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THE SELECTION AND APPLICATION OF MAGNETIC SEPARATION EQUIPMENT. PART I

D.G. MORGAN and W.J. BRONKALA
Applied Magnetic Systems, Inc., Greenfield, Wisconsin 53220, U.S.A. (*)

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Abstract A survey of magnetic separators and of their selection in applications for tramp iron removal is given. Magnetic pulleys, suspended magnets, drum magnetic separators, plate and grate magnets are described and selection procedures are outlined.

INTRODUCTION

From the application standpoint, magnetic equipment falls into three broad categories:

1. Tramp iron removal
2. Magnetic particle separation and concentration
3. Product cleaning

An application for magnetic tramp iron removal is usually related to the material handling system involved. The most commonly applied magnetic separators include:

1. Magnetic pulleys; permanent and electric types, applied in belt conveyor systems as head pulleys
2. Suspended magnets, applied over belt conveyor chutes or feeders
3. Magnetic drums of several types, usually applied as a separate installed unit
4. Plate magnets, applied in chutes
5. Grate magnets, applied in product stream as available.

For magnetic particle separation and product purification, a selected plant area is determined and the feed is usually brought to this area for treatment. Magnetic separators applied include:

1. Magnetic pulley separator
2. Magnetic drums of several types
3. Induced roll magnetic separators, high intensity
4. Cross-belt magnetic separators, high intensity
5. Magnetic filters
6. Wet high-intensity magnetic separators (WHIMS)

7. Special magnet types

For magnetic material handling, the magnets usually applied are:
1. Magnetic conveyors
2. Magnetic rolls
3. Rectangular and circular lifting magnets.

TRAMP IRON MAGNETIC SEPARATION

Tramp iron magnetic separators are used to protect handling and processing equipment such as crushers, pulverizers and material handling equipment. They are usually applied on dry material or on material which contains only surface moisture.

Tramp iron comes in many shapes and sizes. By conventional definition, tramp iron means that the particle has some significant size which is sufficient to cause damage. Iron of abrasion, or particles smaller than 3 mm in diameter usually do not cause equipment damage, although they can discolor or contaminate the product. This problem can be handled with purification types of magnetic separators.

On the top size, there are many instances where very large or long pieces of tramp iron can be encountered. Pieces up to 150 kg and pieces reading 2 m in length have been successfully removed.

The size and shape of the tramp iron, together with the material handling system in place or proposed must be considered in selecting the protective magnet.

Magnetic Pulleys

An easy and simple way to achieve tramp iron removal from material handled on a conveyor belt is by means of a magnetic head pulley. Magnetic pulleys are available in both permanent and electromagnetic construction. They are relatively low in initial cost and are easy to install and accomplish continuous and automatic tramp iron removal. A typical installation is shown in Figure 1.

Magnetic Pulley Selection

The magnetic pulley width should be selected to match the belt width. The speed of operation of the conveyor belt should be determined. The maximum capacity to be handled, in cubic meters per hour must then be calculated.

With the above data, Table I can be used to determine the diameter of pulley required to handle the required through

TABLE I: Capacities of magnetic pulleys in cubic meters per hour for tramp iron removal on normal conveyor operation

Pulley diameter (mm)	Width of belt (mm)												Standard belt speed (m/s)
	305	356	406	457	508	610	762	914	1070	1220	1370	1524	
	Capacity (m^3/h)												
305	22	30	41	53	66	99	-	-	-	-	-	-	0.9
381	25	35	47	61	75	113	178	-	-	-	-	-	1.0
457	29	40	53	68	85	127	201	297	-	-	-	-	1.14
508	-	44	59	76	94	142	224	331	470	-	-	-	1.27
610	-	-	67	87	108	161	255	377	538	742	-	-	1.45
762	-	-	-	100	125	187	294	436	623	861	-	-	1.68
914	-	-	-	-	138	207	326	481	688	951	1226	-	1.85
1070	-	-	-	-	-	226	357	530	756	1042	1345	1671	2.0
1220	-	-	-	-	-	246	385	575	821	1132	1461	1818	2.2
1370	-	-	-	-	-	-	-	629	898	1237	1597	1985	2.4
1524	-	-	-	-	-	-	-	-	943	1303	1679	1089	2.54

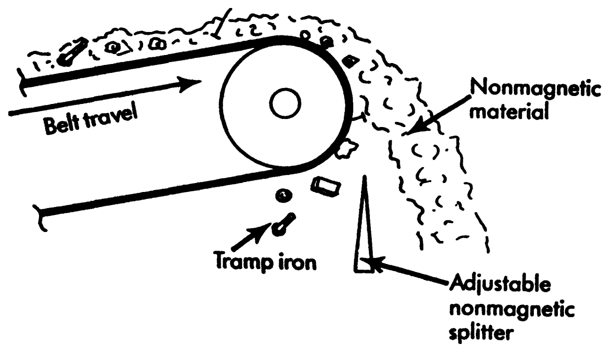


FIGURE 1 Principle of operation of magnetic pulleys

put. The operating belt speed must be checked to determine if the diameter selected is within the recommended belt speed. If it exceeds this figure, the pulley diameter which will handle the belt speed should be selected.

Inclined belts will provide additional areas of contact with the magnetic field of the pulley and can tolerate higher capacities. Table II indicates the correction factors to be applied to the throughput. One can use then Table I with the corrected capacity to make the final selection of the pulley diameter.

TABLE II Correction factors for inclined conveyors

Incline (in degrees)	Correction factor
5	0.955
6	0.946
7	0.937
8	0.928
9	0.919
10	0.910
11	0.901
12	0.892
13	0.883
14	0.874
15	0.865
16	0.856
17	0.847
18	0.838
19	0.829
20	0.820

Suspended Magnets

In some instances, very fast belt speeds and very long or very large tramp iron objects would dictate the selection of a suspended magnet or of a self-cleaning type suspended magnet.

Suspended magnets are available in both circular and rectangular magnet constructions but the rectangular magnet is most commonly applied and permits installation of self-cleaning construction where such an approach is desired.

Suspended magnets can be installed at many points in a material handling system, at any point along a conveyor belt, at the discharge end of feeders or screens and above chutes or launders. Suspended magnets are available in both permanent and electromagnet constructions with the permanent type largely limited to lighter burden applications.

Suspended magnets with very deep magnetic fields are available and are sometimes required when the burden on the belt exceeds the limits of a magnetic pulley.

The burden depth, the belt speed, the clearance required over the burden and the size, shape and mass of the tramp iron will determine the selection and size of the suspended magnet required.

Suspended magnets can be designed to give deeper magnetic field and higher magnetic gradient than other types of magnetic equipment.

The depth of magnetic field produced with a rectangular magnet is largely related to the length of the magnet. There is no standardization of magnet lengths and each manufacturer has design parameters that influence the magnetic field obtained at a specific distance from the magnet face.

The preferred location for a suspended magnet is at an angle over the discharge of a conveyor. At this point the material is moving into the magnet face and the load is breaking open making tramp iron removal easier.

Suspended magnets can be installed at a variety of other points but magnet selection should be modified for increased difficulty of tramp iron removal due to conditions such as ore on top of the tramp iron or a required change in direction of movement of the tramp iron.

A rectangular suspended magnet can be made continuous in the discharge of tramp iron by placing a belt over its face and driving the belt across the magnet face. This discharging feature is particularly effective where long tramp iron is encountered. Automatic discharging suspended magnets can be operated as cross-belts (Figure 2), or as in-lines (Figure 3).

Because the tramp iron must be attracted from a buried location and turned 90° from the movement of the conveyor belt, a larger and stronger magnet is required for cross-belt installation. In some instances, the material handling layout or desired operating location will dictate the use of the cross-belt magnet.

Rectangular magnet selection

Rectangular magnet selection requires determination of the burden depth using one of the following formulae.

For installation flat over the belt of cross-belt mounting:

$$d_b = 2.97\text{x}10^6 \ C/wv \qquad (1)$$

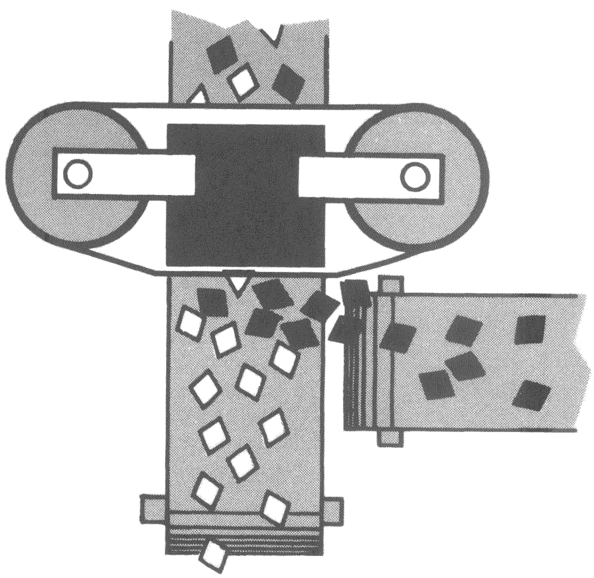


FIGURE 2 Principle of operation of cross-belt suspended magnet

where d_b is the burden depth in mm, C is the capacity in tph of material with bulk density of 1600 kg/m³, w is the belt width in mm and v is the belt speed in mm/s.

For installation at an angle over head pulley, or in-line mounting:

$$d_b = 2.45\text{x}10^6 \ C/wv \qquad (2)$$

For material having a bulk density higher or lower than 1600 kg/m^3, the value of d_b as obtained from Eq.(1) must be multiplied by the factor 1600/k where k is the bulk density of material in kg/m^3.

A suspension height d_s of 75 to 100 mm greater than d_b or the maximum lump size in the burden is required:

$$d_s = d_b + 75 \text{ (or 100)} \qquad (3)$$

where d_s is in mm.

Further, the type and size of tramp iron to be removed must be determined. For 12 to 25 mm balls or cubes a 1000 Gauss

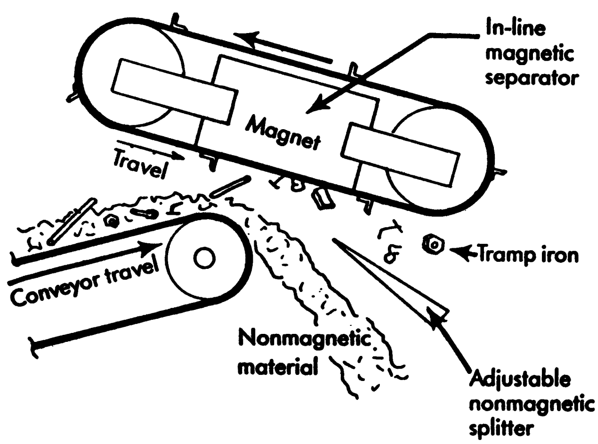


FIGURE 3 Principle of operation of in-line suspended magnet

field is required at the suspension height. For large tramp iron (50 mm or larger) a 500 to 800 Gauss field is required at the suspension height.

For some manufacturers the Gauss curves determine the size of magnet required to obtain the required Gauss reading at the determined suspension height d_s.

Figure 4 shows the Gauss readings for suspended magnets from 600 mm through 1800 mm lengths, manufactured by Applied Magnetic Systems Inc., of Greenfield, WI.

Some manufacturers have developed "force index" values which are used in making their rectangular suspended magnets selections. This information must be obtained from individual manufacturers and applied as specified in magnet selection.

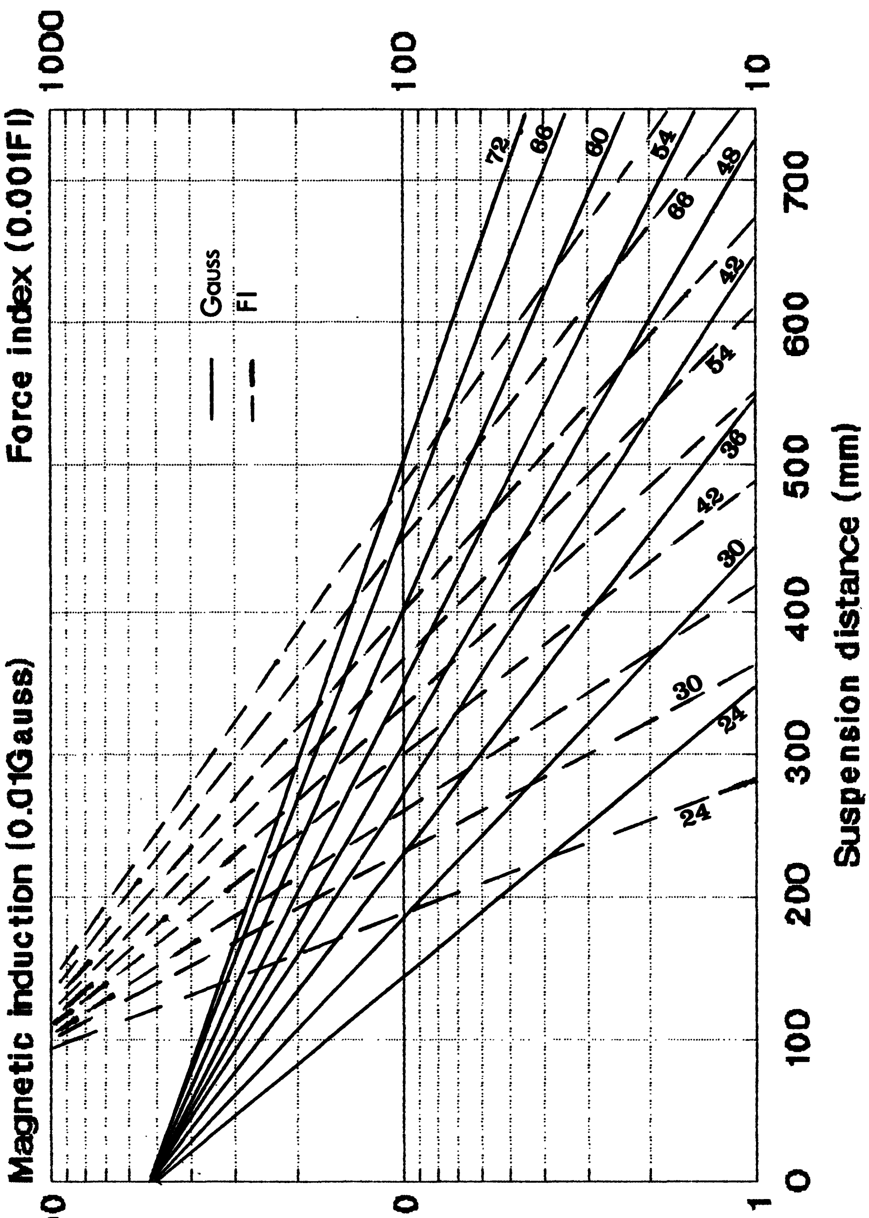
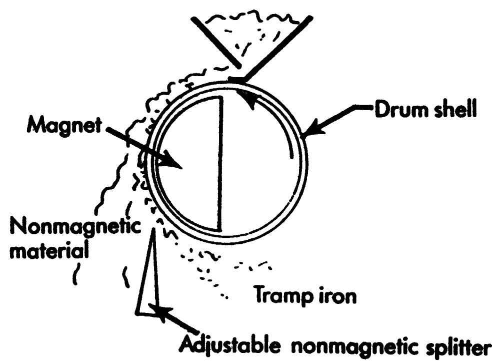


FIGURE 4 Magnetic field and force index for SMT series of oil-cooled suspended electromagnets

Tramp Iron Magnetic Drums

Magnetic drum separators are used for tramp iron removal where magnetic pulleys and suspended magnets are not feasible. In effect, these are individual pieces of process equipment inserted in the process line. The magnet assembly is held in a fixed position inside the drum shell and the drum shell is driven around this magnet assembly (Figure 5).

The magnet assembly develops a field which typically covers 120 to 180° of the drum section. These drums can be fed at the top vertical centerline (overfeed), or near the bottom of the drum (underfeed).



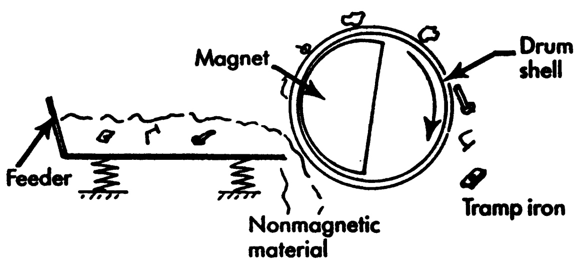


FIGURE 5 Overfeed and underfeed arrangements of drum magnetic separators

Overfed drums produce the highest magnetic removal while the underfed drums produce the cleanest magnetic concentrate with little non-magnetic carry-over.

Drums are available with several magnet configurations. For elongated tramp iron, the poles should generally be alternating across the drum width and remain the same along the drum circumference.

For small particles a magnet having a series of alternating poles along the circumference and uniform across the drum width provides a "shaking" action for the non-magnetic particles. These configurations are shown in Figure 6.

Drums provide a continuous and automatic removal of tramp iron and basically require very little maintenance. The bearings must be greased periodically and the drum shell should be checked for dents and holes.

Magnetic drums are operated both as drums only, such as those used in coarse iron cobbing and autofragmantization plants, or as drums inside a housing as used in tramp iron

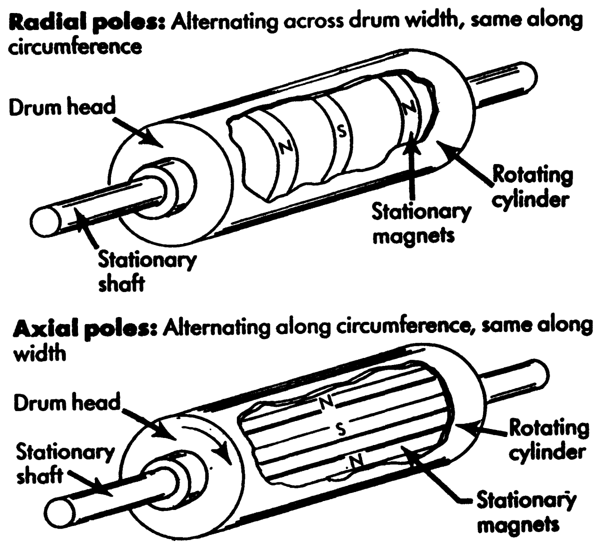


FIGURE 6 Pole configuration s of magnetic drums

removal from smaller sized or dusty material. Magnetic drums are selected on the basis of the volume (in m^3/h) to be handled from rated capacities in manufacturers' catalogues.

Plate Magnets

Where the amount of tramp iron contained in a product is reasonably small, and where automatic removal is not required, plate and grate magnets can be incorporated in chute and duct works to remove both tramp iron and iron of abrasion. Such a plate magnet is shown in Figure 7.

The plate magnet consists of a series of alternating poles, uniform across the chute width and alternately along the chute length. As the material flow passes over the magnet face, tramp iron is trapped on the magnet face while the remaining non-magnetic material proceeds down the chute. These units must be cleaned and inspected daily for they are not effective if the accumulated tramp iron is allowed to remain on the face for months.

The magnetized plates are manufactured in various models and are usually of the permanent magnet type. The largest units will provide protection to about 115 mm of material depth. A chute angle not exceeding 45° is recommended and the plate

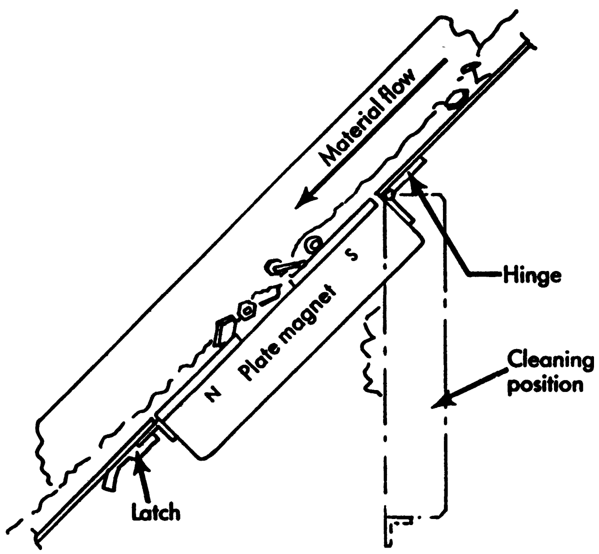


FIGURE 7 Plate magnet

magnet should be installed as close to the feed point as possible.

Grate Magnets

The grate magnet, shown in Figure 8 consists of a series of magnetic tubes which have alternating poles between and along their length. These units are used for granular free-flowing materials, finer than 12 mm and are typically mounted at the discharge of a hopper. The number of rows of tubes provide several passes of relatively finely divided material and can remove substantially all the magnetics.

Here again, since these are non-automatic removal systems, they must be cleaned daily for effective operation.

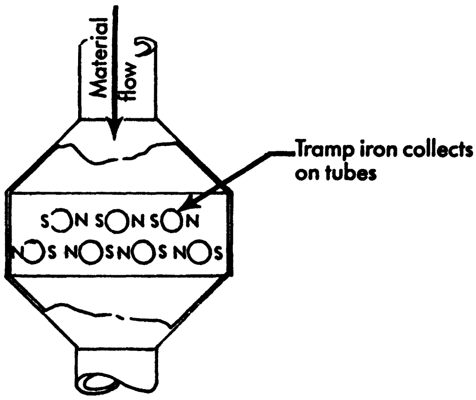


FIGURE 8 Grate magnet

(*) Presently with O.S. Walker Co., Worcester, MA, U.S.A.

D.G. Morgan received the B.S. degree in electrical engineering from the Milwaukee School of Engineering, Milwaukee, Wisconsin in 1958. His professional involvement with the magnetic separation industry began with Stearns Magnetics with a six-months co-operative assignment in 1949 and continued during undergraduate study with positions held such as draftsman, lab tech, production engineer , manager research & development, sales manager and general manager through 1984.
In 1985 he started his own magnet firm, Applied Magnetic Systems, Inc. The company supplied magnetic separation equipment to various industries. Mr. Morgan sold recently the assets on this group to the O.S. Walker Company and is presently employed as the product manager for separation equipment, handling the engineering and sales of magnetic equipment including eddy current separation.

W.J. Bronkala: See the Obituary in this issue.

Keywords: magnetic pulleys, suspended magnets, magnetic drums, plate magnets, grate magnets, magnet selection.