Figure 4 it has to be noticed that the adjacent factory coating does not show any traces of surface preparation and roughening. Therefore the tape could be peeled off from the smooth polyethylene surface without any residues of adhesive, which nevertheless required high peel strength values of 13 to 16 N/cm at 10 mm/min peel speed. According to common procedure in 1976 for pipe diameters smaller than DN 500 [6], the transition from steel to factory coating had not been bevelled. Consequently a 3 to 4 mm wide hollow exists under the tape wrapping (Figure 5). Nevertheless, rust formation could not be observed. Such hollows would be critical even in case of cathodically protected pipes, if circulation of ground water was possible due to incompletely sealed overlaps. Thus is can be assumed, that the hollow had been completely enclosed and sealed by the tape wrapping.

Similar to the behaviour on the factory coating, the tape wrapping can be peeled off without residues of adhesive in a 5 to 7,5 cm wide area adjacent to the factory coating. This effect is a result of the very smooth surface structure in this area, originating from either temporary protective coating or hotmelt adhesive, which had not been removed prior to tape wrapping. In this area the steel surface shows a slightly brown surface, nevertheless, undermining corrosion or material loss could not be observed. The observed peel strength in this area corresponds to the values obtained on the factory coating.

In the welding seam area (weld bead and adjacent 7,5 to 10 cm of steel surface) the tape could only be peeled off in a cohesive peel mode with delamination in

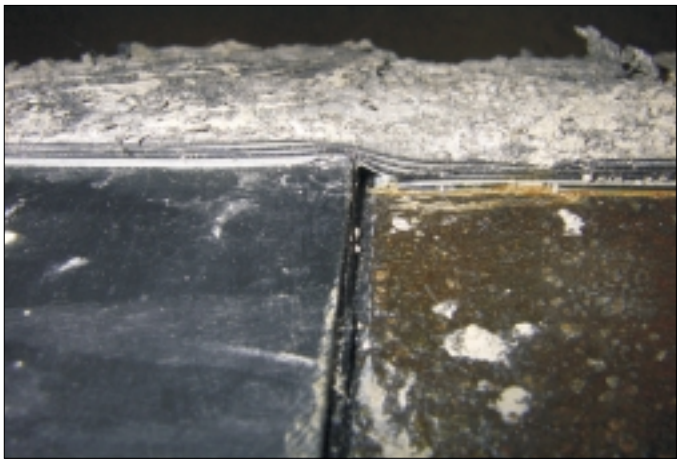


Fig. 5: Hollow in transition to unbevelled factory coating

Fig. 7: Dirt enclosed under tape wrapping

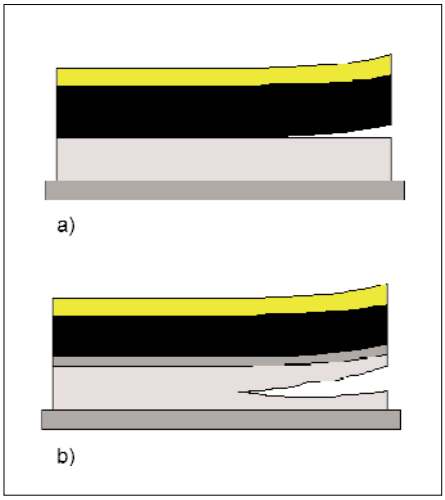
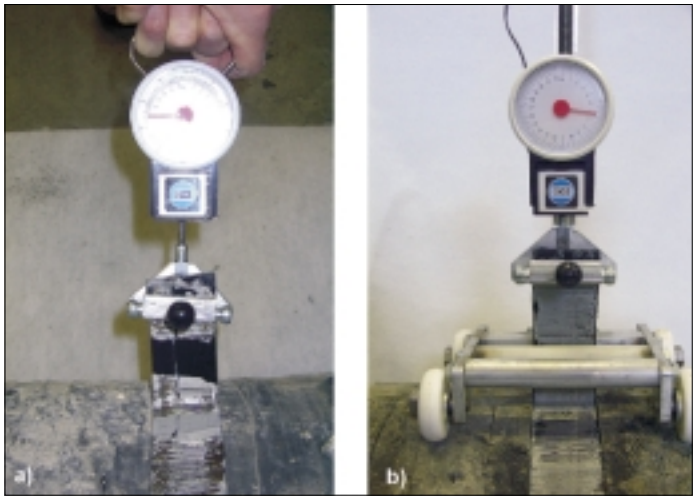


Fig. 8: Delaminative (a) and cohesive (b) peel mode of tapes without and with co-extruded intermediate layers

Fig. 9:
Peel test with spring balance and tensile test device



some parts. The obtained peel strength ranges between 25 and 38 N/cm at 100 mm/min separation rate and 12 to 15 N/cm at 10 mm/min. Also in the weld bead area no corrosion can be observed. Rust visible in Figure 6 originates from outdoor storage of the peeled off pipe segments. The reason for the partly delaminative peel mode is the lacking of a co-extruded intermediate layer between carrier film and butyl rubber adhesive. Such layers, a Denso invention, significantly improve adhesion strength between the tape plies and avoid delamination effects during peel test (see **Figure 8**). Co-extruded layers have firstly been introduced into DENSOLEN tapes in 1981. Today they are natural components of every DENSOLEN tape.

Conclusion

Although the surface preparation had not been carried out according to currently recommended procedures, the DENSOLEN-Tape S40 does not show any decrease in coating performance after 27 years of operation. The observed and mentioned shortcomings in surface preparation should in any case be avoided. Nevertheless, the present example demonstrates the high tolerance of the cold applied DENSOLEN tape technology. The determined peel strength values of DENSOLEN-Tape S40 correspond to the performance of freshly produced material and are in accordance with today's standard requirements for stress-class C-50. No ageing effect can be observed after 27 years of operation.

Properties of DENSOLEN-Tape S40 after 25 years of storage

Customer re-sampling of tape rolls offered the opportunity to test the tape and system properties of DENSOLEN-Tape S40 after 25 years of storage. Test were carried out on two 100 mm wide tape rolls, one of which had been stored in-house, while the other had been stored in an outdoor stockyard. The determined material properties are listed in **Table 1**.

All measured values significantly exceed the standard requirements and correspond to the performance level of new material. Even after 25 years of storage the stress-class C-50 requirements of DIN EN 12068 and DIN 30672 are fulfilled without any difficulties. Ageing effects can not be observed.

Table 1: Properties of DENSOLEN-Tape S40 and DENSOLEN-System S40-C (four layer tape wrapping) after 25 years of storage. Tests according to DIN EN 12068, stress-class C-50

Property	Unit	S40 (in-house storage)	S40 (outdoor storage)	Requirements DIN EN 12068 / DIN 30672
Tear resistance	N/cm	69	75	none *
Elongation at break	%	540	530	none **
Tape-tape peel strength (23°C)	N/cm	34	35	≥ 15
Tape-tape peel strength (50°C)	N/cm	4,0	3,6	≥ 2
Peel strength to steel (23°C)	N/cm	18	19	≥ 10
Peel strength to steel (50°C)	N/cm	2,8	2,5	≥ 1
Indentation resistance, residual thickness	mm	0,8	0,8	≥ 0,6
Impact resistance	Nm	22	22	≥ 15

* Requirements DIN 30672-1 (1991): ≥ 30 N/cm, ** Requirements DIN 30672-1 (1991): ≥ 250 %

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