CEMA Standard No. 401

ROLLE R CONVEYORS - NON POWERED

Unit Handling Conveyors

Conveyor Equipment Manufacturers Association
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FOREWORD

During the past century roller conveyors have developed from the original wooden rollers, with steel pins on the ends rotating in a frame, to the present day all metal construction with anti-friction bearings.

The first attempt to establish a standard method of evaluating the merits of the various sizes and designs being offered in the marketplace was the 1962 edition of ANSI/CEMA Standard No. 401.

The purpose of this work is to establish certain minimum standards of comparison for use by concerns which specify, manufacture, and use non-powered roller conveyors.

For additional information relating to definitions and selection of common components, see the latest edition of the following publications: ANSI/CEMA Standard No. 102, Conveyor Terms and Definitions; ANSI/CEMA Standard No. 402, Belt Conveyors; ANSI/CEMA Standard No. 403, Belt Driven Live Roller Conveyors; ANSI/CEMA Standard No. 404, Chain Driven Live Roller Conveyors; ANSI/CEMA Standard No. 405. Slat Conveyors; and ANSI/CEMA Standard No. 406, Lineshaft Driven Live Roller Conveyors.

The illustrations throughout this book are schematic in nature and represent the general nature of a particular device. The illustrations are not intended to represent the recommended safety configurations since guarding has been omitted to permit clarity in showing the operational characteristics of the device. Refer to the current editions of ANSI/ASME B20.1, Safety Standard for Conveyors and Related Equipment; ANSI/ASME B15.1, Safety Standard for Mechanical Power Transmission Apparatus; and ANSI Z244.1, American National Safety Standards for Lock-out/Tag-out of Energy Sources - Minimum Safety Requirements; Title 29, Code of Federal Regulations (29 C.F.R.) Part 1910.147, The Control of Hazardous Energy (lock-out/tag-out); Title 29, Code of Federal Regulations (29 C.F.R.) Part 1910 Subpart O, Machinery and Machine Guarding. Consult ASME or ANSI for the latest editions.

In 2003 edition, all drawings were cleaned up and enhanced, Foreword was updated to include new Safety References, A Safety Notice regarding Industry Standard Safety Labels was added, Terms and Definitions have been edited to conform with those in ANSI/CEMA Standard No. 102 “Conveyor Terms and Definitions”.

In 2019, it was reviewed for consistency with CEMA Application Guide for Unit Handling Conveyors, 2nd Ed. The Formula for determining Width between Frames (or Guard Rails) was updated.
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SAFETY NOTICE

The Conveyor Equipment Manufacturers Association 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 which 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 non-member 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 non-members of the Association. Safety Labels and Safety Label Placement Guidelines, originally published in the Brochure, are also available free on the CEMA Web Site at http://www.cemanet.org/safety-labels-2/

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.


SECTION 1 - DEFINITIONS

For general definitions see also ANSI/CEMA Standard No. 102, Conveyor Terms and Definitions.

- **Axle** - A shaft, either rotating or non-rotating, on which are mounted drive, driven, or supporting wheels or rollers.

- **Bearing** - A machine part in or on which a journal, shaft, axle, pin or other part rotates, oscillates or slides.

- **Coupling** - A member used to join conveyor sections to make an integral conveyor.

- **Cross Ties** - Structural members which maintain frame rail spacing on unit handling conveyors.

- **Frame Rails** - Members which support the conveying component of powered and non-powered conveyors.

- **Grade** - The rate of incline or decline in terms of degrees from the horizontal; percent of rise to the horizontal distance; or inches of vertical rise per foot of horizontal projection.

- **Rated Life of Bearings** - Manufacturer's ratings based on load speed factors.

- **Roller** - A round part free to revolve its outer surface. The face may be straight or tapered, covered, concave or flanged, corrugated, ribbed or fluted. Rollers may have live axle or dead axle construction.

- **Roller Centers** - Distance between centerlines of adjacent rollers. For curves, roller centers are measured at the inside radius.

- **Roller Conveyors** - A series of rollers supported in a frame over which objects are advanced manually, by gravity, or by power.

- **Roller Conveyor Curve** - A circular section of roller conveyor. The curve radius is measured to the inside face of the inside frame rail. The hand of a curve is determined when facing in the direction of travel (see Figure 1).

  Curves may have either:
  
  A. Straight face rollers (see Figure 2)
  B. Differential rollers (see Figure 3)
  C. Tapered rollers (see Figure 4)

- **Straight Section** - An assembly of frame rails, cross-tie members and rollers. Rollers may be set high or low in frame rails (see below).
• **Supports** - Arrangement of members used to maintain the elevation or alignment of the conveyor. Supports can take the form of hangers, floor supports, or brackets and can be either stationary or portable.

• **Width** - The dimension inside to inside of the conveyor frame rails.

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![Figure 1. Curves](image1)

![Figure 2. Straight Face Rollers](image2)

![Figure 3. Differential Rollers](image3)

![Figure 4. Tapered Rollers](image4)
SECTION 2 - APPLICATIONS

Use of Roller Conveyors

Roller conveyors are widely used in unit handling systems because of their simplicity, economy, and ease of maintenance. Application is in the form of level pushlines or graded lines utilizing the natural force of gravity.

Conveyability

Unit loads conveyed on roller conveyors may vary extensively in weight, size, and surface condition. The weight is restricted only by the strength of the conveyor components and the ability to move and stop the unit load.

The factors that limit the use of roller conveyors are generally related to the specific requirements of handling the unit load and the site conditions.

A unit load is generally conveyable if the surface that is resting on the conveyor is smooth, firm, and long enough to span over three or more rollers. Characteristics and application limitations are significant factors to be considered in roller conveyor selection.

Some examples of limitations are:

A. Cartons containing relatively fragile products will require analysis of the degree of gravity flow that can be utilized.
B. Unit loads that are in process of manufacture and may be subject to damage if they impact against a preceding unit load may eliminate the use of gravity or limit the application to level lines. Such unit loads could be fragile electronic equipment or heavy parts with finished machined surfaces.
C. Heavy unit loads, such as palletized items, cannot usually be conveyed long distances by gravity flow unless speed control devices are utilized.
D. Functions such as in-process assembly, packing, testing, and order picking are usually performed on level roller conveyors. However, limited use of gravity flow may be utilized to provide accumulation.

System Layout

Roller conveyors are usually employed as part of a system. Some factors affecting system layout are as follows:

A. Unit load data and selection of conveyor width
   Dimensional data is used to establish the basic width of a system, radius of curves, and arrangement of conveyor merge points. Note that width requirements of curves generally establish system width. (See Figure 5)

B. Use of gravity flow lines
   The critical points of elevation must be established and care exercised in determining the correct grade requirements. Note that curve sections require more grade than straight sections. The layout is developed to show the various elevations as related to the site and requirements for additional equipment established.
C. **Stoppages on gravity flow lines**
Gravity flow lines are subject to stoppages due to unit load jamming or guide rail friction. Access must be provided to permit personnel to clear stoppages.

**Component Specifications**

The general specifications for roller conveyor usually include the following in order of importance:

**Formula for Determining Width between Frames (or Guard Rails) for curves**

\[
\text{Between Rail Width} = \sqrt{(\text{Inside Radius} + \text{Load Width})^2 + \left(\frac{\text{Load Length}}{2}\right)^2} - \text{Inside Radius} + 2"
\]

A. **Conveyor Width**
Unit load dimensional data is used to establish the basic width of a system, radius of curves, and arrangement of conveyor merge points. Note that width requirements of curves generally establish system width.

B. **Roller Spacing**
Normally, a unit load is supported by a minimum of three rollers. However, certain characteristics, such as “off center” condition of center of gravity and soft or flexible riding surfaces, will dictate the use of closer spaced rollers. The economic factors of using a larger number of lower capacity rollers in place of a smaller quantity of higher capacity rollers should be considered.

C. **Roller Capacity**
1. Select roller size based on manufacturer’s rating and the type of bearing most suitable for environment. In general, roller conveyors are furnished with a simple commercial grade ball bearing, open construction, and without lubrication. For environments that are dusty or wet, bearings are available that include steel
labyrinth seals, felt seals, and lubrication features. Seals and lubricated bearings produce a retarding force and require additional grade for gravity flow.

2. The number of rollers that will be effective in supporting the load is a function of the load surface and the out-of-level condition of roller surface due to manufacturing tolerances.

Cartons tend to flex. Therefore, practically all rollers under the cartons are effective. Foundry flasks, engine blocks, and steel containers do not flex and can ride on two rollers at any one time. It is good practice to estimate that 50% of the rollers are effective for extremely stiff articles.

3. Consider impact on the rollers when selecting tubing diameter and wall thickness.

4. Apply service factors to roller capacity to cover speed, life, and impact as noted in, “Bearings for Conveyor Rollers”.

D. **Frame Size and Capacity**
Roller conveyors are normally two-rail, single roller construction. However, multiple rail and roller combinations may be used to advantage on certain applications.

The actual selection is generally determined by one or more of the following:
1. Total load per foot (i.e., live load and dead load)
2. Span between supports
3. Roller/rail combinations from catalogs
4. Consideration of site conditions

E. **Supports**
1. The construction and spacing of supports is determined by the load on the frame members.
2. Supports are generally provided as standard hardware. They are rated at gross load capacity and can be selected from catalogs. Light and medium duty supports are generally adjustable, but heavy duty supports are usually non-adjustable.

F. **Curves**
Roller conveyor curves are furnished in three basic styles:

- **Straight Face Rollers (see Figure 2)**
  Curve is fitted with the same straight faced rollers as in the straight sections. This construction does not provide any differential action and does not maintain load orientation.

- **Differential Rollers (see Figure 3)**
  Curve is fitted with two or more rows of straight faced rollers. This construction provides a differential action and does assist in maintaining load orientation.

- **Tapered Rollers (see Figure 4)**
  Curve is fitted with tapered rollers which are usually a taper for a specific radius. This construction provides the optimum differential action and maintains load orientation.
General Note: Curves which connect to power conveyors should include a straight portion at each end, approximately one load length long to provide free entry and exit.

G. Load Guide Rails
Guide rails are utilized to retain unit loads on conveyors. These take the form of frame guides, accomplished by setting the rollers low in the frame, or auxiliary members added to the frame. Auxiliary guide rails are set to the required width, which may be different than the basic width of the conveyor frame.

H. Special Accessories and Devices
Systems generally utilize roller conveyor accessories and devices which are specially designed to provide a specific function. Various accessories, such as spur sections, converging sections, hinged sections (gate sections), Switch sections, herringbone sections, disappearing roller sections, transfer cars, turntables, rollovers, ball and caster tables, and roller spirals are available. These help to increase the versatility of a roller system. However, it should be taken into consideration that some of the above special sections may require manual assistance to move unit loads to and from the conveyor. Some examples of these special accessories are showed here.

Figure 5. Spur Sections (Converging & Diverging)  
Figure 6. Merging Sections (Frogs)

Figure 7. Herringbone Sections (To Center and retard)  
Figure 8. Rollovers
Figure 9. Hinged Section (Gate)

Figure 10. Switches
SECTION 3 - BEARINGS FOR CONVEYOR ROLLERS

General

Ball bearings can be classified as “Precision” or “Commercial” grade. In conveyor applications, “Commercial” bearings will most often satisfactorily meet design specifications and will cost considerably less than “Precision” bearings.

“Commercial” bearings are usually made of machined and/or stamped metal components, and both inner and outer races are unground. Most “Commercial” bearings are made of carbon steel components; however, some applications call for stainless steel, aluminum, or a combination of metal and plastic components. Much wider tolerances are allowed in the manufacture of “Commercial” bearing components and the fit-up of the assembly than what is allowed in “Precision” bearings.

The bearing formulas contained in this standard refer to “Commercial” bearings produced with case hardened carbon steel raceways and balls. Bearing races are heat treated but not through hardened. At least 1/3 (33%) of the race thickness at the core must remain unhardened to prevent brittleness. Case depth should not exceed 1/3 thickness of the part. Hardness as measured by equivalent Rockwell C scale should be 60 with a tolerance of -2 to +3 (equivalent Rockwell C of 58-63).

Basic Conveyor Bearing Load Rating

As of the date of this printing, the “Basic Conveyor Bearing Load Rating” is being reviewed for possible harmonization with the European ISO standard and any changes made to the applicable ABMA (formerly AFBMA) standard. Until such time as this review is complete, CEMA will continue to adhere to the “Basic Conveyor Bearing Load Rating” defined in 1962.

Bearing life calculations are made on the basis of load ratings. The “Basic Conveyor Bearing Load Rating” is defined as that constant, radial bearing load which a group of apparently identical bearings can endure for one million revolutions with 90 percent of the bearings surviving.

The “Basic Conveyor Bearing Load Rating” can be calculated by the following equation:

\[ C = f \left( \frac{Z}{2} \right)^{2/3} D^{1.8} \]  

Where:

- \( C \) = Basic Conveyor Bearing Load Rating (lbs)
- \( f \) = A factor which depends on the geometry of the bearing components, the accuracy to which the bearing parts are made and the material
- \( Z \) = The number of balls
- \( D \) = The ball diameter (in)

Values of \( f \), \( Z \), and \( D \) for commonly used ball sizes are given on Table 1. Graphical solutions to Equation (1) are found on Charts 1 and 2.

Equation (1) was developed empirically in the English System of measurement; therefore, calculations must be performed in English System and answers converted to metric.
In those instances where results of Equation (1) differ significantly from the catalog rating, consult manufacturer for the basis of the rating.

In applications where need for greater carrying capacity and extended life requires the use of “Precision” bearings, the load ratings should be established by reference to the current edition of ANSVABMA (formerly AFBMA) Standard 9 (Load Ratings and Fatigue Life for Ball Bearings).

**Rating Life**

No bearing gives an unlimited length of service. If it is exposed to moisture, dirt, or to elevated temperatures, it may fail after a period of service which cannot be predicted. However, if effectively protected, well lubricated, and otherwise properly handled, all causes of damage are eliminated except material fatigue due to repeated stresses under rotation.

Fatigue is unavoidable, but the number of revolutions the bearing may make before fatigue starts is a function of the bearing load. The term "life" can be defined as the length of service limited by fatigue. Life can be measured in number of revolutions or in number of hours of operation at a certain speed of rotation.

Experience has indicated that the life of an individual bearing cannot be predicted. However, the dispersion in life of a group of apparently identical bearings does follow a definite statistical distribution. Therefore, it has been established that the "Rating Life" is defined as that life which 90 percent of the group of bearings will reach or exceed before evidence of fatigue occurs. This life is commonly referred to as the \( L_{10} \) life.

**Load/Life Relation**

The rating life of “Commercial” grade conveyor bearings operating at loads other than the “Basic Conveyor Bearing Load Rating (C)” can be predicted by the following equation:

\[
L_{10} = \left( \frac{C}{P_e} \right)^2 \times 10^6 \text{ revolutions} \quad (2)
\]

Where:

\[
L_{10} = \text{“Rating Life” (rev)}
\]
\[
C = \text{“Basic Conveyor Bearing Load Rating” (lbs)}
\]
\[
P_e = \text{Applied radial load on bearing (lbs) (Formula shown below)}
\]

**NOTE**: When applied load \( P_e \) is equal to the “Basic Conveyor Bearing Load Rating” \( C \), the Rating Life \( L_{10} \) is equal to one million revolutions.

**Service Life**

The Load/Life relationship expressed above establishes a “Rating Life” which is based on laboratory conditions of continuous running and constant load. Roller conveyors seldom operate at constant load and constant speed. Reduced loads and speeds frequently result in SERVICE LIFE which is 30 to 40 times the RATING LIFE calculated above (Equation 2). For computation purposes in selection of conveyor bearings use:
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\[(L_{10})S = N(L_{10})\]  \( (3) \)

Where:

- \((L_{10})S\) = Conveyor Bearings Service Life
- \(N\) = Approximately 30
- \(L_{10}\) = Rating Life

Life in hours of operation for conveyor rollers may be calculated as follows:

\[ t = \frac{(L) \pi D}{12(60)(S)} \]  \( (4) \)

- \(t\) = Hours of Life
- \(L\) = Service Life \((L_{10})S\), (rev)
- \(D\) = Roller diameter, (in)
- \(S\) = Roller surface speed, (fpm)

Graphical solution to Equation (4) can be found on Chart 3 for a life of one million revolutions.

**Equivalent Radial Load**

In application, conveyor bearings may change their operating speed or load during their life expectancy. Economy requires that when bearings are used under several conditions of operation during their life, the effect of each operating condition be added together for determination of the anticipated life. To do this, all loads are transposed to a common Equivalent Load \((P_e)\) by calculating the average as follows:

\[ P_e = \left[ \frac{P_1^2N_1 + P_2^2N_2 + \ldots + P_n^2N_n}{N_1 + N_2 + \ldots + N_n} \right]^{1/2} \]  \( (5) \)

Where:

- \(P_e\) = Equivalent Radial Load (lbs)
- \(P_1\) = Radial Load at Condition 1 for \(N_1\) revolutions
- \(P_2\) = Radial Load at Condition 2 for \(N_2\) revolutions
- \(P_n\) = Radial Load at Condition \(n\) for \(N_n\) revolutions

**USE OF PRECISION OR SEMI-PRECISION BEARINGS IN CONVEYOR ROLLERS**

Some manufacturers offer rollers utilizing precision or semi-precision bearings in their construction to allow higher load ratings and longer life. Such bearings must incorporate inner race self-alignment capabilities or internal clearances of sufficient degree to accommodate axle or shaft deflection produced under the maximum load to be imposed on the roller plus the misalignment of the bearings allowed in the manufacturing process. If this is not considered, axle deflection under load will produce a couple at the bearing support point, inducing thrust into the bearing, thus defeating the original intent for which the semi-precision bearing was applied.
Shaft and axle deflection may be calculated from equations given in most technical manuals. Precision or semi-precision bearings provide high speed capabilities and reduced operating noise level. Some roller producers make use of plastic or rubber housings or plastic shaft bushings to insure alignment between shaft and bearings. Bearings are press fitted into housing or tube to prevent slippage.

USE OF PLASTIC BALL OR JOURNAL BEARINGS IN CONVEYOR ROLLERS

Plastic bearings have substantially reduced load capacity as compared to conventional steel bearings. However, this is frequently offset by the advantages in applications requiring corrosion resistance, extremely quiet operation, and/or light weight. Plastic ball bearings are generally constructed with molded plastic raceways and are fitted with either carbon or stainless steel balls.

Journal units are also molded and are generally of two-piece construction with the inner member provided with a hexagonal bore to prevent rotation on the hexagonal shaft normally used. Journal bearings which have “blind” or closed ends are frequently used in food processing applications where entry of liquids into the roller tube must be prevented to eliminate bacteria buildup. Such designs are mounted by the use of cantilever mounted “stub” shafts.
Chart 1
Plot of Function $C = f \ Z^{2/3} \ D^{1.6}$
Chart 2
Plot of Function $C = f(Z^{2/3}D^{1.6})$
Chart 3
Plot of Function \[ t = \frac{L \pi d_r}{(12)(60)S} \]
For \( L = 1,000,000 \) Revolutions
Table 1. Factors for Evaluating Equation (1)

<table>
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<th>Number of Balls</th>
<th>$Z^{2/3}$</th>
<th>Ball Diameter D (in)</th>
<th>$D^{1.8}$</th>
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SECTION 4 – TECHNICAL DATA

Note: Calculations must be performed in the English system, and answers may be converted to metric.

Roller and Shaft Deflection

Shaft Deflection through the bearing should not exceed one degree. The angle of deflection is determined by the following equation:

\[
\theta = \frac{57.3 \ P \ a \ b}{2 \ E \ I}
\]  

(6)

when \( \theta \) is one degree,

\[
P = \frac{2 \ E \ I}{57.3 \ a \ b}
\]  

(7)

Where:

- \( E \) = 30 x 10^6 psi for structural steel
- \( a \) = As shown (in)
- \( I \) = Moment of Inertia (in^4)
- \( b \) = As shown (in)
- \( P \) = Allowable load on each bearing (lbs)
- \( \theta \) = Angular deflection (deg)

In addition to the shaft deflection and the bearing capacity, the strength and deflection of the roller tube must be considered in the design of the conveyor.

For a roller of given diameter and wall thickness, the roller length must be limited so that the fiber stress in the tube does not exceed allowable limits for material used.

When roller lengths exceed 30”, axle deflection is often the limiting factor in place of bearing capacity.
CALCULATION OF FRAME RAIL LOAD RATINGS (Two Rail Sections)

Frame Load Ratings are based on a uniformly distributed load, which will produce either:

1) A deflection not to exceed 1/360th of the unsupported span, that is:
   • for a 10'-0" span, maximum deflection is 0.333"
   • for an 8'-0" span, maximum deflection is 0.267"
   • for a 5'-0" span, maximum deflection is 0.167".

2) A stress not to exceed allowable limits for material used.

The maximum deflection of a beam supported at both ends with a uniformly distributed load is given by:

\[ D = \frac{5}{384} \frac{W I^3}{E I} \]  

(8)

The total load including frame and rollers is given by

\[ W = \frac{8 f s}{l} \]  

(9)

Where:

- \( f \) = stress (psi)
- \( I \) = moment of inertia (in\(^4\))
- \( E \) = modulus of elasticity (30 x 10\(^6\) psi for structural steel)
- \( c \) = distance from neutral axis to extreme fibre (in)
- \( D \) = deflection at center (in)
- \( I \) = distance between supports (in)
- \( W \) = total load, including frame and rollers
- \( s \) = section modulus (in\(^3\)) (use sum of section moduli for two rail frames)

Substituting and solving for the stress

\[ f = \frac{9.6 E c D}{I^2} \]  

(10)

Procedure

1) Determine the stress produced by the maximum deflection by using Equation (10)

\[ f = \frac{9.6 E c D}{I^2} \]

When stress is the determining factor, the actual deflection can be determined by transposing values in the stress equation and solving as follows.

\[ D = \frac{f I^2}{9.6 E c} \]  

(11)
2) If the stress in above equation exceeds the allowable, insert the appropriate stress in the following equation:

\[ w = \frac{96 f s}{l^2} \]  

(12)

Where \( w \) is load in pounds per foot

- for a 10'-0" span, \( w = \frac{66.7 f S}{10^4} \)
- for a 8'-0" span, \( w = \frac{104 f S}{10^4} \)
- for 5'-0" span, \( w = \frac{267 f S}{10^4} \)
PROPERTIES OF COMMON HEXAGON SHAFTS

\[ I_1 = 0.06 \ d^4 \]
\[ S_1 = 0.12 \ d^3 \]

\[ I_2 = 0.06 \ d^4 \]
\[ S_2 = 0.104 \ d^3 \]

<table>
<thead>
<tr>
<th>Hexagon Shaft (in)</th>
<th>[I_1]=in^4</th>
<th>[S_1]=in^3</th>
<th>[I_2]=in^4</th>
<th>[S_2]=in^3</th>
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<tbody>
<tr>
<td>1/4</td>
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PROPERTIES OF COMMON ROUND SHAFTS

\[ I=\text{in}^4 \]
\[ S=\text{in}^3 \]

<table>
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<tr>
<th>Round Shaft (in)</th>
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