(6) PYRITE AND PYRRHOTITE

Pyrite and pyrrhotite are the only minerals other than native sulphur used in the manufacture of sulphuric acid. Pyrite is known to occur separately in Amjhore area of Bihar and as associated mineral in the complex base metal sulphides of copper, lead and zinc and also in the Kolar gold deposits. Pyrrhotite is known to occur in association with pyrite in Saladipura area, Rajasthan and also in the other sulphide deposits.

Both pyrite and pyrrhotite were usually beneficiated by gravity methods when they are liberated at a coarse size, or by flotation when the grain size was fine. Depending upon the size of liberation either heavy media separation alone or followed by Jigging/Tabling were employed for the lumpy and coarse grained sulphides.

Pyrite samples from Amjhore and Kolar areas were tested in NML. Amjhore Pyrites were lumpy in nature and hence heavy media separation and jigging were employed while tabling was employed to recover the sulphides from the fines. Pyrite samples from kolar and Nilgiris were beneficiated by Tabling and flotation methods. Pyrite Pyrrhotites from Saladipura were beneficiated by flotation only.

A Pyrite from Amjhore, Shahabad Dist., Bihar

Altogether nine different samples were received from the Amjhore area sponsored by M/s. Pyrite, Phosphates and Chemicals Ltd. for beneficiation studies. All the samples were to be beneficiated to a grade over 38% S in lumpy size for use in the fertilizer industry at Sindri.

Visual Examination of the samples obtained from time to time indicated that some pure lumps of pyrite and some pyrite-shale interlocked lumps were seen. Microscopic examination revealed very fine grained crystals (4-5 microns) of pyrite disseminated in the shale which was the chief gangue mineral. Small quantities of quartz, mica and calcite also occurred along with the shales.

Batch No. 1

Four samples with different sulphur contents were received for beneficiation studies. The samples were crushed to pass 125 mm screen and the −10 mesh fines were separated out. The lumps i.e. −125 mm +10 mesh portions were treated by HMS and the −10 mesh portions which contained a reasonable amount of S were kept separate. These fines may by mixed with lumpy concentrates with or without further treatment.

Sample No. 1

Complete analysis of the sample was as follows :

Constituent	*Assay %*
Total S	20.8
S as FeS_2	19.5
S as FeS	Trace
Fe	18.5
SiO_2	36.0

The sample which contained lumps upto 200 mm was reduced to 125 mm size and the −10 mesh size portion was separated. The lumps were treated by Heavy Media Separation where in a concentrate at 2.9 sp. gr. obtained. When the −10 mesh fines containing 26.01% S were combined, concentrate analysed 41.6% S with 79.4% recovery.

Attempts to recover S from the HMS tailings i.e. float at sp. gr. 2.9 by flotation did not yield any encouraging results.

Sample No. 2

This sample was of better grade than the sample No. 1 and analysed as follows :

Constituent	*Assay %*
Total S	25.9
S as FeS_2	25.1
S as FeS	Trace
Fe	21.3
SiO_2	30.15

Heavy media separation tests with the −125 mm +10 mesh at sp. gr. 2.9 yielded a concentrate analysing 39.4% S with 74.5% recovery i.e. slightly poorer grade of concentrate. When the −10 mesh fines assaying 24.98% S were also combined with the concentrate, the product analysed 38.97% S with 76.0% S recovery. Float at 2.9 sp. gr. which contained 24.0% S did not produce any favourable results when tried by flotation method.

The behaviour of the sample No. 2 indicates the higher dissemination of pyrite in the shale, which was not possible to recover.

Sample No. 3

This sample analysed slightly better than sample No. 1 but lean against sample No. 2. The complete analysis of the sample was as follows :

Constituent	*Assay %*
Total S	21.4
S as FeS_2	21.2
S as FeS	Trace
Fe	19.6
SiO_2	30.85

The sample was crushed to 125 mm size and as in the earlier cases, the −125+10 mesh portion was subjected to heavy media separation. The concentrate obtained at sp. gr. 2.9 analysed 38.21% S with 71.3% S recovery. When the −10 mesh fines analysing 36.67% S were also combined, the concentrate analysed 38.1% S with 76.8% distribution.

Sample No. 4

This sample analysed highest S and the complete analysis was as follows :

Constituent	*Assay %*
Total S	34.8
S as FeS_2	34.3
S as FeS	Trace
Fe	28.6
SiO_2	24.5

Heavy media separation tests with − 125 mm+10 mesh portion at sp. gr. 2.9 produced a concentrate analysing 46.05% S with 85.9% S distribution. When the − 10 mesh fines were also combined, the mixed concentrate analysed 45.57% S with 90.3% distribution.

It may be seen from the test results that depending upon the dissemination of pyrite in the shales and variation in liberation size from one zone to the other had effected the grade and recovery of the end products.

Similar tests conducted with the mixed sample where in all the four types of samples were mixed in equal proportions at sp. gr. 2.9 produced a concentrate analysing 42.09% S, 38.36% Fe and 17.96% insolubles with an overall S recovery of 75.1%. When the fines assaying 32.87% S were combined with the concentrate, the end product analysed 41.5% S, 37.94% Fe and 18.65% insolubles with 78.9% S recovery in it.

Batch No. 2

Two sulphide samples were received in this batch and said to contain 50% and 70% pyrites and the balance of shales. From the test samples it may be seen that the samples were synthetic since no float was obtained between sp. gr. 2.8 and 2.2. These samples were also tested by heavy media separation of − 125+6 mm lumps. In addition the HMS tests were conducted with different lots crushed to 100 mm and 75 mm separately. The −5 mm fines were also beneficiated by jigging.

Sample No. 1

This sample was similar to sample No. 1 of the 1st batch of sample and analysed as follows :

Constituent	*Assay %*
Total S	19.00
FeS_2	35.63
Fe	20.00
SiO_2	4.45

This sample was marked to contain 50% pyrite and 50% shales. HMS tests conducted at sp. gr. 2.8 with a feed crushed to 125 mm, 100 mm and 75 mm respectively produced concentrates analysing 41.64% S with 91.7% recovery, 43.29% S with 90.8% recovery and 40.24% S with 87.7% recovery in them. When the respective −5 mm fines analysing

32.88% S, 30.4% S and 32.4% S were mixed with the 125 mm, 100 mm and 75 mm concentrates. analysed 41.14% S, 42.3% S and 39.92% S with 95% to 96% recovery.

The combined −5 mm portions obtained from the different tests analysed 31.9% S and when treated in mineral jig produced a concentrate analysing 42.29% S with 70.1% recovery (for fines).

Sample No. 2

This sample was similar to sample No. 2 of the first batch and analysed as follows :

Constituent	*Assay %*
Total S	25.30
FeS_2	47.51
Fe	24.70
SiO_2	33.88

The heavy media separation tests conducted with the sample lots crushed to 125 mm, 100 mm and 75 mm after removing −5 mm fines at sp. gr. 2.8 respectively produced concentrates analysing 41.4% S with 96.1% recovery, 43.0% with 93.0% recovery and 38.3% S with 91.4% recovery in them. When the —5 mm fines from each lot assaying 35.22% S, 36.76% S and 36.3% S respectively were combined with the concentrates, the end products analysed 41.16% S with 99.1% recovery, 42.57% S with 98.8% recovery and 38.2% S with 97.9% recovery in them.

The combined —5 mm fines when treated in jig produced a concentrate analysing 43.7% S with 85.0% recovery with reference to fines only.

It may be seen from the overall tests results that −125 or −100 mm to +5 mm was the optimum size for the separation of sulphides from the shales. Treatment of the fines would definitely improve the grade, but the recoveries shall be low.

Batch No. 3

Three different samples were received in the 3rd batch for beneficiation and two of them were almost similar while the other one was lean in nature. The samples consisted of 200 mm lumps to fines, and were crushed to 125 mm size. Heavy media separation tests were conducted with −125 mm +5 mm and subsequently −5 mm+10 mesh size also. The rest of the fines were not treated. In addition to these, jigging tests were also conducted at 19 and 10 mm size.

Sample No. 1

Complete analysis of the sample was as follows :

Constituent	*Assay %*
Total S	25.32
S as FeS_2	24.85
S as FeS	Trace
Fe	24.12
SiO_2	29.40

Heavy media separation tests at sp. gr. 2.9 with −125 mm +5 mm size produced a concentrate assaying 38.3% S with 78.9% S recovery in it. Jigging test conducted with the ore sample at 19 mm size produced a concentrate of 34.8% S with 57.2% recovery. Similar tests with 10 mm size feed after sizing to +5 mm and −5 mm produced a combined concentrate of 35.6% S with 72.0% distribution. Although jigging produced quite satisfactory results, S losses in the tailings were rather high.

Sample No. 2

This sample was of poorer grade than the sample No. 1 and had the following analysis :

Constituent	*Assay %*
Total S	17.36
S as FeS_2	17.00
S as FeS	Trace
Fe	21.00
SiO_2	39.90

HMS tests conducted with this sample at sp. gr. 2.9 produced a concentrate analysing 34.27% S with 60.3% recovery. Jigging tests at 19 mm size yielded a concentrate analysing only 23.42% S with 47.3% recovery. Jigging tests at 10 mm size after sizing on 5 mm screen resulted in the combined concentrate analysing only 29.43% S with 48.6% S recovery. The poor response of the sample was due to the low pyrite content of the sample and also

the intimate association. This sample alone could not yield a concentrate and acceptable grade.

Sample No. 3

The sample was almost similar to sample No. 1 in analysis but produced better quantity of concentrates. The sample analysed as follows :

Constituent	*Assay %*
Total S	25.12
S as FeS_2	24.95
S as FeS	Trace
Fe	24.92
SiO_2	29.36

HMS tests conducted with $-125 + 6$ mm feed at sp. gr. 2.9 produced a concentrate analysing 41.0% S with 74.1% S recovery in it. Jigging tests with 19 mm size feed produced a concentrate analysing 39.85% S with 41.1% recovery. Tests with -10 mm sized feed produced a combined concentrate analysing 40.75% S with 83.1% recovery.

Over all HMS and Jigging tests results indicated that although sample No. 1 and S. No. 3 analysed almost alike, the former sample contained more of pyrite in lumpy nature whereas the latter one contained of medium and fine grained pyrite. Hence it produced better grades of concentrate with jigging at 10 mm size. Sample No. 2 contained bulk of fine grained pyrite which was in very close association with the shales.

HMS tests were conducted with a composite sample, prepared by mixing the three types of samples in equal proportion. The concentrate obtained at sp. gr. 2.9 analysed 38.31% S with 72.3% S recovery. The untreated -5 mm fines and the HMS tails put together formed 56.7% of the feed and analysed 11.16% S with 27.7% S distribution in them. As this was richer in S to reject, flotation tests conducted with different grinds of fineness and reagent combinations but without success. HMS tests conducted with the -5 mm $+10$ mesh portion of the untreated fines produced a concentrate assaying 51.8% S with an additional 2.9% S recovery. Hence when the HMS tests were conducted with -125 mm $+10$ mm size feed, the concentrate forming 44.5% of the feed analysed 38.7% S with 72.2% S distribution in it. If the -10 mesh untreated fines were combined with the $-125 + 10$ mesh HMS concentrate, the product analysed, 37.4% S with 79.2% S distribution. This product meets the specifications both by size and analysis levels.

Jigging tests with the composite sample at 5 mm size after sizing produced a combined concentrate analysing 37.68% S with 58.3% S distribution only.

Pilot Plant Studies

After taking up bench scale beneficiation studies on 3 batches of samples from Amjhore Pyrite deposit, a pilot plant scale investigation was also sponsored by M/s. PPCL on a 300 tonne representative sample.

The sample consisted of lumps of 300 mm size down to fines. All the sample was crushed to 125 mm size. The ROM sample analysed as follows:

Constituent	*Assay %*
Total S	16.5
S as FeS_2	16.2
S as FeS	Trace
Fe	19.6
SiO_2	39.44

The sample was treated in the "Wemco" HMS Plant. The feed to HMS plant was wet-screened on 8 mesh screen where in the HMS conc. was prewetted and the fines were separated. The medium of sp. gr. 2.95—3.00 for the tests was prepared by the suspension of atomised ferrosilicon in water kept under constant agitation both by mechanical strirring and bubbling of compressed air. The sink and float products were washed separately and the wash waters and ferrosilicon are recirculated after reclamation by magnetic separation.

The concentrate obtained from the continuous treatment analysed 38.5% S with 65.4% distribution. The -8 mesh fines analysed 14.99% S with 7.2% distribution. When these products were combined, the concentrate analysed 33.3% S with 72.6% distribution.

As the untreated -8 mesh fines when combined with the HMS concentrate, lowered the grade attempts have been made to beneficiate it. The -8 mesh portion was treated in Harz Jig wherein a concentrate analysing 26.1% S with 4.9% distribution was produced.

This when combined with the HMS concentrate, the product analysed 36.21% S with 70.3% S distribution in it.

Batch HMS tests with −125 mm +8 mesh material at sp. gr. 3.1 produced a concentrate analysing 39.99% S with 61.9% S distribution. This concentrate when combined with the −8 mesh jig concentrate, analysed 38.5% S with 66.8% S distribution in it.

Amjhore Pyrites: Sample No. 1

The pyrite sample received from PPCL consisted of 250-0 mm lumps and analysed as follows:

Constituent	*Assay %*
Total S	26.48
S as FeS	Trace
Fe	16.24
SiO_2	35.60
Al_2O_3	12.40
S as FeS_2	20.67
Moisture	0.70

The ROM sample was crushed to 115 mm size and sized on 6 mm and 10 mesh screen. The −115 +6 mm lumps were treated by Heavy media separation at sp. gr. 2.9 to 2.7. The sink product obtained at medium sp. gr. 2.9 analysed 38.47% S. The −6 mm +10 mesh product was treated on jigs and the jig concentrate analysed 37.14% S. The −10 mesh fines when treated on wilfley table, yielded a concentrate analysing 37.01% S. The combined HMS, jig and table concentrates represented 43.4% of the total feed and analysed 38.19% S with a S distribution of 63.7% in it.

Alternatively when the ore was crushed to 19 mm and after sizing on 6 mm and 10 mesh screen, the coarser products were treated respectively in Harz and Denver mineral jigs. These concentrates respectively analysed 36.02% S and 33.26% S. The −10 mesh fines were treated on Wilfley table and the table concentrate analysed 33.32% S. The combined jig and table concentrates analysed 35.3% S with 61.6% distribution, representing 45.9% of the feed.

Test with Sample No. 2

The sample No. 2 crushed to 19 mm size followed by sizing on 13 mm screen and jigging yielded concentrates analysing 35.43% S and 37.15% S. The combined jig concentrate represented 51.3% of the feed and analysed 36.38% S with 73.1% S distribution in it. The original sample No. 2 assayed 26.7% S.

B Pyrite and Pyrrhotite ores from Saladipura area —Sikar Dist., Rajasthan.

The major iron sulphide deposit is situated in Saladipura area in Rajasthan. The deposit chiefly consists of pyrite and pyrrhotite with trace amounts of Cu, Pb and Zn. The gangue was composed of quartz and ferromagnesium minerals with minor quantities of magnetite, rutile, calcite etc. Both pyrite and pyrrhotite were coarse grained in nature and had inclusions of chalcopyrite, sphalerite and galena.

3 batches of samples were received for beneficiation studies at NML from different parts of the mines.

Batch No. 1

Two samples were received in this batch and both of them happened to be samples prepared from the cores of the bore holes.

Sample No. 1

This sample was prepared by mixing the two sample box contents drawn from the upper strata of the deposit and contained low metallics. Complete analysis of the sample was as follows:

Constituent	*Assay %*
Total S	20.80
S as FeS_2	14.38
S as FeS	6.42
Fe	27.80
SiO_2	29.03
Cu, Pb & Zn	Trace
As	Nil

A series of flotation tests were conducted under different conditions in order to determine the optimum grind, reagent requirement etc. From the tests it was confirmed that a grind passing 83% through 200 mesh, pH 5.5 for floatation of the sulphides, 0.12 kg/tonne of potasium ethyl xanthate were required to produce a sulphide concentrate analysing 33.3% S with 96.1% distribution. When the concentrate was cleaned twice the cleaner concentrate analysed 42.7% S with 75.5% S distribution in it.

Sample No. 2

This sample also was prepared by mixing the contents of two sample boxes originally drawn from the drilling core. The sample was of higher grade and analysed as follows:

Constituent	*Assay %*
Total S	40.8
S as FeS_2	38.9
S as FeS	Trace
Fe	42.1
SiO_2	7.5
Cu, Pb, Zn & As	Trace

Tests conducted under different conditions indicated that with 91.5% —200 mesh grind, 0.12 kg xanthate, pH 5.2 produced a concentrate analysing 45.56% S with 95.6% S distribution in it. When the concentrate was cleaned once, the product analysed 47.32% S with 88.9% S distribution in it.

Batch No. 2

One lot of pyrite pyrrhotite was received for the concentration of sulphides and also to recover the zinc in the sample. The sample analysed as follows:

Constituent	*Assay %*
Total S	16.20
S as FeS_2	10.60
Fe	20.07
SiO_2	38.30
Zn	1.60
Cu	0.30
Pb & Ni	Trace

A series of floatation tests indicated that with a feed ground to 91% —200, 0.12 kg of pot. eth. xanthate and pH 6.8 was optimum to produce a concentrate analysing 2.90% Zn and 33.0% S with 80.9% Zn and 91.0% S distribution in it. Use of higher xanthates did not improve the results.

When the concentrate obtained under optimum conditions was cleaned twice, the cleaner concentrate analysed 3.7% Zn, and 39.0% S with 74.7% Zn and 76.1% S distributions in it.

Attempts to float the sphalerite from the bulk sulphide concentrates with NaCN & $CuSO_4$ at pH 10.5 produced a zinc concentrate analysing 5.9% Zn only with 18.7% Zn distribution in it. Results also indicated the presence of the bulk of the sphalerite remained with the pyrite-pyrrhotite concentrate only. Hence it is not possible to concentrate the zinc minerals from the sulphide ore sample.

Batch No. 3

Two different lots of pyrite-pyrrhotite samples drawn from level 1 & 2 were sent for beneficiation studies. Sample from level 2 was richer than the sample from level 1.

Sample No. 1

The sample drawn from level I analysed as follows:

Constituent	*Assay %*
Total S	15.81
S as FeS_2	9.50
S as FeS	6.21
Fe	21.30
SiO_2	42.02
Al_2O_3	10.35
CaO	4.56
MgO	3.27
Cu	0.12
Zn	1.20
Pb	Trace
Co, As, & Ni	Not detected

Jigging tests with —10 mm + 10 mesh portion produced a concentrate analysing 31.43% S with 27.5% recovery. The jig tails when ground to 10 mesh and treated on table, the concentrate analysed 32.06% S with 36% recovery. The —10 mesh portion also when treated on table, yielded a concentrate analysing 41.6% S with 13.8% recovery. Thus the overall combined jig and table concentrates analysed 33% S with 77.4% recovery.

Tabling with 28 mesh sized feed produced a combined concentrate analysing 38.02% S with 67.9% recovery only; when the pyrrhotite from the sample was separated by magnetic separation and treated on shaking table at 28 mesh size, the concentrate analysed 44.46% S with 50.1% recovery. When the magnetic portion analysing 30.49% S was combined with table concentrate, the product analysed 38.5% S with 75.9% recovery.

Flotation tests conducted under optimum conditions of 51% —200 mesh grind, 0.2 kg/tonne of

xanthate and 0.045 kg/tonne of pine oil yielded a concentrate of 39.2% S with 67.4% distribution. When the flotation tailings were subjected to magnetic separation, a pyrrhotite concentrate analysing 30.8% S was recovered. When the flotation and magnetic concentrates were combined, the product analysed 36.5% S with a total recovery of 90.1% S in it. After a single cleaning, the flotation concentrate, analysed 44% S with 64.8% recovery. When the refloat concentrate and the magnetic concentrate were combined, the product analysed 39.59% S with 87.5% recovery in it. This grade concentrate will be acceptable for the industry.

Sample No. 2

This sample was drawn from the level 2 of the deposit and analysed as follows:

Constituent	*Assay %*
Total S	31.35
S as FeS_2	28.22
S as FeS	3.13
Fe	29.24
CaO + MgO	5.53
SiO_2	26.35
Zn	0.61
Cu	0.09
Al_2O_3	0.92
Pb	Trace
Ni, As & Co	Not detected

Jigging tests with —10 mm + 10 mesh material yielded a concentrate assaying 40.91% S with 38.2% S distribution. When the jig tails were ground to 10 mesh and treated along with the —10 mesh untreated portion on shaking table, a concentrate assaying 39.6% S with 50.7% distribution was obtained. When the jig and table concentrate were combined, the concentrate analysed 40.2% S with 88.9% S distribution.

Tabling tests with a sized 28 mesh feed produced a combined concentrate analysing 40.83% S with 86.0% S distribution in it. When the slimes were treated in a flotation cell, a concentrate assaying 35.06% S with an additional recovery of 6.8% S was obtained.

This flotation concentrate when combined with the jig and table concentrates, the end product analysed 40.3% S with 92.8% recovery.

When the jig tails along with the —10 mesh portion was combined and subjected to flotation yielded a concentrate analysing 46.5% S with 52.5% distribution. This when combined with —10 mm +10 mesh jig conc. analysed 40.98% S, the combined jig and flotation concentrate analysed 44% S with 91.2% S distribution in it.

Straight flotation tests under optimum conditions of 47% —200 mesh grind, 2 kg/tonne of xanthate and 0.045 kg/tonne of pine oil, produced a concentrate analysing 45% S with 90.6% S distribution in it. When the tails were put to magnetic separation, a pyrrhotite concentrate analysing 30.95% S resulted with an additional S recovery of 6.4%. When the flotation concentrate and the magnetic concentrate were combined, the product analysed 44.2% S with 97.2% S distribution in it. Flotation tests conducted at different pulp densities and reagent combination did not show any improvement over the results. Separation of pyrrhotite before flotation also did not improve the recovery of sulphur.

Pilot plant studies

In addition to the various bench scale tests, continuous, pilot plant tests were also undertaken on a 150 tonne representative run of mine ore drawn from the Saladipura pyrite-pyrrhotite deposit. The sample in its as received state contained lumps upto 150 mm with minor quantity of fines. Complete chemical analysis of the sample was as follows:

Constituent	*Assay %*
Total S	23.00
S as FeS	1.86
S as FeS_2	21.40
Fe	27.44
SiO_2	30.61
Cu	0.08
Pb	Trace
Zn	0.55
Ni	Trace
As	not detected

Series of batch scale flotation tests conducted with representative sample indicated that a grind of 93% —200 mesh with 0.24 kg of xanthate at pH 5.5 were optimum to produce a concentrate assaying 40.5% S with 91.8% distribution.

Tabling at 28 mesh size after sizing and flotation of the table tailings under optimum condition produced a combined table and flotation concentrate analysing 42.7% S with 86.9% distribution. In this case the grade of the concentrate was better and the recovery was slightly lower than the flotation process.

Both direct flotation and tabling followed by flotation methods were treated on plant scale operations.

The ROM was passed through the primary jaw crusher followed by secondary gyratory crusher and stored in the bin. From bin, the ore was fed to a ball mill operating in closed circuit with a rake classifier. The classifier overflow was sent to conditioner and then to flotation cells. The flotation concentrate was thickened in a thickener and filtered in vacuum disc filter. Thickner overflow water was recirculated to the flotation circuit. After making a large number trials on the flotation time, reagent amounts and reagent addition points it is concluded that 0.21 kg/tonne of xanthate, 3.0 kg/tonne of H_2SO_4 (to pH 5.0) and the bulk of the collector added at the last 25% of the flotation time were optimum for good grade and recoveries. Under these conditions a concentrate analysing 41.5% S with 94.8% recovery was obtained.

In the case of tabling followed by flotation, the ore from the bin was passed through a rod mill and the discharge was treated in a cyclone. The under-flow was treated on the table and the over-flow along with the table tails was ground in a ball mill and treated in the flotation circuit. The combined concentrate obtained by this method analysed 46.8% S with 63.8% distribution. The tailing losses in this conc. were high, on account of the large capacity of the ball mill which produced lot of slimes while grinding the table tails.

Saladipura Pyrite (Rajasthan):

The sample received from M/s. PPCL, designated as "blend sample" analysed as follows:

Constituent	*Assay %*
Total S	19.55
Fe	21.14
SiO_2	35.40
Al_2O_3	10.50
Cu, Pb & Zn	Trace

Mineralogical examination of the sample showed the presence of pyrrhotite and pyrite as the chief sulphide minerals. Minor amounts of sphalerite, magnetite, titanite etc. were also observed. Quartz, tremolite, actionlite, biotite and carbonate formed the bulk of the gangue. Sulphides were liberated from the gangue at about 65 mesh size.

The sample was crushed to 12.5 mm size and the —6 mesh fines were removed before jigging. The jig concentrate analysed 31.0% S with 39.6% S distribution in it. The jig middlings analysing 16.5% S were crushed to 6 mesh fines. These fines were stage-crushed to 28, 48 and 65 mesh size and treated separately on wilfley table. The concentrates thus obtained analysed 30.3% S with 36.5% S distribution, 30.2% S with 37.2% S distribution and 32.1% S with 37.2% S distribution respectively.

Tabling tests conducted at 28, 48 and 65 mesh size with the ROM sample produced concentrates assaying 37.5% S with 64.1% S distribution 36.3% S with 69.4% S distribution and 36.4% S with 70.8% S distribution respectively.

Humphrey's Sprial test at 28 mesh size yielded a concentrate assaying 33.7% S with 61.4% S distribution in it.

C Pyrites from Maharastra

A sample of low grade pyrite from Karwar area in Maharastra State was received from the Director of Geological Survey of India for beneficiation studies to produce a pyrite concentrate assaying 48% S and above. The sample consisted of lumps from 12 mm to 175 mm in size. Complete chemical analysis of the sample received was as follows:

Constituent	*Assay %*
Total S	22.62
Fe	33.65
Cu	Nil
Ni	Nil

Microscopic examination of the sample indicated that pyrite was the chief ore mineral followed by the principle gangue minerals chlorite and anthophillite.

Pyrite was liberated from the gangue at 100 mesh size. As the liberation was at finer size, gravity methods may not produce concentrates of desired analysis.

Tabling tests conducted at 48 mesh size after sizing produced a combined concentrate analysing 37.44% S with 72.7% recovery in it. Tabling tests with —65 + 150 mesh size product and flotation with —150 mesh size fines produced a combined concentrate assaying 41.27% S with 86.4% recovery.

Flotation studies with a feed of 70% —200 mesh with ethyl xanthate in acid circuit produced a concentrate analysing 48.21% S with 90.4% S recovery. Tests conducted with the addition of $CuSO_4$, Na_2S in both alkaline and acid circuits, did not improve the grade of the concentrate.

D Pyrites from Tamil Nadu

Three samples of low grade auriferous pyrite samples from Wynaad area of Nilagiri Dist. of Tamilnadu State were received. The samples A and B were drawn from Harewood mine of the same locality.

Sample No. A

The sample was lumpy in nature and microscopic examination indicated the presence of pyrite, quartz, pyrophyllite, dolomite and traces of magnetite and hydroxides of iron and analysed as follows :

Constituent	*Assay %*
Total S	1.46
SiO_2	74.60
$Al_2O_3 + Fe_2O_3$	17.20
CaO	2.50
MgO	1.70
As & Cu	Nil
Au	0.6 dwt/ton (fire assay)

A fair liberation of pyrites was indicated at 35 mesh size.

Tabling tests with a sized feed of 35 mesh produced a combined concentrate analysing 37.2% S with 69% S recovery. Flotation tests conducted under different conditions indicated that a grind passing through 65 mesh, at pH 7.4 to 7.8 with 0.5 kg/tonne of Pot ethyl xanthate produced a concentrate analysing 41.9% S with 87% recovery.

Sample No. B

The sample was soft and exhibited crystalline pyrite associated with pyrophyllite, quartz, dolomite and limonitic matter. Complete chemical analysis of the sample was as follows :

Constituent	*Assay %*
Total S	1.7
SiO_2	56.4
Al_2O_3	15.6
Fe_2O_3	7.0
CaO	5.9
MgO	4.5
LOI	8.7

Tabling tests conducted with —28 mesh material produced a concentrate analysing 38% S with 75% S distribution in it. Tabling tests with 35 mesh material followed by flotation of the table tails produced a combined table-flotation concentrate assaying 43.65% S with 89% recovery.

Flotation tests with a feed ground to 100 mesh employing sodium carbonate and sodium metasilicate as depressants for the gangue and Pot Amyl xanthate as collectors for the pyrite, produced a concentrate assaying 43.2% S with 95.6% distribution.

Sample No. C

This sample was drawn from Harewood mine and showed more metallics than those from Alpha mine. The ore was composed of fines and lumps upto 75 mm in size. Complete chemical analysis of the sample was as follows :

Constituent	*Assay %*
Total S	2.42
SiO_2	65.50
Total Fe	15.50
S from Pyrrhotite	0.56
Gold	3.7 dwt/ton (fire assay)

Microscopic examination of the sample indicated the presence of pyrite, marcasite, pyrrhotite followed by the gangue minerals quartz, magnetite, siderite, calcite, hematite, felspar and chloritic minerals. Minute particles of gold were observed as inclusions in pyrite. In general the sample was weathered considerably. Pyrite was liberated from the gangue at 65 mesh size.

Tabling at 65 mesh size with sized feed produced a combined concentrate assaying 6.05% S and 10.64 dwt/T of gold with 63.9 and 80.5% recoveries of S and Au respectively. Table concentrate produced with 35 mesh feed yielded a concentrate with 63.7% S and 88.0% Au recoveries in it.

Flotation studies with 65 mesh grind employing $CuSO_4$ as activator, and ethyl. xanthate as collector yielded a concentrate assaying 28% S with 63.3% S and 99.1% Au recovery in it. Similar tests with Amyl xanthates produced a concentrate with 28% S with 56% distributed and 74.2 dwt/T Au with 92.3% recovery in it.

The results indicate that the concentration of sulphides was difficult to meet the industrial specification.

A series of cyanidatlon tests to recover the gold from the ore indicated that the pyrite flotation concentrate when calcined at 750°C and then subjected to cyanidation resulted in 92% gold recovery.

(E) Gold and Sulphide recovery from Nandidurg mines of Kolar Gold Field, Karnataka

A sample of gold tailing after cyanidation was received for the recovery of sulphides, sulpharsenides and gold. The sample analysed as follows :

Constituent	*Assay %*
Total S	1.58
Sulphate S	0.47
Fe	10.69
Al_2O_3	7.97
SiO_2	58.93
CaO	7.13
MgO	5.47
As	0.47
Cu	Trace
Au	0.5 dwt/t (fire assay)
LOI	3.49

Flotation tests conducted under different conditions of pH, reagents and collectors indicated that the best concentrate obtained analysed only 13.68% S with 37.1% S distribution. Hence it was concluded that recovery of sulphides was not possible.

Flotation followed by cyanidation tests indicated that 95.9% S may be extracted with 43.3% gold distribution in it.

The consolidated results of the above samples are given in the following Table No. 46.

References

(1) Studies on beneficiation of low grade pyrite pyrrhotite sample from Saladipura Area, Sikar Dist., Rajasthan Part -I (NML. IR. NO. 414/67).

By P. K. Sinha & P. I. A. Narayanan.

(2) Studies on beneficiation of low grade pyrite pyrrhotite sample from Saladipura Area, Sikar Dist., Rajasthan Part-II (NML. IR. NO. 415/67).

By S. K. Banerjee & P. I. A. Narayanan.

(3) Beneficiation of a pyrite pyrrhotite sample from Saladipura Area, Sikar Dist., Rajasthan. (NML. IR. NO. 573/70).

By B. L. Sengupta & G. P. Mathur.

(4) Beneficiation studies with pyrite pyrrhotite sample from Saladipura area of PPCL. (NML. IR. NO. 703/72).

By K. Vijayaraghavan, M. L. Viswakarma, P. V. Raman & G. P. Mathur.

(5) Batch and pilot plant scale beneficiation studies on a low grade pyrite pyrrhotite sample from Saladipura area Rajasthan. (NML. IR. NO. 612/70).

By P. D. Prasada Rao, C. Satyanarayana, K. Vijayaraghavan, G. S. Ramakrishna Rao & G. P. Mathur.

(6) Beneficiation of three pyrite samples from Amjhore, Bihar (NML. IR. NO. 500/69).

By P. D. Prasada Rao, S. B. Dasgupta & P. I. A. Narayanan.

(7) Heavy Media Separation tests with the pyrite samples from Amjhore, Shahabad Dist., Bihar (NML. IR. NO. 469/68).

By M. V. Ranganathan & P. I. A. Narayanan.

TABLE 5.5—BENEFICIATION RESULTS OF PYRITE AND PYRRHOTITE SAMPLES

Locality & State	Feed Assay % S	Beneficiation Method	Assay % S in the conc.	Recovery % S in the conc.	Remarks
1	2	3	4	5	6
I. Bihar					
Amjhore (1)	19.5	HMS & untreated —10 mesh fines	41.6	79.4	HMS tails on flotation did not help in further recovery of S.
Amjhore (2)	25.1	,,	39.4	74.5	
Amjhore (3)	21.4	,,	38.1	76.8	
Amjhore (4)	34.8	,,	45.57	90.3	
Mixed sample of 1, 2, 3 & 4	25.2	,,	41.5	78.9	
Amjhore (5)	19.0	HMS and jigging	42.29	70.1	
Amjhore (6)	25.3	HMS at 125 mm	41.4	96.1	
		Jigging of —10 mm fines	43.7	85.0	For fines only
Amjhore (7)	25.32	H.M.S.	38.3	78.9	Jigging at 19 mm gave better grade with low recovery.
Amjhore (8)	17.36	H.M.S.	34.27	60.3	
Amjhore (9)	25.12	HMS with lumps and jigging with fines	40.75	83.1	
Composite (7+8+9)	22.6	HMS with+10 mesh lumps	37.40	79.2	Fines were untreated
Amjhore (10)	16.5	HMS with —125 mm+8 mesh and untreated fines	33.30	72.6	Pilot plant scale tests.
		HMS with lumps+jigging of fines	36.21	70.3	
Amjhore (11)	**1st Sample**	**HMS** at 2.7-2.9, jigging			
	Total S% 26.48	and tabling			
	S as FeS_2 20.67	—115 mm+6.0 mm—sink 2.9	38.44		
		— 6 mm+10 mesh Jig conc.	37.14	38.19	63.7
		— 10 mesh tabling.	37.01		
		— 19 mm+6 mm Jig conc	36.02		
		— 6 mm+10 mesh Jig conc	33.26	35.3	61.6
		— 10 mesh table conc.	33.32		
	2nd Sample				
	26.7	— 19 mm+13 mm Jig conc.	35.43		
		— 13 mm+10 mesh Jig conc.	37.15	36.38	73.1
II. Rajasthan					
Saladipura (1)	20.8	Flotation with two cleanings	42.7	75.5	
Saladipura (2)	40.8	Flotation	45.56	95.6	Attempts to recover Zn 1.6% in feed are not successful.
Saladipura (3)	16.2	Flotation	39.0	76.1	
Saladipura (4)	15.8	Magnetic conc.+flotation conc. with cleaning	39.59	87.5	Magnetic separation to recover pyrrhotite
Saladipura (5)	31.35	Flotation+Magnetic conc. from tails	44.2	97.2	
Saladipura (6)	23.00	Flotation	41.5	94.5	Pilot Plant scale tests
		Tabling+Flotation of table tails	46.8	63.8	
Saladipura (7)	**Blend Sample**	**Crushing & Jigging:**			
	19.55%	—12.5 mm+0.6 mm Jig conc.	31.0	39.6	
		Tabling of Jig middling	30.3	39.6	
		,, ,, mixed with 0.6 mm fines	30.2	36.5	
		Crushed to 28 mesh & tabling	32.1	37.2	
		,, 48 ,,	37.1	64.1	
		65 ,,	36.3	69.0	
		Spiralling at 28 mesh	33.7	61.4	

(8) Batch heavy media separation tests with four pyrite samples from Amjhore, Shahabad Dist., Bihar. (NML. IR. NO. 513/69).

By M. V. Ranganathan & P. I. A. Narayanan.

(9) Pilot plant studies on beneficiation of Amjhore pyrite sample employing HMS and jigging and proposals for setting up of a 1600 tonnes/day treatment plant (NML. IR. NO. 556/70).

By M. V. Ranganathan, P. D. Prasada Rao, C. Satyanarayana, R. K. Kunwar, K. Vijayaraghavan, S. K. Banerjee, G. P. Mathur & P. I. A. Narayanan.

(10) Beneficiation of Auriferous pyrites from Wynaad, Nilgiry—Tamil Nadu (NML. IR. NO. 17/53).

By G. V. Subrahmanya & P. I. A. Narayanan.

(11) Recovery of sulphur and gold from the tailings of Nandydrug mines—Kolar Gold Fields—Karnataka (NML. IR. NO. 103/56).

By S. B. Dasgupta & P. I. A. Narayanan.

(12) Beneficiation of low grade pyrite from Karwar, Ratnagiri Dist., Maharastra. (NML. IR. NO. 14/52).

By M. C. Sen, & P. I. A. Narayanan.

(13) Studies on beneficiation of a blended sample of pyrite from Saladipura Area by gravity methods.

By S. Biswas, L. Sahoo, P. K. Sinha, B. K. Paul, H. B. Barari & S. K. Banerjee. (IR. NO. 903/76).

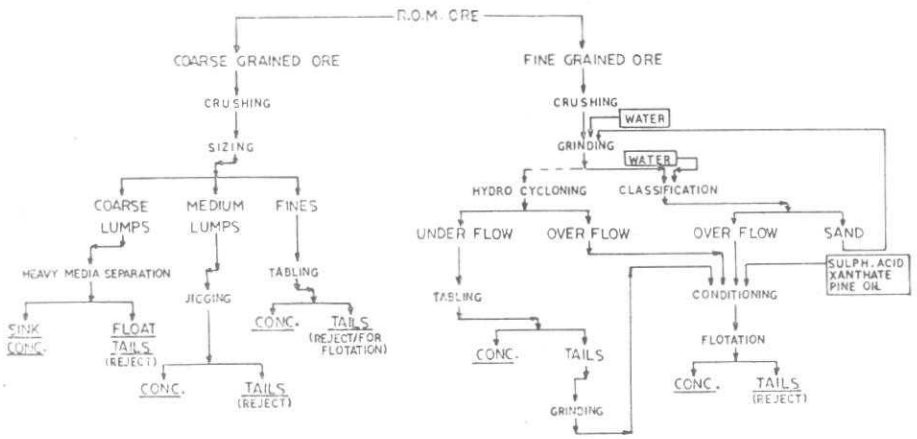

Fig 5.3-General Flowsheet for Beneficiation of pyrite-pyrrhotite Ores