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SCREW CONVEYORS for Bulk Materials

CONVEYOR EQUIPMENT MANUFACTURERS ASSOCIATION

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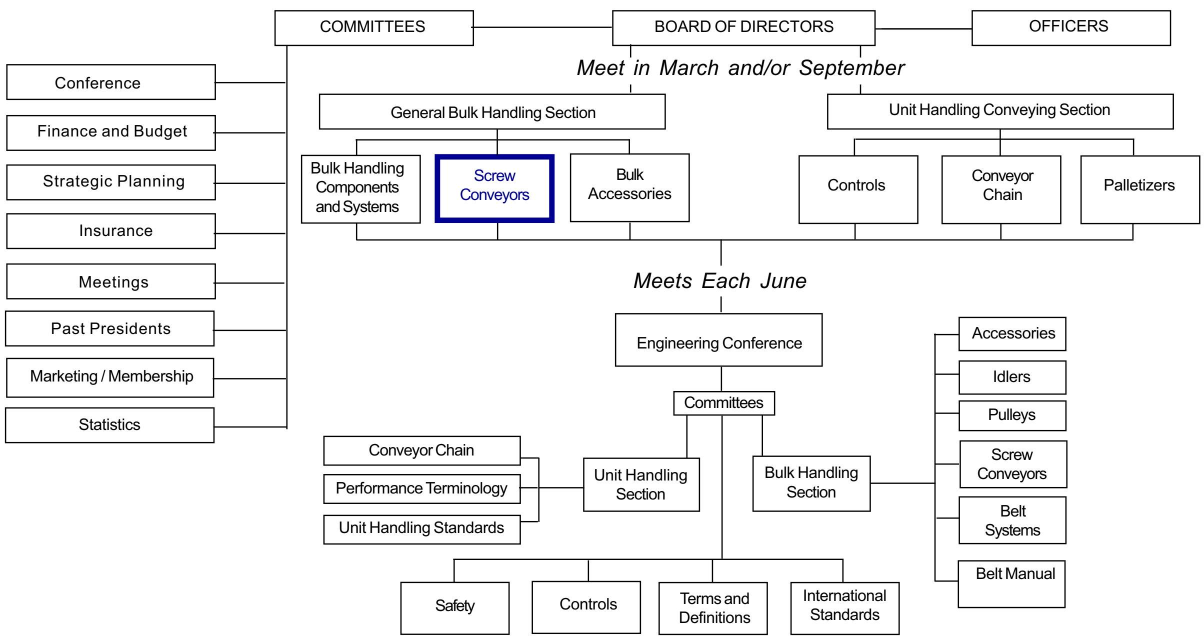

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Prepared by the Screw Conveyor Engineering Committee of the Engineering Conference
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Safety Notice

The Conveyor Equipment Manufacturers Association (CEMA) has developed industry ***Standard Safety Labels*** for use on the conveying equipment of its member companies. The purpose of the labels is to identify common and uncommon hazards, conditions, and unsafe practices that can injure, or cause the death of, the unwary or inattentive person who is working at or around conveying equipment. The labels are available for sale to member companies and nonmember companies.

A full description of the labels, their purpose, and guidelines on where to place the labels on typical equipment, has been published in CEMA's ***Safety Label Brochure (No. 201).*** The brochure is available for purchase by members and nonmembers of the Association.

PLEASE NOTE: Should any of the safety labels supplied by the equipment manufacturer become unreadable for any reason, the equipment USER is then responsible for replacement and location of these safety labels.

Replacement labels and placement guidelines can be obtained by contacting your equipment supplier or CEMA.

A VHS safety instruction tape, entitled ***Screw Conveyor, Drag Conveyor, and Bucket Elevator Safety Video,*** has also been developed by the CEMA Screw Conveyor Section. It describes key safety practices people should adhere to when working with and around these different conveyors. It is available for purchase from CEMA.

NOTE: *Some pictures and diagrams of screw conveyors in this book are without covers or have exposed screws or shafting and are for illustration purposes only. Conveyors should never be used without covers, guards, or protective equipment.*

Contents

Foreword

While the screw conveyor as we know it today is the descendant of the oldest form of conveyor in recorded history, utilizing the oldest mechanical device employed by mankind, the inclined plane (wrapped around a core to form a helix), this book is the first attempt to bring together the collective knowledge and experience of leading manufacturers to codify what has come to be acceptable engineering practice for the benefit of user and manufacturer alike.

The Screw Conveyor Engineering Committee of the CEMA (Conveyor Equipment Manufacturers Association) Engineering Conference was assigned the task of bringing together under one cover the accumulated experience of many individuals and their companies in an effort to provide a common basis for the selection and installation of screw conveyors of sizes and capacities to handle the most commonly encountered bulk materials of commerce and industry.

This book is not intended as the final word on all screw conveyor engineering, but rather to serve as an engineering guide. Those who have contributed so generously of time and effort to its compilation strongly recommend that help from conveyor manufacturers be enlisted to check selection of sizes, capacities and types of conveyors where there is the least element of doubt, and always when materials of unknown, unusual or changeable character are involved. Today's rapidly changing technology and the continuous introduction of new materials—or old materials with new characteristics—emphasizes this recommendation as a means to the satisfactory performance of a conveyor or conveyor system.

The Conveyor Equipment Manufacturers Association believes that this publication represents a milestone in the long historical development of the screw conveyor as a vital machine for the transport of a wide variety of materials.

NOTE: *Environmental as well as many other conditions vary with each installation. As a result, this engineering manual is intended merely as a guide to conveyor selection. Neither the Conveyor Equipment Manufacturers Association nor its member companies warrant that adherence to the guidelines set forth in this brochure will necessarily result in proper selection, manufacture, installation or maintenance of conveyor equipment and/or a conveyor system. Unless there are specific written specifications or recommendations pursuant to a written contractual commitment, the Conveyor Equipment Manufacturers Association and its member companies hereby disclaim all responsibility for any equipment and/or system malfunction, any violations of law, property damage, personal injury or any other damages resulting from equipment and/or system selection, design, installation, maintenance, or operation carried out by the contractor or user.*

Nomenclature

The following list covers the symbols used in this book:

A	Area, square inches
A_b	Cross-sectional area of coupling bolt, square inches
A_p	Projected area of pipe and bushing bolt hole, square inches
a	Coupling bolt hole diameter, inches
C	Capacity, cubic feet per hour
C_F	Capacity factor
C_f	Screw feeder capacity, cubic feet per hour at one RPM
c	Coefficient of linear expansion, inches per inch per degree F
D	Diameter, inches
D_d	Coupling shaft diameter, inches
D_p	Pipe diameter, inches
D_s	Conveyor screw diameter, inches
E	Modulus of elasticity
e	Combined efficiency of drive motor and reduction gear
F_b	Hanger bearing factor
F_d	Conveyor diameter factor
F_f	Flight factor
F_m	Material factor
F_o	Overload factor
F_p	Paddle factor
F_v	Empirical Vertical Screw Conveyor Factor
HP	Horsepower
HP_a	Friction horsepower of empty feeder conveyor
HP_b	Friction horsepower of material only, in feeder conveyor
HP_f	Friction horsepower of empty screw conveyor
HP_m	Friction horsepower of material only, in a screw conveyor
HP_v	Horsepower to convey material vertically
I	Moment of inertia
J	Polar moment of inertia
K	Percent of trough loading, expressed decimally
L	Length, feet

L_1	Feeder conveyor length, feet
l	Length, inches
L_f	Equivalent length of feeder, feet
N	Speed of conveyor, RPM
n	Number of coupling bolts at each end of screw section
P	Pitch of screw flight, inches
psi	Pounds per square inch
R	Ratio of lump sizes
RPM	Revolutions per minute
r	Load radius, inches
S	Allowable working stress, psi
S_1	Allowable shear stress in coupling bolts, psi
S_2	Allowable bearing stress for coupling bolts, pipe and bushing, psi
S_3	Allowable shear stress in pipe, psi
S_4	Allowable shear stress of unhardened coupling, psi
S_5	Allowable shear stress of hardened coupling, psi
T	Torque, inch pounds
T_1	Torsional shear rating of coupling bolts, inch pounds
T_2	Torsional bearing rating of coupling bolts, inch pounds
T_3	Torsional rating of pipe, inch pounds
T_4	Torsional rating of unhardened coupling, inch pounds
T_5	Torsional rating of hardened coupling, inch pounds
t_1	Higher of any two temperatures, degrees F
t_2	Lower of any two temperatures, degrees F
W	Weight or apparent density of material, pounds per cubic foot
w	Weight of a section, part or piece, pounds
Z_p	Polar section modulus of pipe or coupling shaft

CHAPTER 1

Screw Conveyor History and General Application

Screw Conveyor History

If we overlook the possibility that some caveman used some round tree branches under a rock to replace sliding friction by rolling friction, thereby inventing the roller conveyor, undoubtedly the first conveyor as such was designed by Archimedes (287 to 212 B.C.)—Greek mathematician, physicist and inventor—for removing water from the hold of a ship built for King Hiero of Syracuse. Apparently the idea was a success, for this same device was next used to raise water from a river to irrigate farm land.

The Archimedean conveyor was of the internal helical screw type. It was mounted at an angle with its lower end in the water and the upper end arranged to discharge the water to a flume or irrigation ditch. The device was powered by a slave who turned a crank fixed to its upper end. Even in contemporary times a similar machine is said to have been used in the Netherlands—except for the substitution of electrical power for muscle power. In modern industry, the Archimedean screw exists in the form of a tubular conveyor, to the inner surface of which is fastened a helical ribbon. The exterior of the tube is supported on rolls, and the tube is revolved by a pinion meshing with an externally mounted ring gear.

It is said that Archimedes may have been the originator of two other forms of screw conveyors. One, a tube formed into a helix around a central shaft or core; the other, a helix rotating within a stationary casing, is the forerunner of the modern screw conveyor in its most common form.

A little before 1790, an American inventor, John Fitch, designed a steam boat to be propelled by a section of screw conveyor flighting that appears in the drawings of that day to be almost identical to flighting used in present day screw conveyors. It appears, though, that this method of ship propulsion was at once a victim of technological obsolescence brought on by the success of paddle wheels. The term, "screw," still lives on as the usual terminology for a ship's propeller.

During the many centuries of individual or small group self-sufficiency following the days of Archimedes, there was little need for continuous mechanical handling devices because there was little need for volume production, and even if there had been, there was no satisfactory source of power available.

It was about 1900 years later that screw conveyors again were proposed, when it became imperative that some means be found to handle mechanically the grain harvests made necessary to serve the needs of the rapidly growing American population. In 1783, the man who might be called the patron saint of mechanized materials handling, Oliver Evans, laid out on paper his first mechanized flour mill which incorporated not only screw conveyors but bucket elevators and belt conveyors as well. All these devices were tied together by a system of wooden toothed gears, wooden pulley and leather belts, and all were driven from a single water wheel.

The first mill built by Evans in 1785 actually was a reconstruction of a 1742 mill thought by some to have been built by his grandfather. The screw conveyor as first designed by Evans consisted of a round wooden core on which were mounted in helical form a series of wooden plows or flattened wooden pegs. The whole screw assembly revolved in a wooden trough or "box" as it was called then. Appropriate sliding gates in the trough bottom could be opened to deliver grain to the mills as needed. Soon, though, Evans improved on his design by making the screws of helically formed sheet metal sections mounted on a wooden core that might be anywhere from five to twenty feet long. He still maintained his trough of "close fitting" boards.

In Rock Creek Park, Washington, D.C., visitors may inspect a restored mill of the Oliver Evans era. The Pierce Mill was built around 1820 (the exact year is open to argument) by one Isaac Pierce and his son, Abner. The mill is in running order and has all of the types of conveyors that Evans used, including screw conveyors with wooden flights on wooden cores on which wrought iron journals were pressed.

During this period the country grain elevator evolved of necessity to handle what then was thought to be vast volumes of grain needed by the growing and hungry population. Conveyors of the types Evans used in his "automatic" flour mills were ready made for grain elevator service. The technology of mechanization was keeping pace with the demands of the spreading population.

The metal screw conveyor flights were originally of the sectional flight variety, formed from flat sheets cut in circular form with a hole in the center then split on one side and the two edges pulled apart to form one flight section of a screw. Successive flights were then joined by riveting, shingle fashion, to make a continuous helix of whatever length was called for. At some unknown date, the wooden core was replaced by an iron pipe when the proper sizes of such pipes became available.

The next technological advancement of importance in screw conveyor design was patented March 29, 1898, by Frank C. Caldwell under patent number 601429. This was a continuous, one piece screw flight formed by rolling a continuous strip of steel into a helix. This construction is now known as the "helicoid" flight, and simplified manufacture and assembly by eliminating the joints in the sectional flight screws. Both types of screws are still produced.

Early screw conveyors used wooden bearings and there are still applications where such bearings are specified. Cast iron support hangers for the bearings and cast iron trough ends came along with the all-metal screws. The first use of metal in a trough probably was a sheet metal box liner curved to follow the periphery of the screw, and fastened in the wooden "box" or trough.

Since the screw conveyor came into general use a little over a century ago for moving grains, fine coal and other bulk material of the times, it has come to occupy a unique place in a growing area in the general field of materials handling and processing. Many refinements in design, materials and methods have come into general use. Welding has supplanted rivets to provide smooth conveying surfaces along with greater strength and rigidity in screws and troughs. Ball bearings for hangers have become less bulky so they now occupy little more space than did the older plain sleeve bearings. Such bearings in the box or trough ends provide improved thrust capacity. Improved methods of sealing to keep out foreign materials and to retain lubricants have greatly expanded the use of anti-friction bearings in screw conveyors.

Enclosed drive speed reduction units in place of open gearing greatly reduces hazards to workmen and reduces maintenance work largely to a matter of periodic inspection. The screw conveyor engineer has a tremendous latitude in the selection of materials to best meet the operating conditions of a particular conveying job, when it falls outside the broad capabilities of standard screws made of ordinary steel.

Whole new families of bulk products are being handled as a matter of course today that were not even thought of just a few years ago, and the advance of technology is such that additional new products are being discovered and developed almost daily for industrial and agricultural use. Many such products are toxic to human beings, or are toxic at certain stages of their processing. Others are merely irritating or unpleasant to work around. Screw conveyors often are the answer to handling these products. Highly developed seals and methods of using them help to confine the products conveyed—along with any dust, gas or fumes—within the trough and out of contact with anyone in the area. They also help to protect materials from contamination by foreign matter.

CHAPTER 2

Bulk Material Characteristics, Material Code, Conveyor Size and Speed, Component Groups

BULK MATERIAL CHARACTERISTICS

A study has been made to define the characteristics of bulk materials in terms which are readily recognized. These characteristics and terms are indicated in the Material Classification Code Chart (Table 2-1). It can be seen that different materials having the same classification code number may be handled with screw conveyors having the same specifications. Also, should it be desired to handle a material not given in the Material Table, in some cases it is possible to make at least a preliminary selection of material code number by comparing the material with similar listed materials.

It should be borne in mind that because of the peculiar action of a conveyor screw in moving bulk materials, the condition of the material in transit may be quite different from the condition at rest.

Materials, first of all, are classified according to particle size. It is important to have a screen analysis made of the material, if at all possible. For example if a material is said to consist of ½ inch and under, it may be similar to granules of plastic. Or it may have only 10% of ½" particle size, with 90% fines grading to micron sizes. Some materials may require use of cover gaskets and/or seals; others may not, depending upon material characteristics.

Lumpy materials must be checked against the Lump Size Table (Table 2-5). Very often larger screw conveyors must be used solely to accommodate the lumps than otherwise would be required from a standpoint of normal capacity.

Irregular, stringy, and interlocking materials that mat or cling together require special consideration. Stringy materials, particularly if long enough, may wrap around the pipe shaft of the conveyor screw or around the intermediate hanger bearings, thus effectively clogging the conveyor. Materials that mat may also be those that pack under pressure. If the material does pack under pressure, it may jam the conveyor screw and seriously damage the conveyor. All materials with these characteristics must be carefully studied in detail with respect to their actions in a screw conveyor.

Materials are also classified as to their flowability. This, unfortunately, is a relative term and not easily measured. However, so far as the operation of screw conveyors is concerned, flowability is related to two factors, one the angle of slide and the other the internal friction of the material. The angle of slide may be determined by tilting a plate carrying a quantity of the material. The angle of internal friction may be evaluated from shear cell test data. Changes in moisture content, temperature, particle size distribution and chemically corrosive action of the material all affect the flowability.

Experience with screw conveyors shows that the more free flowing the material is, the less horsepower will be required to transport it. The converse also is true. Because flowability isn't easily reduced to numerical terms, in some instances actual experience has been the guide in codifying the flowability of the materials in Table 2-2.

Judging a material just from its angle of repose is misleading. Some materials which have a very high angle of repose when stored in a bin may have a very low angle of repose in the "as conveyed" condition in a screw conveyor. An example of this is wheat bran. Its particles vary widely in shape and size, yet it appears to have a relatively low angle of "repose," or rather angle of slide, while moving through a screw conveyor.

It is known that some materials which are uniform in particle shape and size are quite free flowing when dry. Screened dry sand is free flowing. The addition of moisture, however, changes the flowability character. Likewise, dry granulated sugar is free flowing, but this material is hygroscopic and will pick up moisture from the air. If this happens, its flowability is changed considerably. The flowability of most materials is affected by changes in their moisture content, with consequent changes in their ability to be conveyed.

The abrasiveness of materials is also a relative quantity and isn't easily defined with accuracy. Some materials are more abrasive than others. It will be found that nonabrasive or very mildly abrasive materials may be handled with screw conveyors with standard gauge screws and troughs as specified in the Component Group 1A for Normal Service, Table 2-7. Very abrasive materials require heavier than standard components. See Component Groups in Tables 2-8 and 2-9. Most abrasive materials in the following Material Table, Table 2-2, are handled at lower cross-sectional loads than are the nonabrasive materials. This is done to attain the maximum economical life of the conveyor and its parts.

The selection of components for handling abrasive materials should also be considered in view of the amount of service to which the conveyor will be subject. Continuous, 24-hour-per-day operation will cause more wear than if the conveyor were operating but a few hours per day.

All of the foregoing bulk material characteristics are described in more detail in CEMA Standard No. 550 entitled *Classification and Definitions of Bulk Materials.* Chapter II of that publication fully explains size classification and coding, flowability coding and abrasive coding. In addition there are certain other miscellaneous bulk material characteristics that are defined in Chapter 1 as hazards affecting conveyability. The effect of some of these hazards as they affect screw conveyor design follows.

K. Some bulk substances are sensitive to small changes in temperature or pressure. For example, materials containing vegetable oils or fats can become spoiled by the heat of friction in a hanger bearing.

L. Dusty materials—especially those that are very dusty—should be carefully considered. Previous experience with similar materials is the best guide. Flange gaskets and special trough end seals may be needed. See Chapter 5 for several classes of construction.

M. Some materials such as dry Portland cement will aerate and develop fluid characteristics as a result of transport in a screw conveyor. The "as conveyed" apparent density is much lower than the normal apparent density. Many dusty and aerated materials can bypass an intermediate discharge spout. As the material becomes more fluid-like, the flowability increases markedly, and in some cases the aerated material will flood and run like water with the result that the cross-sectional load increases and control of the rate of flow is lost. Consult your conveyor manufacturer regarding materials which may aerate greatly.

N. Dusts associated with certain bulk materials are flammable or even explosive when mixed with air in the proper concentration. It therefore may be necessary to contain dust laden material at all times within the conveyor enclosure. Grain dust is an example. The very nature of a screw conveyor—being an enclosed conveying device—may be used for handling materials with flammable or explosive dusts, although more sophisticated than standard enclosures may be required. Consult Chapter 5, Classes of Enclosures.

P&Q. Contaminable and degradable materials must be recognized because their salability or use may be affected by improper conveying or ill-considered conveyor specifications. Suitable non-lubricated bearings should be used. Low conveyor speeds normally will prevent excessive degradation.

R. Materials in this category are similar to those described under L and N, except that exposure of the dust or fumes may be hazardous to personnel. Tight enclosures and spouting connections—usually gasketed—are required. Elaboration of the enclosures depends upon the severity of the hazard.

S&T. Corrosion protection requiring the use of special metals is a common problem. Here again "corrosion" is a relative term which isn't easily defined numerically. Consult Chapter 5, Materials of Construction. The choices of materials of construction, such as the types of stainless steel or other special metals, should be referred to the conveyor manufacturer.

U. Certain bulk materials are hygroscopic. They absorb water from the moisture in the ambient atmosphere. The water they pick up changes their flowability, of course, and this has been taken into account for the usual behavior of such materials as listed in Table 2-2.

V&X. Bulk materials which interlock and mat usually will require screws of heavier than standard construction and flight edges that can cut their way through the material. Intermediate hanger bearings may have to be eliminated. A similar condition exists for materials which pack under pressure.

W. Oils or chemicals that may be contained in bulk materials require special consideration. Some of these constituents may make the materials sticky and cause adherence to the working parts of the conveyor. Ribbon type conveyor screws sometimes help. It is best to consult your conveyor manufacturer when attempting to handle such materials.

Y. Light and fluffy materials require consideration similar to those which are dusty or which tend to aerate as they are conveyed. See paragraphs L and M.

Z. Elevated temperatures are encountered in many phases of material processing. Screw conveyors should be fabricated of heavier than standard construction and designed to withstand the inevitable expansion and contraction that takes place. Intermediate hanger bearings must be protected against heat or omitted. End bearings and drive equipment may be separated from the trough end to reduce their exposure to heat. Consult Chapter 5, Expanstion of Screw Conveyors Handling Hot Materials.

Table 2-1
Material Classification Code Chart

Major Class	Material Characteristics Included		Code Designation
Density	Bulk Density, Loose		Actual Lbs./cu. ft.
Size	Very Fine	No. 200 Sieve (.0029") And Under	A_{200}
		No. 100 Sieve (.0059") And Under	A_{100}
		No. 40 Sieve (.016") And Under	A_{40}
	Fine	No. 6 Sieve (.132") And Under	B_6
	Granular	½" And Under	$C_{½}$
		3" And Under	D_3
		7" And Under	D_7
	Lumpy*	16" And Under	D_{16}
		Over 16" To Be Specified X = Actual Maximum Size	D_x
	Irregular	Stringy, Fibrous, Cylindrical, Slabs, Etc.	E
Flowability	Very Free Flowing—Flow Function > 10		1
	Free Flowing—Flow Function > 4 But < 10		2
	Average Flowability—Flow Function > 2 But < 4		3
	Sluggish—Flow Function < 2		4
Abrasiveness	Mildly Abrasive	— Index 1-17	5
	Moderately Abrasive	— Index 18-67	6
	Extremely Abrasive	— Index 68-416	7
Miscellaneous Properties Or Hazards	Builds Up and Hardens		F
	Generates Static Electricity		G
	Decomposes—Deteriorates in Storage		H
	Flammability		J
	Becomes Plastic or Tends to Soften		K
	Very Dusty		L
	Aerates and Becomes Fluid		M
	Explosiveness		N
	Stickiness-Adhesion		O
	Contaminable, Affecting Use		P
	Degradable, Affecting Use		Q
	Gives Off Harmful or Toxic Gas or Fumes		R
	Highly Corrosive		S
	Mildly Corrosive		T
	Hygroscopic		U
	Interlocks, Mats or Agglomerates		V
	Oils Present		W
	Packs Under Pressure		X
	Very Light and Fluffy—May Be Windswept		Y
	Elevated Temperature		Z

*Refer to Chapter 2, Lump Size Limitations.

PREFACE TO MATERIAL TABLE 2-2

The Material Table 2-2 lists a wide range of bulk materials that can be handled in screw conveyors. The table shows in the first column the range of density that is usually experienced in handling that material. The average density is not specifically shown but is often assumed to be at or near the minimum.

The next column shows the material code number. This consists of the average density, the usual size designation, the flowability number, the abrasive number followed by those material characteristics which are termed conveyability hazards.

The component series column refers to selection of conveyor components as used in Tables 2-7, 2-8 and 2-9 of this Chapter.

A very fine 100 mesh material with an average density of 50 lbs. per cubic foot, that has average flowability and is moderately abrasive, would have a material code $5OA_{100}36$. If this material were very dusty and mildly corrosive the number would then be $5OA_{100}36LT$.

The Material Factor is used in the horsepower formula to determine the horsepower to operate a horizontal screw conveyor. The calculation of horsepower is described in Chapter 3.

The indication of suitability for handling the material in a vertical screw conveyor is only a guide. See Chapter 7.

The information and data in the Material Table, Table 2-2, has been compiled by members of CEMA and represents many years of experience in the successful design and application of screw conveyors for handling the listed materials. The indicated physical characteristics of these materials are not the result of any particular laboratory tests but were learned from the actual industrial operation of countless screw conveyors.

The Material Table includes various grains, seeds, feeds, etc. that are commonly handled in many conveyor types. The published unit weights, the component series and material factors F_m are for average conditions. For instance, wheat when dry or with a low moisture of less than 10% is very free flowing, and the F_m factor of .4 can be used. When higher moistures are prevalent, a material factor of .5 or .6 is suggested. This phenomena is common to all grains and some other substances.

It should also be noted that soybeans are shown as being very abrasive. Heavy conveyor construction is recommended. This is because soybeans, especially when dirty and harvested at a low moisture, are extremely abrasive. On the other hand, hard iron bearings which are commonly used with abrasive materials cannot be recommended because of spark generation and consequent dust explosions. This phenomena is also true of rough rice and to a lesser degree on other grains.

THE MATERIAL TABLE IS A GUIDE ONLY. THE MATERIALS CODE AND THE MATERIAL FACTOR F_m ARE BASED ON EXPERIENCE OF SEVERAL CONVEYOR MANUFACTURERS. A SPECIFIC MATERIAL SAMPLE MAY HAVE PROPERTIES THAT VARY FROM THOSE SHOWN IN THE TABLE. THE RANGE OF DENSITIES WILL ALSO VARY DEPENDING ON MOISTURE CONTENT AS WELL AS ITS SOURCE.

Table 2-2
Material Characteristics

Material Description	Loose Bulk Density Lbs/Cu Ft	CEMA Material Code	Component Series	Material Factor	V
Adipic Acid	45	45A_{100}35N	2B	0.5	x
Alfalfa, Meal	14-22	18B_{6}45WY	2D	0.6	x
Alfalfa, Pellets	41-43	42$C_{1/2}$25	2D	0.5	
Alfalfa, Seed	10-15	13B_{6}15N	1A-1B-1C	0.4	
Almonds, Broken	27-30	29$C_{1/2}$35Q	2D	0.9	
Almonds, Whole, Shelled	28-30	29$C_{1/2}$35Q	2D	0.9	
Alum, Fines	45-50	48B_{6}35U	1A-1B-1C	0.6	
Alum, Lumps	50-60	55B_{6}25	2A-2B	1.4	
Alumina	55-65	58B_{6}27MY	3D	1.8	
Alumina, Fines	35	35A_{100}27MY	3D	1.6	
Alumina, Sized or Briquette	65	65D_{3}37	3D	2.0	
Aluminate Gel (Aluminate Hydroxide)	45	45B_{6}35	2D	1.7	x
Aluminum Chips, Dry	7-15	11E45VN	2D	1.2	
Aluminum Chips, Oily	7-15	11E45VY	2D	0.8	x
Aluminum Hydrate	13-20	17$C_{1/2}$35N	1A-1B-1C	1.4	x
Aluminum, Ore (See Bauxite)			—	—	
Aluminum Oxide	60-120	90A_{100}17MN	3D	1.8	
Aluminum Silicate (Andalusite)	49	49$C_{1/2}$35S	3A-3B	0.8	x
Aluminum Sulfate	45-58	52$C_{1/2}$25	1A-1B-1C	1.0	
Ammonium Chloride, Crystalline	45-52	49A_{100}45FRS	3A-3B	0.7	
Ammonium Nitrate	45-62	54A_{40}35NTU	3D	1.3	
Ammonium Sulfate	45-58	52$C_{1/2}$35F0TU	1A-1B-1C	1.0	
Antimony Powder		A_{100}35	2D	1.6	x
Apple Pomace, Dry	15	15$C_{1/2}$45Y	2D	1.0	x
Arsenate of Lead (See Lead Arsenate)			—	—	
Arsenic Oxide (Arsenolite)*	100-120	110A_{100}35R	—	—	
Arsenic, Pulverized	30	30A_{100}25R	2D	0.8	
Asbestos Rock, Ore	81	81D_{3}37R	3D	1.2	
Asbestos, Shredded	20-40	30E46XY	2D	1.0	
Ash, Black, Ground	105	105B_{6}35	1A-1B-1C	2.0	
Ashes, Coal, Dry, 1/2"	35-45	40$C_{1/2}$46TY	3D	3.0	x
Ashes, Coal, Dry, 3"	35-40	38D_{3}46T	3D	2.5	
Ashes, Coal, Wet, 1/2"	45-50	48$C_{1/2}$46T	3D	3.0	
Ashes, Coal, Wet, 3"	45-50	48D_{3}46T	3D	4.0	
Ashes, Fly (See Flyash)			—	—	
Asphalt, Crushed, 1/2"	45	45$C_{1/2}$45	1A-1B-1C	2.0	x
Bagasse	7-10	9E45RVXY	2A-2B-2C	1.5	
Bakelite, Fines	30-45	38B_{6}25	1A-1B-1C	1.4	x
Baking Powder	40-55	48A_{100}35	1B	0.6	x
Baking Soda (Sodium Bicarbonate)	40-55	48A_{100}25	1B	0.6	x
Barite (Barium Sulfate), 1/2" - 3"	120-180	150D_{3}36	3D	2.6	
Barite, Powder	120-180	150A_{100}35X	2D	2.0	x
Barium Carbonate	72	72A_{100}45R	2D	1.6	
Bark, Wood, Refuse	10-20	15E45TVY	3D	2.0	
Barley, Fine Ground	24-38	31B_{6}35	1A-1B-1C	0.4	x
Barley, Malted	31	31$C_{1/2}$35	1A-1B-1C	0.4	x
Barley, Meal	28	28$C_{1/2}$35	1A-1B-1C	0.4	x
Barley, Whole	36-48	42B_{6}25N	1A-1B-1C	0.5	x
Basalt	80-105	93B_{6}27	3D	1.8	
Bauxite, Crushed, 3"	75-85	80D_{3}36	3D	2.5	
Bauxite, Dry, Ground	68	68B_{6}25	2D	1.8	
Beans, Castor, Meal	35-40	38B_{6}35W	1A-1B-1C	0.8	x
Beans, Castor, Whole, Shelled	36	36$C_{1/2}$15W	1A-1B-1C	0.5	x
Beans, Navy, Dry	48	48$C_{1/2}$15	1A-1B-1C	0.5	
Beans, Navy, Steeped	60	60$C_{1/2}$25	1A-1B-1C	0.8	

*Consult Conveyor Manufacturer.
V - Those materials which show an X may be handled in vertical screw conveyors.

CHAPTER 3

Horsepower Requirements, Torsional Ratings for Conveyor Screws, End Thrust, Typical Horizontal Screw Conveyor Problem

HORSEPOWER REQUIREMENTS, HORIZONTAL SCREW CONVEYORS

The horsepower required to operate a horizontal screw conveyor is based on proper installation, uniform and regular feed rate to the conveyor, and other design criteria.

The following factors determine the horsepower requirement of a screw conveyor operating under the foregoing conditions.

C	=	Capacity in cubic feet per hour. See Chapter 2.
e	=	Drive efficiency. See Table 8-1.
F_b	=	Hanger bearing factor. See Table 3-1.
F_d	=	Screw diameter factor. See Table 3-2.
F_f	=	Flight factor. See Table 3-3.
F_m	=	Material factor. See Chapter 2.
F_o	=	Overload factor. See Figure 3.1.
F_p	=	Paddle factor. See Table 3-4.
L	=	Total length of conveyor, feet.
N	=	Operating speed, RPM (revolutions per minute).
W	=	Apparent density of the material AS CONVEYED, lbs. per cubic foot. See Chapter 2.

The horsepower requirement is the total of the horsepower to overcome conveyor friction (HP_f) and the horsepower to transport the material at the specified rate (HP_m) multiplied by the overload factor F_o and divided by the total drive efficiency e, or:

$$HP_f = \frac{LN\,F_d F_b}{1{,}000{,}000}$$

$$HP_m = \frac{CLW\,F_f\,F_m\,F_p}{1{,}000{,}000}$$

$$\text{Total } HP = \frac{(HP_f + HP_m)\,F_o}{e}$$

The derivation of these formulas is given in the Appendix.

It is apparent that with capacity, conveyor size and speed plus conveyor length all known, that factors F_m, F_d and F_b are quite important. Small changes in these factors cause significant changes in the required horsepower. A discussion of these factors follows.

The factor F_b is related to the friction in the hanger bearings, due to rubbing of the journals in the bearing metal and including, for sleeve type hanger bearings, an allowance for the entry into the bearing of some foreign material. This factor is empirically derived.

Factor F_d has been computed proportional to the average weight per foot of the heaviest rotating parts and to the coupling shaft diameter.

The factor F_m depends upon the characteristics of the material. It is an entirely empirical factor determined by long experience in designing and operating screw conveyors. It has no measurable relation to any physical property of the material transported.

The overload factor F_o is a correction for calculated horsepowers of less than five horsepower. This factor is necessary because screw conveyors often require a greater torque range than small motors are able to provide. In other words, small overloads or minor choke conditions could easily stall a drive and create an intolerable nuisance in a continuous process. Increasing the horsepower of these small motors has been found a satisfactory means of correcting such undesirable conditions, and the factor F_o does just that.

Factors F_f and F_p are provided as correction factors for the various conveyor screw flight forms. They are empirically derived but have relation to the net effective area of the screw flight.

While it is good procedure in the conveying of bulk materials to run the conveyor until it is empty, prior to a work stoppage, frequently conveyors must of necessity be stopped while fully loaded. In that event, starting the conveyor again may possibly cause serious overloading of the driving motor. The characteristics of the material have much to do with the restarting of a fully loaded screw conveyor. Some materials will settle and pack or otherwise change their "as conveyed" characteristics. For example, Portland cement may take on the characteristics of a solid. Granulated sugar may pick up moisture from the atmosphere and form a crust or cake. These situations will require a larger than normal driving motor.

It is quite important that a conveyor system operate as demanded by its controls. Start-up conditions or temporary overloads should not cause interruptions in service, so all components of the drive, as well as the motor, should be chosen accordingly.

It is generally accepted practice that most power transmitting elements of a screw conveyor be sized and selected to handle safely the rated motor horsepower. If, for example, a screw conveyor requires 3.5 horsepower as determined by the horsepower formula, a 5 horsepower motor must be used, and it is desirable that all power transmitting elements be capable of safely handling the full 5 horsepower. However, on a screw conveyor made up of several lengths of conveyor screw, only the drive shaft has to handle the full motor load. The succeeding screw lengths and couplings only have to handle loads proportionate to the distance these parts are from the drive shaft. For economy, ease of design and maintenance, it is usual to select conveyor couplings, coupling bolts and other rotating parts such that all are of the same size and interchangeable, even if they are a bit larger than necessary.

The foregoing load carrying requirements really constitute a minimum. Shock loading, metal fatigue from 24-hour-per-day continuous service, etc., must be considered in addition.

Table 3-1
Hanger Bearing Factor, F_b

Component Group	Bearing Type	F_b
Group A	Ball	1.0
Group B	Babbitt Bronze *Graphite bronze *Canvas base phenolic *Oil impregnated bronze *Oil impregnated wood	1.7
Group C	*Plastic *Nylon *Teflon	2.0
Group D	*Chilled hard iron *Hardened alloy sleeve	4.4

*Nonlubricated bearings or bearings not additionally lubricated.

Table 3-2
Screw Diameter Factor, F_d

Screw Diameter Inches	F_d	Screw Diameter Inches	F_d
4	12.0	14	78.0
6	18.0	16	106.0
9	31.0	18	135.0
10	37.0	20	165.0
12	55.0	24	235.0

Table 3-3
Flight Factor, F_f

Type of Flight	Conveyor Loading			
	15%	30%	45%	95%
Standard	1.0	1.0	1.0	1.0
Cut Flight	1.10	1.15	1.20	1.3
Cut & Folded Flight	N. R.*	1.50	1.70	2.20
Ribbon Flight	1.05	1.14	1.20	—

*Not recommended.