PIPE / TUBE CONVEYORS A MODERN METHOD OF COAL AND ASH TRANSPORTATION

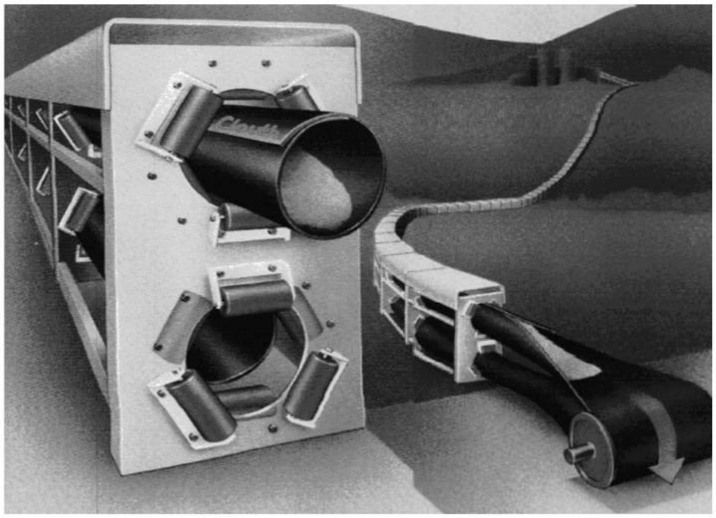
by:
Frank J. Loeffler, P.E.
President
Loeffler Engineering Group

INTRODUCTION

For more than 100 years the troughed belt conveyor has been used to transport bulk materials. Its success has been attributed to its relatively low capital cost, high degree of reliability and availability, and low operating and maintenance costs. The only significant problems with conventional conveyors have occurred at transfer points when the transported materials were sticky, dusty or there was a need to provide a totally enclosed system to protect the product from the environment or contain dribble from the return belt.

The pipe or tube conveyor solves these problems by transporting the product in a circular cross section formed by overlapping the belt edges and using idlers arranged in a hexagonal pattern to form a tubular shape (see figure #1).

FIGURE No. 1 - Cross Section



The belt encloses the product being conveyed and protects the product from the elements and the environment from the product. The return belt is also formed into a circular cross section, rolled with the carrying side of the belt inward to prevent material clinging to the belt from dislodging at the return idlers.

The only area where the belt is open is at the head and tail end area=s. This limits the possible clean up to the relatively short transition section=s where the belt changes from flat to the circular shape. The most critical area is at the head discharge. This problem can be easily solved by a short Adribble@ collection belt to convey collected material to the discharge chute.

The pipe / tube conveyor also eliminates the need for transfer points to change direction. The pipe / tube conveyor has the ability to form horizontal curves over a much smaller radii than conventional trough belt conveyors, since the belt is constrained on all sides by the idler rolls. This eliminates all the environmental problems and expense of belt cleaners, pulleys, drives, chutes, dust collectors, power distribution and the cost of maintenance associated with transfer points.

For the reasons stated above, the pipe conveyor is an obvious excellent choice for the handling of dusty fly ash, limestone, lime and wet sticky coal, lignite or petroleum coke. What we hope to accomplish in the following pages is to provide sufficient data to allow designers of conventional conveyors familiar with the CEMA method of conveyor belt calculation a method to modify the CEMA equations so they can be used for pipe conveyor preliminary design. The methods outlined in this paper are not meant to influence the pipe/tube conveyor manufacturer=s design and standards but to provide a guideline for preparing a specification.

DESIGN CONSIDERATIONS

Pipe conveyors= have several specialized requirements regarding capacity, lump size and idler spacing. These are included in tables 1 and 2 to assist in developing a proper layout and specification for a pipe / tube conveyor.

The power industry has accepted the CEMA handbook (Conveyor Equipment Manufacturers Association) as the standard to use for designing trough belt conveyors. Since pipe conveyors are relatively new and there is no recognized standard, this paper suggests modifications to the CEMA standards for idler selection and horsepower / tension calculations that could be used to specify the minimum requirements for equipment selection.

CONVEYOR CAPACITY

Table No. 1 shows the pipe/tube conveyor capacity and recommended belt speeds.

Table No.1
PIPE CONVEYOR - CAPACITY CHART

Pipe Dia.	Mat=l. Cross Section(1)	Recommended Maximum Belt Speed	CAPACITY		Maximum Lump Size (2)	Standard Troughed Conveyor Equivalent (3)
(in.)	(sq. ft.)	(FPM)	(cu.ft./hr)	(tph @100#/ft^3)	(in.)	(in.)
6	0.147	400	3,528	176	2.00	18
8	0.262	430	6,760	338	2.75	24
10	0.409	460	11,288	564	3.50	24
12	0.589	500	17,670	884	4.00	30
14	0.802	570	27,428	1,371	4.75	36
16	1.047	660	41,461	2,073	5.50	42
20	1.636	740	72,638	3,632	6.50	48
24	2.356	820	115,915	5,796	8.00	60
28	3.207	900	173,178	8,659	10.00	66
34	4.729	980	278,065	13,903	12.00	84

(1) Based on 75% Load cross Section.
(2) Based on maximum lump size = 1/3 the pipe diameter.
(3) Based on 35E troughing idlers and 22E material surcharge angle.

IDLER SELECTION

Table No. 2 provides the suggested maximum idler spacing as a function of pipe diameter and material density and provides the recommended roll diameter and minimum idler roll shaft diameter (Bearing Size).

Table No. 2
STANDARD IDLER SPACING

Pipe Diameter	IDLER SPACING		Idler Roll Diameter	Idler Bearing Diameter
(In.)	Up to 50 pcf	Over 50 pcf	(in.)	(In.)
6	4' - 0"	4' - 0"	2 2@	:@
8	5' - 0"	4' - 0"	2 2@	:@
10	6' - 0"	4' - 6"	3 2@	:@
12	6' - 6"	5' - 0"	3 2@	:@
14	7' - 6"	5' - 6"	3 2@	:@
16	8' - 3"	6' - 0"	4 2@	:@
20	10' - 6"	7' - 3"	4 2@	:@
24	12' - 0"	8' - 3"	5 2@	1"
28	13' - 9"	9' - 0"	6 2@	1"
34	16' - 6"	11' - 6"	7 2@	1 3@

Table No. 3 provides the required percentage of standard, idler spacing for reduced spacing along horizontal and vertical curves, as a function the curve radius to pipe diameter, for both fabric and steel cord belts.

Table No. 3
IDLER SPACING IN CURVES

% of Standard Idler Spacing	CURVE RADIUS	
	Fabric	Steel Cord
100	600 x D	1000 x D
90	500 x D	900 x D
80	400 x D	800 x D
70	300 x D	700 x D
65	250 x D	650 x D
60	200 x D	600 x D

D = Pipe Diameter in Feet

TRANSITION DISTANCE

Table No. 4 provides the recommended minimum transition distance to form the pipe shape.

Table No. 4

PIPE CONVEYOR - TRANSITION DISTANCES

	Fabric Belt:	Steel Cord Belt:
Pipe Diameter	Transition Length	Transition Length
(in.)	(ft.)	(ft.)
6	13	25
8	17	34
10	21	42
12	25	50
14	29	58
16	34	67
20	42	84
24	50	100
28	59	117
34	71	142

IDLER FRICTION - Kx TERM

In CEMA Kx is defined as .00068 (Wb+Wm) + Ai/Si where:

Wb = Weight of belt in Lbs/Ft
Wm = Weight of material in Lbs/Ft
.00068 = Coefficient of rolling friction for the idler bearings
Si = Idler spacing in feet
Ai = Seal and grease churning friction
(Also includes return idlers)

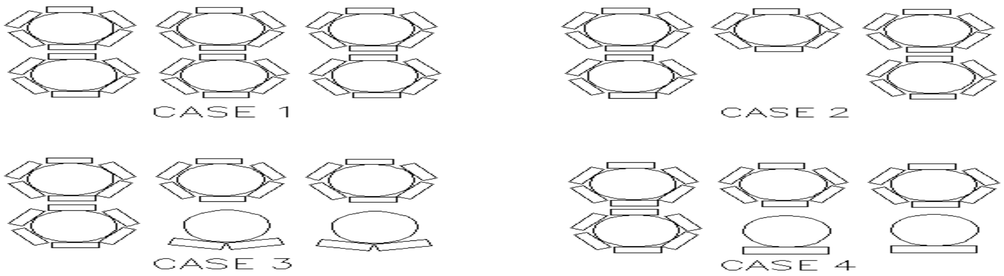
For pipe conveyors it is desirable to separate the Kx term into separate values for trough and return belt because the value for return Kx is much larger than for standard conveyors.

To develop the Ai factors for pipe conveyors, we first reduce Ai by 6/7 to delete one of the return idler bearings (assumes returns at twice trough idler spacing). The value must also be modified by a factor of two since standard conveyors have three rolls vs. six rolls for pipe conveyors. The Ai factors were then adjusted for the ratio of the pipe conveyor idler roll diameter vs. CEMA standard and for pipe conveyor idler bearing diameter vs. CEMA standard.

Trough Belt Aip Term;

Ai CEMA = 1.5 for a CEMA C6 idler with : @ diameter bearing (3 rolls)
Ai Pipe = Ai CEMA x 6/7 X 2
(Base Value) = 1.5 X 6/7 x 2 = 2.6

The pipe conveyor Ai value must also be adjusted for other roll diameters and bearing diameters. Roll diameters greater than 6" will reduce Ai, while rolls less than 6" will increase Ai. The roller bearings also effect the Ai term. Bearings larger than .75" will increase the value of Ai and bearings smaller than .75" will lower the Ai value. This can be calculated as follows: Pipe Ai (Aip) = $2.6 \times \frac{6}{\text{Roll Dia.}} \times \frac{\text{Brg Dia.}}{.75}$



A complicating factor to develop the return belt Ai factor is based on the choice of idler roll arrangements. It is common practice to eliminate some of the idler rolls between panels of full rolls.

Figure No. 2 - Idler Arrangement

There are four basic configurations that are used. The belt being naturally rigid because of its shape and therefore return belt sag is minimal. This allows the designer to consider the following:

CASE 1 - For curved sections of the conveyor a six idler return panel is used. This is also the panel of choice when the return belt passes over obstructions such as structural members or machinery.

CASE 2 - Eliminates every other return set of rollers and spaces the returns similar to conventional conveyors with return idlers at twice the trough idler spacing.

CASE 3 - Uses a full panel followed by two (2) panels with two (2) roll V-returns.

CASE 4 - Uses a full panel followed by two (2) panels with a single roll returns.

These arrangements are shown in Figure No. 2

If we use Si as the trough idler or panel spacing, we will therefore have various values of return belt Ai for each of the various cases. These are developed as follows:

Case1 RAi = 6.2 (6" Diameter Pipe Conveyor)

This value of Ai is for Case 1 return belt is the same as the trough belt. Since Case 1 return idlers have eighteen (18) rolls for three (3) panels it follows that Case 2 has twelve (12) rolls, Case 3 has ten (10) rolls and Case 4 has eight (8) rolls:

Case 2 RAi = Case 1 RAi x 12/18

Case 3 RAi = Case I RAi x 10/18

Case 4 RAi = Case I RAi x 8/18

This is summarized as follows:

Table No. 5
PIPE CONVEYOR - IDLER Ai VALUES

Pipe Diameter	Trough Belt TAip	Return Belt (RAip)			
		Case 1	Case 2	Case 3	Case 4
6	6.2	6.2	4.1	3.4	2.8
8	6.2	6.2	4.1	3.4	2.8
10	4.5	4.5	3.0	2.5	2.0
12	4.5	4.5	3.0	2.5	2.0
14	4.5	4.5	3.0	2.5	2.0
16	3.5	3.5	2.3	1.9	1.6
20	3.5	3.5	2.3	1.9	1.6
24	3.8	3.8	2.5	2.1	1.7
28	3.2	3.2	2.1	1.8	1.4
34	3.5	3.5	2.3	1.9	1.6

**NOTE: Case 1 return Ai should be used for curved conveyor sections and Cases 1 - 4 used for straight sections based on selected design.

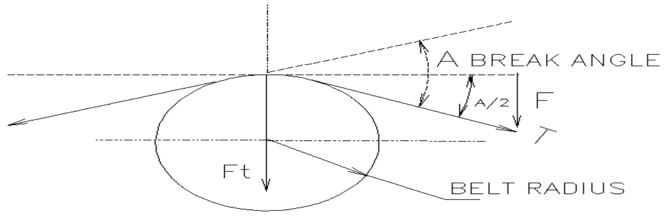
It follows that the standard equations for conventional conveyor idler friction:
Te = Lkt Kx where Kx = .00068 (Wb + Wm) + Ai/Si

<u>Should Be Replaced With:</u>

Trough belt $Kxt = .00068 (Wb + Wm) + \frac{TAip}{Si}$

Return belt $Kxr = .00068 Wb + \frac{RAip}{Si}$

It is important to note that pipe conveyors and pipe conveyor idlers do **NOT** conform to CEMA standards and that the above table is only an approximation. CEMA standards are based on the use of tapered roller bearings and many pipe conveyors use ball bearings. There are also wide variations in bearing seal configurations. It is of extreme importance for long pipe conveyors to have the idler roll manufacturers provide a maximum Ai value for their idler rolls. The reason we provide suggested values is that preliminary engineering requires a starting point for selecting the curve radii, determining a realistic route for the conveyor, approximations of electrical loads and preliminary equipment selection.



Another area of importance is the value used for idler spacing Si. Since many pipe conveyor installations have multiple curves, convex, concave and horizontal that significant length of the conveyor is curved. It is therefore important to use the average idler spacing since idler spacing is often reduced in the curved sections to permit smaller curve radii (see table No. 3). By the same reasoning, return belt panels often use fewer than six (6) rolls to reduce idler costs and idler friction.

In straight sections the return idlers can be arranged in a AVee@ or a single straight roll between full six (6) roll panels. Frequently two (2) reduced roll panels are used between six (6) roll panels which will significantly effect the Ai value (see table No.5). This should be taken into consideration on longer conveyors in selection of the Ai and Si (Ave) values.

It is recommended that the conveyor length associated with curved and straight sections be calculated separately to account for changes in idler spacing at curves and for the change in Ai for various idler roll configurations selected.

CURVE FRICTION

Another difference between pipe conveyors and conventional conveyors is that the profile often contains many curves, vertical and horizonal, taking advantage of the pipe conveyors ability to select the most economical route.

Each time the conveyor undergoes a change in direction the belt forms a curve by the side, top or bottom rolls holding the belt in the desired radius. This action places additional load on the idlers which can be calculated as follows:

Figure No. 3 - Additional Idler Load

$Ft = 2F$

$F = T \, SIN \, (A/2)$

$Ft = 2T \, SIN \, (A/2)$

From this equation it can be seen that the additional idler load is a function of belt tension and the break angle only and that the radius or length of curve does NOT effect the total additional load. Therefore, curve location is important.
Generally speaking, curves near the head end on the trough side will have greater belt tension and therefore result in a higher idler load then those on the return side.
It should also be pointed out that the type of curve and conveyor geometry will also effect the idler load. Convex curves are the worst case since the component of belt pull is in the same direction as the gravity forces of the belt and load. For horizontal curves these forces will generally be at right angles to each other and for concave curves the forces will be at 180E.

This is further complicated by the fact that the tension entering and exiting the curve will vary by the friction and lift along the curve. Since all the values we are using are prorated from standard conveyors we will ignore these factors for simplification and select a conservative solution using the resultant load without the influences of gravity and tension change. This assumption enabled us to prepare a simplified equation and tabular summary of friction losses attributed to curves.

The actual belt tension increase will be the idler load Fe multiplied by the idler bearing friction term of the Kx equation or .00068. NOTE: Seal friction is already accounted for by the revised Ai term. To this term we added belt flexure loss Ky. For the table value this is assumed to be .016.

Table No. 6
ADDITIONAL BELT TENSION FOR FRICTION LOSSES IN CURVED SECTIONS

Curve Tension (32EF)									
	Belt Tension Ct								
Break Angle	1,000	2,000	5,000	8,000	10,000	15,000	20,000	25,000	30,000
5E					14	22	29	36	44
10E			15	23	29	44	58	73	87
15E			22	35	44	65	87	109	131
20E		12	29	46	58	87	116	145	174
25E		14	36	58	72	108	144	181	217
30E	9	17	43	69	86	130	173	216	259
35E	10	20	50	80	100	150	201	251	301
40E	11	23	57	91	114	171	228	285	342
45E	13	26	64	102	128	191	255	319	383
50E	14	28	70	113	141	211	282	352	423
60E	17	34	83	133	167	250	334	417	500
70E	19	38	96	153	191	287	383	478	574
80E	21	43	107	172	214	322	429	536	643
90E	24	47	118	189	236	354	472	590	708

NOTE: These values should be increased for temperatures below 32EF by the CEMA kt factor.

PIPE SHAPING LOSSES

These are additional energy losses associated with changing the belt from flat to circular. These values are generally presented as a function of pipe diameter. Typical values are shown in Table 7.

Table No. 7

CIRCULAR FORMING FRICTION (Cf)

Pipe Diameter	Additional Te Cf (lbs.)
6	50
8	60
10	70
12	80
14	90
16	100
20	120
24	130
28	150
34	180

To be added for each flat to round transition

FLEXURE LOSSES

CEMA defines the Ky term as the resistance of the material flexure over idler rolls. These values are a function of the material and belt weight per foot, belt tension and idler spacing. CEMA defines the range of Ky as .016 to .035 and uses .015 for return belt Ky. The Ky factor=s presented in CEMA are based on a maximum idler spacing of 5' - 0" and are shown to increase with spacing. This results from increased belt sag distance (assuming sag % is a function of idler spacing) and hence greater flexure.

For pipe conveyors over 8" diameter the idler spacing exceeds the 5' - 0" CEMA maximum but the deflection is much less because of its pipe shape compared to a flat belt. Since the Ky term is influenced by deflection we suggest using the Ky values tabulated for the three (3) foot spacing but, as with CEMA, limit this value to .016 as a minimum.

HP/TENSION CALCULATION COMPARISON

Conventional Conveyors	**Pipe Conveyors**	**Remarks**
L Kt Kx	L Kt Kxt (2)	Trough Belt Idler Losses
(1)	L Kt Kxr (2)	Return Belt Idler Losses
L Kt Ky Wb	L Kt Ky Wb	Belt Flexure Losses
L Ky Wm	L Ky Wm	Material Flexure Losses
.015 L Wb	.015 LWb	Return Belt Flexure Losses
H Wm	H Wm	Material Lift or Drop

N.A.	Cf N (3)	Circular Forming Friction
N.A.	$Ct_1 + Ct_2 + Ct_3 + ...Ct_N$	Curve Tension
Accessories	Accessories	(4)

(1) Included with trough belt idlers.
(2) It is often desirable to split the conveyor length -L into Lc - length of curved section and Ls - length of straight section to account for closer idler spacing and return idler configuration that may differ in curves.
(3) N = Number of circular forming sections.
(4) Accessories include: Pulley=s, belt cleaners, skirtboards and load acceleration.

BREAK-IN PERIOD

Repeated tests on conventional conveyors have shown that idlers Abreak-in@ with time and that it can require a significant time period for them to stabilize at a constant value of friction loss.

This has also been shown to be a significant factor in the design of a pipe conveyor because of the number of idler rolls. Therefore, the designer is cautioned to consider the empty belt case for the break-in period. This becomes a critical factor for decline conveyors which can be regenerative during normal operating conditions. It is often possible that empty belt running will exceed the full load demand HP.
This is further compounded when there is the need to Abreak-in@ a new conveyor running empty during sub-zero temperatures. Selection of the proper cold weather grease should be an important design consideration.

CONCLUSION

Pipe conveyors will become more common place as a means of transporting bulk materials as applications increase. They are cleaner and can reduce emissions by eliminating conveyor transfer points. Pipe conveyors are finding acceptance in the petroleum industry for handling petroleum coke. With pet coke now being used and being considered by several utilities as a BTU booster providing a reduction in fuel cost, more pet coke will also be handled at power plants.

Petroleum coke looks like coal, has the same density and approximately the same angles of repose and slide as coal but the problem with pet coke is that it is more like wet dusty coal. It contains many fines and the moisture tends to make them adhere to the belt covers.

Pipe conveyors are also desirable for retrofit work because they are better at negotiating horizontal curves and can operate at steep angles of inclination.

Pipe conveyors are now being used in co-generation plants and mines servicing power plants. Reducing emissions in the plant proper and/or the coal mines will provide significant benefits to utilities.

CASE HISTORY

A pipe conveyor has recently been commissioned by Applied Industrial Materials Corporation (AIMCOR) at a major oil company=s refinery. This conveyor is to move petroleum coke from the coker area to a barge loader, a distance of about 3,000 feet.

Design criteria include the following:

Capacity	500 tons per hour
Product Size	3 inch nominal, 4 inch maximum
Product Moisture	4 - 15%
Product Temperature	100 - 200 degrees
Pipe Conveyor Diameter	12 inch
Belt Width	43 inch fabric
Belt Speed	840 feet per minute
Lift	22 feet
Belt Tension (Maintained by automatic take-up winch)	15,000 pounds
Open Conveyor to Receive Product	40 feet
Open Conveyor to Discharge Product	40 feet

This pipe conveyor was recommended for this job more for the environmental operational benefits that for economic benefits.

However, at this length, and considering the extra costs of transfers, dust collectors, straight line construction versus curves, etc., we estimated the cost of the pipe conveyor to be very price competitive with a conventional conveyor.

Start up problems were minimal except for original belt alignment to prevent twisting and belt opening. This was accomplished with shims moving the rollers in such a manner to place friction and/or pressure on the belt to cause it to move in the desired direction. This was a slow and painstaking trial and error effort with an empty belt. Fortunately, once it was lined up correctly, there have been only minimal corrections required.

The belt required five vulcanized splices to install. Two of those splices have been replaced during the first half year of operation. This problem may have been the result of a lack of experience by the vulcanizer on belting of this type utilizing such high tension. It also may have been a breakdown in communication between several parties. We hope that we have overcome this problem now. We have had and continue to have a problem when we experience high winds. The open belt in the drive/take up area moves radically when hit by strong wind, causing dangerous fluctuation in the belt tension and threatening to jam the belt. We think that we must enclose this area.

The benefits of the pipe conveyor versus the conventional conveyor are obvious to the experienced eye viewing the pipe conveyor in operation after several months of operation. The reduction is spillage and dusting is immediately apparent. Dribbles are restricted to the discharge end of conveyor, while it is open. The reduction in transfer points, especially where there are curves are also striking. This cleanliness in operation gives substantial saving in clean up. There are more rollers than a conventional conveyor but since these have sealed pre-lubed bearings there are fewer lubrication points. Also, with fewer transfers, there are fewer dust collectors to install, operate and maintain.

Overall, we believe the pipe conveyor is an excellent piece of equipment, well worth a premium price over conventional conveyors when handling a dusty product.