VII. MAGNETIC SEPARATION

This is one of the concentration processes that utilize the differences in magnetic properties of various minerals present in the ore body. The magnetic fraction may be valuable or gangue depending upon its use in a particular flow sheet or process and so also the non-magnetic fraction, e.g., separation of magnetite (magnetic) from quartz (non-magnetic), separation of tin bearing mineral cassiterite (non-magnetic) from magnetite (magnetic) impurity etc.

When a material is placed in a magnetic field H, the magnetic field inside the material will be the sum of the external magnetic field and the magnetic field generated by the material itself. The magnetic field that exists in such a material is called the magnetic induction or magnetic flux density, B, and it is defined as follows:

$$B = \mu_0 (H + M) \qquad \text{.......................(13)}$$

Where, M = intensity of magnetization (a property of the material)
μo = permeability of free space

The magnetic property of minerals of most interest to mineral processing engineers is the magnetic susceptibility (χ) which is defined by c= M/H. The most commonly tabulated value of magnetic susceptibility is the specific susceptibility in electromagnetic units. The specific susceptibility (χ_s) is defined as the ratio of specific magnetization (M_s) to the magnetizing field, $\chi_s = M_s/H$. All minerals are affected in some way when placed in a magnetic field, although the affect is too small to be detected in most of the minerals. Magnetic susceptibility of some common minerals is given in Table -4.

Table 4 : Magnetic susceptibilities of common minerals

Mineral	Specific susceptibility (10-8 m^3/kg)	Mineral	Specific susceptibility (10-8 m^3/kg)
Calcite	-0.3 to -1.4	Pyrrhotite	10 to 30,000
Quartz, Feldspar, Magnesite	-0.5 to -0.6	Hematite	10 to 760
Kaolinite	-2	Ilmenite	46 to 80,000
Halite, Gypsum, Anhydride	-0.5 to -2.0	Magnetite	20,000 to110,000
Serpentinite	120 to 2900	Dolomite	-1 to -41
Illite, Montmorillonite	5 to 13	Sandstones, Shales, Limestone	0 to 1200
Biotite	5 to 52	Serpentine	110 to 630
Goethite	26 to 280	Clay	10 to 15
Chalchopyrite	0.6 to 10	Coal	1.9
Pyrite	1 to 100		

In general, minerals can be classified in two broad categories, according to whether they are attracted or repelled by a magnetic field.

Diamagnetic : Diamagnetic minerals are made up exclusively of diamagnetic ions and are repelled along the lines of magnetic forces to a point where the field intensity is smaller. Diamagnetic ions have no unpaired electrons. All their d- and f- electrons are in closed shells. The forces involved here are very small and diamagnetic minerals cannot be concentrated magnetically.

Paramagnetic : Paramagnetism in minerals generally arises from ions with unpaired electron spins, most commonly of the first transition series. They are attracted along the lines of magnetic force to points of greater field intensity. Paramagnetic minerals can be concentrated in high intensity magnetic separators.

Ferromagnetism : Ferromagnetism is a special case of paramagnetism, involving very high forces. In a few minerals, notably Fe, Ni, Co, Mn, Cr, Ce, Ti and Pt group metals, the interaction between the spins cause spins on adjacent atoms in the minerals to become aligned parallel to each other. This suggests that all unpaired spins may become parallel and that a permanent magnetization may exist even in the absence of external magnetic field (remanence). They can be separated in a low intensity magnetic separator.

Fundamentals of magnetic concentration

Concentration is achieved by simultaneously applying to all particles in an ore a magnetic force that acts on magnetic particles and a second force or combination of forces which acts in a different direction and affects both magnetic and non-magnetic particles. The most commonly applied nonmagnetic forces are gravitational, centrifugal and fluid drag. Other forces that usually enter in an incidental manner are frictional, electrostatic, Van Der Waals, and capillary. A magnetic separator is generally classified as low intensity if its maximum field intensity is less than about 2000 gauss (H= 1.6 x 105 A/m, B=0.20 T). Low intensity magnetic separators (LIMS) are used to treat ferromagnetic and highly paramagnetic minerals such as iron and magnetite. High intensity magnetic separators (HIMS) generally have field strengths of 10 to 20 kilogauss. These separators are used to treat weakly magnetic minerals, such as hematite.

Magnetic separators are commonly classified into two broad groups, namely, wet and dry based on their usage. A more definitive classification within these two basic groups is made based on the relative magnetic field strength of the individual units, i.e. wet low intensity magnetic separators, wet high intensity magnetic separators etc. Table-5 shows the basic groupings of the most commonly used magnetic separators.

Table 5 : Basic Groupings of Common Magnetic Separator

Wet magnetic separators		Dry magnetic separators	
Low :	Drum separators Bowl traps Magnetizing coils and blocks Demagnetizing coils	Low :	Magnetic pulleys Rectangular suspended magnets Magnetic drums-radial pole types Magnetic drums-axial pole types Plate magnets Grate magnets
High :	High intensity separators	High :	Induced roll magnetic separators Cross belt magnetic separators Ring type magnetic separators

Common Types of Magnetic Separators Used for Concentration

Ore Cobbing Magnetic Pulleys : Ore cobbing or concentrating magnetic pulleys utilize more poles across the pulley width so as to develop as uniform field depth as possible and a sufficient area of collecting magnetic poles to carry the large amount of magnetic material commonly encountered in such applications. Generally, ferromagnetic minerals are used for concentration.

Magnetic Drums : Magnetic drums with axial pole design are used to concentrate ferromagnetic minerals. Feed materials up to 1-inch diameter can be treated. The drum speed can be varied between 20-45 rpm in low intensity whereas it is up to 200 rpm for high intensity separators.

Induced Roll Magnetic Separator : It develops high intensity magnetic fields and is capable of removing particles that do not respond to the low intensity magnetic separator. This is widely used to treat beach sands, wolframite, tin ores, glass sands and phosphate rocks.

Cross-belt High Intensity Magnetic Separators : A cross belt runs across the face of the electromagnetic pole, and the sharp magnetized points of this upper pole attract the weakly magnetic material. The cross belt transports it to a suitable discharge point. Selective mineral concentration of weakly magnetic minerals e.g. ilmenite, monazite, garnet, chromite, wolframite, etc., can be separated by using this instrument.

Ring Type Magnetic Separators : The basic construction is similar to the cross belt but a magnetized steel ring is substituted for the cross belt.

Low Intensity Wet Drum Magnetic Separators : This is used to concentrate ferromagnetic particles such as iron of abrasion, magnetite and some pyrrhotites. The feed size is limited to 1/8 inch or even finer. Two well known usage are the concentration of magnetic taconite ores and the recovery of magnetite media in heavy media separation plants.

High Intensity Wet Magnetic Separators : High intensity separators generally use a field strength of about 20,000 gauss. Use of a matrix of shaped iron pieces which produce high field gradients to act as collection sites for paramagnetic particles. The commonly used matrix to form the high gradient sites is balls, rods, grooved plates, expanded metal and fibers. High gradient magnetic separators use uniform field of a solenoid. The core is filled with a matrix of secondary poles such as ball bearings or wire wool to obtain the high gradient.

Super Conducting Separators: Small laboratory super conducting solenoids with fields up to about 60 kilogauss are commonly available and are used for the production of large volumes of relatively permanent magnetic field. Negligible power loss is an important advantage.