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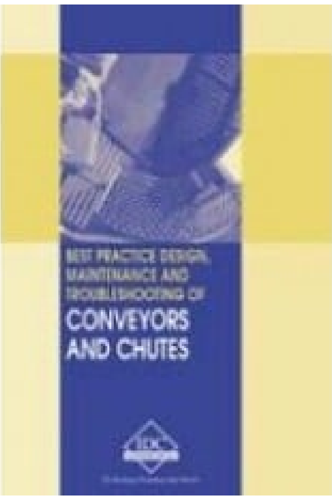
CC-E - Best Practice Design, Maintenance and Troubleshooting of Conveyors and Chutes



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Short Description

Designed for engineers and technicians from a wide range of abilities and backgrounds, this manual covers basic conveyors, selection, safety, legal obligations, terminology and background. It is an excellent introduction to troubleshooting and maintenance of conveyors and chutes.

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Designed for engineers and technicians from a wide range of abilities and backgrounds, this manual covers basic conveyors, selection, safety, legal obligations, terminology and background. It is an excellent introduction to troubleshooting and maintenance of conveyors and chutes.

It is intended to cover the fundamentals of belt conveying and would be useful for those with little experience in this area. Also featuring numerous tips and case studies throughout, this manual is a collection of important information in one place.

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Introduction - Best Practice Design, Maintenance and Troubleshooting of Conveyors and Chutes

1 Introduction

1.1 Introduction

Material handling plays an important part in the modern economy. No modern industrial plant: be it a coal mine, power plant, cement plant or a metallurgical plant, would be conceivable without an efficient transport system. Conveying equipment, of one or several types, is usually employed to mechanize material handling, loading and unloading operations. Conveying equipment works in conjunction with process equipment, such as that used for crushing, screening, blending etc. Overall mechanization of the processes becomes effective with appropriate selection of material handling equipment. This equipment not only substitutes manual labor, but also helps in the rational matching with all equipment responsible for the manufacturing processes, thereby enhancing the overall mechanization. Nowadays the operation and control of an entire plant is done from a properly networked centralized control room. Even the troubleshooting is carried out from there for detecting problem areas and initiating maintenance activities.

The boiler stoking system in a thermal power plant requiring supply of coal round the clock, materials transported in blast furnaces and materials conveyed from underground and open pit mines are some of the important areas where material handling plays a vital role.

1.2 Classification and characteristics of materials

The type of material handled and its physical as well as mechanical properties are the principal factors determining the type and design of conveying equipment and its accessories. Bulk materials include various heap-loaded, granular and powdered materials such as coal, ore, molding sand, saw dust, food grains and so on.

Bulk materials are characterized by their physical and mechanical properties, such as:

- **Lump size:** This refers to the quantitative distribution of the particles of a particular bulk material according to their sizes and is also known as granulometric composition of the material. It is characterized by the particle size denoted by diagonal *a*(Figure 1.1) in mm. A number of parameters related to conveyors and auxiliary equipment are determined by this characteristic:

Figure 1.1

Particle size

Lump size is determined through a consecutive screening of the material through meshes of different sizes. According to the uniformity of lumps in its composition, a bulk material is classified as sized or graded and unsized or non-graded.

A material, in which the ratio between the largest characteristic particle a_{max} and the smallest characteristic particle a_{min} is above 2.5, is considered to be unsized.

In sized materials, i.e. more or less homogeneous ones, $a_{max}: a_{min} < 2.5$. Sized materials are characterized by their average lump-size, for example:

In the unsized material, if the weight of a group of particles of lump size ranging between 0.8 a_{max} and a_{max} is greater than 10% of the total weight of the sample, then the material is characterized by lump-size a_{max} and if it is otherwise, the characterization is done as 0.8 a_{max}.

Tables 1.1 and 1.2 below show sizekWise classification of bulk materials and the recommended maximum lump size for different belt widths.

Table 1.1

Material characteristics

Material Characteristic	**Size (mm)**
Large-Lumped	Over 160
Medium-Lumped	60 to 160
Small-Lumped	10 to 60
Granular	3 to 10
Fine	0.5 to 3
Very Fine	Below 0.5

Table 1.2

Maximum lump size for different belt widths

Belt width in mm	Uniform lumps (mm)	Mixed with roughly 80% fines (mm)
300	-	-
350	50	100
400	75	125
450	100	150
500	100	175
600	125	200
650	125	250
750	150	300
800	150	300
900	175	325
1000	200	375
1050	200	375
1200	300	450
1350	300	500
1400	300	600
1500	350	600
1600	375	600
1800	450	600
2000	450	600

1.3 Properties of the conveyed material

- **Bulk density:**It is the weight of the material per unit of volume in bulk (the volume including the voids or air pockets present in the heap) and is generally denoted by **g** with the units of measurement being tons/cubic meter and pounds/cubic inch. The bulk density of some of the most frequently used materials is mentioned in Table 1.2. It is an important consideration particularly when the capacity of a conveyor and the pressure on the walls and outlet of a hopper is to be calculated. The loose bulk density of a material can be determined by weighing samples of a known volume of uncompacted material. Most ores have varying bulk densities based on the amount of impurities present and the particle size. It is therefore essential to evaluate a reasonable number of samples in order to determine the likely range in the bulk density values.
- **Specific weight:**It is the weight of the material particles dried at a temperature of 100 to 105°C, with respect to the volume of water displaced by them. The specific weight of materials must be taken into

account in order to calculate the capacity of pneumatic and hydraulic material handling equipment.

- **Particle size and shape:** The size of the lumps and the lump to fines ratio can influence the burden surcharge angle, while the particle shape can affect material flow in the chute and also the amount of belt wear.
- **Maximum lump size:** This is, in turn, dependent on the material characteristics and the crusher type employed. Large lumps tend to occur on conveyors handling mining products and primary ores. It is important for the maximum lump size to be established, as large slabs of material can pass through crushers.
- **Angle of repose:**This defines the mobility or flowability of material and is defined as the angle between the surface of a freely formed pile of the material and the horizontal. When a loose material spills unobstructed on a horizontal plane it assumes a slope. The angle of this slope with respect to the horizontal plane is its angle of repose: j. (Refer Figure 1.2). The Angle of Repose is used as the base value for determining the burden surcharge angle.
- **Angle of surcharge:**This is the angle to the horizontal which the surface of the material assumes when the material is at rest on a horizontal supporting surface vibrating vertically. This feature also defines the mobility or flowability of the material. Angle of surcharge is approximately 5 to 15° less than the angle of repose:

Figure 1.2

Angle of repose

- **Internal friction angle:** Materials with high internal friction angles will normally give higher burden surcharge angles and are less likely to slump when the belt flattens out at the discharge pulley. The internal friction angle can be determined by a material shear test, which in turn gives an indication of the behavior of different materials on a troughed belt conveyor.
- **Coefficient of friction:** This factor is taken into account for bulk material in contact with steel, wood, concrete, rubber and so forth when designing conveying machines and auxiliary equipment. The friction factor determines the angle of inclination of walls and ribs of hoppers, chutes and also the maximum inclination of certain conveyors.
- **Abrasivity:** The tendency of the particles of bulk materials to wear away the surface they are in contact with, when in motion, is known as the

abrasivity of the material. The extent of abrasion depends on the hardness, surface condition, shape and size of the particles. Some bulk materials such as bauxite, iron ore, sand and coke are highly abrasive.

- **Specific properties:** These include moisture content, stickiness, fragility, hygroscopy, toxicity, corrosiveness etc. All these properties need to be considered when designing conveying machines and auxiliary equipment, and effective measures are taken to neutralize their harmful influence. Let us briefly discuss some of these properties:
- **Moisture Content:** Tends to have a marked influence on the burden surcharge angle as well as slumping of the conveyed material at the discharge pulley.
- **Cohesion:**This property is based on the angle of repose, the method of classifying the cohesive properties of a material is provided by ISO 3435.
- **Temperature:**Is a very important consideration. Any material temperature that is significantly higher than the ambient temperature may prove detrimental to the belt cover, necessitating the use of a special heat-resistant rubber (see Table 1.3 and Table 1.4).

Table 1.3

Properties of most commonly used bulk material (approximate values)

Material	**Bulk Density, g** **Tons per cu.m**	**Angle of Repose,** j **degree**
Anthracite, fine, dry	0.8 to 0.95	45
Gypsum, small-lumped	1.2 to 1.4	40
Clay, dry, small-lumped	1.0 to 1.5	50
Gravel	1.5 to 1.9	45
Foundry sand, shake-out	1.25 to 1.30	45
Ash, dry	0.4 to 0.6	50
Limestone, small lumped	1.1 to 1.5	38
Coke	0.36 to 0.53	50
Wheat	0.65 to 0.83	35
Saw dust	0.16 to 0.32	39
Sand, dry	1.4 to 1.65	45
Iron ore	2.1 to 2.4	50
Coal, run of mine	0.8 to 1.0	38
Cement, dry	1.0 to 1.3	40
Crushed stone, dry	1.8	45
Slag, blast furnace, crushed	1.3 to 1.4	25

Table 1.4

Bulk material characteristics

Material	Material bulk/density (kg/m^3)	Surcharge angle degrees	Recommended maximum inclination degrees	Code
Alum, fine	721-802			B35
Alum, lumpy	802-962			D35
Alumina	802-1042	10	10-12	B27M
Ammonium nitrate	721			•C36NUS
Asbestos shred	320-401			E46XY
Ash, black, ground	1683	15	17	•B35
Ashes, coal, dry, 13mm and under	561-641	20	20-25	C46TY
Ashes, coal, dry, 76mm and under	561-641			D46T
Ashes, coal, wet 13mm and under	721-802	25	23-27	C46T
Ashes, coal, wet 76mm and under	721-802			C46T
Ashes, fly	641-721	20	20-25	A47
Ashes, gas-producer, wet	1250			D47T
Asphalt, binder for paving	1283-1363			C45
Asphalt, crushed, 13mm and under	721			C35
Bagasse	112-160			E45Y
Bark, wood, refuse	160-320	20	27	E46Y
Barley	609	10	10-15	B15N
Barytes, powdered	1924-2245			B26
Bauxite, ground, dry	1090	15	20	B26
Bauxite, mine run	1283-1443	15	17	037
Bauxite, crushed 76mm and under	1202-1363		20	D37

Bentonite, crude	561-641			D46X
Bentonite, 100 mesh and under	802-962		20	A26XY
Bones	545-641			*
Bonemeal	882-962			B36
Borax, 50mm to 100mm lumps	962-1042			D36
Borax, 40 to 50 mm lumps	882-962			D36
Brewer's grain, spent, dry	401-480			C45
Brewer's grain, spent, wet	882-962			C45T
Brick, hard	2004			D47Z
Brick, soft	1603			D47
BuckWheat	641-673	10	11-13	B25N
Carbon, black, pefletised	320-401			B15Q
Cardon, black, powder	64-112			•A35Y
Carborundum, 61mm and under	1603			D27
Cement, Portland	1507	20	20-23	A26M
Cement, Portland, aerated	962-1202			A16M
Cement rock (see limestone)	1603-1764			D36
Cement clinker	1202-1523	15-20	18-20	D37
Cement mortar	2132			37Q
Chalk, lumpy	1202-1363			D26
Chalk, 100 mesh and under	1042-1202			A46MXY
Charcoal	289-401	15	20-25	D36Q
Chips, paper mill	320-401			E45
Chips, paper mill, softwood	192-480			E45
Clay (see also bentorite, diatomaceous earth, fullers earth, kaolin and Marl)				
Clay, calcined	1283-1603			B37

Clay, dry, fines	1603-1924	15	20-22	C37
Clay, dry, lumpy	962-1202	15	18-20	D36
Coal, anthracite, river or culm, 32mm and under	962	15	18	B35TY
Coal, anthracite, sized	882-962	15	16	C26
Coal, bituminous, mined 50 mesh and under	802-866	20	24	B45T
Coal, bituminous, mined and sized	721-882	15	16	
Coal, bituminous, mined, run of mine	721-882	20	18	D35T
Coal, bituminous, mined slack, 13 mm and under	689-802	20	22	C45T
Coal, bituminous, stripping, not cleaned	802-962			D36T
Coal, Lignite	641-72	20	22	D35T
Coke, loose	369-561		18	D47QVT
Coke, petroleum calcined	561-721		20	D36Y
Coke, breeze. 64mm and under	401-561	15-20	20-22	C37Y
Concrete, 51mm slump	1764-2405		24-26	D26
Concrete, 102mm slump	1764-2405		20-22	D26
Concrete, 152mm slump	1764-2405		12	D26
Copper ore	1924-2405		20	•D27
Copper ore, crushed	1603-2405			D27
Copra, lumpy	353	10	9	D25
Com grits	641-721			B25W
Cryolite, dust	1202-1443			A36
Cryolite, lumpy	1443-1603			D35
Diatomaceous earth	176-224			A36MY
Dolomite, lumpy	1443-1603		22	D26
Earth, as excavated - dry	1122-1283	15	20	B36
Earth, wet, containing clay	1603-1734	20	23	B46
Feldspar, 13mm screenings	1122-1363	20	18	B36

Feldspar, 38mm to 76mm lumps	1443-1734	15	17	D36
Feldspar, 200 Mesh	1603			
Fish, meal	561-641			B45W
Flour, wheat	561-641		21	A45PN
Flue dust, boiler house, dry	561-641			A17MTY
Fluorspar, 13mm screenings	1363-1683			C46
Fluorspar, 38mm to 76mm lumps	1734-1924			046
Flay ash, dry (see flue dust)				
Foundry sand, loose (see sand)	1283-1443			B47
Foundry refuse, old sand cores, etc	1122-1603			D37Z
Fullers earth, dry	481-561	10		B26
Fullers earth, oily	962-1042			B26
Fullers earth, oil filter, burned	641			B26
Fullers earth, oil filter, raw	561-641	15	20	•B26
Garbage, household	802			•E45VW
Glass batch	1283-1603		20-22	D27Z
Granite, 13mm screenings	1283-1443			C27
Granite, 38mm to 76mm lumps	1363-1443			D27

Granite, broken	1523-1603			027
Gravel, bank run	1443-1603	20	20	
Gravel, dry, sharp	1443-1603		15-17	D27
Gravel, pebbles	1443-1603	15	12	Q36
Gypsum dust, non-aerated	1491			
Gypsum dust, aerated	962-1122	20	23	A36Y
Gypsum, 13mm screenings	1122-1283	20	21	C36
Gypsum, 38mm to 76mm lumps	1122-1283	15	15	D26
Ice, crushed	561-721			D16
llmenite ore	2245-2565			B27
Iron ore	1603-3206	15	18-20	•D36
Iron ore, crushed	2164-2405		20-22	•C26
Iron oxide, pigment	401	20	25	A45
Kaolin clay 76mm and under	1010	15	19	036
Kaolin talc, 100 mesh	673-898	20	23	A46Y
Lead ores	3206-4329	15	15	'B36RT
Limestone, agricultural 3mm and under	1090		20	B26
Limestone, crushed	1363-1443	20	18	C26X
Limestone, dust	1283-1363		20	A46MY
Malt, meal	577-641		E25	
Manganese ore	2004-2245	20	20	'D37
Nickel-cobalt, sulphate ore	1282-2405			•D27T
Oats	417	10	10	C25M
Paper pulp stock	641-962			•E15MV
Phosphate, acid fertilizer	962	15	13	B25T
Phosphate, triple super ground fertilizer	801-882	20	30	B45T
Phosphate rock, broken, dry	1202-1363	15	12-15	026

Phosphate rock, pulverized	962	20	25	B36
Pyrites, iron 52mm to 76mm lumps	2164-2325			D26T
Pyrites, pellets	1924-208			C26T
Quartz, dust	1122-1283			A27Y
Quartz, 13mm screenings	1283-1443			C27Z
Quartz 38mm to 76mm lumps	1363-1523			027Z

1.3.1 Estimation of surcharge angle

In the absence of reliable information on the surcharge angle, the following method may be employed to serve as a guide in the selection of a suitable value. The process is based on reducing the angle of repose and allows for:

- Belt velocity and angle of inclination at the loading point
- Material properties
- Special allowance for trippers

The nominal surcharge angle in degrees is given by the equation,

Surcharge angle = $X - K_v - K_m - K_s$

Where:

X is the angle of repose in degrees

K_v is the velocity or slope reduction allowance in degrees

K_m is the material reduction allowance in degrees and

K_s is the special reduction allowance in degrees

Velocity/ slope reduction allowance - K_v

This factor takes into consideration both the belt velocity as well as the angle of the conveyor at the loading point. Values of K_v for a wide range of belt velocities and loading angles are given in the table below. These values are, in turn, proportional to the time taken for accelerating the material at the loading point, assuming the coefficient of friction between the belt and the material as 0.5. These values are for typical transfers in which some amount of material is redirected at the loading point. These values could reduce further in the event of there being effective material redirection. On the other hand, they could increase in the event of the feed chute not providing any material redirection (see Table 1.5).

Table 1.5

Typical K_v values in degrees

Conveyor angle at loading point	**Belt velocity in m/sec**					
	1	**2**	**3**	**4**	**5**	**6**
0	2	4	6	8	10	1
1	2	4	6	8	10	1
2	2	4	6	9	11	1
3	2	4	7	9	11	1
4	2	5	7	9	12	1
5	2	5	7	1	12	1
6	3	5	8	1	13	1
7	3	5	8	1	13	1
8	3	6	8	1	14	1
9	3	6	9	1	15	1
10	3	6	9	1	16	1
11	3	7	10	1	17	2

12	4	7	11	1	18	2
13	4	8	11	1	19	2
14	4	8	12	1	21	2
15	4	9	13	1	22	2
16	5	10	15	2	24	2

Material reduction allowance - K_m

Table 1.6 gives the values of Km for different materials as described.

Table 1.6

Material reduction allowance - K_m

Material	**K_m in degrees**
Fine material having *5%* moisture or interlocking material	5°
Dry material with low fines content such as crushed rock	10°
Dry, free flowing fine material	15°

Special reduction allowance - K_s

The value of K_s for belt sag, trippers and horizontal curves will depend partly on the design features of the conveyor and also the nominal surcharge angle obtained from other factors. In case the nominal surcharge angle is high, say more than 15°; there must be some additional reduction in the surcharge angle to account for these special features.

Typical values of K_s

For conveyors with tripper – 5 to 10°

For high belt sags exceeding 1% of the idler centers - 5°

Refer to Appendix C for surcharge angles

1.4 Classification of conveying machines

Owing to the wide range of conveying machines available, such as those differing in the principle of operation, design features, direction and means of conveyance, a general classification of material handling equipment is almost impossible.

According to their principle of operation, conveying machines can be categorized as those based on intermittent action and continuous action, the salient features of which are mentioned below.

1.4.1 Intermittent action machines

- Cyclic operation is a characteristic feature of these machines
- They operate on an alternately reciprocal principle; they run loaded in one direction and idle in the other
- Examples of intermittent action machines include cars, trucks, rail mounted cars, cable cars and tractors
- Loading and unloading are generally accompanied by stoppages
- They possess great flexibility in the path of transport, with the path being provided with a number of branches at times
- They are suitable for small and medium capacity work
- They are difficult to put into automatic operation

1.4.2 Continuous action machines

- A feature specific to continuous action machines is that their load carrying member conveys the load in a practically uninterrupted stream or in small successions (buckets, tubs etc)
- They move along a precisely determined path
- Examples of this type include various types of conveyors and pneumatic and hydraulic transport installations
- They are suitable for all capacity ranges, from small to very high
- They are most suited for automatic operation

1.4.3 Auxiliary equipment

Auxiliary equipment forms a special group and is designed for operation in conjunction with conveying machines. They are not an independent means of conveyance. Auxiliary equipment comprise chutes, troughs, hoppers, gates, feeders and so on.

1.5 Selection of conveying machines

Following are the technical factors to be considered when selecting a conveying machine:

Nature and properties of the material to be conveyed:

- **Required capacity of the equipment** – If the capacity is high, economic considerations will dictate selection of the equipment that is compact and low in cost.

- **Direction and length of conveying run –**This is of prime importance in selecting the equipment type. Certain types of machines easily permit change of direction in one or both planes; others operate in a straight path and in one direction. While some are adopted to convey materials a considerable distance, others are limited by their length.
- **Storage of material at the head and tail end –**The method of loading and unloading of material also has an important bearing in the selection of a conveying machine. While some of them are self loaders, others may require certain additional loading devices. Loose material can be stored in heaps, from which they are loaded on to the conveying machines with the help of buckets, scrapers or by other means. The material stored in a bin is discharged on to the conveying machine by gravity.
- **Processing steps and the movement of loads –**In most cases, conveying machines are related to the overall manufacturing cycle, depend on it and serve to carry a load processed en route.
- **Specific local conditions –** These include the area of the site at disposal, its topography, type and design of the building, mutual layout of handling machines and processing equipment, humidity, ambient temperature, environment protection etc. It is also important to know whether the machine will be installed outdoors or indoors.

After selecting the machine on the basis of the technical factors discussed above, a detailed review also has to be carried out from the economic point of view. An optimum solution would be the type of conveying machine that meets all the processing requirements while ensuring a high degree of mechanization and favorable working condition. Such equipment will, in the long run, ensure minimum per unit handling cost and will recoup the initial outlay in the shortest possible time.

1.6 Trends

Following are the most visible modern trends in bulk material handling:

- Reduction in the amount of movement of bulk load to a minimum. This means that load is to be handled from the initial to the final point of conveyance, with minimum number of transfers, for example, by using a single or minimum number of machines. It must be ensured that the shortest path is always taken. On the other hand, there is a trend towards bringing the process plant closer to the source of material.
- Increase in handling capacity.
- More reliable operation, improvement in working condition and minimum

maintenance requirement. Which is an essential prerequisite for automation of the manufacturing process.

- Automatic control of individual conveying machines and group of installations, automatic loading/ unloading operations and distribution of loads.
- Light weight machines of small size.