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KING RIVER DELTA PROJECT
MACQUARIE HARBOUR TASMANIA

91-3227

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SUMMARY

New separatory tests on sediment characterising the inshore fifteenth of the King River Delta's total mass were completed during the year. Results advance understanding gained from similar tests Cities Service ran on bulk sample in 1975. That sample came from a single point on the Delta's exposed surface close to the river mouth, thus was not representative of the deposit's interior and offshore parts.

In new tests contents of Au, Ba, Co, Cu, Fe, and S were measured in products of four types of separation. Gold was segregated by leaching as well. Overall, the tests contribute another 140 assay figures to the total of several thousand obtained previously.

Size tests show that rejecting the coarser half of the Delta's inshore sediment allows about 85% of its sulphur, 75% of its gold and cobalt and 65% of its barium to be retained.

Sink fractions of heavy liquid separations, indicating elemental recovery rates obtainable with refined spiral or cone systems, confine about the same proportions of sulphur, gold and cobalt to 14% of the sediment's total mass; such concentrate runs some 20% S, 1% Ba, 0.5% Cu, 0.05% Co, and 0.55g/tAu.

The copper value, representing a recovery rate of, say, 45% is encouraging, nearly doubling percentages extracted in Cities' tests. At a final recovery rate of 40% the Delta would yield copper worth a minimum A\$ 187 000 000 at current price and exchange rate.

Sulphide flotation results show that given acceptable pre-concentrate as headfeed the technique splits Delta material effectively.

A 24-hour cyanide leach extracted about a quarter of the gold in sulphide flotation concentrate, and about half after concentrate was roasted. Thiourea recovered almost a third of the gold in 3 hours at about 45° C. From Scout tests alone, the results are promising.

Cottesloe is actively searching for qualified companies willing to take part in the Delta project. Of seven approached during the year, four refused.

Discussions with others continue.

At present overseas investors are reluctant to sink capital in ventures in Australia, while within it, local investors prefer opportunities on the mainland : these are considered less restrictive and of lower risk than the majority of projects in Tasmania.

Eleven more candidate companies have been identified and are to be visited soon should negotiations in progress come to naught. New candidates use sulphur in making fertilisers and other chemicals, or produce sulphides.

One possibility is to combine forces with west Tasmania mining companies generating waste pyrite. Treatment of this pyrite with that derived from the King River Delta could form the basis of an Australian sulphur production industry.

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Cottesloe Corporation commissioned additional lab study of samples from the licence area in 1989. During 1990 results were received. Work was carried out at Government's ore-dressing and analytical plant in Launceston.

Material examined comprises two composite samples prepared from sediment pumped from boreholes driven into upper parts of the easternmost or shoreward third of the King River Delta. Drilling was undertaken on behalf of Planet Resources NL of Melbourne by a contractor. Planet was at the time participating in the Delta project. A map showing location of the borehole appears at p8 of the previous annual report in this series, together with lists showing specific samples making up the composites.

In summary Composite KDY represents the uppermost layer of the Delta and Composite KDB that below it. These two layers form the Delta proper, involving none of the basal material, barren of mineral-bearing tailings, of which Layer 3 is partly and Layer 4 wholly composed. Lab numbers assigned to KDY and KDB are 900180 and 900181 respectively.

Five categories of tests were run, three physical and two chemical; notably sizing, separation in heavy liquid, concentration by shaking table, sulphide flotation and leaching.

Results of tests of the first two categories are shown in Table 1, those of the following pair in Table 2.

Overall results demonstrate that most useful components of Delta sediment are distributed unevenly with respect to masses of its coarser grained and masses of its lower density fractions. Useful components tend to be segregated in the fine-grained and higher density fractions. This implies that in dredging and treating Delta sediment a first stage or pre-concentrate may be produced mechanically, a fast inexpensive procedure.

Though this likelihood was recognised some time ago the new results contribute valuably in confirming it, and in providing numbers which have wider applicability than early data based on Cities Service's single-site sample. Comments on each of the five categories of test follow.

Size distribution

Inspection of the top two sets of figures in Table 1, those depicting elemental distribution with respect to particle size, reveals that-but for minor exceptions - contents of cobalt, gold, barium, iron and sulphur all increase as size of host sediment particles decreases. Copper duplicates this pattern at the lowest end of the particle size range, but amounts of it present increase progressively above, say, 50 to 100 microns.

A size/grade link is particularly evident in the case of cobalt and sulphur, two elements which distribution figures indicate occur together. Iron displays a similar pattern, indicating that cobalt and sulphur occur chiefly in pyrite. On the basis of past mineralogical work it appears most excess iron is resident in siderite, limonite and magnetite.

Distribution patterns of gold and barium also resemble each other though probably because of similarities in mode of occurrence rather than as a result of a genetic association.

In practical terms the sizing data show that <180-micron material, containing 46% of KDY's mass, retains 87.2% of its sulphur, 81.2% of its cobalt, 73% of its gold, 66.7% of its iron and 59.9% of its barium. For KDB's <125-micron material figures are : S, 80.8%, Co, 70.8%, Au, 70.1%, Ba, 63.4% Fe, 57.3% in 45.2 % of KDB's mass.

Comparing grade figures of KDY and KDB shows that all investigated elements except barium reach somewhat higher levels in KDY than in KDB. Increase in KDY relative to KDB are approximately these : Au 56%, Cu 19%, S 19%, Co 15%, Fe 9%. These numbers suggest the difference probably arises from selective removal of low density particles from upper horizon of that sector of the Delta drilled for Planet Resources, the sector now normally above sea level. Periodic flooding of the King River inundates the sector, stirring up top horizons and flushing out relatively light-weight grains. In dry weather, dust storms develop there, wind bearing away these grains. Percentage increases above roughly match densities of mineral species in which the various elements are likely to occur, gold-partly unlocked-in native state, copper partly in chalcopyrite, sulphur and cobalt in pyrite, iron partly in siderite.

TABLE I

A. Sizing

Reg. No 900180

Size Fraction	% Mass	Assays						Distribution %					
		g/t			%			Cu	Co	Au	Ba	Fe	S
		Cu	Co	Au	Ba	Fe	S						
+ 250µm	29.3	1834	26	0.10	0.18	4.35	0.59	31.4	10.0	19.0	20.7	16.8	5.2
-250µm + 180µm	24.7	1624	26	0.05	0.20	5.04	0.90	23.5	8.4	8.0	19.4	16.5	6.6
-180µm + 75µm	34.6	1477	103	0.23	0.27	9.55	5.15	30.0	46.7	51.6	36.7	43.8	53.2
- 75µm	11.4	2266	234	0.29	0.52	15.2	10.3	15.1	34.9	21.4	23.2	22.9	35.0
Calc. Head	100.0	(1708)	(76)	(0.15)	(0.25)	(7.56)	(3.35)	100.0	100.0	100.0	100.0	100.0	100.0
Assay Head		1699	77	0.21	0.26								

Reg. No 900181

Size Fraction	% Mass	Assays						Distribution %					
		g/t			%			Cu	Co	Au	Ba	Fe	S
		Cu	Co	Au	Ba	Fe	S						
+ 212µm	30.1	1670	38	0.05	0.19	5.88	0.66	35.5	17.3	13.9	20.3	25.5	7.1
-212µm + 125µm	24.7	1235	32	0.07	0.185	4.84	1.37	21.5	11.9	16.0	16.3	17.2	12.1
-125µm + 38µm	34.6	1155	94	0.14	0.32	7.91	4.68	28.1	49.1	44.7	39.3	39.4	57.9
- 38µm	10.6	1993	136	0.26	0.64	11.7	6.04	14.9	21.7	25.4	24.1	17.9	22.9
Calc. Head	100.0	(1419)	(66)	(0.11)	(0.28)	(6.94)	(2.80)	100.0	100.0	100.0	100.0	100.0	100.0
Assay Head		1425	67	0.12	0.28								

B. Heavy liquid separation

Reg. No 900180

Product	% Mass	Assays						Distribution %					
		g/t			%			Cu	Co	Au	Ba	Fe	S
		Cu	Co	Au	Ba	Fe	S						
H/L S/K	16.8	5107	502	0.55	0.75	32.1	21.10	47.6	85.6	73.4	50.2	67.0	89.4
H/L F/T	83.2	1131	17	0.04	0.15	3.20	0.51	52.4	14.4	26.6	49.8	33.0	10.6
Calc. Head	100.0	(1797)	(98)	(0.13)	(0.25)	(8.05)	(3.96)	100.0	100.0	100.0	100.0	100.0	100.0

Reg. No 900181

Product	% Mass	Assays						Distribution %					
		g/t			%			Cu	Co	Au	Ba	Fe	S
		Cu	Co	Au	Ba	Fe	S						
H/L S/K	12.2	5329	483	0.57	1.11	32.5	19.4	42.9	71.3	66.4	44.1	59.6	82.5
H/L F/T	87.8	983	27	0.04	0.195	3.06	0.57	57.1	28.7	33.6	55.9	40.4	17.5
Calc. Head	100.0	(1514)	(83)	(0.10)	(0.31)	(6.65)	(2.86)	100.0	100.0	100.0	100.0	100.0	100.0

Barium, believed to occur mainly in minute particles of barite, is known from previous studies by Aberdare/Elisna to reach its highest concentration in deep-water, offshore sectors of the Delta where sediment is finest grained. KDB material, forming the interior part of the Delta's shoreward sector, is the ancestral equivalent of sediments of to-day's deep water toe and submerged Delta face sampled by Aberdare. The KDB zone comprises successive foreset beds, progressively buried as the Delta has grown and topset beds, represented by KDY material, have advanced seaward over the zone.

Heavy liquid separation

Separations were made in TBE, SG 2.96. Results are near self explanatory and need little comment. Note that KDY contains about 37% more dense material than KDB, roughly what the explanation proposed above requires.

Note again the correspondance in distribution of cobalt and sulphur. The sink fraction, comprising one seventh the mass of KDY captures 89% of the sulphur and 85% of the cobalt. About one-eighth of KDB contains 82% of its sulphur and 71% of its cobalt. Sink fractions also collect two-thirds to three-quarters of gold in the composites.

Grade concentrations effected are noteworthy. Relative to head values in KDY and KDB, sulphur content rises 5.3 to 6.8 times, cobalt 5.1 to 5.8 times, gold 4.0 to 5.7 times, iron 4.0 to 4.9 times, Ba 2.5 to 3.6 times.

Copper contents of sinks rising 2.8 to 3.5 times to grades of about 0.5% Cu, imply recoveries of some 43 to 47½%, nearly double the unalluring 25% Cities' tests confined to gravity concentrates comprising a similar one-eighth to one-seventh of their spot samples total mass. As Cities calculated it could extract the Delta's copper profitably, even at that depressed recovery rate, gains apparent in these latest data clearly are significant. (In total the Delta contains at least 160,000 tons of copper. At a recovery rate of 40%, the current copper price of about US\$ 1.05/lb, an exchange rate of A\$ 1.00 = US\$ 0.79, this copper fraction is worth A\$ 187 000 000, minimum.)

Barium contents of sink fractions, indicating that pre-concentrate totalling a bare seventh of the Delta's sediment mass will run well over 1% barite deserve mention too. Ultra fine water-ground barite, which Delta barite resembles, commands a price of about US\$ 150/tonne.

Table concentration

Results of these tests should show and do resemble those of heavy liquid separations. Examining the figures shows table concentrates give grades which for Co, Au, Ba, Fe, and S nearly all exceed those of heavy liquid sink fractions, primarily because the concentrates represent smaller percentages of the composites, more exclusive in composition. However this reduction in mass results in proportions of the six target elements recovered being lower than those attained by heavy liquid separation. Differences are reduced if recoveries represented by table middlings are combined with those of table concentrates; but this increases mass involved to levels well beyond those of corresponding sink fractions.

Deficiencies in table concentration figures relative to those of heavy liquid separations commonly result from entrainment, electrostatic locking, and comparatively slow, erratic response of individual particles to table motion.

In full-scale gravity plant these limitations can be overcome so that degrees of separation approximating those obtained employing heavy liquids occur. The main steps required are prior screening, magnetic and electrostatic separation, then use of banks of cones or spirals and, last, re-circulation of various products of roughing stages through cleaning circuits. (Heavy liquid results of table 1 could be similarly improved if closer estimates of pre-concentrate recovery rates ultimately obtainable become needed)

Flotation

Tests were run on the two table concentrates discussed above. Limited recoveries inherent in those concentrates then were carried over into the flotation tests, in turn distorting results from them. This should be borne in mind in reviewing Table 2 flotation data. At commercial scale substantial percentages of the elements here remaining in table middlings and tailings would report to pre-concentrate, permitting greater fractions of Delta sediment's total sulphide to be recovered in the subsequent, flotation step.

This consideration apart, flotation results of Table 2 demonstrate once more that most valuable elements respond well to such a second phase of concentration, with over 85% of the pyritic component, some 70% of the cobalt, and 55% to 60% of the gold being confined to about one-twelfth of headfeed.

Virtually all barite and non-sulphidic ferruginous heavy minerals are isolated in flotation tailings, together with approximately 70% of the copper.

TABLE 2

A. Table concentration

Reg. No 900180

Product	% Mass	Assays						Distribution %					
		g/t											
		Cu	Co	Au	Ba	Fe	S	Cu	Co	Au	Ba	Fe	S
T C	10.7	3418	570	0.88	0.63	29.9	25.2	20.5	69.1	41.8	27.3	42.4	78.8
T M	15.6	1955	56	0.13	0.27	7.27	1.42	17.2	10.0	9.0	17.2	15.1	6.5
T T	73.7	1505	25	0.15	0.185	4.34	0.68	62.3	20.9	49.2	55.5	42.5	14.7
Calc. Head	100.0	(1779)	(88)	(0.22)	(0.25)	(7.52)	(3.41)	100.0	100.0	100.0	100.0	100.0	100.0

Reg. No 900181

Product	% Mass	Assays						Distribution %					
		g/t											
		Cu	Co	Au	Ba	Fe	S	Cu	Co	Au	Ba	Fe	S
T C	5.0	3803	834	1.17	1.25	40.0	37.0	13.4	55.4	48.1	23.2	31.1	67.2
T M	17.9	1991	65	0.09	0.30	7.99	1.59	25.4	15.6	13.4	20.2	22.4	10.5
T T	77.1	1116	28	0.06	0.195	3.85	0.79	61.2	29.0	38.5	56.6	46.5	22.3
Calc. Head	100.0	(1406)	(75)	(0.12)	(0.27)	(6.38)	(2.72)	100.0	100.0	100.0	100.0	100.0	100.0

B. Sulphide flotation

Reg. No	Plant	Product	% Mass	Assays						% Distribution					
				Cu%	Co%	Au g/t	Ba g/t	Fe %	S %	Cu	Co	Au	Ba	Fe	S
900180	F.F.	Flot. Conc.	8.74	0.67	0.079	0.95	770	33.7	36.3	11.4	79.3	56.5	2.7	40.7	89.2
		Flot. Tails	91.26	0.14	0.002	0.07	2700	4.7	0.42	48.4	20.7	43.5	97.3	59.3	10.8
		Calculated Head	100.0	(0.19)	(0.002)	(0.15)	(3530)	(7.2)	(3.6)	100.0	100.0	100.0	100.0	100.0	100.0
		Assay Head		0.19	0.010		2600	7.5	3.7						
900181	F.F.	Flot. Conc.	7.29	0.67	0.069	0.71	1050	31.2	33.4	28.9	64.1	58.3	2.8	36.2	87.1
		Flot. Tails	92.71	0.13	0.003	0.04	2700	4.32	0.39	71.1	35.9	41.7	97.2	63.8	12.9
		Calculated Head	100.0	(0.17)	(0.003)	(0.09)	(2770)	(6.3)	(2.80)	100.0	100.0	100.0	100.0	100.0	100.0
		Assay Head		0.16	0.008		2800	6.6	2.82						

Copper in the latter fractions is believed to exist mainly in the form of fine sulphide films of secondary origin, deposited indiscriminately on both dense and low density particles of all Delta sediment. It should be possible to strip much of this copper quickly, at low cost, by heap leaching flotation tailings. The other 30% would be extracted with cobalt and gold in smelting sulphide flotation concentrate.

Leaching

Tests run so far have focused on recovery of the sulphide flotation concentrate's gold alone.

Several tests were made, one set employing cyanide, the other thiourea which-unlike the former-is considered safe, both to plant operators and the environment in general. Results appear in Table 3.

The first cyanide leach, run for 24 hours at room temperature on 50% solids with 0.2% NaCN and 0.6% CaO extracted approximately one-quarter of the gold present.

The second test was run on roasted sulphide, for a like period, also at room temperature, with 0.4% NaCN and 1.2% CaO. This extracted a third of the gold present in sulphides of composite KDY, and half that in sulphides of KDB.

The first thiourea leach, run at room temperature for 5 hours, recovered only 7.7% and 3.3% of gold present in KDY and KDB, respectively.

The second, run for three hours at 45°C, gave better results, extracting 26% of the gold from KDY and 38% of gold in KDB : specifications, 750ml water, 30g sample, 20g/l H_2CSNH_2 , 4.6g/l H_2SO_4 , 6.0 g/l $CuSO_4.5H_2O$.

Tests of the five categories discussed were well run, lucidly presented and, within limitations of procedures designed and required by Cottessloe, appear accurate. Results are consistent : calculated grades closely match those arrived at by direct assay. Lab and staff responsible are to be complimented.

TABLE 3 Extraction of gold from sulphide flotation concentrate

	KDY	KDB	AVG
Deltasediment, g/tAu			
Assay head	0.21	0.12	0.165
Avg of 4 calculated heads	0.165	0.105	0.135
Probable head	0.17	0.11	0.14
Sulphide flotation concentrate			
Fractional head mass, %	8.74	7.29	8.01
Flot tail, g/t Au	0.07	0.04	0.055
Flot.con,g/tAu	0.95	0.71	0.83
Au distribution in flot.con,%	56.5	58.3	57.4
Cyanide leach,% of flot.con.gold extracted			
Unroast concentrate	27.5	24.5	26.0
Roast concentrate	36.8	52.0	44.4
Thiourea leach, % of flot.con.gold extracted			
Method A	7.7	3.3	5.5
Method B	26.1	38.1	32.1

Elemental sulphur recoverable from the Delta's 5 000 000 to 7 000 000 tonnes of pyrite remains the major asset of the deposit.

Without reserves of brimstone and without natural gas high in H₂S from which elemental sulphur can be derived, the Commonwealth, along with every other Australasian country, has to meet needs by importing the commodity from Canada.

Table 4 lists sulphur imports and the value of each.

As Frasch reserves in the U.S dwindled, as oil and gas costs involved in superheating steam required by the process rose, and as costs of producing sourgas feedstock increased, sulphur prices soared. Reference to the table shows the average cost per tonne in 1986 is 750% above the 1974 figure.

Long term, sulphur prices are likely to continue this ascent. The search for new reserves of sourgas generally calls for deeper and deeper drilling. Second, freight charges continue to rise as vessel and fuel costs climb. Trans-Pacific shipment charges are substantial.

The obvious step is to produce elemental sulphur in Australia, first for the Nation's own needs, then for export to neighbouring countries. The former step would reduce overseas spending : the latter would generate foreign earnings.

Technology to recover sulphur from pyrite is well established and was used in Europe, profitably, for decades. Joint output of the two largest plants, in Norway and Finland, amounted to over 200 000 tonnes per annum, the equivalent of about half the quantity Australia imports from North America each year. (Details of the pair of procedures employed are given in the 1989/90 Annual Report on R 8804)

Australia's base and precious metal mines yield tens of thousands of tonnes of pyrite annually and did so in the past as well. Some of the pyrite is converted into acid, but the bulk goes to tailing dumps and slime dams. In other cases it is disposed of underground, backfilling stopes.

TABLE 4 AUSTRALIA'S SULPHUR IMPORTS

YEAR	TONNES	VALUE A\$'000	A\$/TONNE
1974	685,282	14,451	21.09
1975	281,757	7,534	
1976	205,757	7,408	
1977	407,675	12,873	
1978	496,804	16,042	
1979	436,221	19,042	
1980	686,865	45,710	
1981	555,517	42,807	
1982	458,774	38,925	
1983	392,581	32,930	
1984	470,495	39,642	
1985	392,940	57,863	
1986	394,101	70,559	179.04

Source : BMR's Annual Mineral Industry Reviews
1977,1980,1983,1986.

Given domestic, NZ and Asian demands for elemental sulphur, the existence of proven ways of extracting it from pyrite economically and, third, availability of pyritic concentrate - essentially free of cost - in dumps and in tailings from operating treatment plants, Australia's continued purchase of sulphur abroad is senseless, foreign spending that is wholly unnecessary. Sulphur should be produced from waste pyrite in Australia.

Pyrite of Tasmanian origin could form the basis of such an industry. A joint venture with Cottesloe by West Coast mining companies producing pyritic tailings would be a logical start. Resultant production would be considerably greater than that from the Delta alone, and establishing a single, centralised processing plant, would permit economies of scale to be realised.

As Cottesloe determined previously, sulphur recovered from Delta pyrite is sufficient to meet 10 to 15% of Australia's likely annual demand for the next twenty years. With input of additional pyrite from Mt Lyell, Rosebery, Hellyer and Que River it should be possible to meet about half to two-thirds of Australia's yearly requirement.

Participants with additional mines in other states should be able to build on the Tasmanian industry projected, constructing similar sulphur recovery units on the mainland - at Broken Hill for instance.

Cottesloe is presently assembling data on all Australian pyrite reserves of size, with an eye to further leasing. Possibly some mainland reserve may prove superior to the Delta deposit, because of size, contents of possible byproducts, lower royalties, proximity to markets and energy sources, or other factors.

With reference to sulphur technology, Cottesloe has been in contact with a state-run Polish company, Chemadex. Chemadex develops and builds processing plant and has been doing so, with apparent success for over thirty years. Approximately a quarter of the 100 projects undertaken to date concern production or treatment of sulphur compounds. Sixteen involve treatment of pyrite specifically. Plants constructed treat up to 360,000 mty.

Cottesloe's particular interest lies in high temperature cyclonic furnaces Chemadex designed and now manufactures. Unlike standard fluidised-bed furnaces the Chemadex variety handle very fine-grained pyrite. For equivalent throughput the latter are much smaller and lighter in weight, thus less expensive to build, transport, mount,

and house. Allegedly they cost less to operate too.

In present form the furnaces yield SO₂ gas, but work is underway on modifications which will allow half the sulphur in feedstock to be recovered in elemental state, as it is in the Outokumpu process discussed in our report last year.

The Chemadex furnaces also yield clean, high grade iron oxide cinder. Non-ferrous metals may be recovered from a vapour phase and from slimes resulting from downstream treatment of another furnace byproduct.

Chemadex' description of one of these furnaces and the way in which it operates is attached to this report as an appendix.

Two of the Company's biggest furnaces, type NPC 1800, would handle all Delta pyrite production, anticipated to be between 250 000 and 300 000 tonnes per year. These units currently cost approximately A\$ 450 000 apiece.

Co-product iron oxide from a west coast pyrite treatment centre possibly could be absorbed by Savage River Mines to supplement its waning reserves. In an example cited by Chemadex, cinder produced from a pyritic charge of fairly typical composition runs 66% combined iron oxides and 0.8% S, probably suitable for addition to and dilution by Savage River concentrate. This concentrate assays 68.0 Fe and 0.08% S.

Cottesloe and several agents appointed for the purpose continued efforts in North America, Britain, Australia and elsewhere to locate qualified companies willing to join the Delta venture. Seven were approached.

Four of these, specifically a large mining house headquartered in Canada, a French oil company, a SE Asian alluvial minerals group and a New Zealand gold dredging company ultimately declined to participate.

Discussions continue with each of the remaining three, an American sulphur producer, a major international chemicals company, and a US/Australian investment group with mining interests.

Technical merits of the Delta enterprise are accepted by almost every company examining the data and concept. However the risk of possible opposition to the project by Tasmania's more militant environmentalists proves, repeatedly, to rank as a deterrent. Potential participants concede that mining the Delta, removing its toxic components and redistributing cleaned sand and silt on the floor of Macquarie will indeed reverse the devastation caused by Lyell's accumulated spoil and thus benefit the environment. However the view persists that the environmental lobby, assessing all mining and other industrial grounds on emotional rather than rational grounds, would oppose the project. Attitudes towards such a project in mainland states are considered less unreasonable, less groundlessly obstructive.

Other factors discouraging participation in the enterprise are tax and royalty levels, interest rates applicable in financing capital construction, and the present state of Australia's economy. At the moment, greater returns on available capital can be obtained via investment in fixed deposit accounts at banks than are likely to result from investment in start-up projects in which initial pay-out generally lies some years ahead.

In summary, ventures outside Australia, and Tasmania in particular, are considered more enticing.

- On the technical front several more tests are to be run.
- . Sink products of the TBE separations or, if insufficient quantities remain, of new such separations will be
 - analysed for contents of Ag, As, Bi, Ce, Cd, Cr, Mo, Ni, Pb, Sb, Se, Zn, and LOI
 - sized
 - . Both latter two steps, the analyses and sizing, will be repeated on sulphide flotation concentrate.
 - . A bulk sample of Delta sulphide will be prepared.
 - . Hydrometallurgical means of recovering elemental sulphur from Delta pyrite will be investigated. A small research firm in Canada claims to have devised and is perfecting a process of this nature. Pyrite is broken down bacterially.

In continuing the search for suitable partners with whom to develop and exploit the Delta deposit Cottesloe is focusing on four groups.

The first comprises those three organisations mentioned previously with which discussions are in process. The chemicals member of this trio is one of the leading consumers of Australia's imported sulphur, manufacturing and marketing fertilisers. It has branches in NZ and the Far East and thus is well set up to export surplus sulphur which may be produced domestically.

Companies with west Tasmanian plants yielding waste pyrite constitute an additional target, perhaps together with Savage River. Mines/Cleveland Cliffs.

Two other fertiliser companies on the mainland and one based in the UK comprise a third group of potential partners.

The fourth includes four US chemical companies, and a German one : all have operating branches in Australia.

Appendix

020



A 1

DESIGNER AND SUPPLIER OF
COMPLETE PLANTS

399021

CHEMADEX

KRAKÓW

TENDER

for Cottlesloe Corporation Princetown
New Jersey in scope of the cyclone
furnaces for pyrite combustion

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1. SUBJECT OF TENDER

Fulfilling the intention of the received letter of inquiry dated the 10th may 1990 we offer our experience and know-how in a field of the pyrite combustion in a cyclone furnace together with a production of the process gas containing SO_2 in a shape which enables a production of e.g. sulfuric acid as well as the iron oxide alloy in a shape of liquid. This liquid alloy can be granulated or can be designed for a processing in which copper and other valuable components can be recovered.

In accordance with Your letter of inquiry we offer :

- a/ delivery of the cyclone furnace itself,
- b/ delivery of the complete plant necessary for the pyrite combustion and metal recovery,
- c/ elaboration of the technical report in which the results of Cottlesloe pyrite tests together with a kind of products and an outlay analysis are given,
- d/ working out of a base or technical design and the essential equipment for the complete plant delivery,
- e/ common building of the pilot plant and common tests.

2. INTRODUCTION

"CHEMADEX" enterprise from many years develope an activity in a field of the pyrite combustion improvement. The great achievement is an elaboration of the plant for a production of the sulfuric acid using the post-flotation pyrite burned in the cyclone furnace. As a result of this burning process one obtains also the iron oxide alloy in the shape of liquid.

The scheme of such plant is shown in a figure enclosed.

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In order to put this new process into practice the small plant provided with the cyclone furnace for a production of SO₂ containing process gas and a granulated iron oxide alloy as well as the dusts containing vapors of non-ferrous metals was builded.

3. CYCLONE FURNACE ASSIGNMENT

The cyclone furnace is designed for combustion of the post-flo-tation pyrites which are characterized by grains with the considerable size reduction and a substantial content of various non-ferrous metals.

The pyrite granularity should be contained in the following limits:

grain with diameter 2,0	-	0,2 mm in amount max	1,0 - 3,0%
0,2	-	0,03mm in amount max	15,0 - 20,0%
0,03	-	0,00mm in amount max	70,0 - 80,0%

chemical composition of pyrite :

org. S	39,0 - 49,0%
Zn	0,0 - 1,0%
Pb	0,0 - 2,0%
Cu	0,0 - 1,0%
As	0,0 - 6,0%

The remainder : others

The cyclone furnace can be employed for a partial burning of the pyrite cinders which are waste obtained during the pyrite combustion process realized in fluidized furnaces.

As a result of a process realized according to the "CHEMADEX s" technology of production one obtains the process gas which contains SO₂ in amount above 1%. This amount of sulfur dioxide is sufficient for ensuring the dipping acid production.

During the pyrite combustion process realized in a cyclone fur-

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nance the nitric oxides are formed. This nitric oxides in conversion on NO_2 amount altogether to about 15 mg/m^3 . In a slightly acidified water circulating in a scrubber about 50% of NO_2 will dissolve whereas the remainder amount of NO_2 will get together with a gas to a drying-absorption system. If the whole of produced sulfuric acid will be designed for a fertilizer production - such an amount of NO_2 is of no importance. However if this acid is designed for other purposes - NO_2 has to be taken out with a drying tower system. Then it is necessary to establish the acid circulations by this means that a transfer of a drying acid into the absorption tower is impossible. In this case an acid with concentration 93 - 95%, obtained from a drying tower, contains the whole of the nitrogen dioxide and can be used successfully for a fertilizer production. On the other hand the pure acid with concentration 98,5%, obtained from the absorption process, can be used for other purposes.

We anticipate to elaborate in the year 1991 the elementary sulphur production technology instead of a H_2SO_4 production.

4. DESCRIPTION OF TYPE NPC/RZ 1800/1200 x 2C CYCLONE FURNACE CONSTRUCTION

The cyclone furnace consists of the following principal components: a cyclone chamber, the reaction cyclones and a separation chamber.

The scheme of a cyclone furnace is shown in the Fig. 1.

The cyclone chamber 1

1/ is provided with the outlet connector pipe 2

2/ designed for taking in a heated air; the inlet connector pipe is situated in the middle of a chamber length and tangen-

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tially to its circumference:

Under this connector pipe there is situated the connector pipe 3 for the gap type burner provided with an igniter and adapted to the combustion of a fuel in a suitable form. During this process which carries on at temperature up to 1473°K and with a considerable rapidity there a slight amount of the nitric oxide is formed. The cyclone chamber is provided with the shaped outlets which are situated on the opposite flat walls. This outlets lead into the two reaction cyclones 4. Cylindrical parts of this reaction cyclones adjoin to the ends of the cyclone chamber.

In the middle of the reaction cyclone cover there are situated the pipes 5 supplying a crumbled raw material. At their outlets there are situated concentric compression chambers connected with the connector pipes to the air at an increased pressure. Owing to this construction the descending direction of a raw material displacement in the reaction chambers is ensured.

The vertical axis of the cyclone chamber is displaced in relation to the vertical axes of the reaction cyclones thereby the flowing gas is blown along the tangential line into the reaction cyclones gathering a vortex motion in the same time. The swirling gas stream carries the dispersed pyrite away and during a descending vortex motion a fusion of the pyrite particles and throwing them away take place on the reaction cyclone walls. The liquid alloy flows down the walls under its weight and in accordance with a gas flow direction.

At the end of a tapered cone of the cyclone there is an oval opening which is situated on ends of the separation chamber 6 for each reaction cyclone respectively. This separation chamber has a shape of a horizontal cylinder. In the middle of its length

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this chamber is provided with the connector pipe 7 for the liquid alloy drainage situated in the bottom part and with the gas outlet connector pipe 8 situated in the upper part of chamber. The whole furnace is provided with the manholes and the measuring connector pipes. The furnace has a steel construction. The furnace for low capacities is constructed from a water jacket which is pinned inside and to which a lining is stuck. The furnace for higher capacities has the tube construction similar to the hermetic waterwalls construction designed for power boilers. This tube construction is pinned inside too. The tube construction affords possibilities for a production under any pressure. The particular principal components of the cyclone furnace are manufactured separately and a partitioning is so designed that a suitable flow of a cooling water is ensured.

5. DESCRIPTION OF PYRITE COMBUSTION TECHNOLOGICAL PROCESS REALIZED IN CYCLONE FURNACE

The set of the process devices designed for a pyrite roasting with a simultaneous production of a gas containing SO_2 comprises the type NPC/RZ cyclone furnace, the cooling gas piping 9 and a multifunctional fluidized cooler 10 showed in Fig. 1. The process starts from a supplying with the atmospheric air by means of a compressing blower 11. This air flows through coils of a preheater which is situated in the fluidized bed of the cooler 10. The preheated air flows into the bottom heater and next into the tube heater and warms up to a temperature $873^{\circ}K$ - $1023^{\circ}K$.

Air heated in such a way is supplied into the cyclone chamber by means of the gas piping 12. In this chamber a further heating

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of a gas is achieved through a combustion of an additional fuel. The swirling mixture of an air and combustion gases reaches the temperature above 1273°K and is supplied along a tangential line into two reaction cyclones. In the same time the pyrite is pouring through an opening⁵. The streams of hot combustion gases carry the pyrite away and initiate the essential reaction which result is a production of a gas containing SO_2 .

This process is a two-stage process. In the beginning it runs as a dissociation of FeS_2 and next as an oxidation of Fe and S_2 . In this stage the process relevant to a burning of sulphur from the sulfides of non-ferrous metals also occurs which causes their evaporation. As a result of this process occurring at a temperature about 2073°K the fused iron oxides and a gas containing vapours of non-ferrous metals as well as their oxides are obtained. The vortex motion of a gas causes a deposition of the alloy droplets on the cyclone wall and a flow down into the separation chamber 6 where a separation of the droplets from a gas takes place. The separated alloy is supplied from the separation chamber 6 into a granulating device and a gas is supplied into the fluidized cooler 10.

On the way a gas is cooled in a gas piping 9 and then it is supplied into the chamber 12 and through the nozzles into the fluidized bed.

This gas includes the droplets of the iron oxide alloy, the vapours of non-ferrous metal oxides and SO_2 .

The fluidized bed consists in part from the quartz sand and in part from the particles of the congealed iron oxide alloy as well as the liquefied molecules of the non-ferrous metal oxides. The increasing in thickness fluidized layer is drained off through the

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connector pipe 13 and makes a dusty product which contains about 40% of the non-ferrous metals. The gas cooled to a temperature about 400°C flows through the connector pipe into a cleaning and washing complex. The proposed process of a H_2SO_4 production is showed in the scheme enclosed.

The above mentioned process provides a wet system of the gas cleaning and the gas cooling together with taking out of the slimes which are rich in non-ferrous metals.

Afterwards the gas is processed by means of a double catalysis system and in the absorption complex takes place the production of the 94,5 - 98,5% sulfuric acid. The production technology and the apparatuses of the sulfuric acid production complex represent the highest achievements of the world engineering and ensure an easy and complete operation.

Realized in the above mentioned way the fusing process of the pyrite containing 39 - 49% of total S and 5 - 0,0% of a moisture is characterized by the following parameters :

Combustion temperature $T = 1870^{\circ}\text{K}$

Rate of the pyrite combustion in the type NPC/RZ/1800/1200 x 2C furnace respectively:

$Q = 17,1 \text{ t/h} - 20,0 \text{ t/h}$ /referred to dry pyrite/

Fuel consumption per kg of dry pyrite:

$W = 737,6 \text{ kcal/kg} - 13,4 \text{ kcal/kg}$ depending on a sulphur content

Production of a vapour at pressure e.g. $p_n = 7 \text{ kG/cm}^2$:

$P = 32,6 \text{ t/h} - 37,5 \text{ t/h}$

Air quantity : $V_p = 40,000 \text{ Nm}^3/\text{h}$

Pressure drop with a gas flow in a furnace : $p = 1600 \text{ mm H}_2\text{O}$

Content of SO_2 in a dry gas :

$S = 11,0\% - 15,5\%$

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Production of an iron oxide alloy :

$Q = 12,3 \text{ t/h} - 12,9 \text{ t/h}$

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Production of a dry concentrate of non-ferrous metal dusts :

$K = 400 \text{ kg/h} - 500 \text{ kg/h}$ with a non-ferrous metal content depending on their content in a pyrite.

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Content of a total sulphur in an iron oxide alloy is smaller than 0,8%.

Sulfur acid with a concentration 94,5 - 98,5%.

6. ADVANTAGES AND EFFECTS OF "CHEMADEX'S" PROCESSING USE

The new manufacturing process of the pyrite combustion realized in a cyclone furnace was developed for a plant with capacity 20 tons of pyrite per hour. Such unit can be used as a modernization of the existing appropriate fluidized units and simultaneously can be easily compared from the point of view of the running parameters which characterized two kinds of the process technology and of the investment cost estimation.

When comparing the investment costs for the discussed unit, a comparison of the basic values looks as follows:

Fluidized furnace - dimensions : $Dz = 13,0 \text{ m}, H = 15,0 \text{ m}, Q = 480,0 \text{ t}$

Cyclone furnace - dimensions : $3,0 \times 5,0 \text{ m}, H = 6,3 \text{ m}, Q = 45,0 \text{ t}$

A small weight of the cyclone furnace causes both a considerable saving of its investment costs and reducing its building and assembly costs. In general the investment costs in the "CHEMADEX s" cyclone process compared with the investment cost of the fluidized process are lower by 10 - 20% depending on an expected way of a product preparation i.e. if the iron oxide alloy is granulated or is received in a shape of liquid and if concentrate of liquefied molecules of the non-ferrous metal oxides is received

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in a form of a dust or a slime.

The main advantages and effects are obtained in the following elements of the manufacturing process.

The permanent decrease of the dimensions of the flotation pyrite molecules related to the flotation process development is conducive to an intensification of the "CHEMADEX s" process and owing to this fact the above mentioned process ensures the utilization of dusty flotation pyrites manufactured at present and in future. This feature eliminates the problems connected with the negative results of the dusty pyrite use in the fluidized processes.

The use of the multifunctional fluidized cooler eliminates the necessity of using a waste-heat boiler which is sensitive to a content of the arsenic, zinc and lead intensifying a coating of the vapour pipes with dusts. In the fluidized cooler the tubes of the superheater evaporators are immersed in the fluidized bed. Due to this immersion there occurs a permanent cleaning of tubes and the liquefying dusts do not impend over the continuous work of the cooler. The immersion of tubes which receive heat from the fluidized bed is the solution which is seven times as intensive than a system used in a waste-heat boiler.

The "CHEMADEX 's" cyclone process gives furthermore the effects in a form of dust and slime obtainment. These dusts and slime include non-ferrous metals in the amount dependent on their content in the pyrite and by the way the all non-ferrous metals excluding Cu and 20 - 30% of zinc contained in the pyrite are recovered altogether.

Dusts appear under the various forms, most often as the oxides and also as the sulfides and the sulfates. The dust received

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in a dry form can be used in a fire bridge process or in Dorschl furnace whereas slimes which are richer in the selenium can be used in the hydrometallurgy processes.

Instead of the dusty cinder pyrites produced in the fluidized process, from a cyclone furnace flows out the liquid iron oxide alloy which chemical composition depends on the composition of a pyrite. In our case the alloy will contain total S in max. amount 0,8% and $\text{Fe}_3\text{O}_4 + \text{Fe}_2\text{O}_3 + \text{FeO} = 66,7\%$ while in the case of pyrites which are richer in FeS_2 a content of the iron oxides can be as high as 92,0%.

Depending on the purpose and local conditions the alloy can be produced in a form of granules in an appropriate crystallizer in which the size of the most often obtained granules having a diameter 1 - 5 mm can be regulated. The granules of the alloy can be designed for the utilization in metallurgy as 5 - 10% addition to a sintered ore. It can be also a sintered product received in a liquid form and subjected to the necessary metallurgical processes. The produced dry gas contains 11,1% of SO_2 and the drops of the iron oxide alloy in the amount as low as 5 g/Nm³ which considerably simplifies a gas cleaning system and, owing to the minimum oxygen content, restricts a SO_3 forming.

The "CHEMADEX's" cyclone process allows to utilize the cinder pyrite from a fluidization process by adding them in an amount 10-20% to the pyrite containing the total S above 45% with a maintenance of normal parameters of the SO_2 production and ensuring the normal production of H_2SO_4 .

The use of the "CHEMADEX's" cyclone process allows to achieve the production costs on the same level as in the fluidization process however the total profit is higher by 33% due to a sale of the iron oxide alloy in amount 551 kg/t H_2SO_4 and the dust containing 44% of non-ferrous metals in amount 19 kg/t H_2SO_4 .

7. PROCESSING OF IRON OXIDE ALLOY

The employment of the cyclone furnace for the pyrite roasting enables to use of the iron oxide alloy processing which is the most economical among such production technologies in use to-day. As a result of this processing one obtains:

- metallic copper - bearing alloy
- inoculated cast iron
- residuary slag
- dusts

The alloy processing consists in using of a metallurgical process in order to attain a separation of copper and non-ferrous metals by the directly employment of the single-stage and better the two-stage reduction of the liquid oxide alloy in the electric furnaces. This oxide alloy in a shape of liquid is drained off continuously from the cyclone furnace into the arc-resistance furnace and is exposed to the reduction during adding of a limestone and a quick-coke.

A consumption of the electric energy necessary for a temperature maintenance is 20-40 kWh/t.

The metallic alloy obtained from a electrical furnace in the amount about 8% of the iron oxide alloy supplied contains about 80% of copper and silver included in the supplied alloy. This alloy is considered as a high quality copper-bearing raw material for the copper-works. As a result of the mentioned processing one obtains a dust too. This dust obtained in the amount 1,5% of the iron oxide alloy supplied e.g. up to a contents of 5% Zn, 3% As, 0,8% Cu, and 1,5% S and can be designed together with the dusts from the flui-

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dized cooler for the processing with other metals. A slag containing 55-58% of iron, which includes the minimum amount of Zn and As can be used as an addition to an iron ore for the ironworks or can be exposed to the reduction in the second stage of the processing realized in an electrical furnace.

The electrical energy consumption in this furnace is 70-100kWh/t and a limestone as well as a quick-coke is used. The product obtained from the second stage is a slag containing up to 0,12% Cu and can be cast or granulated.

The metallic alloy containing up to 0,001% As, 0,04% Zn, 0,08% S, 0,68% Cu is drained off periodically and formed as the ingots designed for a inoculated cast iron production. The above mentioned of the metal recovery from the alloy has a general feature consisting in the utilization of the iron oxide alloy in a shape of liquid. This eliminates the use of a fuel necessary for fusion of that alloy.

8. OFFERED SIZES OF CYCLONE FURNACES

The sizes of the cyclone furnace can be worked out or selected for any quantity of the pyrite in limits from 2,4 t/h to 60,0 t/h. However we offer the following standard sizes of the furnaces :

a/ type NPC/800 x 2G/500 cyclone furnace

capacity V - 2,4 tons of pyrite per hour

dimensions : height h = 1,600 m, width 0,8 x 1,2 m

b/ type NPC/1500 x 2G/1000 cyclone furnace with a shell

for a vapour production capacity

capacity = 13,0 t/h pyrite

dimensions h = 4,8 m, width 2,0 x 4,0

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c/ type NPC/1800 x 2C/1200 cyclone furnace with a shell for a vapour production capacity $V = 20,0$ t/h of pyrite dimensions $h = 6,3$ m , width $3,0 \times 5,0$ m

9. RESEARCH AND TESTS

If after delivering of the informations You will see that our tender is interesting, we offer the further co-operation in order to state the parameters and the production technology necessary for Your raw material precisely and to direct of the utilization of the product obtained.

To-day we have a pilot plant which capacity is 2 tons of pyrite per hour.

The performing of the complete tests necessary for a determination of the final production technology needs about 70 hours of the plant operation. Taking into consideration appreciable costs connected with this operation we propose to realize the previous stage as follows : the elaboration of a technical report with regard to the simulated laboratory tests as well as the selection of the parameters of the process technology.

In order to realize this job we have to receive the following data :

- physical and chemical composition of the pyrite,
- size distribution,
- intentions or possibilities of waste processing,
- form in which this waste should be produced.

Depending on a range and a quantity of the measurements the costs of a technical report will amount about 50,000 USD.

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The further co-operation can e.g. consists in a building of a pilot plant in Your works with simultaneous conclusion of the agreement about the mutual co-operation or in another jointly agreed form.

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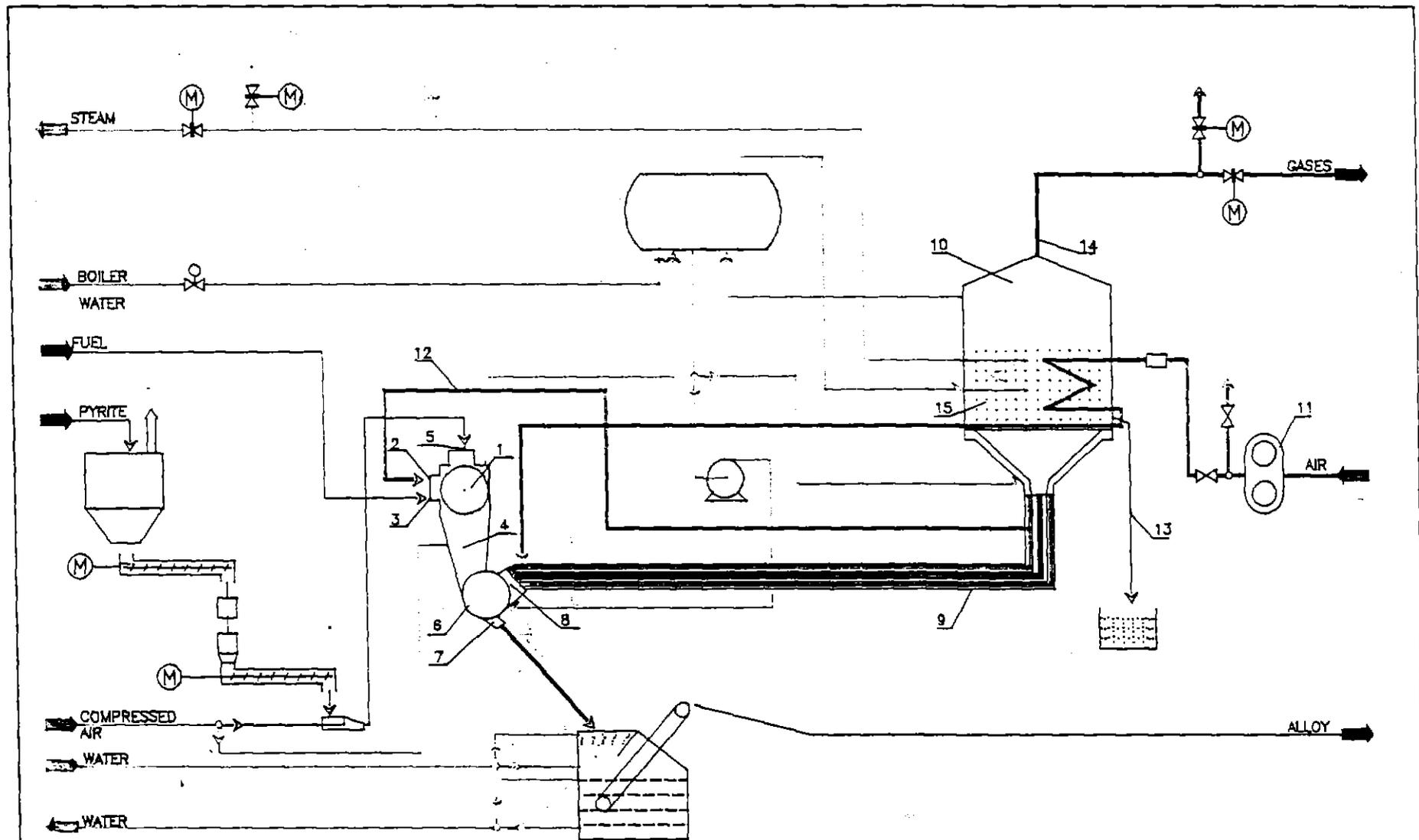
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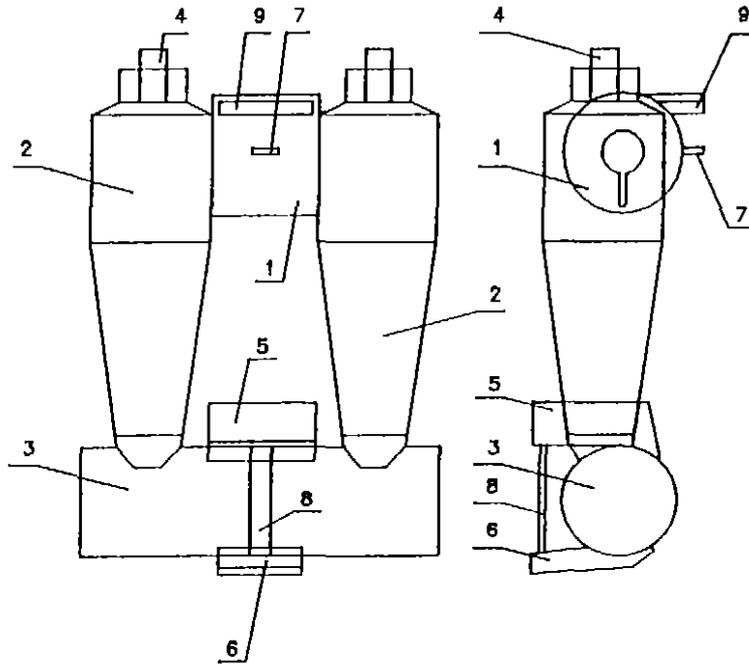
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	OPRACOWAL	DATA	PILOT PLANT FOR ROASTING OF PYRITE IN CYCLONE FURNACE WITH ALLOY GRANULATION	
	J.Malinowski	1987.08		
	Nr. oprac.	12651 - 1	A4	Ark. Ark.



- 1 - BURNING CHAMBER
- 2 - REACTION CHAMBER
- 3 - SEPARATION CHAMBER
- 4 - FEEDING PIPE
- 5 - OUTLET OF POST-REACTION GASES
- 6 - OUTLET OF LIQUID ALLOY
- 7 - BURNER
- 8 - DECOMPRESSION PIPE
- 9 - AIR NOZZLE

	OPRACOWAL	DATA	CYCLONE FURNACE		A4	Ark. Ark.
	J.MALINOWSKI	90.06	Nr. oprac.	12651-2		



REFERENCES OF CHEMADEX

No	Specification	Country	Capacity MT/year	Start-up or delivery year
1.	Deystuff Complex ISMAILA	EGYPT	3,600	1957
2.	Phosphorite enrichment plant M'DILLA	TUNISIA	250,000	1967
3.	Phosphorite enrichment plant METALOUI	TUNISIA	300,000	1967
4.	Phthalic anhydride condensation plant PAPKESZI	HUNGARY	2,000	1967
5.	Formalin plant NOVI SAD	YUGOSLAVIA	10,000	1967
6.	Ethyl oxide and glycol plant PŁOCK	POLAND	30,000	1968
7.	Borax plant REKA DEVNIA	BULGARIA	10,000	1968
8.	Octanol plant OŚWIECIM	POLAND	15,000	1968
9.	Claus plant PŁOCK	POLAND	10,000	1969
10.	Carbon black plant JASŁO	POLAND	10,000	1969
11.	Acid dyestuff plant ZGIERZ	POLAND	2,000	1970
12.	Noble stabilizer plant BORYSZEW	POLAND	300	1970
13.	Fatty acid plant NOWY DWÓR MAZOWIECKI	POLAND	65,000	1970
14.	Gas pyrolysis plant PŁOCK	POLAND	65,000	1970
15.	Detergent plant NOWY DWÓR MAZOWIECKI	POLAND	24,000	1970
16.	Plasticizer plant BORYSZEW	POLAND	1,000	1970
17.	Lubricant oil hydrorefining plant PŁOCK	POLAND	140,000	1970
18.	Pesticide plant SARZYNA	POLAND	1,000	1970
19.	Dipac accelerant plant ŻARÓW	POLAND	250	1970
20.	Deystuff intermediate products plant ZGIERZ	POLAND	700	1971
21.	Helactine dyestuff plant ZGIERZ	POLAND	850	1971
22.	Cyanuric dyestuff plant BYDGOSZCZ	POLAND	300	1971
23.	Dispersed dye plant JASŁO	POLAND	3,000	1971
24.	Octanol plant OŚWIECIM	USSR	45,000	1971

No	Specification	Country	Capacity MT/year	Start-up or delivery year
25.	Octanol/butanol plant PLEVEN	BULGARIA	30,000	1971
26.	Pyrite pretreating unit UVAROVO	USSR	900 t/h	1971
27.	Pyrite pretreating unit KINGISEPP	USSR	900 t/h	1971
28.	Pyrite-based sulphuric acid plant DOROGOBUZ	USSR	360,000	1973
29.	Phosgene plant BYDGOSZCZ	POLAND	850	1973
30.	Pyrite-based sulphuric acid plant ROVNE	USSR	360,000	1974
31.	Pyrite-based sulphuric acid plant BALAKOVO	USSR	360,000	1974
32.	Benzene-based caprolactam plant TARNÓW	POLAND	25,000	1974
33.	Cyclohexanone plant PUŁAWY	POLAND	50,000	1975
34.	Pyrite-based sulphuric acid plant BALAKOVO	USSR	360,000	1975
35.	Pyrite-based sulphuric acid plant NOVGOROD	USSR	360,000	1975
36.	Sodium carbonate plant MERSIN	TURKEY	60,000	1975
37.	Claus plant PŁOCK	POLAND	150,000	1975
38.	Soda ash plant HALDIA	INDIA	20,000	1975
39.	Roaster gas-based sulphuric acid plant GŁOGÓW	POLAND	180,000	1975
40.	Pyrite-based sulphuric acid plant BALAKOVO	USSR	360,000	1976
41.	Pyrite-based sulphuric acid plant NOVGOROD	USSR	360,000	1976
42.	Pyrite-based sulphuric acid plant DJAMBUL	USSR	360,000	1980
43.	Pyrite-based sulphuric acid plant SUMY	USSR	360,000	1978
44.	Pyrite-based sulphuric acid plant TCHEREPOVETS	USSR	360,000	1979
45.	Pyrite-based sulphuric acid plant MELEUZ	USSR	360,000	1983
46.	Pyrite-based sulphuric acid plant TCHEREPOVETS	USSR	360,000	1984
47.	Cyclohexanone plant CHEMKO STRAŽSKE	CZECHOSLOVAKIA	80,000	1984
48.	Nitric acid plant GORAŽDE	YUGOSLAVIA	135,000	1982
49.	Phosphogypsum drying and pelletizing plant COMEL	USSR	180,000 3 x	1982

No	Specification	Country	Capacity MT/year	Start-up or delivery year
50.	Roaster gas-based sulphuric acid plant LEGNICA	POLAND	100,000	1986
51.	Roaster gas-based sulphuric acid plant MIASTECZKO ŚLĄSKIE	POLAND	160,000	1980
52.	Roaster gas-based sulphuric acid plant MURGUL	TURKEY	98,000	1983
53.	Pyrite-based sulphuric acid plant MADEN (start-up)	TURKEY		1980
54.	Roaster gas-based sulphuric acid plant KROMPACHY	CZECHOSLOVAKIA	60,000 90,000	1986
55.	Formalin plant NOVI SAD	YUGOSLAVIA	18,500	1981
56.	Ammonia storage plant GORAZDE	YUGOSLAVIA	2,000 m ³	1982
57.	3 pumping stations	KUWAIT		1980
58.	Maleic acid plant NOVOMOSKOVSK	USSR	24,000	1981
59.	Phthalic acid plant TCHERKIESK	USSR	25,000	1981
60.	Engineering design services	W. GERMANY		1980—1982
61.	Electrical precipitators	W. GERMANY		1981
62.	Spare parts	EGYPT		1982
63.	Spare parts	INDIA		1982
64.	Spare parts	CZECHOSLOVAKIA		1984
65.	Animal waste utilization plant SKHODER	ALBANIA	1,000	1983
66.	Reactors for phthalic anhydride plant	ROMANIA		1984
67.	Engineering design services	AUSTRIA/JORDAN		1982
68.	Fertilizer complex AL-KAIM (start-up and operating)	IRAQ		1982 and still
69.	Water glass plant KAFR EL ZAYAT	EGYPT	6,000	1986
70.	Modernization of nitric acid plant GORAZDE	YUGOSLAVIA		under erection
71.	Formalin plant GORAZDE	YUGOSLAVIA	10,000	1987
72.	Roaster gas-based sulphuric acid plant BUKOWNO (modernization)	POLAND		under erection
73.	Roaster gas-based sulphuric acid plant JESENIK	CZECHOSLOVAKIA	73,000	1990 (postponed)
74.	Repair of 2 boilers KROMPACHY	CZECHOSLOVAKIA		1986
75.	Cyclohexanone plant		80 000	under erection

No	Specification	Country	Capacity MT/year	Start-up or delivery year
76.	Cyclohexanone plant NOVGOROD	USSR	80,000	under erection
77.	Roaster gas-based sulphuric acid plant SZOPIENICE (modernization)	POLAND		1990
78.	Oleum plant GRODNO	USSR	200,000	under erection
79.	Oleum plant NOVGOROD	USSR	200,000	under erection
80.	Pyrite roasting plant LAC	ALBANIA	60,000	under erection
81.	Catalytic purification of waste gases „Swingtherm” JELENIA GÓRA	POLAND	2x12.000 m ³ /h	1986
82.	Catalytic purification of waste gases „Swingtherm” CZECHOWICE	POLAND	2x 4.500 m ³ /h	1988
83.	Catalytic purification of waste gases „Swingtherm” NOWY SĄCZ	POLAND	2x12.000 m ³ /h	1988
84.	Catalytic purification of waste gases „Swingtherm” KRAKÓW	POLAND	2x 3.000 m ³ /h	under erection
85.	Catalytic purification of waste gases „Swingtherm” GORZÓW	POLAND	1x 6.000 m ³ /h	under erection
86.	Calcination Section in the Soda Ash Plant NESTEMICE	CZECHOSLOVAKIA		1990 (postponed)
87.	Brine Purification Section in the Soda Ash Plant NESTEMICE	CZECHOSLOVAKIA		under erection
88.	Polycrystalline Silicon Plant	ROMANIA		under erection
89.	Nyaza Salt Mines UVINZA (Technical services)	TANZANIA		1988 and still
90.	Sulphuric Acid Plant and Aluminium Sulphate Plant NAZARETH	ETHIOPIA	14,000 13,600	under erection
91.	Animal waste utilization Plant FIER	ALBANIA	1,000	under erection
92.	Animal waste utilization Plant KORCZE	ALBANIA	1,000	under erection
93.	Animal waste utilization Plant TIRANA	ALBANIA	1,000	under erection

No	Specification	Country	Capacity MT/year	Start-up or delivery year
94.	Engineering design services ORTNER Ges. m.b.H. (dedusting and ventilation)	AUSTRIA	-	1989-1990
95.	WATER GLASS (sodium silicate) NESTEMICE	CZECHOSLOVAKIA	30,000	under erection
96.	LATHES with spare parts and special equipment. Al Kaim	IRAQ	2 sets	1990
97.	SODIUM BICARBONATE "LZ.Ch." - INOWROCLAW	POLAND	25,000	under erection