

## 4 INVESTIGATING THE POSSIBLE USES OF MAGNETIC FIELDS DURING FLOTATION

### 4.1 Introduction

In low-grade nickel deposits, the host minerals often depress the flotation of the nickel sulphide minerals. These host rock minerals include pyrrhotite, quartz, and serpentine minerals. Applying an oscillating magnetic field to a flotation column and utilising the magnetic properties of the ore to selectively increase the flotation performance of the nickel sulphide minerals was investigated.

Pyrrhotite is nearly always associated with pentlandite, the main nickel sulphide mineral (Wang and Heiskanen, 1990). Excessive amounts of pyrrhotite in the flotation concentrate result in high sulphur dioxide emissions when the nickel sulphides are pyrometallurgically treated (Agar, 1991). To reduce the flotation of pyrrhotite, depressants are added to selectively depress the pyrrhotite. Magnetic fields applied to the flotation cells could possibly reduce the pyrrhotite recovery and thus reduce the amount of depressants necessary to attain the desired sulphur grade in the flotation concentrate. The possibility of selectively depressing pyrrhotite flotation was also investigated.

In froth flotation it is both the grade of the concentrate as well as the recovery of the sulphide minerals that are important. Quartz associated with sulphide minerals often reports in the concentrate and lowers the grade of the concentrate. If the concentrate is treated pyrometallurgically, it is critical that the sulphur grade is not too low, since it will cause poor performance in the pyrometallurgical treatment process.

In many low-nickel grade deposits, the original peridotites were altered to serpentines (Edwards et al, 1980). The serpentine minerals generally interfere with the flotation of nickel sulphides. The possibility of improving the flotation of pyrrhotite and pyrite in the presence of chrysotile by magnetic fields were investigated.

## 4.2 Experimental set-up and procedures

### 4.2.1 Column flotation experiments

#### 4.2.1.1 Experimental set-up

Conditioning of the pyrrhotite and pyrite was the same as that described before. A column as described in figure 3-9 was used for the flotation experiments; all the procedures as described earlier were followed. The visual set-up was used to observe the behaviour of the minerals attached to the air bubble in the presence of an oscillating magnetic field.

#### 4.2.1.2 Experimental procedure for the flotation of pyrite and pyrrhotite in an oscillating magnetic field

Magnetic pyrrhotite was separated from the milled (-150 $\mu$ m +63 $\mu$ m) nickel sulphide sample using a permanent magnet. The magnet was dragged through the sample and collected the magnetically susceptible pyrrhotite. The magnetic minerals were removed from the magnet and this procedure was repeated on the magnetic fraction a further 3 times to remove any non-magnetic minerals that was trapped with the magnetic particles. The flotation sample was made up of one gram each of pyrite and pyrrhotite. Experimental conditions are outlined in table 4-1.

*Table 4-1: Experimental conditions to examine the effect of magnetic field strength and frequency on the flotation of pyrite and pyrrhotite sample(-150 $\mu$ m +63 $\mu$ m).*

Experiment		Varying magnetic field	Varying magnetic field in presence of chrysothite
<b>Flotation Device</b>		Column	Column
<b>Flotation Time</b>	sec	30	30
<b>Conditioning Time</b>	min	10	10
<b>Conditioning Temperature</b>	°C	20	20
<b>PH</b>		7.4	7.4
<b>Airflow rate</b>	l/min	0.074	0.074
<b>Xanthate Concentration</b>	mg/l	8	8
<b>Aerofroth 615</b>	mg/l	20	20
<b>Magnetic Field Frequency</b>	Hz	50	50
<b>Magnetic Field Strength</b>	Gauss	Variable	800
<b>Magnetic Field Type</b>		Coil	Coil

#### **4.2.1.3 Experimental procedure for the flotation of chrysotile, pyrite and pyrrhotite in an oscillating magnetic field**

Approximately 50g of chrysotile obtained from GEFCO was mixed with 100ml of distilled water. The mixture was dispersed with an Ultra Tarrax disperser for 2 minutes to break up the chrysotile fibers. A sieve was used to wash out the

-106 $\mu$ m fraction and the undersize fraction was filtered and dried. Before adding the appropriate mass of chrysotile to the conditioning vessel, the chrysotile was mixed with 10ml of distilled water and dispersed for 10 seconds. One to four mass percent of chrysotile was added to 1g each of pyrite and pyrrhotite and conditioned in 200ml of 10mg/l PAX solution. The concentrate and the residue samples were washed in water to remove the chrysotile before the samples were dried and weighed. The flotation conditions and reagents used are shown in table 4-1.

A sample, as prepared for the flotation experiments, was transferred into the cell for the visual observation set-up. The visual set-up, described before, was used to visually observe the effect of the magnetic field on the behaviour of the particles attached to an air bubble in the presence of a magnetic field.

### ***4.2.2 Hallimond flotation of pyrrhotite and quartz in a magnetic field***

#### **4.2.2.1 Experimental set-up**

The conditioning and flotation set-up for the Hallimond tube were the same as described previously.

#### **4.2.2.2 Experimental procedure**

Pure quartz was crushed in an alumina mortar and pestle in the presence of fine (-63 $\mu$ m) pyrite. Half a gram of pyrite was added to 100 grams of quartz during grinding. The pyrite smeared onto the quartz surfaces enhanced the hydrophobicity of the quartz. The -106 +63 $\mu$ m quartz fraction was then sieved out.

Betacol TA from Beta-chem, an amine collector, was added as an additional collector to enhance the flotation of the quartz particles. The concentration of the xanthate was 20mg/l, while the amine concentration was 3mg/l.

The pyrrhotite was prepared as described before. The flotation time was increased to 60 seconds and the airflow rate was 0.074l/min.

*Table 4-2: Experimental conditions used to examine the effect of an oscillating magnetic field on the flotation of pyrrhotite and quartz.*

<b>Flotation Device</b>	Hallimond Tube	
<b>Flotation Time</b>	60	sec
<b>Conditioning Time</b>	10	min
<b>Conditioning Temperature</b>	20	°C
<b>pH</b>	7.4	
<b>Airflow rate</b>	0.074	l/min
<b>Xanthate Concentration</b>	20	mg/l
<b>Amine Collector</b>	3	mg/l
<b>Magnetic Field Frequency</b>	50	Hz
<b>Magnetic Field Strength</b>	Variable	Gauss
<b>Magnetic Field Type</b>	Coil	

The effect of a magnetic field on the flotation behavior of the quartz and the pyrrhotite was visually observed by the set-up described in figure 3-6.

## 4.3 Results and Discussion

### 4.3.1 *Effect of magnetic fields on flotation of pyrite and pyrrhotite*

Figure 4-1 shows the flotation results for pyrite and pyrrhotite in the presence of an oscillating magnetic field. The flotation of pyrrhotite was not significantly affected by a magnetic field up to 500 Gauss at 50Hz; this was expected since the pyrrhotite particles did not oscillate. However, when the pyrrhotite particles oscillated, shown as the dotted line in figure 4-1, the flotation recovery decreased slightly. Pyrite, which is paramagnetic, was not affected by the magnetic field. These results indicate that pyrrhotite can be depressed by a magnetic field if the

combination of magnetic field strength and frequency induces oscillations on the pyrrhotite particles.

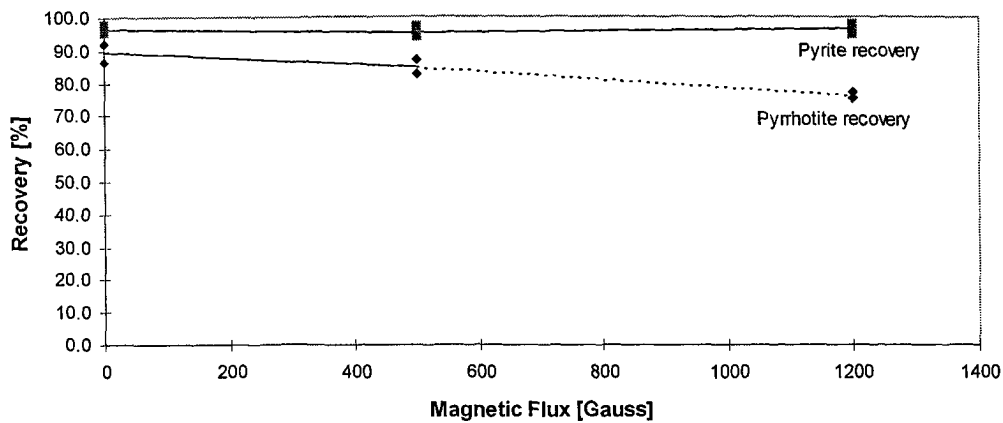


Figure 4-1. Influence of the magnetic field strength of an oscillating magnetic field on the flotation recovery of pyrrhotite and pyrite. The dotted lines indicate magnetic field conditions where rotation of the magnetically susceptible particles was observed.

#### 4.3.2 Effect of chrysotile and magnetic fields on the flotation of pyrrhotite and pyrite

Figure 4-2 shows the influence of the amount of chrysotile in the sample on the recovery of pyrite and pyrrhotite. It is clear that the recovery of both pyrrhotite and pyrite decreased with an increase in the chrysotile concentration. The pyrrhotite recovery was more strongly affected than that of pyrite. Pyrite recovery decreased only slightly from 98% to 85% as the chrysotile concentration was increased to 6%. The magnetic field of 800 Gauss and a frequency of 50Hz did not have any significant influence on the flotation response of the pyrite.

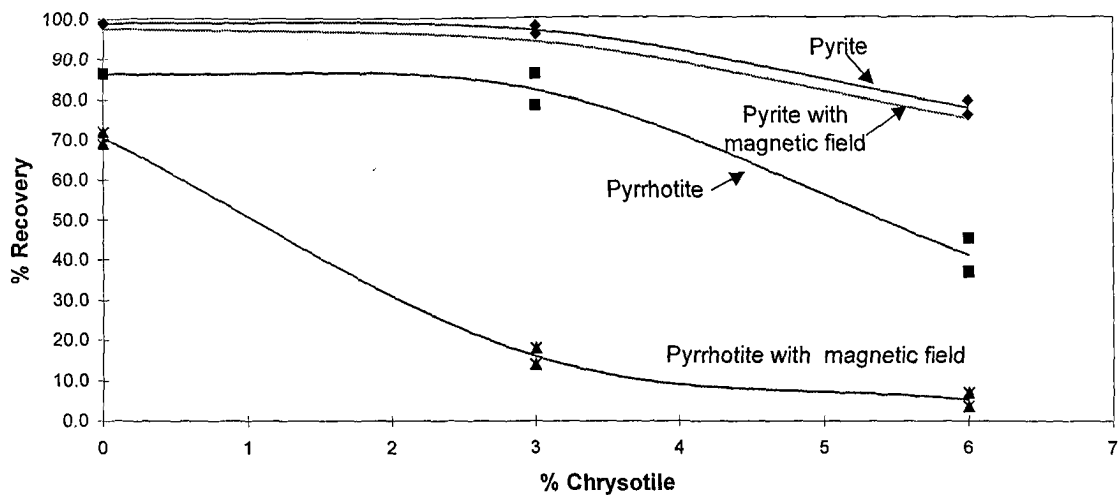


Figure 4-2. Effect of chrysotile and an oscillating magnetic field on the flotation of pyrite and pyrrhotite.

The pyrrhotite recovery decreased significantly from approximately 88% to 50% with an increase to 6 mass percent chrysotile. However, when a magnetic field of 800 Gauss and a frequency of 50Hz was applied to the flotation column, the pyrrhotite recovery decreased dramatically with an increase in the chrysotile concentration.

The experimental set-up as shown in figure 3-6 was used to visually observe the effect of a magnetic field on the flotation of pyrrhotite in the presence of chrysotile. It was seen that a large part of the bubble was covered with chrysotile fibers. When a magnetic field was applied to this bubble, the pyrrhotite particles did not move around the surface of the bubble, but rather detached from the bubble as a result of the magnetically induced torque on the particle. This inhibition of the movement of the particles by the fibrous chrysotile resulted in a dramatic decrease in the flotation recovery of the pyrrhotite.

### 4.3.3 Effect of magnetic field on the flotation of pyrrhotite and quartz

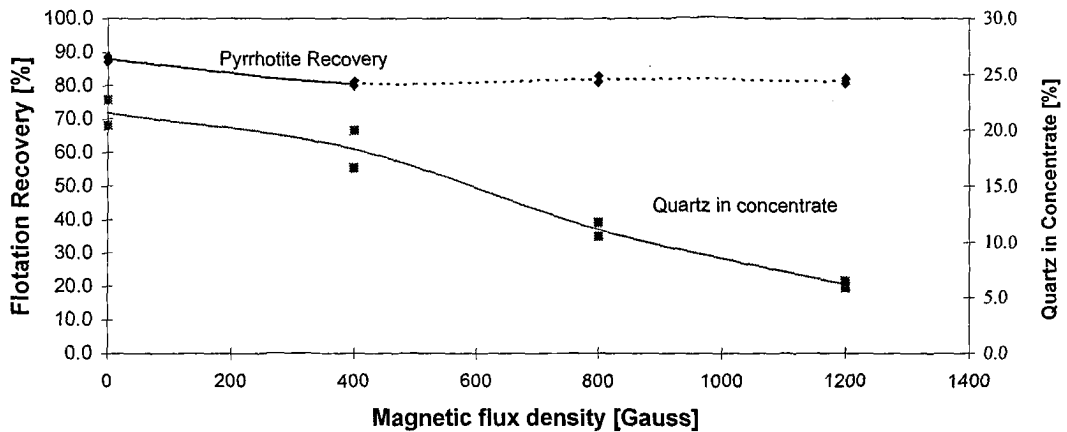


Figure 4-3: Influence of the magnetic strength of an oscillating magnetic field on the flotation recovery and grade of pyrrhotite. Rotation were induced on the pyrrhotite particles at magnetic flux densities greater than 400 Gauss.

Figure 4-3 shows the pyrrhotite recovery and the percentage of quartz in the concentrate obtained from various flotation tests at different magnetic field strengths. As was expected, the pyrrhotite recovery was unaffected by the magnetic field due to the relative high amount of collector used in this experiment. At these high collector concentration levels, the strength of the particle bubble bond is strong enough to prevent the pyrrhotite particles from dislodging from the bubble.

The concentration of quartz in the concentrate stayed fairly constant up to a magnetic flux density of 400 Gauss. The concentration of quartz in the concentrate decreased slightly up to a magnetic flux density of 400 Gauss. However, a more significant decrease in quartz concentration in the concentrate was observed once the pyrrhotite particles started to oscillate at flux densities greater than 400 Gauss.

The quartz was rendered partly hydrophobic by a combination of the pyrite coating, which formed during grinding with the pyrite, and by the addition of an amine collector. Both the quartz and pyrrhotite thus floated and rose into the magnetic field. Using the optical set-up as shown in figure 3-6, it was observed that the oscillating pyrrhotite particles collided with the quartz particles. Quartz is not bonded as strongly as pyrrhotite to the air bubbles and consequently the quartz particles lost contact with the bubble when the oscillating pyrrhotite particle collided with the quartz. This caused the flotation of the quartz to decrease.

#### **4.4 Discussion and conclusions**

Pyrrhotite can be selectively depressed to a slight extent by applying a magnetic field whilst pyrite recovery is not influenced by the magnetic field.

The flotation of weakly hydrophobic quartz can be depressed in the presence of pyrrhotite and an external oscillating magnetic field; this improved the grade of the concentrate. The pyrrhotite particles on the bubble oscillated and collided with the quartz particles on the bubble causing the weakly hydrophobic quartz to lose contact with the air bubble.

Chrysotile depressed the flotation of pyrrhotite, but with an applied magnetic field, the recovery of pyrrhotite decreased even further. It was found that the chrysotile fibers attached to the air bubble and inhibited the movement of the pyrrhotite particles to the sides of the air bubble where it is free to oscillate. Consequently, the oscillations of the particle at the bottom of the air bubble tended to break the contact between the bubble and the particle.