The Sixth Edition of the CEMA Belt Book "*Belt Conveyors for Bulk Materials"*

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ABSTRACT

This presentation looks at the sixth edition of *Belt Conveyors for Bulk Materials,* published in April 2005 by the Conveyor Equipment Manufacturers Association (CEMA).

CEMA is a trade association representing the leading North American manufacturers and designers of conveyor equipment. The purpose of CEMA is to promote within the industry standardization of design, manufacture and application that will not impede development of conveying machinery and component parts or lessen competition. CEMA is considered the leading resource for conveyor safety, dimensional, and application standards

A member of the CEMA Board of Directors, Todd Swinderman served as chairman of the association's *"Belt Book"* Committee, the task force charged with updating the book. In this presentation, Swinderman will discuss the major changes seen in the new edition, as compared to the previous editions and as compared to other major standards such as DIN.

AN INTRODUCTION TO CEMA

The Conveyor Equipment Manufacturers Association—CEMA--was formed as a not-for-profit association in 1933 by the leading US manufacturers of conveyors. The purposes of the Association are:

> *To promote the common interests of its members and the members of the conveyor manufacturing industry when such interests do not conflict with the common good.*
>
> *And to promote among its members and the industry standardization of design, safety, manufacture and application on a voluntary basis and in such a manner that will not impede development of conveying equipment and component parts or lessen competition.*

Today membership is open to companies in the United States, Canada, and Mexico whose principal business is the manufacture, the design, or sale of conveyors and conveyor components. To qualify for membership companies must be in business for at least one year and manufacture, design or sell systems or components for which CEMA maintains records. CEMA maintains records for orders and shipments in two main categories of systems and components, Bulk Material Handling and Unit Handling. The approximately 100 CEMA member companies represent about 50% of the sales of bulk and unit handling systems and components in the North American market. In 2004 North American material handling equipment and services sales amounted to $5 billion USD.

CEMA members meet three times a year. Two of the meetings are business meetings and the third is the Engineering Conference. Most of the work on developing and maintaining standards and technical publications is done by the engineers who attend the annual Engineering Conference. CEMA works by a consensus process so that all interested

members have to agree upon what is accepted and printed as a standard. This process produces standards that are by nature conservative and cover a broad range of member company's products and design methods. CEMA publications and industry information is available from the CEMA web site, www.cemanet.org.

THE CEMA BELT BOOK

In 2000 the General Bulk Handling Section directed the Engineering Conference to undertake the task of updating **Belt *Conveyors for Bulk Materials.*** A committee was formed and it took one year to develop a plan of action and second year to secure the approval from the General Bulk Handling Section and the funding from the CEMA Board of directors. Work began in earnest in 2002 on planning the 6th edition of the book.

The first edition of ***Belt Conveyors for Bulk Materials*** was published in 1966. It was compiled based on the industry experience and resources of the major manufacturers of the time on a voluntary basis. Much of the data was empirical based on experiments done at the University of Pittsburg and the engineering and R&D departments of member companies. The ***"CEMA Book"*** was substantially revised in 1979 with the printing of the 2nd edition. The 3rd edition in 1988, the 4th edition in 1994 and 5th edition in 1997 were updates to the 2nd edition.

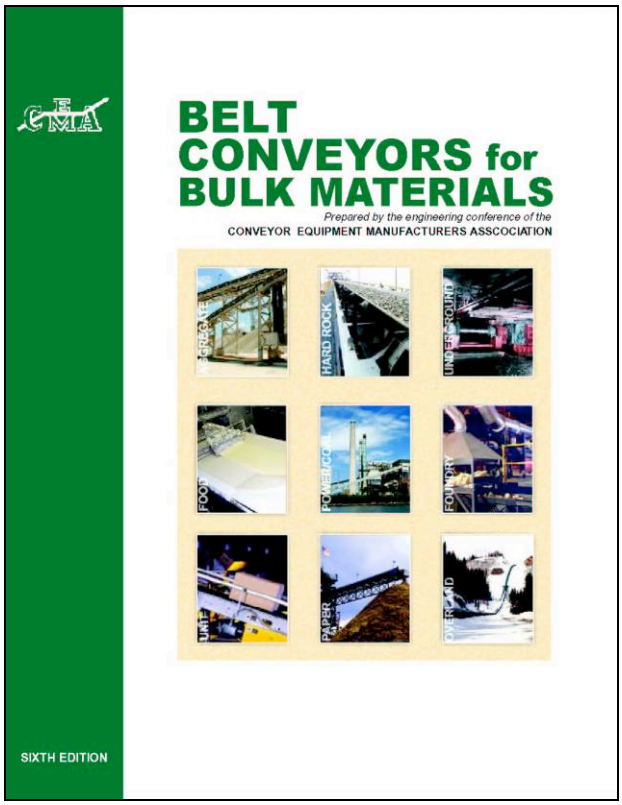
The 6th edition was published in April of 2005 and is available from the CEMA web site www.cemanet.org, or by contacting CEMA at 6724 Lone Oak Boulevard, Naples Florida USA 34109. (Phone: 239-514-3441, Fax: 239-514-3470)You can also get it from many other sources that sell technical books. Single copies sell for about $300 USD plus shipping.

THE CHALLENGES OF THE NEW EDITION

The ***"Belt Book"*** Committee's task was made difficult because almost all the original records on the development of the equations, charts and factors used as the basis of the CEMA method have been lost over time. The Committee began seeking volunteers for writing the 6th edition and discovered that during the time between the 3rd edition and the 6th edition there had been a major change in the structure of the conveyor business that made it difficult for most companies to provide the level of resources and volunteer time needed for the first total re-write of the book since 1979. That shift was the movement of the technical talent from the manufacturers to consulting companies. This change was driven by the need for manufacturers to reduce costs to stay competitive in a maturing industry. At the same time consulting companies have limits on how much time they can donate to such an effort because time and expertise is their "product". The CEMA Book had always been done on a volunteer basis and there was major resistance to the idea that CEMA may have to pay for some basic research to update the book.

To convince the membership that the book needed major revisions and that the input of the consulting companies was needed the Committee researched the market. Many of the major industry and university technical leaders were polled on what they would like to see changed in the book. Major end users were consulted and a search of the academic literature was made looking for input. Four major themes emerged from this market research. First it became apparent that the chapter on power calculations was outdated and produced results with too wide a range of over and under powering conveyors. Secondly end users, manufacturers and consultants felt there was a lack of specific CEMA standards on a variety of topics such as safety, spillage and dust, belt feeders. Third, there was a strong desire from the engineering profession for a metric version of the book. Last of all many of the tables, charts and factors in the book were based on empirical information and in a format that was not conducive for use in computer programs.

Once the Association members were convinced of the fundamental shift in the technical talent pool and the need for substantial changes in the technical content of the book, consulting firms were invited to join CEMA and the Board appropriated the necessary funds for basic R&D to improve the technical content. Work on the re-writing book began in early 2003. About the time that the funding was appropriated the bulk material handling industry was on the rebound and those who were once able to volunteer were now torn between their commitment to CEMA and their commitment to their customers. The ***"Belt Book"*** was originally scheduled for publication in December of 2004 and this struggle for resources delayed the printing until April of 2005.



THE 6TH EDITION OF *BELT CONVEYORS FOR BULK MATERIALS*

Based on the input from end users, the conveyor industry and academia the Committee set 3 major goals for the new edition and the conversion of the book into metric units and other languages is under consideration for a future edition.

1. Provide a power calculation method that is capable of predicting power requirements for a conveyor of any length or configuration within 100% ± 10%.
2. A digital friendly format with equations, charts and graphs compatible with computer programming.
3. A complete update of every chapter with new technology, photos, charts, and tables with an emphasis on conveyors that can be well designed, economical and safe to operate.

The Engineering Conference of CEMA carefully considered the possibility of incorporating metric units into the 6th edition of Belt Conveyors for Bulk Materials. It was the Conference's decision that the 6th edition would be prepared in English units.

There are many conversion programs and publications available for the understanding and use of SI units. The reader is referred to *IEE/ASTM SI-10 Standard for the Use of the International System of Units (SI): The Modern Metric System* as a reference. The 6th Edition's Appendix A presents an abbreviated guide relevant to belt conveyor calculations.

There are many other substantial changes in the 6th edition that are worthy of study by conveyor and component designers. All together there are two new chapters, and over 600 equations, figures and tables in the 6th edition, most of them new. A few of the major changes from the 5th to the 6th edition are discussed in this paper.

Chapter 1, Applications and Economics, 16 pages

Chapter 1 discusses the capabilities of belt conveyors which have greatly expanded since the original writing of the 5th edition. There is a section on the trade offs between upfront and future costs as well as a few of the rules of thumb for when conveyors are feasible over other means of bulk haulage.

Chapter 2, Design Considerations, 28 pages

Chapter 2 addresses many of the CEMA recommended design details that are often overlooked in a competitive bidding situation. When you buy conveyors by the kilo you can expect troubles by the ton as many critical design details are often left out. In the past suppliers could claim to meet the CEMA standards because CEMA did not take a position on such things as access for inspection, maintenance and cleaning or designing structures to accommodate needed accessories. Chapter 2 and many other chapters address the need to design for safe and economical operation and maintenance. It will be argued that designing to the new CEMA recommendations will make conveyors too expensive, but there are many examples of modern, well designed conveyors that incorporate the features recommended through out the book. The initial cost may be greater but the total cost of ownership will be lower if the conveyors are well managed and maintained. Control of fugitive materials is becoming more important to workers and nearby residents. Operating a clean bulk material handling facility is as much a function of the manager's state of mind as it is the equipment. Chapter 2 and the other discussions through out the book on the subject of the true cost of owning and operate a conveyor meet the goal of the Committee for advancing CEMA's position on well designed conveyor systems.

Chapter 3, Conveyability of Bulk Solids, 8 pages

Chapter 3 incorporates the now accepted practice of testing bulk solids for their basic friction values. These values are used through out the book.

Chapter 4, Capacities, Belt Widths and Speeds, 12 pages

Chapter 4 has been updated with corrected capacity tables and a calculation method for trough angles and edge distances other than CEMA standard. Belt widths of 18 (450 mm) to 120 (3000) inches and speeds of up to 1400 fpm (7 m/s) are referenced as standard widths and speeds for today's conveyor systems.

Chapter 5, Idlers, 26 pages

Chapter 5 incorporates the new CEMA idler class, Class F. Equations are given for calculating the impact force from lumps and homogenous streams of material as an aid in selecting impact idler sets.

Chapter 6 Belt Tension and Power Engineering, 94 pages

Chapter 6 has been completely revised to describe power calculations for three classes of conveyors. The three classes and their definitions are:

Basic Conveyor

A Basic Conveyor is defined as:

- A single flight of less than 800 ft in length.
- A single free flowing load point.
- Inclined or horizontal but with out curves.
- A belt with a fabric carcass.
- Flat or equal roll troughing idlers.
- A single drive.
- Unidirectional or reversing up to 500 fpm.
- A single gravity or fixed take up
- A maximum belt tension of 12,000 lbf.

Standard Conveyor

A Standard Conveyor is defined as:

- A single flight of less than 3000 ft in length.
- Single or multiple free flowing load points.
- Inclined, declined or horizontal with or without vertical curves.
- A belt with a fabric carcass.
- Flat or equal roll troughing idlers.
- Unidirectional or reversing at any speed.
- Single or multiple drives.
- Gravity or automatic take ups.
- A maximum belt tension of 16,000 lbf.

Universal Conveyor

A Universal Conveyor is defined as:

- A conveyor of any length.
- Single or multiple freely flowing load points.
- Inclined, declined and/or horizontal flights with horizontal or vertical curves.
- A belt with a fabric carcass or steel cord belt.
- Any belt profile.
- Unidirectional or reversing.
- Single or multiple drives.
- Gravity or automatic take ups.

The approach to Basic Conveyors parallels the DIN method. For Basic Conveyors the primary component of the power requirement is often the energy needed to elevate the material and other energy requirements are minor so a simple approach using the DIN effective friction factor, *f*, is often adequate for these conveyors.

The approach to Standard Conveyors is to offer the CEMA historical method as published in the 5th edition as an alternate to the Universal Method. This approach was taken for several reasons. First of all there are many companies who have programmed this method in their computers and immediately changing to the Universal Method could be costly and time consuming. Secondly the Standard Method will produce reasonably accurate predictions for those conveyors defined as Standard Conveyors.

The Universal Method was developed to meet the first two goals of the Committee:

1) A power calculation method that is capable of predicting power requirements for a conveyor of any length or configuration within 100% ± 10%.
2) A digital friendly format with equations, charts and graphs compatible with computer programming.

The Universal Method can be applied to all conveyors from Basic Conveyors to the most complex configurations and unlimited lengths.

The Universal Method calculation is similar to the CEMA historical method in that it sums various sources of loss for the total resistance to movement. It is different in that it focuses on addressing individual flights (reference subscript “n”) as needed for long and complicated conveyor paths and in the detail and accuracy of calculation of the various constituent resistances. This section quantifies the tension changes at each flight while the discussion of tension management below addresses how they all accumulate appropriately into a total conveyor.

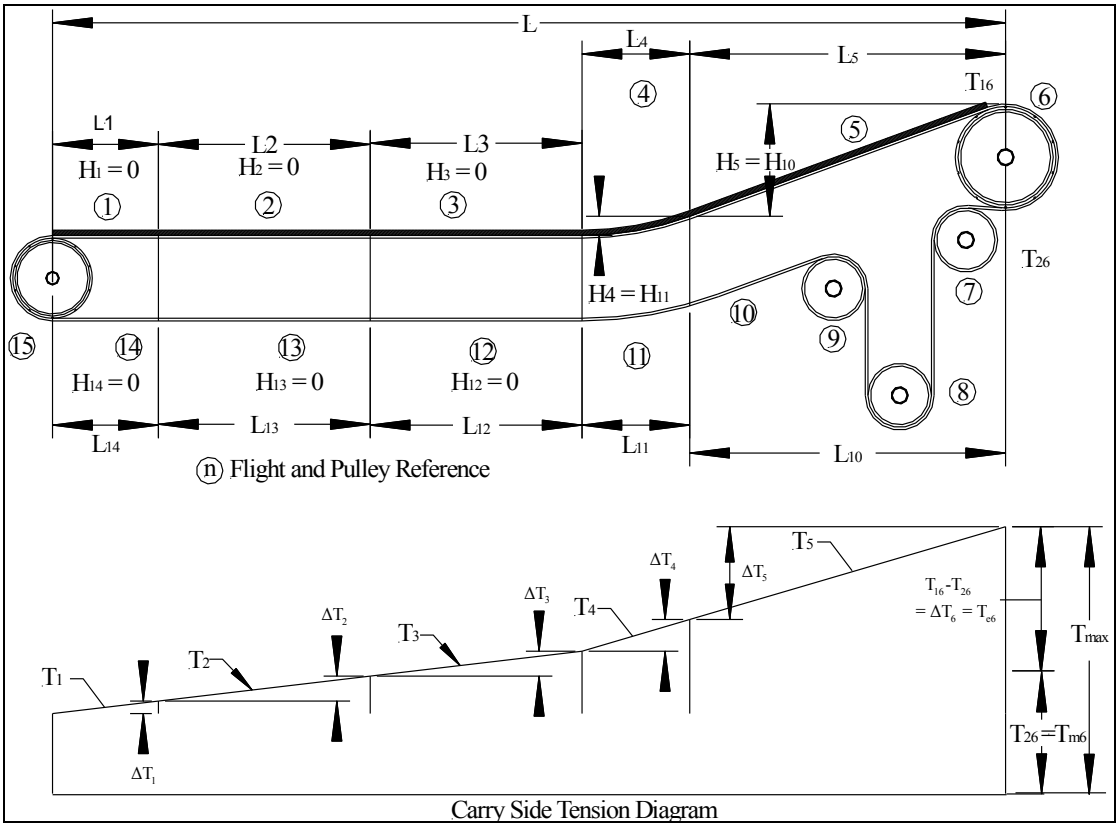
$$\Delta T = \hat{A} \Delta T_{Energy\,n} + \hat{A} \Delta T_{Main\,n} + \hat{A} \Delta T_{Point\,n} \quad \text{(Universal Method equation)}$$

The total □T is then converted into the drive horsepower requirements based on the belt speed.

$$HP = \frac{\Delta T \times V}{33{,}000} \quad \text{(Horsepower)}$$

An important change in the Universal Method is breaking the historical factor for idler bearing resistance, K_x, into measurable components, K_{iV} (in x lbf/rpm) =torsional speed effect, K_{is} (in x lbf)=seal torsional resistance per roll and K_{iT}=Temperature correction factor and incorporating C_{iW} (in x lbf/lbf) = idler torsional load effect.

The historical belt resistance to moving over the idlers factor, K_y, has been replaced with several factors that have been put into equation format for more precise calculation. $\square T_{bin}$ (lbf) =change in tension from viscoelastic deformation of the belt cover, $\square T_{imn}$ (lbf) = change in tension due to idler misalignment and $\square T_{mzn}$ (lbf) = change in tension due to bulk material relative movement between idlers. Dividing the conveyor into flights and analyzing each on separately is the primary improvement to the Universal Method that improves the accuracy of the power requirements.



Because many of the CEMA reported resistances and factors are the maximum consensus values from a number of manufacturers, the factor, $R_{xx,}$ is used to test the sensitivity of each contribution to the □T calculations. For example the change in tension due to belt cleaners, $□T_{bcn,}$ can be calculated using the default CEMA default value of 5 lbf/in of belt width or the actual value can be obtained from the manufacturer. $□T_{bcn}$ could be particularly important for conveyors with down hill sections, where drift times are critical or where multiple belt cleaners are used. In this case $R_{xx} = R_{bc}$ the subscript denoting belt cleaner. For a complete tension analysis the changes in tension due to belt cleaners must be evaluated at the maximum with $R_{bc} = 1.0$ and the minimum with $R_{bc} = 0.0$. $R_{bc} = 1.0$ would represent a fully functioning belt cleaner and $R_{bc} = 0.0$ would represent a worn out belt cleaner or a belt cleaner no longer in contact with the belt.

The user is advised to gather specific data on the components used for a final design. When component specific values are used the Universal Method should predict the actual power consumption of a conveyor with in the goal of 110% ±10%. Engineers and consultants can use the Universal Method as a platform for developing computer programs based on their specific design criteria and achieve even closer predictions of actual power requirements.

Chapter 7, Belt Selection, 26 pages

Chapter 7 has been updated with new charts and figures for fabric, steel cable and PVC belts.

Chapter 8, Pulleys and Shafts, 22 pages

Chapter 8 has been updated to current pulley design practice including design of stepped shafts.

Chapter 9, Curves, 18 pages

Chapter 9 on Curves has been updated and includes a new section on Horizontal Curves. New equations are given for minimum radii of convex and concave curves.

Chapter 10, Steep Angle Conveying, 56 pages

Chapter 10 has been greatly expanded to include Cleated Belts, Pocket Belts, Pipe/Tube Conveyors, Suspended Belts and Sandwich Belts. There are many tables for the capabilities and capacities of the different types of steep angle conveyors to help designers determine if a steep angle conveyor might be an appropriate choice.

Chapter 11, Accessories, 36 pages

Chapter 11 has been expanded with an up to date discussion on the application of many of the accessories that are available to enhance conveyor performance. The section on belt cleaning has been greatly expanded as this topic has become more important to conveyor operators. In addition there is more information on all the common accessories used on conveyors including access doors, impact beds, sealing systems, belt tracking devices, electrical accessories and more.

Chapter 12, Transfer Points, 76 pages

Chapter 12, Transfer Points includes an in depth discussion on how to minimize dust and fugitive materials. The chapter is completely new with sections on curved chutes, dust control and the design of belt feeders. The material trajectory section has been re-written to make the prediction of trajectories more accurate.

Chapter 13, Drives and Controls, 48 pages

Chapter 13 has been completely re-written with useful information on the current preferred drive and control arrangements for conveyors.

Chapter 14, Operations, Maintenance and Safety, 12 pages

Chapter 14 includes information on CEMA's safety label program and a new trouble-shooting guide. Included for the first time is a discussion of automatic lubrication.

Chapter 15, Takeups, 12 pages

Chapter 15 is a new chapter dedicated to manual and automatic takeups.

Chapter 16, Advanced Technology, 26 pages

Chapter 16 is a new chapter on emerging technologies and advanced analysis of the dynamic behavior of conveyors. Chapter 16 expands on the discussion of such dynamic phenomenon as belt flap and transient behavior. Chapter 16 includes sections on air supported conveyors and the use of DEM in modeling bulk material flow in chutes.

Appendix A, SI Units, 4 pages

Appendix A provides a very basic comparison of imperial and metric units. There are several useful conversion charts.

Appendix B, Nomenclature, 13 pages

Appendix B lists the nomenclature used in the 6th edition by Chapter.

Appendix C, K_x and K_y, 9 pages

Appendix C is taken from the 5th edition and included for reference use with the CEMA Historical Method of power calculations for Standard conveyors.

Appendix D, Conveyor Installation Standards 13 pages

Appendix D has been revised to include the latest thinking on as built tolerances for conveyors. A section on safety labels and their use is a new addition to this Appendix.

Appendix E, Belt Conveyor Idler Roll A_i` Test Procedure, 6 pages

Appendix E is a new Appendix providing a standard test method for determining idler rolling resistance as A_i is used in the 5th edition and included for reference use with the CEMA Historical Method of power calculations for Standard conveyors.

Appendix F, Belt Conveyor Idler Roll K_{is}` Test Procedure, 6 pages

Appendix F is a new Appendix providing a standard test method for determining, K_{is}, idler seal resistance, as used in the 6th edition.

CONCLUSION

The 6th edition of ***Belt Conveyors for Bulk Materials*** is a very useful resource for students and those seeking a general overview of the possible applications for modern belt conveyors. The Book covers many of the emerging belt technologies in enough detail to allow the interested owner or engineer to assess the suitability of alternate designs for their applications.

Earlier editions of ***Belt Conveyors for Bulk Materials*** have been used for decades by conveyor engineers in South Africa and around the world. The Universal Method for calculating power requirements for conveyors, introduced for the first time in the 6th edition, is a major step forward for the industry, allowing better analysis of the contributions of each conveyor flight and component to arrive at the most economical design and operating solution. With the growing importance of health and safety, in South Africa and world wide, the new design considerations put forth in the "*CEMA Book"* will help owners and users of conveyors specify safer and cleaner conveyors.

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AUTHOR INFORMATION

R. Todd Swinderman is CEO and Chief Technology Officer of Martin Engineering, a US-based multinational company specializing in solving problems in the movement and storage of bulk solids. Mr. Swinderman holds a degree in Mechanical Engineering from the University of Illinois, and is a registered Professional Engineer. As an inventor, Mr. Swinderman has over 30 US patents. He is the lead author of Martin Engineering's series of *FOUNDATIONS* books on improving conveyor performance by controlling fugitive materials. As chair of the book committee of the Conveyor Equipment Manufacturer's Association, Swinderman was the driving force behind the recently published sixth edition of "the CEMA book" ***Belt Conveyors for Bulk Materials.***