International Comparison of Fire Resistant Conveyor Belts

Bernd Küsel

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1. PHOENIX Company Overview

2. Conveyor Belt Families

3. Elastomers and their Properties

4. International Approval Tests

5. Experience with self-extinguishing Conveyor Belts

6. Outlook
1.1 PHOENIX Background

✓ More than 100 years of conveyor belt design and production.

✓ Focused on mining. Belt factories for coal mining in Germany, China and India.

✓ Supplier of all outstanding conveyor belts (strongest, longest, heaviest etc., World Records)

✓ First self-extinguishing PVG conveyor belt worldwide (approved 28 years ago).

✓ First self-extinguishing steel cord conveyor belt worldwide (22 years ago for Göttelborn mine).

✓ First self-extinguishing steel cord conveyor belt as per new strict requirements for Australia (19 years ago for Moranbah mine).

✓ First self-extinguishing steel cord conveyor belt for China (12 years ago for Chengzhuang mine).
1.2 Highlights in Underground Mining

The first self-extinguishing steel cord conveyor belt

The strongest underground conveyor belt

The first self-extinguishing solid woven conveyor belt
PHOENIX Conveyor Belt Systems GmbH

- is a major supplier of MSHA approved textile conveyor belts for the Central Appalachian Coalfields;

- supplied MSHA approved drift steel cord conveyor belts for Consolidation Coal’s Enlow Fork and Bailey mines;

- has been supplying conveyor belts to US coal mines for 10 years.
2.1 Conveyor Belt Families

Conveyor Belts

- **Steel**
  - Cover material: Rubber
    - Number of plies: 1
      - Also available with additional PHOENOTEC® transverse reinforcement
    - Number of plies: 2
      - With PHOENOTEC® transverse reinforcement
      - Also available with additional PHOENOTEC® transverse reinforcement
    - Number of plies: 3 (and more)
      - Also available with additional PHOENOTEC® transverse reinforcement

- **Textile**
  - Cover material: Rubber
    - Number of plies: 1
      - PHOENAMID® C
        - Also available with additional PHOENOTEC® transverse reinforcement
    - Number of plies: 2
    - Number of plies: 3 (and more)
      - UNIFLEX®
        - Also available with additional PHOENOTEC® transverse reinforcement
        - PVC carcass impregnation
  - Cover material: PVC
    - Carcass impregnation: PVC

Ku07-3
2.2 Textile Conveyor Belt Carcass Types

- Multi-ply Conveyor Belt
  *(the usual type of belt in the USA)*

- Two-ply Conveyor Belt
  *(more modern type, also frequently used in the USA)*

- Mono-ply (solid woven) Conveyor Belt
  *(most modern type)*
### 3.1 Common Rubber Types

Conveyor belt covers consist of 10 to 20 different ingredients. The main component is one or more elastomers:

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR</td>
<td>Polybutadiene rubber</td>
</tr>
<tr>
<td>CR</td>
<td>Poly-β-chlorobutadiene rubber (e.g. Chloroprene, „Neoprene“)</td>
</tr>
<tr>
<td>EPM</td>
<td>Copolymer of ethylene and propylene</td>
</tr>
<tr>
<td>EPDM</td>
<td>A terpolymer of ethylene, propylene and a di- or polyene</td>
</tr>
<tr>
<td>IIR</td>
<td>Copolymer of isobutylene and diene (butadiene or isoprene rubber -„Butyl“)</td>
</tr>
<tr>
<td>IR</td>
<td>Synthetic cis-polyisoprene rubber</td>
</tr>
<tr>
<td>NBR</td>
<td>Copolymer; acrylonitrile and butadiene rubber (e.g. Nitrile)</td>
</tr>
<tr>
<td>NR</td>
<td>Cis-polyisoprene natural rubber</td>
</tr>
<tr>
<td>SBR</td>
<td>Random copolymer of styrene and butadiene rubber</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinylchloride (a Plastomer!)</td>
</tr>
</tbody>
</table>

Other components are carbon black, sulphur, accelerators, fire retardants, antioxidants, fillers, oils, plasticizers, stabilizers etc.
### 3.2 Basic Properties of Common Rubber Types

<table>
<thead>
<tr>
<th>Property</th>
<th>BR</th>
<th>CR</th>
<th>IIR</th>
<th>NBR</th>
<th>NR</th>
<th>SBR</th>
<th>EPDM</th>
<th>PVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaking strength</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Tear resistance</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Cold flexibility</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Heat resistance</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Weather resistance</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Oil resistance</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Flame resistance</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

1 = excellent, 6 = inadequate

Taken from www.ConveyorBeltGuide.com
3.3 Fire resistance – CR, PVC, SBR

**International Covers**

Since polychloroprene rubber (CR) is highly fire resistant by nature, only a little amount or no addition of fire retardants is necessary. In case of a fire, thanks to the high content of halogens (chlorides, bromides), endothermal processes are initiated which withdraw energy and extinguish the fire.

Polyvinylchloride (PVC) shows a similar behavior.

**MSHA Covers**

In case of styrene butadiene rubber (SBR), a big amount of fire retardants has to be added, which deteriorate the physical properties of the compound. Even by addition of big amounts of fire retardants the safety features of CR cannot be achieved.
3.4 Replacement of Flame Retardant Conveyor Belts

Some 30 years ago, the flame retardant conveyor belts (grade DIN-K or ISO 340) based on SBR - these grades are similar to the existing MSHA grade - had to be replaced by self-extinguishing conveyor belts based on CR in European underground coal mining.

Since then the use of flame retardant conveyor belts was only allowed above ground.
## 4.1 Biggest Coal Producing Countries And Their Safety Requirements

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (Mt, 2005)</th>
<th>Conveyor Belt Safety Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>2226</td>
<td>+++</td>
</tr>
<tr>
<td>USA</td>
<td>951</td>
<td>+</td>
</tr>
<tr>
<td>Europe</td>
<td>737</td>
<td>+++</td>
</tr>
<tr>
<td>India</td>
<td>398</td>
<td>+++</td>
</tr>
<tr>
<td>Australia</td>
<td>301</td>
<td>+++</td>
</tr>
<tr>
<td>South Africa</td>
<td>240</td>
<td>++</td>
</tr>
<tr>
<td>Russia</td>
<td>222</td>
<td>++</td>
</tr>
</tbody>
</table>
### 4.2 International Conveyor Belt Safety Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>China</th>
<th>USA</th>
<th>India</th>
<th>Australia</th>
<th>Europe</th>
<th>South Africa</th>
<th>Russia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drum Friction</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Propane Grate Burner</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>High-Energy Propane Burner</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Large Scale Gallery</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Laboratory Scale Gallery</td>
<td>no</td>
<td>proposed</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Bunsen/Spirit Burner</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Surface Resistance</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Toxicity</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Oxygen Index</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

Note: In most countries, the physical and geometrical parameters are specified. In the USA there is no conveyor belt standard/norm.
4.3 ISO340/DIN22103 and MSHA ASTP5007
Conveyor Belt Flammability Tests

A small piece of belt is held over a spirit/bunsen burner flame. After a certain time the burner is retracted and the duration of flames is recorded.
Conveyor belts must not propagate fire. To test this, a belt specimen (1.5 - 2.5 m long x 1200 mm wide) is ignited by a propane burner. After the ignition source has been removed, the flames must self-extinguish and a defined undamaged length must remain.

Key
1. Direction of air flow
2. Additional bar
3. To be clear of any cross bracing
4. Propane burner
5. DN 15 heavy series tube
6. Detail of trestle
7. Bars made of austenitic chrome/nickel steel, diameter 10 mm, length 1.4 m
8. Gallery entrance
9. Test piece
10. Edge of test piece to be flush with front of trestle
11. 350 mm to flow line
12. Rod retainers
13. DN 15 heavy series trestle
14. Detail of rod retaining angle
4.5 Large Scale Fire Test (EN 12881-2)

An 18 m long x full width belt specimen is placed over 300 kg of timber which is set on fire. The maximum permissible flame spread is 10 m.
4.6 Drum Friction Test (DIN22100 et al.)

The test simulates a belt slipping over a jammed pulley or a pulley rotating under a stationary belt.

The surface temperature has to remain below 325°C and no flame or glow may be visible.
4.7 Laboratory Scale Gallery Test (DIN 22100 and 22118)

A 1200 mm long x 120 mm wide belt specimen is placed over a propane burner. After the ignition source has been removed, the flames must self-extinguish and a defined undamaged length must remain.
4.8 Surface Resistance Test (DIN 20284 et al.)

An electrostatic charge may build up on the conveyor belt surface and ignite a mixture of flammable gases. Therefore the conveyor belt surface resistance must be below 300 MΩ.
Under normal operating conditions, conveyor belts must not put the health at risk. Under the influence of heat or fire, belt decomposition substances must not cause irritation of the skin or eyes; the protective action of the filter self-rescuer must be kept. DIN 22100 describes aerobic, chromatographic and pyrolytic hygiene tests, which have to be passed successfully.

In the smolder pot test, a belt sample is burned carbonized, then air and water vapour are added. This airflow must not increase the filter self-rescuer's airway resistance by more than 5 mbar.
4.10 Fire Resistance Test Sample Sizes

- MSHA
- Drum friction
- Laboratory scale
- Propane burner
- Large scale
4.11 Toxicity Comparison

By far the major threat during a fire, aside from heat, is carbon monoxide – an odorless gas. Both elastomers (CR, SBR) and PVC develop roughly the same amount of carbon monoxide.

In addition, small amounts of hydrogen chloride are generated; usually more from CR and PVC than from SBR.

Since CR and PVC are self-extinguishing and SBR is not, the total amount of harmful substances is obviously drastically lower in case of CR and PVC.

All of the basic materials do not offer toxicity potential under conditions of normal usage.
4.12 Limiting Oxygen Index Test (ISO 4589 et al.)

A specimen is positioned vertically in a transparent test column and a mixture of oxygen and nitrogen is forced upward through the column. The specimen is ignited at the top and the initiating flame is removed. The oxygen concentration is adjusted until the specimen just supports combustion. The concentration reported is the volume percent.
4.13 Australian Test Certificate
5.1 UNIFLEX vs. Multiply Conveyor Belts

UNIFLEX Conveyor Belts are the most modern type for underground coal mining. They consist of a PVC impregnated solid woven carcass and chloroprene rubber covers.

- **Low Elongation**
  Due to the very low elongation, Uniflex conveyor belts can be used on longer center distance conveyors with smaller take-ups.

- **Fatigue Strength**
  Flex fatigue of both the splice and the carcass increases over time under operating conditions. The fatigue strength of Uniflex belts is significantly higher.

- **Splice Strength**
  The strengths of both vulcanized and mechanical splices are significantly higher for Uniflex.

- **UV Resistance**
  Uniflex conveyor belts are resistant against ultraviolet light.

- **Edge Stability**
  The Uniflex carcass is by design able to withstand considerable contact force with conveyor structure, without tearing or separating as is experienced with multiply belts.

- **Wide Tension Range**
  Belt breaking strengths are available from 330 to 1800 piw, allowing for longer centers and fewer drives on higher tension applications.

- **Safety**
  The Uniflex carcass and covers are self-extinguishing, offering a higher degree of safety as per the strictest international requirements.

- **Impact and Rip Resistance**
  The carcass is inherently more durable and abuse resistant. The impact and rip resistance of Uniflex belts are significantly higher.
## 5.2 Comparison of Self-Extinguishing Textile Conveyor Belts

<table>
<thead>
<tr>
<th>Feature</th>
<th>PVC solid woven</th>
<th>CR multiply</th>
<th>PVG solid woven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wear resistance</td>
<td>poor</td>
<td>good</td>
<td>excellent</td>
</tr>
<tr>
<td>Robustness, impact and rip resistance</td>
<td>good</td>
<td>good</td>
<td>excellent</td>
</tr>
<tr>
<td>Edge stability</td>
<td>good</td>
<td>poor</td>
<td>excellent</td>
</tr>
<tr>
<td>Suitability for belt-to-belt drives</td>
<td>poor</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Suitability for man riding</td>
<td>poor</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Tracking stability</td>
<td>good</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Slope conveying</td>
<td>poor</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Cleanliness (carry-over)</td>
<td>poor</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Noise level</td>
<td>poor</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Elongation properties</td>
<td>excellent</td>
<td>good</td>
<td>excellent</td>
</tr>
</tbody>
</table>
### 5.3 Physical Properties of Cover Compounds

<table>
<thead>
<tr>
<th></th>
<th>SBR (USA)</th>
<th>CR (International)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Tear resistance</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Because of the negative effects of fire retarding chemicals in a SBR compound, the overall physical parameters deteriorate.
The prices for conveyor belts depend on the belt construction, the ingredients, the production facilities etc. etc.

As a rule of thumb, prices for self-extinguishing rubber conveyor belts will be 10 to 30 % higher than for flame retardant types. Self-extinguishing PVC conveyor belts will be 10 to 20 % cheaper than flame retardant rubber belts.

The higher safety and the better operational performance easily compensate the additional costs for self-extinguishing rubber conveyor belts.
In 1996, PHOENIX provided the MSHA with samples of

- St 7500 Phoenocord steel cord conveyor belt and
- EP 3150/1 Uniflex textile conveyor belt

in self-extinguishing grade as per the German standard for underground conveyor belts resp. as per the then proposed new MSHA rules for the USA, free of charge.

PHOENIX will be pleased to assist the MSHA also in future.
Additional Literature
The success story of self-extinguishing steel cord conveyor belts in underground coal mining

In 1975, the German mining authorities implemented stricter requirements for conveyor belts to be replaced within a specified time with so-called self-extinguishing types as per DIN standard 22129. This article describes the performance of such high strength steel cord conveyor belts in underground coal mining, including Phoenoeco reinforcement, a carrying coal over a conveying lift of 340m in the so-called Barbiertunnel. It was commissioned in January 1976 in Saarberg's Essenrode mine. Ensdorf produces approximately 2,500t of coal per year. After 20 years and 70Mt of conveyed raw coals the conveyor belt and all of its original splices are still in operation.

In January 1979, 360t/m² of 1,200mm wide Phoenoecd St 5000 were commissioned at Ruhkopf's Friedrichsdorf mine. This belt conveys raw coals over a lift of 390m. Still, the Phoenoecd conveyor belt including all its original splices is in good condition. No standstill caused by either of the conveyor belts or their splices has ever occurred.

The strongest one

The strongest conveyor belt on earth is a Phoenoecd St 7500 operating at Ruhkopf's Prosper Hasel mine. The actual conveyor belt strength is 8,200 N/mm. The diameter of the 72 steel cords is 12.5mm giving an elastic modulus of 500kN/mm². The belt has 10 plus 12mm thick rubber covers including Phoenoecd protection system. Its width is 1,400mm.

The stringent safety requirements were passed by the belt with excellent results. A dynamic splice fatigue strength as per DIN 22110/03 of 38 per cent was achieved, which was the world's record. The 21,700mm long splices are the longest in the world. This unique super belt conveys 1,800t/h raw coal over a distance of 3,745m from a depth of 750m underground to the surface at a speed of 5.5m/s. At the same time, 1,000t/h washing refuse is conveyed back underground on the bottom run.

The belt was put into operation in November 1980. After 15 years of operation and 85Mt conveyed material it is still in good condition.

Conveyor belt construction

A Phoenoecd conveyor belt based on DIN 22129 is a complex construction consisting of:

- Open stranded fire-resistant steel cords.
- Polyurethane rubber: rubber blocking covers.
- Special core adhesion rubber.
- Single synthetic cord transverse reinforcement.

Drive data of Phoenoecd St 7500

The conveyor belt must have the greatest possible wear and damage-resistant properties in addition to having the inherent characteristics of resisting the influence of mining water and other operating hazards, thus maintaining its initial safety and performance standards.

All material – elastomers and polymers – must have adequate fatigue strength, high resistance to aging, Polyurethane rubber (PU) – as one of the main ingredients in self-extinguishing steel cord conveyor belts – offers a prior fire safety advantage and high resistance to aging. In case of the formerly used flame-resistant grades which were based on styrene-butadien rubber (SBR), fire retardants had to be added.

The weakest point in a conveyor belt is the joint. The field splices must achieve the same surface life as the belt itself. They must also be in compliance with the underground safety requirements. All the high-strength steel cord conveyor belts in German underground mining were made under Phoenix super vision, with Phoenix splicing material, based on patented Phoenix splicing designs. Extensive development, testing and practical experience have made this success possible.

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Putting out the fire - World Coal Magazine

The success story of self-extinguishing steel cord conveyor belts in German underground coal mining is making coal miners from other countries take note as regulations there become stricter. Bernd Kusel, of German-based Phoenix, describes these successes.

Putting out the fire
Conveyor belts have proven their outstanding reliability and efficiency in the last 3 years. The revolutionary conveyor belt construction consists of PVC impregnated solid woven fabric and rubber cover.

**Development**

In 2002, world coal production was at 3.07 billion t. Last year the figure was even higher, mainly because of an impressive growth in China from 1.40 to 1.60 billion t.

Globally, the share of underground coal mining will reach 70% of all mined coal in 2015. In the two biggest coal producing countries, China and the US, the share is already above 80%.

On the side of increasing mechanization of underground coal mining, belt conveyors are becoming more and more the indispensable choice due to their reliability and economy.

The operating conditions in underground mining are rough and require sturdy equipment. Conveyor belts are especially subjected to extreme stresses from impact, shock, material, friction and component misalignment, etc.

In order to behaviorally improve the performance of underground conveyor belts, the unique PVC conveyor belt was developed. This consists of PVC, rubber, fabric and steel.

The positive features of PVC solid woven conveyor belts include their low elongation, the high mechanical fastener retention, the absence of ply separation and the possibility of using smaller pulley diameters. Disadvantages, however, are their low wear resistance and slippery surface. Rubber conveyor belts feature high wear resistance, high traction and low sensitivity to temperature.

Thus, the logical but very ambitious task was to combine the advantages of PVC and of rubber conveyor belts. In spite of their opposing characteristics, PVC conveyor belts have proven their outstanding reliability and efficiency in the last 3 years. The revolutionary conveyor belt construction consists of PVC impregnated solid woven fabric and rubber cover. PVC is an amorphous thermoplastic made by polymerization, lacking the chains of the amorphous vinyl chloride. Unlike rubber, polyvinylidene fluoride melts at about 450°C.

Rubber can be extruded easily and is almost completely resistant to high elongations. This is due to the inadmissible process of vulcanization, which consolidates the molecules. To achieve this, the raw rubber is mechanically mixed with a number of coating ingredients such as fillers, anti-degrading agents, accelerators, etc., and then cured.

In 1989, after extensive research and development work with a particular focus on the dynamic and thermal stability, Phoenix realized the durable combination of the PVC and rubber components.

Without safety tests for the use in underground coal mining were passed then and the worldwide first approval was attained in mid-1979 from the German mining authorities.

For most countries in the world, polyvinylidene fluoride (PVDF, Neoprene) components are required to pass the safety tests. Table 1 shows the resistance of the different belt types. For example, 100% PVC shows the highest tear resistance, being accepted by most mining authorities.

No detailed chart of PVC conveyor belts are available in the public domain. However, the latest development in the field of conveyor belts shows that PVC conveyor belts are now more and more used in underground coal mining.

**Conclusion**

In most countries with underground coal mining has been until now the number of plus in a conveyor belt, with many multiply available belts being replaced by modern PVC constructions. The total of belt types is a more and more concentrated to the most reliable and efficient construction that is the most reliable in underground coal mining.