Aspects of Corrosion Protective Tape Technology

Corrosion protective tape coatings have been used for decades on all types and sizes of below ground pipelines. Results thus obtained are as versatile as the available range of products. The following paper points out important aspects that have to be considered to ensure long term performance of corrosion protective tape coatings.

1. Tape composition and structure

The proper choice of a suitable tape coating systems starts with a general requirement for tape structure and composition. This requirement is valid for all pipe diameters and operating conditions.

Regarding composition all available tape coatings can be divided into following classes and combinations thereof:

Carrier film material
- Polyethylene
- PVC

Adhesive material
- Butyl rubber
- Bitumen

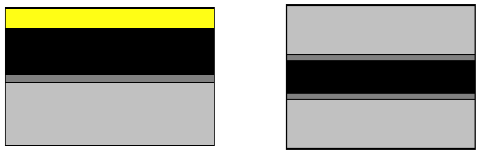
Among possible tape compositions the combination of PE carrier film with butyl rubber adhesive has proven best corrosion protection performance [1], [2].

In contrast PVC as carrier film material, particularly in case of contained plasticizers, is susceptible to embrittlement. Bitumen is a questionalble material also as it provides a significantly lower ageing resistance than butyl rubber based adhesives.

Having made the choice for butyl rubber and polyethylene as the material basis, the question of the most suitable tape structure is brought up.

As a minimum requirement the innerwrap tape or corrosion protection tape should always be a three-ply structure with butyl rubber adhesive layers on both sides of a PE carrier-film [3], [4]. Figure 1 shows typical cross sectional views of high performance three-ply corrosion protection tapes.

Fig. 1
Cross sectional view of corrosion prevention tapes
a) asymmetrical **b)** symmetrical



Among these structures the asymmetrical one is to be preferred, because its thick inner adhesive layer ensures better filling of surface irregularities and potential hollows. Furthermore state-of-the-art asymmetrical corrosion prevention tapes like BUTYLEN-Tape AS39P, AS40 Plus or AS50 have a four-ply structure, containing an additional layer between carrier film and adhesive. This intermediate layer is coextruded from a blend of butyl rubber and polyethylene and thus ensures a homogenous transition from butyl rubber to PE. The well known delamination effect (Figure 2) and a potential long term permeability through the interface between carrier film and adhesive is avoided by the tape structure shown in Fig 1a).

Fig. 2
a) Delamination during peel-test

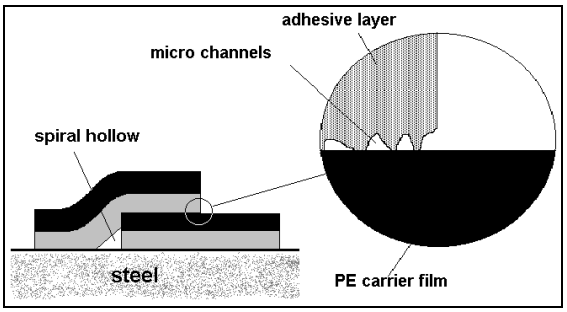
b) Cohesive peel mode by co-extruded intermediate layer of high-performance tape

State-of-the-art mechanical protection tapes like BUTYLEN-Tape R20HT (Figure 3) also contain a coextruded intermediate layer between carrier film and adhesive.

Fig. 3
Mechanical protection tape with co-extruded intermediate layer

Why is a three-ply structure of the innerwrap tape such indispensable? As can be seen from Figure 4, an interface and potential penetration path for water and oxygen remains in the tape overlap, if an only two-ply tape is used for the innerwrap.

Fig. 4
Incompletely sealed tape overlap of two-ply tape wrapping

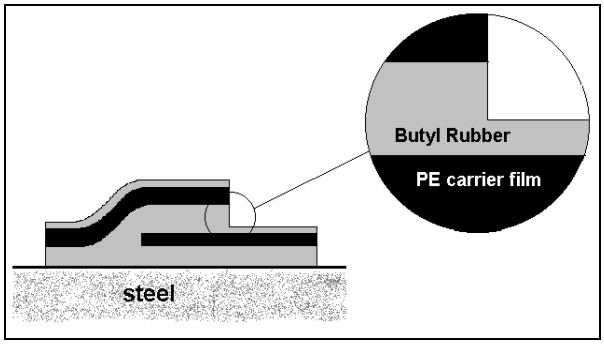


After some years of operation the incompletely sealed tape overlaps inevitably lead to spiral corrosion followed by complete undermining corrosion. A big percentage of bad experiences with tape coatings all over the world originate from the effect shown in Figure 4.

Fig. 5
Spiral corrosion

On the other hand, no interface with penetration paths remains within a wrapping from high-performance three-ply tapes. The outstanding feature of butyl rubber is its ability to self-amalgamate in the overlap areas, resulting in a completely sealed, impermeable and sleeve-type coating.

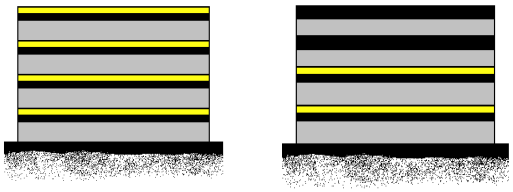
Fig. 6
Completely sealed tape overlap of high performance three-ply tape wrapping



2. Tape Systems

Tape systems should always contain at least two layers of such three-ply tape. The completely sealed innerwrap, depending on mechanical stresses, is most often combined with a mechanically protecting outerwrap from a three-ply or two-ply tape.

Fig. 7
Creation of tape systems by combination of three-ply or three-ply and two-ply tapes
a) one-tape system **b)** two-tape system

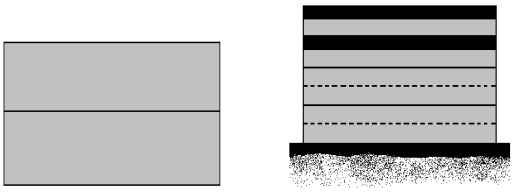


The even distribution of polyethylene and butyl rubber layers afford a maximum resistance to mechanical stresses like indentation and impact.

Mechanically highly resistant tape systems according to highest stress-class C-50 always show a structure as shown in 7a) or 7b), the latter one (e.g. BUTYLEN-System AS40Plus - R20HT) being economically preferred.

A variation of a two-tape systems makes use of a butyl rubber tape instead of a three-ply tape for the innerwrap. Such butyl rubber tapes are highly conformable and therefore find use in wrapping of irregularly shaped objects like weld-on branch lines, where the requirement for simple application predominates the importance of maximum mechanical resistance. Tape systems containing butyl rubber tapes afford minor mechanical resistance than one-tape or two-tape systems shown in Figure 7.

Fig. 8
cross section of



a) butyl rubber tape **b)** high-performance two-tape system with butyl rubber tape

Fig. 9
Typical field of application for type 8b) two-tape system: Coating of weld-on branch line

A special attention has to be directed to tape systems for elevated operating temperatures, since tape coatings on pipes operated above +50°C are exposed to particular stresses. These operating conditions can be compensated for by the measures listed below.

1. Thermal elongation of carrier film leads to wrinkle formation, which would partly lift off tape system from pipe surface.

   → Recommendation: Use of a butyl rubber tape without carrier film for the innerwrap.

2. Adhesives get smooth at elevated temperatures, which would result in reduced peel and shear forces.

   → Recommendation: Use of a special butyl rubber formulation, which is highly stabilised against thermal degradation and which is self-reinforcing by cross-linking at elevated temperatures.

3. Carrier film of the mechanical protection tape gets smooth at elevated temperatures, which would result in reduced resistance to load forces.

   → Recommendation: Use of a high density polyethylene carrier film and additional use of a load distributing nonwoven rockshield.

4. Elevated operating temperatures often go together with alternating temperatures, which lead to a longitudinal movement of pipe and increase the risk to shear off the coating.

   → Recommendation: Use of a rockshield, which decouples moving pipe from surrounding soil.

Fig. 10
Cross-section of tape system for elevated operating temperatures (BUTYLEN-System ET100 - R20HT)

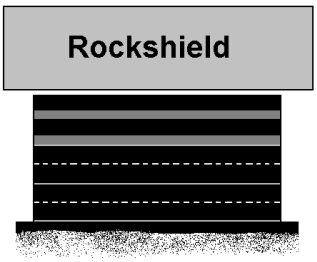


Table 1
Selected properties of BUTYLEN-System ET100 - R20HT at elevated temperatures

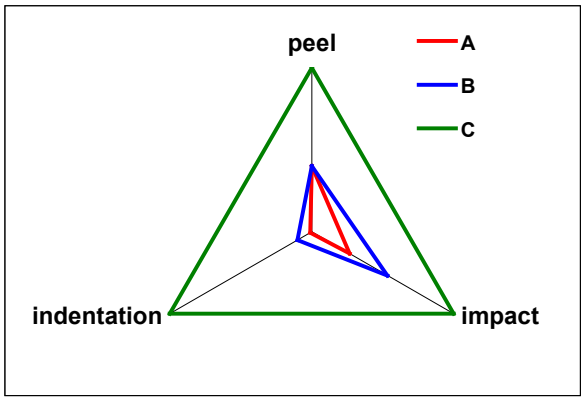
property	typical value	comment
indentation resistance	0,9 mm	at - 85 °C, 10 N/mm² or - 100 °C/1N/mm²) residual thickness of tape system (without rockshield)
peel strength	0,8 N/cm	at 100 °C *)
lap shear strength	5 N/cm	at 70°C *)
	4,5 N/cm	at 100°C *)

*) after 7 days conditioning at test temperature

3. Standard requirements – stress classes

Technical properties of a corrosion protective tape coating are being described in corresponding national and international standards. It should be noticed that frequently employed ASTM-standards contain well suitable test procedures to determine single properties, but they neither define acceptance criteria nor do they assess all properties of a tape coating together.
In contrast material standards like European standard EN 12068 ([5], [6]) not only describe how to determine the relevant tape and coating properties, by their concept of stress classes they also give a well suitable tool for classification of tape coatings. The mechanical stress classes A, B and C essentially differ concerning requirements for peel strength, impact resistance and indentation resistance. Corresponding ratios are shown in Figure 11.

Fig. 11
Differences in requirements for peel strength, impact resistance and indentation resistance of stress-classes A, B and C according to EN 12068



When choosing a corrosion protective tape coating referring to stress classes it has to be considered that the performance level of a standard factory coating, e.g. three layer PE coating, exceeds the performance level of a field coating by. From figure 12 and 13 it is also apparent that for tape coatings a higher temperature stress class (50 instead of 30) always indicates a higher peel strength or indentation resistance or both at 23 °C only.

Fig. 12
Typical residual thickness of a three-layer PE coating compared to stress-class C-50 and C-30 tape coatings (at 23 °C)

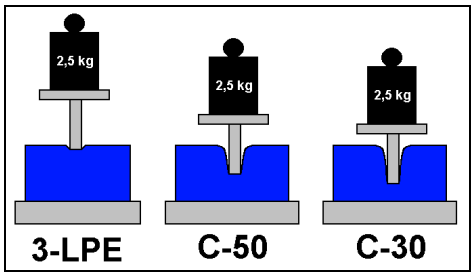
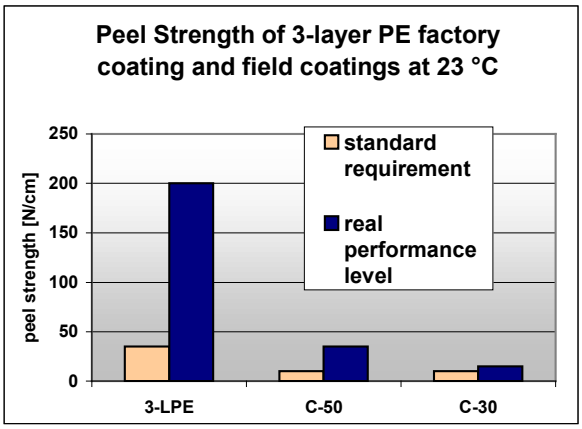


Fig. 13
Typical peel strength of a three-layer PE coating compared to stress-class C-50 and C-30 tape coatings and standard requirements (at 23 °C according EN 12068)



Whenever possible, a field coating with properties close to the performance level of the existing line coating should be chosen. Therefore a stress-class C-50 tape system (e.g. BUTYLEN-System AS40 Plus – R20HT) should be used for standard wrapping of welded joints, bends or full pipe length. Even if the pipeline is operated at temperatures below 50 °C, the higher peel strength and indentation resistance of a C-50 system ensure a higher safety level also at room temperature and narrow the gap to the performance level of the existing pipe coating.

However, on small diameter pipes, which are exposed to less load forces and impact energies, a stress-class
B-50 system could be a cost efficient alternative. Such systems of the BUTYLEN type provide the same level of peel strength and lap shear resistance as corresponding stress-class C-50 systems.

Only in case of irregularly shaped objects, which require easy to apply tapes, a smoother but mechanically less resistant two-tape system according stress class C-30 or B-30 should be used.

Table 2
Tape systems guideline

operating temp.	field of application	recommended tape system
≤ 30 °C	- irregularly shaped objects (e.g. weld-on branch lines) - low / medium load forces	- butyl rubber tape with mechanical protection tape (stress class C-30 or B-30 , e.g. BUTYLEN-System E10-PE3)
≤ 50 °C	- all fields of application - medium load forces - medium impact energies	- one-tape system stress-class B-50 (e.g. BUTYLEN-System AS50)
	- all fields of application - high load forces - high impact energies	- one-tape system stress-class C-50 (e.g. BUTYLEN-System AS40 Plus) or - two-tape system stress-class C-50 (e.g. BUTYLEN-System AS40 Plus - R20HT)
50 up to 100 °C	- all fields of application - medium / high load forces	- high temperature butyl rubber tape with mechanical protection tape and rockshield (e.g. BUTYLEN-System ET100 – R20HT)

4. Application

A corrosion protective tape coating can only be as good as the quality of its workmanship. Therefore application properties and application technique play a major role in corrosion protective tape technology.

Tape coatings should be applied
- without wrinkles and hollows
- with sufficient tape tension
- with constant tape overlap

Observance of the above requirements can as much as possible be ensured by
- use of appropriate (= pipe diameter dependent) tape width
- limitation to an upper limit of tape width even on large diameter pipes
- employment of wrapping machines whenever possible

Particularly the choice of a suitable tape width influences the quality of the tape coating. In case of hand wrapping sufficient tape tension can only constantly be applied by limitation to a maximum tape width of 150 mm. The seeming advantage of faster application when using higher tape width is more than compensated for by the disadvantage of a sometimes questionable quality of wrapping due to poor adhesion and wrinkle formation.

Table 3
Tape width guideline for insulation of girth welds, bends and full pipe lengths

pipe ∅	tape width [mm]	application by
recommended		
1" – 2"	30	- hand
2 ½" – 11"	50	- small hand wrapping device - hand
12" – 78"	100	- small to medium size hand wrapping device - motor driven wrapping machine
possible		
≥ 28"	150	- small to medium size hand wrapping device
-	> 150	- only by line travel wrapping machines

The range of DEKOMAT hand or motor driven wrapping machines shown in Figure 14 - 17 posses a variety of important features for perfect site suitability and simple use.

- built-in break mechanism for constant tape tension
- integrated tape-up mechanism for tape interleaving
- low weight
- minimum clearance requirement
- possibility to attach extension arms to wrapping machine for large diameter pipes (DEKOMAT KGR, figure 15)
- simple mounting and movement across pipe supports (DEKOMAT 11, Figure 17).

Fig 14
Tape wrapping with DEKOMAT 1 hand wrapping machine

Fig 15
DEKOMAT KGR Junior hand wrapping machine with extension arms

Fig 16
DEKOMAT 11 motor driven wrapping machine for coating refurbishment on a 24” pipeline

Fig 17
Easy mounting of DEKOMAT 11 wrapping machine on a 36” pipeline (girth weld insulation)

It is unnecessary to mentioned that quality of surface preparation is another important factor, which affects quality of corrosion protective coatings. Concerning this, cold applied tapes in general and BUTYLEN-Tapes in particular offer a high level of site suitability, since they tolerate a surface cleanliness according to ST2 [7] obtained just by wire brushing.

Literature

[1] H.-G. Schöneich, 3R international, volume 40, No. 1, 2001, page 67-68.

[2] W. Schwenk, G. Heim, B. Wedekind, T. Schäfer, 3R international, volume 35, No. 12, 1996, page 676-685.

[3] B. Wedekind, 3R international, volume 13, No. 5, 1974.

[4] P. Bohle, CEW, Vol. XXVIII, No. 10, 1993, page 61-63.

[5] EN 12068 (1999), "External organic coatings for the corrosion protection of buried or immersed steel pipelines used in conjunction with cathodic protection - Tapes and shrinkable materials."

[6] H. E.Driesen, 3R international, volume 34, No. 10/11, 1995, page 601-606.

[7] ISO 8501-1 (1988), "Preparation of steel substrates before application of paints and related products - visual assessment of surface cleanliness."

Dr. Michael Quast
DEKOTEC GmbH
Felderstr. 24
51371 Leverkusen
Germany
www.dekotec.net