T_e = 18,798 lbf (Table 6.152 Tension gain in flight 9, Head Pulley)

$V = 600 \frac{ft}{min}$ $1\ Hp = 33{,}000 \frac{ft-lbf}{min}$

Reference Equation 6.139   Pulley n = 9 with E_n = 0.95 SF_d = 1.1

Reference Footnote in Table 6.152 $\Delta T_{bc} + \Delta T_{pr} = 700$ lbf

$$P_{bn} = \frac{\Delta T_{en} \times V}{33{,}000}$$ (Hp) (Linear power seen by the belt at pulley, n)

$$P_{b9} = \frac{(18{,}798\ lbf + 700\ lbf) \times 600 \frac{ft}{min}}{33{,}000 \frac{lbf\text{-}ft}{min}} = 354.5\ Hp$$

$$P_{dn} = \frac{P_{b9} \times SF_d}{E_n}$$ (Hp) (Minimum rotary power applied to pulley, n)

P_{d9} must be divided by the drive train efficiency to determine the motor power required. See Chapter 13 Table 13.31 for typical drive train efficiencies.

$$P_{d9} = \frac{354.5\ hp \times 1.1}{0.95} = 410.5\ Hp\ (306.6\ kW)$$

$\therefore$ Consider a 450 Hp (350 kW) motor

Figure 6.158
Example calculation for power required at the drive pulley

CHAPTER 6 CONCLUSION

The technology of conveyor design and component technology continues to evolve, so conveyor design is still part art and part science. Because of the iterative nature of conveyor design there is almost always more than one acceptable solution for a set of initial assumptions. An experienced conveyor engineer should be able to use the Universal Method to design a conveyor that delivers the desired capacity and predicts the tension required under the expected range of conditions and requirements. The tension required is then modified by the drive train efficiency to predict the power required for the conveyor. While this chapter refers to safe design of components and the safe operation of the conveyor as a system, there are many other safety, operational and maintenance issues that must be addressed in a complete bulk material handling system. Contact a CEMA Member for conveyor design assistance.

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INTRODUCTION

This chapter addresses the general requirements and method of proper selection of conveyor belting. it is impossible to treat all of the many conveyor belt constructions available. Only those basic types and grades of conveyor belting that apply to a majority of conveyor applications will be covered.

Anyone using the data in this chapter should recognize that a belt selection determined by the data will be conservative. While the selected belt will meet the specified conditions, it may not always be the most economical construction available. This is particularly true because of the continuing developments in the fields of elastomers and synthetic fibers for use in conveyor belts.

DETERMINING BELT SPECIFICATIONS

For major conveyor belt applications, analyze the complete duty and operating requirements of the conveyor to develop the final specification.

Such a complete analysis of a conveyor must consider the following details:

- Material conveyed: general description; bulk density, lbf/ft^3 (kgf/m^3); maximum lump size; presence of oils or chemicals, if any; maximum temperature of load, if hot; requirements for fire resistance.
- Maximum loading rate or required maximum capacity, 2,000 lbf (1,000 kgf) per hour tph (mtph).
- Belt width, inches (mm).
- Belt speed, feet per minute, fpm, (m/s).
- Profile of conveyor: distance along conveyor path, tail to head, feet; lift or drop, ± feet (m), or elevations of top and bottom of any inclines or declines; angles of slope of all inclines or declines; locations and radii of all vertical curves.
- Drive: single-pulley or two-pulley; if dual drive, distribution of total motor power at primary and secondary drive pulleys; angle of belt wrap on drive pulley(s); location of drive; pulley surface, bare or lagged; type of lagging; type of starting to be used.
- Pulley diameters: check against the actual belt specification.
- Takeup: type, location, and amount of travel.
- Idlers: type, roll diameter, angle of trough; spacing, including transition distance at head and tail.
- Type of loading arrangement: numbers of chutes; lumps-to-belt free fall distance; skirtboard length; impact idlers or bed, if any; angle of loading to belt.
- Lowest and highest operating temperature, and extreme weather anticipated.
- Type of belt splice to be used: vulcanized or mechanical.
- Type(s) of belt cleaners to be used.

FACTORS IN THE COMPOSITION OF CONVEYOR BELTING

While a belt conveyor system is composed of many important parts, none is more economically important than the conveyor belt itself, which, in most cases, will represent a substantial part of the initial cost. Therefore, the selection of the conveyor belt must be made with great care.

In general, a conveyor belt consists of three elements: top cover, carcass, and bottom cover. Figure 7.1 illustrates a cross section of a typical belt. The primary purpose of the covers is to protect the belt carcass against damage and from any special deteriorating factors that may be present in the operating environment.

The belt carcass carries the tension forces necessary in starting and moving the loaded belt, absorbs the impact energy of material loading, and provides stability for proper alignment and load support over idlers under all conditions of loading.

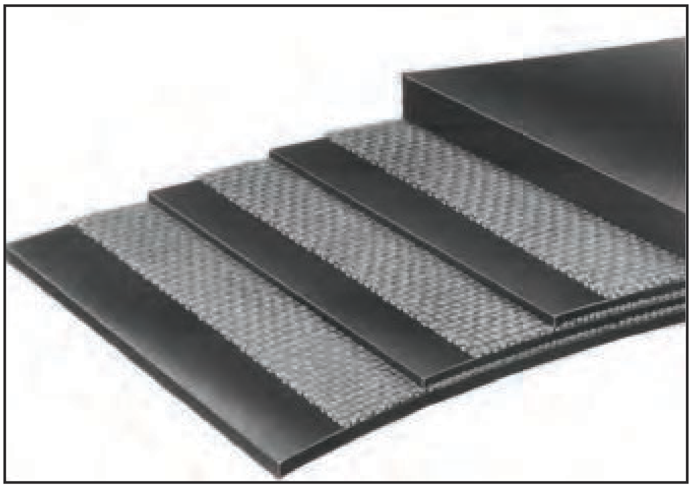

Figure 7.1
Cross section of a multi-ply fabric-reinforced belt (cut/slit edge)

Although covers and carcass are treated as separate components, successful operation depends upon their working together as a single integral unit to provide the required belt characteristics.

CONVEYOR BELT COVERS: CHARACTERISTICS, COMPOSITION, AND DESIGN

Conveyor belting is currently available in a wide range of types and constructions. Varieties of conveyor belting are suitable to fit an extraordinary range of conveyed material, operating conditions and design criteria.

The development of a broad range of synthetic rubbers, polymers, elastomers, and fibers over the past forty years has increased the service life and extended the operational envelope of conveyor belting. Previously, natural rubber covers and cotton fiber reinforcement (carcasses) were the only options.

Today, conveyor belt covers will consist of compounds comprised of natural rubbers, styrene-butadiene rubber (SBR) blends of natural and other synthetics, nitriles, butyl, ethylene propylene-based polymer (EPDM), polychloroprene (Neoprene or CR), polybutadiene (PB), polyvinyl chloride (PVC), urethanes and silicones, etc., and the list goes on and continues to grow. Each of these elastomers has specific usefulness for various ranges of properties and operating conditions.

Conveyor belting and its corresponding cover composition(s) can be designated as either (1) general purpose belting, or (2) special purpose belting. Each of these two broadly classified groups should be further defined depending upon the specific end use.

General Purpose Rubber Covered Belting

General purpose covers and belting serve a broad range of industrial applications including mining, ore processing, lumber, paper/pulp, and agriculture, to name a few. By and large, these belts will have covers of natural rubber, SBR, polybutadiene, and acrylonitrile (ACN) or blends thereof. These cover compounds are further defined by the Association for Rubber Products Manufacturers, (ARPM), formerly a group within the Rubber Manufacturers Association (RMA) and belting industry as either Grade I or Grade II.

Manufacturer's Brand

It is common practice to imprint the belt cover with the identity of the manufacturer and the type of belt. If cleaning of the conveyor belt is a critical issue or the belt is very long, then the brand should be placed on the bottom cover to prevent fines from accumulating in the brand and subsequently falling from the belt.

ARPM RMA Grade I

These covers consist of natural or synthetic rubber or blends which will be characterized by high cut, gouge, and tear resistance and very good to excellent abrasion resistance. They are recommended for service involving sharp and abrasive materials, and for severe impact loading conditions.

ARPM RMA Grade II

The elastomeric composition of these covers will be similar to that of Grade I with good to excellent abrasion resistance in applications involving the conveyance of abrasive materials, but may not provide the degree of cut and gouge resistance of Grade I covers.

When covers are tested in accordance with ASTM D412, the tensile strength and elongation at break shall comply with the requirements of Table 7.2, for the grade of cover, as appropriate.

Grade	Minimum Tensile Strength (psi)	Minimum Tensile Strength (Mpa)	Minimum Elongation @ Break (%)	Maximum Volume Loss ISO 4649 Part B (mm^3)
I	2,500	17	400	125
II	2,000	14	400	175

Table 7.2
Properties of rubber covers

The tensile strength and elongation at break values are not always sufficient in themselves to determine the suitability of the belt cover for a particular service. The values in the above table should only be specified for conveyors or materials with a known history of performance and in cases where it is known that compliance with the value will not adversely affect other in-service properties.

Cover and Ply Adhesion

When belting is tested in accordance with ASTM D378, the adhesion for cover and between adjacent plies should not be less than the values given in Table 7.3.

Adhesion Between Adjacent Plies		Adhesion Between Cover and Ply for Cover Thickness:			
Any Ply Thickness		1/32” (0.8 mm) through 1/16” (1.6 mm)		Greater than 1/16” (1.6 mm)	
30 lbf/in	5 kN/m	16 lbf/in	2.8 kN/m	25 lbf/in	4.4 kN/m

Table 7.3
General purpose rubber cover and ply adhesion

Special Purpose Belting

Special purpose belting and its components (covers) are just that: those that require special characteristics and properties. Conveyor applications and systems that operate outside the normal parameters covered under general purposes will include high temperatures (above 175 °F (80 °C)), low temperatures, (below 40 °F (5 °C)), fire/flame resistance, oil exposure, food (“FDA”) processing, and chemical resistance. Conveyor belt manufacturers provide products to meet these and other demands with a wide variety of elastomers and carcass constructions. The following list of conveyor cover compound types is not all inclusive, but is a general guide for special applications:

Hot Materials Handling

Cover compounds consisting of butyl (and bromo/chloro butyl) or EPDM can resist the degrading effects of high temperatures up to approximately 400 °F (200 °C). Some specially formulated SBR-based compounds will perform in high temperature environments, but not generally to the same range or degree as EPDM or butyl-based covers. Neoprene (polychloroprene) and Hypalon (chloro-sulfonated polyethylene, a trademark of E. I. du Pont de Nemours and Company) based compounds also exhibit good heat aging properties. Belting with silicone or Viton (fluorocarbon polymers, a trademark of DuPont Performance Elastomers L.L.C..) covers will withstand very high temperatures best, with extended operating range up to approximately 700 °F (370 °C). High temperature belting is currently classified by type depending on the retained physical properties after exposure to a given temperature for 70 hours (ASTM D865). ARPM classifications are given in Table 7.4.

Classification Type	Test (70 h) Temperature	Maximum Retained Tensile (from original)	Maximum Retained Elongation (from original)	Maximum Hardness Point Change (from original)
ARPM-HR Class 1	212°F (100°C)	-25%	-50%	+20
ARPM-HR Class 2	257°F (125°C)	-30%	-50%	+20
ARPM-HR Class 3	302°F (150°C)	-40%	-60%	+20

Table 7.4
ARPM belt classifications for high temperature applications

Polyester and nylon fibers/textiles will melt at temperatures above 500 °F (260 °C). Loss of dimensional stability and softening will occur well before this temperature is reached. Glass fiber carcasses are often recommended where operating temperatures exceed 400 °F (200°C).

Oil Resistant Belting

Belt covers designed to resist swelling and degradation in oily environments will often incorporate Nitrile based polymer (NBR), polyvinyl chloride (PVC), or urethane. The type of oil encountered as well as the temperatures in which the belt must operate is of prime importance. Highly aromatic and asphaltene-based materials, as well as exposure to diesel fuel, are best handled with a NBR or urethane-based compound. PVC belting will resist light oil (e. g., mineral and napthenic oils) degradation at lower temperatures. Neoprene/polychloroprene compounds will also resist low aromatic oils and fuels satisfactorily. Currently there are two classifications:

- MOR/VR, for vegetable based or light petroleum oils (which has a maximum of 15% volume swell with ASTM #1 oil, or 140% with ASTM #3 or #609 oil).
- EOR/SOR for extremely oily environments (which has a maximum of 5% volume swell with ASTM #1 oil, or 30% with ASTM #3 or #609 oil).

Food Processing

Food processing entails belt exposure to both vegetable oil and animal fats. In such environments, PVC and NBR-based belt constructions predominate. Both have good resistance to swelling and degradation under these conditions.

Fire/Flame Resistance

Belting requiring flame resistance is engineered to meet underground mining regulations and specifications. Currently, belt and belt compounds using SBR, NBR, CR (Neoprene) and PVC are routinely utilized. Cover compounds are designed to meet specific national or international standards. These standards typically define laboratory tests which either demonstrate that the belt is able to self extinguish after being set on fire (Bunsen burner or gallery tests), or which establish that the belt will not initiate a fire from the heat generated when the belt is stalled against a rotating steel drum, (drum friction test). The latter simulates a potential mine condition where a belt is stalled against a rotating drive pulley.

In the USA, the standard for underground fire resistant belting for gaseous (coal) mines was changed on December 31, 2008 and is now designated by the US Mine Safety and Health Administration's (MSHA) standard CFR Title 30 Section 14. The test procedure is also described in ASTM D378 and the standard is designated as ARPM FR Class I fire resistant belting. The former MSHA fire resistant belt standard for underground mines is no longer supported by MSHA, but the test method is described in ASTM D378 and this standard is designated as ARPM FR Class II fire resistant belting.

Low Temperature Environments

Generally, most general purpose (Grades I and II) belting and compounds will resist stiffening down to -40 ° F(-40 °C). For most general purpose belting, when there are prolonged periods of downtime during which the belt is exposed to -40 °F (-40 °C) for several days or weeks, hard starts may be difficult or deleterious to the belt because of coldset. When these conditions are expected, belts can be obtained which have suitable low temperature plasticizers and low glass-transition polymers or blends incorporated to permit maximum flexibility and operation.

It is good practice under extremely low temperature conditions not to stop the belt for long periods of time as the belt can take a set on the pulleys, and in wet conditions, ice can build up on the structure and along the bottom of pulleys. Ice can severely damage a high modulus or steel cord belt if trapped on a high tension pulley. In such situations it is recommended to have a slow speed or creep capability that can be used when the belt is not transporting material. The internal heat generated within the belt is enough to keep it flexible.

Chemical Exposure

Conveyor belting manufacturers should be consulted when systems are being operated in specific chemical environments. The condition in which the conveyor belt is operating should be clearly defined. Consider the chemical concentration and temperature, as well as the possible presence of incidental processing chemicals or oils.

Cover Considerations

The covers should be of sufficient thickness and quality to protect the carcass. Covers for general service applications are listed in Tables 7.5 and 7.6, which list suggested minimum thickness for carrying and pulley side covers, respectively.

The cover gauge required for a specific belt is a function of the material conveyed and the handling methods used. Increased cover thickness is required as the following conditions become more severe: material abrasiveness, maximum material lump size, material weight, height of material drop onto the belt, loading angle, belt speed, and frequency of loading as determined by the frequency factor.

Class of Material	Examples	Thickness* (inch)	Thickness* (mm)
Package Handling	Cartons, Food Products	Friction to 1/32	Friction to 0.8 mm
Light or Fine Non-abrasive	Wood Chips, Pulp, Grain, Bituminous coal, Potash Ore	1/16 to 1/8 inch	1.6 to 3.2
Fine and abrasive	Sand and Gravel, Crushed Stone	1/8 to 3/16	3.2 to 4.8
Heavy, Crushed to 8-inch (203 mm)	Run of Mine Coal or Rock Ores	3/16 to 1/4	4.8 to 6.4
Heavy, Large Lumps	Hard Ores, Slag	1/4 to 5/16	6.4 to 7.9
* Cover thicknesses are nominal values subject to manufacturers' tolerances			

Table 7.5
Suggested minimum carry cover (top cover) thickness for normal conditions: ARPM Grade II

Operating Conditions	Thickness (inch) *	Thickness (mm) *
Non-abrasive Materials	1/32	0.8
Abrasive Materials	1/16	1.6
Impact Loading **	3/32	2.4
* Cover thicknesses are nominal values subject to manufacturers' tolerances.		
**Although an increased cover gauge does help protect the carcass if impact is severe, a correct system design that includes carcass design, top cover thickness, and impact-absorbing belt support in the conveyor loading zone is the preferred method of handling.		

Table 7.6
Suggested minimum pulley cover (bottom cover) thickness: ARPM Grade II

Deteriorating Conditions

Table 7.7 establishes the basis for determining cover quality for conditions which attack or cause deterioration of the belt. The actual cover thickness should generally follow the guidelines for a Grade II cover in Table 7.5. For all special materials not listed, or in cases where extreme concentrations of chemical solutions are likely to be encountered, a belt manufacturer should be consulted to determine appropriate cover quality and thickness.

Typical Materials Handled Without Cover Deterioration	
Chemicals	**Materials wetted with or containing the following chemicals and not over 150 °F (65 °C) may be handled satisfactorily on conveyor belts with covers of Grades I and II: Black Sulfate liquor, Ethyl Alcohol Sulfur, elemental, dry, Sulfuric acid (dilute)**
Heat	**Hot fine material up to 150 °F (65 °C) Hot lump material up to 150 °F (65 °C)**
Fertilizers	**Super phosphates,Triple super phosphate Phosphate rock or pebbled, acid treated, to produce super or triple super phosphate**
With loading conditions resulting in maximum cover wear, the top cover thickness may have to be increased by 1/16 to 3/16 inch (1.6 to 4.8 mm) above the values listed in table 7.5 in order to obtain a reasonable life.	

Table 7.7
Deteriorating conditions for conveyor belt covers.

Materials Handled Resulting in Deterioration of Covers

Chemicals not listed may have a deteriorating effect on the rubber covers of conveyor belting, but, because of considerations of concentration and temperature, do not lend themselves readily to classification. Therefore, when handling chemicals not listed in Table 7.7, consult the belt manufacturer for cover quality recommendations.

Molded Covers

For special applications and/or unusual operating conditions, covers with special molded surfaces may be used to advantage. One type has a rough top, or various patterns of molded surface, designed primarily for conveying packages up inclines, but is also occasionally used for conveying light-weight bulk materials on steep inclines. The second type is a ribbed or cleated cover used in bulk conveying to allow the conveyor incline to be increased without backsliding the load. Also, special designs for handling wet materials or slurries permit drainage or retention of fluids as required.

Frequency Factor

The frequency factor indicates the number of minutes for the belt to make one complete turn or revolution. It can be determined using the following formula:

$$\boxed{F_f = \frac{2 \times L}{V}}$$

Equation 7.8
F_f Frequency factor