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CONVEYOR EQUIPMENT MANUFACTURERS ASSOCIATION

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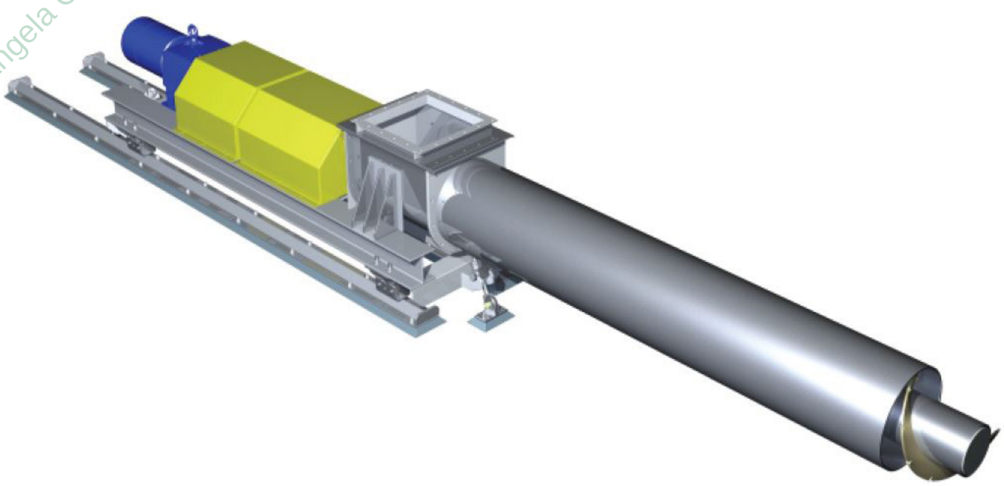
Design Considerations for High Temperature Screw Conveyor Applications



Conveyor Equipment Manufacturers Association, Inc.

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INTRODUCTION

Designing equipment for high temperature applications presents a unique set of challenges. High temperatures can affect structural and mechanical components and if not accounted for properly can lead to premature failures of equipment. High temperature is considered above 200 ºF, although hazards to personnel can exist at lower temperatures. This guide will provide information related to component selection, mechanical design, and general "good practice" design considerations to be considered when designing equipment for these applications.

GENERAL

There are several main areas to consider when designing mechanical conveying equipment for high temperature applications.

1. Materials of Construction
2. Mechanical Design
3. Thermal Expansion
4. Drive Design and Selection
5. Paint
6. Seal and Gasket Selection
7. Safety

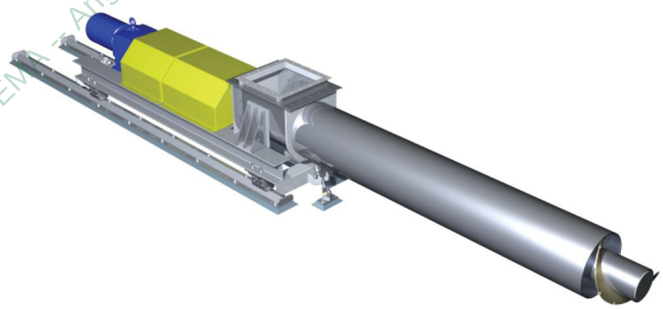

Figure 1. High Temperature Injector Screw Conveyor

MATERIALS OF CONSTRUCTION

Material selection is very important when working with high temperature applications. Many factors contribute to proper material selection, including mechanical strength, mechanical creep, oxidation, and economy of design. Although many grades of steels are available, below are guidelines for selecting material based on some of the most

Suggested Maximum Service Temperature (1) (4)	
AISI Type	**Temperature (ºF)**
A-36 (C.S)	700
SA-516-70 (C.S)	1000
SA-240-304 (304 SS)	1500
SA-240-316 (316 SS)	1500
SA-240-310 (310 SS)	2000

A-36 (C.S.) is the most commonly used mild steel. It is the most economical choice for temperatures up to 700 ºF in dry material handling applications.

SA-516-70 (C.S) is widely available and has good strength values through a wide range of temperatures. It is a good choice for temperatures up to 1000 ºF in dry material handling applications

SA-240-304 (304 SS) is a good choice for temperatures up to 1500ºF. 304SS should also be considered for wet or mildly corrosive material handling applications. [4] [5]

SA-240-316 (316 SS) is a better selection than 304SS for many acids and chlorides because of its higher concentration of molybdenum. 316SS has good strength values up to 1500 ºF. [4][5]

SA-240-310 (310 SS) can be used for temperatures up to 2000 ºF. Caution should be used for temperatures above 1500ºF since strength values sharply decline above this value. This material also has good corrosion resistance in many applications. [4] [5]

Note: REFERENCES (1) thru (6) are at the end of this document

MECHANICAL DESIGN

Strength of Material - As the temperature rises, the strength of the steel decreases. This can affect shafts, pipe and other load carrying members in the equipment design. Values for yield strength of various materials are available from several sources, including ASME and individual steel manufactures. Below are yield strength values for several common materials at different temperatures. These values were obtained from several resources and are reflected by a value range at each temperature where a discrepancy between sources occurred.

Yield Strength [1] [5] [6] (ksi)										
MOC	**70**	**200**	**400**	**600**	**800**	**1000**	**1200**	**1400**	**1500**	**1600**
A-36 (C.S Plate)	36	33	30.8	27.6	24.1	21.4				
SA-516-70 (C.S Plate)	38	34.8	32.5	29.1	25.5	22.6				
SA-240-304 (304 SS)	30-35	25	20.7-23	18.4-20	16.9-19	14-15.5	13-15	11-14	11-13	
SA-240-316 (316 SS)	42	31	35	31	26.5-28	23.4-24	21-22.6	18	17	16
SA-240-310 (310 SS)	30-35	26.5	22.6	20.6	19.4	18.2-20.8	20.7	19.3	15.7	12.2

Temperature in ºF

*Although 310 SS is acceptable up to 2000 ºF, its strength decreases sharply above 1500 ºF. This makes available strength values above 1500 ºF difficult to come by. Contact your steel supplier for additional strength values above 1600 ºF.

Modulus of Elasticity – As the temperature rises, the modulus of elasticity of the steel decreases. This will affect the stress and deflection of the shaft, pipe and any other load carrying members in the equipment design.

Modulus of Elasticity at Various Temperatures (2) ($lbf/in^2 \times 10^6$)											
MOC	**70**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1100**
Carbon Steel	29.3	28.6	28.1	27.5	27.1	26.5	25.3	24	22.3	20.2	17.9
Stainless Steel	28.3	27.6	27	26.5	25.8	25.3	24.8	24.1	23.5	22.8	22.1

Temperature in ºF

THERMAL EXPANSION

When hot material enters a screw conveyor the screw and trough expand along its length. This is called thermal expansion and must be considered to ensure proper equipment alignment. Common areas needing consideration are supports, bearings, hangers, and inlets/discharges.

Supports – When designing conveyor supports thermal expansion of the trough must be accounted for. It is recommended that the drive end be rigidly mounted and the intermediate feet and tail end be allowed to float with the changes in temperature and length. The conveyor supports must be designed in a way to allow for this expansion. This can be accomplished in a number of ways including slotted feet, sliding supports, and various other methods.

Bearings – Thermal expansion will affect the screw and trough at about the same rate. This means the differential expansion between the two may be less than the overall expansion of the conveyor. With this in mind, the bearings need to be designed in a way to account for the differential expansion. As with the supports, the drive end is fixed with a roller bearing or screw conveyor drive and does not allow any expansion. The tail end bearing will allow expansion with a spherical roller type expansion bearing, sleeve bearing or a bearing base which will allow the bearing to move with the shaft.

Hangers – As with the bearings the differential expansion between the screw and trough will require the use of an expansion type hanger. The most widely used of the expansion type hangers is the #326 style.

Inlets/Discharges – The expansion of the trough will cause the inlets and discharges to become misaligned in high temperature applications. This may require utilizing a high temperature flexible transition or a specially designed expansion transition. The use of an expansion trough may also be considered.

Expansion can be calculated using the values in the table below, although these can vary slightly depending on the grade of steel selected and operating temperature.

Coefficient of Linear Expansion (2) (3)	
Carbon Steel	6.5×10^{-6} in/in ºF*
Stainless Steel	9.6×10^{-6} in / in ºF - at 212 ºF** 10.4×10^{-6} in / in ºF - at 1200 ºF**

$$\Delta L = L \times (t_1 - t_2) \times c$$

Equation 1. Thermal Expansion

Where:
ΔL= Change in length, (in)
L = Overall length of the conveyor (in)
t_1 = Maximum upper temperature (ºF)
t_2 = Maximum lower temperature or the lowest ambient temperature expected (ºF)
c = Coefficient of linear expansion (in/in ºF)

Example:
A 40 ft long carbon steel screw conveyor is conveying material at 250 ºF. The normal temperature in the plant is 70 ºF. Calculate the expected thermal expansion

L = 40 ft x 12 in/ft = 480 in
t_1 = 250 ºF
t_2 = 70 ºF
c = 6.5 x 10^{-6} in/in ºF

$$\Delta L = 480 \times (250 - 70) \times (6.5 \times 10^{-6})$$

$$\Delta L = 0.562 \text{ in } \approx \frac{9}{16} \text{ in}$$

DRIVE DESIGN AND SELECTION

When designing for high temperature applications it is important to carefully consider the selection of the power transmission components. High temperature and thermal expansion can lead to premature failure of these components. Below are some criteria to be considered.

<u>Gear Reducer Selection</u> – High temperatures can cause seal, mechanical and/or oil failure in gear reducers. It is important to isolate the gear reducer the high temperatures. There are several ways to do this including a low speed coupling or sprocket/chain arrangement. This will require the use of a foot mounted reducer with a solid output shaft. The use of special lubricants and seals will be required if the ambient temperature is above 125 ºF or the gear reducer oil rises above 200 ºF. Consult your drive manufacturer for specific details related to your gear reducer selection.

<u>Bearing Selection</u> – The limiting factor for temperature in most bearing applications is the grease selected. High temperature grease will need to be used.

- Drive End Bearing – The drive end bearing will be a non-expansion roller or spherical roller type.
- Tail End Bearing – The tail end bearing will be a ball or spherical roller type.

PAINT

Commonly used industrial enamels have an operating range up to 200 ºF. For operating temperatures above 200 ºF a high temperature paint must be used.

High temperature paints have an operating temperature up to 600 ºF - 1100 ºF, depending on the formulation. Consult your paint manufacturer for additional details.

Consult the paint manufacturer for specific application and operating temperatures of the paint being selected.

Paint coatings are not recommended for stainless steel surfaces.

SEAL AND GASKET SELECTION

In high temperature applications it is also important to consider the selection of the seal and gasket materials.

Seal – There are a variety of shaft seal options available when designing a conveyor. Most seal types are adequate for temperatures up to 200ºF. Above this, a high temperature seal design must be used.

For high temperature applications the most common seal type is a flanged gland seal (commonly referred to as a packing gland or stuffing box seal). This type of seal can accept a variety of high temperature packing materials. Two common types are shown below.

1. Graphite Yarn, Graphite Filled mechanical packing has an operating temperature up to 800 ºF.
2. Ceramic embedded fiber (Fiberfrax) has an operating temperature up to 1800 ºF.

Another commonly used seal type, although not recommended, is a lip seal. The material of construction of the lip seal must be suitable for the environment it will be subjected too. Several common materials are listed below.

UHMW – 180 ºF maximum operating temperature
EPDM – 300 ºF maximum operating temperature
Buna-N – 300 ºF maximum operating temperature
Viton – 400 ºF maximum operating temperature
Silicone – 400 ºF maximum operating temperature
PTFE – 600 ºF maximum operating temperature

Gasket – A wide variety of gasket materials are available when designing a conveyor. Some common types and operating temperature are listed below

White Polyethylene – 180 ºF maximum operating temperature
Neoprene Blends – 200 ºF maximum operating temperature
Silicone – 400 ºF maximum operating temperature
PTFE – 600 ºF maximum operating temperature
Ceramic embedded fiber (Fiberfrax) – 1800 ºF maximum operating temperature

SAFETY

As with all conveyor applications, operator safety should be of paramount concern. High equipment temperatures can harm operators and personnel. Although it is ultimately the responsibility of the end user to ensure the equipment is considered "safe" for the intended use, the manufacturer can provide a few features to help prevent injuries.

Safety Labeling – Proper safety labels must be affixed to the equipment warning of high temperatures. CEMA has a standard safety label shown below.

Insulation – In some cases insulation may be required in order to prevent injury. There are several types of insulation. The type selected should be based on the operating temperatures and site conditions. In order to prevent damage during shipping and installation, most insulation is field installed.

REFERENCES

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(5) Rolled Alloys material data sheets for 304SS, 316SS, and 310SS, Rolled Alloys, http://www.rolledalloys.com/alloys/ (June 6, 2013).
(6) AK Steel material data sheets for 304SS and 316SS, AK Steel, http://www.aksteel.com/markets_products/stainless_austenitic.aspx (June 6, 2013).