Conveyor Belts for Underground Coal Mining

The Goodyear Tire & Rubber Company

March 28, 2007
We’re Here For Safety

- Goodyear has been one of the leading global suppliers of conveyor belting to coal industry for 90 years.

- We manufacture belts to exceed all required standards in all regions of the world.

- We continue to invest in R&D to improve all aspects of belt safety.

- We welcome this opportunity to participate in improving belt safety for underground mining.
Overview

• How belts are made

• Trends in belt design

• Goodyear’s continuous quality improvements
  – Improving belt safety

• What we mean by belt safety
  – The attributes of belt fire safety
  – New technologies that will improve belt safety

• Summary
How Belts are Made
How Rubber Belts Are Made

Typical USA Construction

**Top Cover**
- 3/16” - 3/8” gauge

**“Carcass”**
- 1-5 Plies of fabric
- Rubber coating each side

**Pulley Cover**
- 1/16” - 1/4” gauge

Note: USA does not use “Rubber Covered Belt Edges”,
uses thicker coats and unique fabric constructions
How Rubber Belts Are Made

1. Mix Rubber
2. Weave & Dip Fabric
3. Coat Fabric With Rubber
4. Build Carcass Ply Up Fabrics
5. Apply Top & Bottom Covers
6. Vulcanize Belt
7. Inspect & Test
8. Ship to Customer

Standard runs are 1,000’ to 3,000’ rolls
Trends in Belt Design & Application
Longwall Mining

- **Panel Belt**
- **Mainline**
- **Slope Belt**

Steel shields to protect the miners from the loose rocks above and behind.

Elevator/ventilation shaft (exhaust fan helps air flow)

Pillars are the "mains" development part of the mine. The coal is removed through those passages and good air/bad air is exchanged, also miners travel through those passages.
Trends in Belt Design - Panel Conveyors

- Avg Rating (piw)
- Max Rating (piw)
- Avg Thickness (in)

1992:
- PIW: 600 pounds per inch width
- Avg Rating: 0.435
- Max Rating: 750

2006:
- PIW: 1500 pounds per inch width
- Avg Rating: 0.655
- Max Rating: 1000

(+50%)
Trends in Belt Design - Mainline Conveyors

- Avg Rating (piw)
- Max Rating (piw)
- Avg Thickness (in)

PIW (pounds per inch width)

1992:
- Avg Rating: 600
- Max Rating: 800

2006:
- Avg Rating: 1000 (42% increase)
- Max Rating: 1800
- Avg Thickness: 0.745 (inches)
Trends in Belt Design - Slope Conveyors

- Avg Rating (piw)
- Max Rating (piw)
- Avg Thickness (in)

PIW (pounds per inch width)

1992

2000

4000

2006

3000

5800

(+27%) 0.87
Improvements to Belting
Continuous Quality Improvement

- Durability
- Adhesion
- Flammability resistance
- More permanent flame retardants

All Contribute to Improved Safety
Durability

Three Key Areas:

- Abrasion resistance of covers
- Rip/tear strength of carcasses
- Fatigue resistance of belts

**Durability Improves Safety**

Rip/tear/rubber loss could cause fire hazards and other safety issues such as belt breakage
Durability - Abrasion Resistance

- Field studies in coal mining show good correlation to durability.
- Mainlines durability up to 10 years versus 3-5 years.
- More rubber on belts reduces fire hazard.

DIN 53516 Rotating Abrasion mm³
Durability – Panel 1000 piw Construction

- Rip/Tear/Tensile Strength of Carcasses has increased
- Typically lasted only 1-2 moves – now up to 6 moves
- Reduced Stringing

![Bar Chart]

- 1992: Tear Strength = 1300 LBS, Rip Strength = 3760 LBS
- 2006: Tear Strength = 2570 LBS, Rip Strength = 4770 LBS

Increase:
- Tear Strength: +27%
- Rip Strength: +97%
Durability – Mainline 1000 piw Construction

- Rip/Tear/Tensile Strength of Carcasses has increased
- Reduced Stringing

LBS

<table>
<thead>
<tr>
<th>Year</th>
<th>Tear Strength</th>
<th>Rip Strength</th>
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<tbody>
<tr>
<td>1992</td>
<td>1300</td>
<td>3760</td>
</tr>
<tr>
<td>2006</td>
<td>1570</td>
<td>4480</td>
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</tbody>
</table>

+19%  
+21%
Durability - Fatigue Resistance

- Goodyear has invested heavily in dynamic test equipment to improve durability.
- Fatigue curves/actual performance has shown improved durability.
Adhesion

- Low adhesion in belt can cause potential safety issues
  - Belts separate, potentially easier to ignite.
  - Fabric separates/strings on edges, again potentially easier to ignite.
  - Improvements in adhesion in last 10 years have significantly improved minimum and average adhesions.
  - Fabric constructions developed to eliminate edge stringing (common in panel belts).
Goodyear belts exceed the MSHA 2G standards
Goodyear tests every roll of belting for release
More Permanent Flame Retardants

New flame retardants remain in rubber at elevated temperatures
Summary - Changes since 1992

- Belts are thicker/stronger
- Belts are more durable
- Far exceed the current MSHA 2G standard
- Have more permanent flame retardants
Attributes of Safety
Attributes of Belt Flame Resistance Safety

Current standards only considers these attributes:
- Ignition
- Propagation

Current/proposed standards do not measure/control these attributes:
- Density
- Toxicity

FLAME

SMOKE
Belt Safety: What Ignotes First?

- Coal Dust: 320°C
- Idler Grease: 350°C
- 1992 Rubber Belts: 400°C
- 2006 Rubber Belts: 500°C
- BELT Belts: 525°C

ASTM D1929
Belt Safety: Ignition/Propagation Tests

- MSHA 2G
- ISO 340
- B.E.L.T.

Higher level of flame retardants needed
Belt Safety: Smoke

- Smoke is a danger to miners
- Smoke needs to be considered for improved belt safety
- Smoke from a belt can occur without ignition – frictional heat
Smoke

- Other industries have studied and addressed this issue
  - PetroChemical
  - Non-Residential Construction
  - Aerospace
  - Military
  - *Wire & Cable*
Wire Cable Industry Discovered

Causes of Death from Fire*


Courtesy of The Dow Chemical Co.
**Belt Safety: Smoke & Halogens**

There are two groups of flame retardants that can be added to hydrocarbon materials (rubber/plastic etc)

- **Halogenated Materials**
  - Contain Bromine or Chlorine
  - Very effective for propagation resistance
  - Lower cost than alternate materials

- **Halogen Free Materials**
  - Use non halogenated materials.
  - Higher levels needed to be effective for propagation
  - Higher cost than Halogenated materials - depends on type/level of flammability resistance
Wire/ Cable Industry

Benefits of Halogen Free materials

• **Low Smoke**
  – Improved visibility, less irritating.
  – More time to escape, Increases time to exit the fire area.

• **Low Corrosivity**
  – Acid gases from halogens corrode and damage equipment during and after fire.

• **Low Toxicity**
  – Less harmful emissions.
  – Increases time to exit the fire area.

Courtesy of The Dow Chemical Co.
Wire/ Cable Industry
- Typical Test Methods

• Smoke Density:
  - ASTM E662
  - NES 711
  - JCS 397

• Toxicity:
  - NES 713
  - Pittsburgh Protocol
  - BSS 7239

Courtesy of The Dow Chemical Co.
Actual Belt Tests
Smoke Density from Belts

After 4 Minutes – Smoldering before Ignition

- Current Rubber (Halogen): 73
- Rubber A (Halogen Free): 15
- Rubber B (Halogen Free): 5
- BELT Rubber (Halogen): 125
Smoke Density from Belts

After 4 Minutes - Flaming

<table>
<thead>
<tr>
<th>Material</th>
<th>Optical Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Rubber (Halogen)</td>
<td>195</td>
</tr>
<tr>
<td>Rubber A (Halogen Free)</td>
<td>28</td>
</tr>
<tr>
<td>Rubber B (Halogen Free)</td>
<td>18</td>
</tr>
<tr>
<td>BELT Rubber (Halogen)</td>
<td>389</td>
</tr>
</tbody>
</table>

ASTM E662
Toxic Gases from Belts

After 4 Minutes - Smoldering before Ignition

**Carbon Monoxide (CO)**
- Current Rubber (Halogen): 50 ppm
- Rubber A (Halogen Free): 10 ppm
- Rubber B (Halogen Free): 10 ppm
- BELT Rubber (Halogen): 50 ppm

**Hydrogen Chloride (HCl)**
- Current Rubber (Halogen): 500 ppm
- Rubber A (Halogen Free): 6 ppm
- Rubber B (Halogen Free): 5 ppm
- BELT Rubber (Halogen): 1000 ppm
Toxic Gases from Belts

After 4 Minutes – Flaming

Carbon Monoxide (CO)

Hydrogen Chloride (HCl)
MSHA Flame Test

Current Belt

Halogen Free A
MSHA Flame Test

B.E.L.T.  Halogen Free A
Smoke from Frictional Heat

- Drum Friction Test used in other regions of the world
  - Run for 1-2 hours
  - Belt must stay below 325°C
  - PVC belts melt and break
  - Rubber belts glaze over and stay intact
Drum Friction Test

Belt 1

Belt 2
Another Test Method
For Smoke Analyses
Factory Mutual and CSIRO, Australia have used cone calorimeters to study conveyor belts.
Cone Calorimeter Demonstration
Cone Calorimeter Benefits

- Measures key properties in controlled conditions.
- Measurement of both flammability AND smoke.
- Small sample size.
- Used extensively by other industries.
A Systems Approach
Belt Safety: A Systems-Based Approach

- Belt fire safety is **MORE** than just the flame resistance of the belt.
- Smoke density/toxicity needs to be evaluated.
- Temperature detection and suppression can be integral to belt safety.
Infrared (IR) Sensors

Detection of IR Radiation

- IR sensors detect:
  - Emitted IR radiation
  - Reflected IR radiation
  - Transmitted IR radiation

- IR radiation can be used to directly measure the temperature of a material, conveyor belt and coal – not air temperature
Infrared Temperature Detection System

- High resolution IR line scan and quick hot spot detection
- Alarm can be relayed to suppression systems and/or belt controls.
- Currently in use in other conveyor belt applications (power plants/grain handling).
- Used to detect hot spots in coal piles.
Temperature Detection Demonstration
Systems Based Approach

Flammability

Durability

Temperature Detection

Smoke Density

Smoke Toxicity

Rubber Halogen Current Belts
Systems Based Approach

Rubber Halogen Current Belts

Halogen Free Belts with Temperature Detection
Systems Based Approach

Halogen Free Belts with Temperature Detection

BELT Rubber Halogen
Process for Improving Conveyor Belt Safety

- Include all elements of belt safety
- Inclusive, open, transparent process for developing new test standards

  All stakeholders represented in development standards and tests procedures
  - Government agencies
  - Unions
  - Mines
  - Belt manufacturers

- RMA may be an option to pull together all stakeholders
Examples of Consensus Standards Process

How RMA Has Helped Safety

**Welding hoses**
- Standard developed with RMA (hose manufacturers) and CGA (Compressed Gas Association)
- 3 separate hose specifications issued in 1987 - oxygen/acetylene/propane/MAPS

**Anhydrous ammonia hose assemblies**
- Anhydrous ammonia very aggressive material.
- Hose specifications/test procedures issued to ensure hose and hose assemblies are resistant to anhydrous ammonia and that care/maintenance guidelines are communicated.

Industry has seen dramatic improvement in hose/hose assembly performance since 1989
Summary

- **Goodyear supports improved safety for miners**
  - Yesterday, today and tomorrow ...

- **Conveying Belting is safer today**
  - More permanent flame resistance
  - Higher ignition points
  - Better adhesions/durability
  - Thicker constructions

- **Smoke density/toxicity should be considered**
  - Smoke is a significant danger to miners – reaches working areas faster and can’t always be detected
  - MSHA recognizes this by requiring CO monitoring systems in mines today
  - Other industries have successfully addressed - Halogen free

- **Temperature detection has greatly improved in recent years**
  - Measures the actual temperature of surfaces not the surrounding air temperature
  - Redundant systems raises the level safety in mines

- **Rubber Manufacturers Association involvement has proved helpful in other industries**
  - Standardization
  - Accelerated industry consensus
Thank You.