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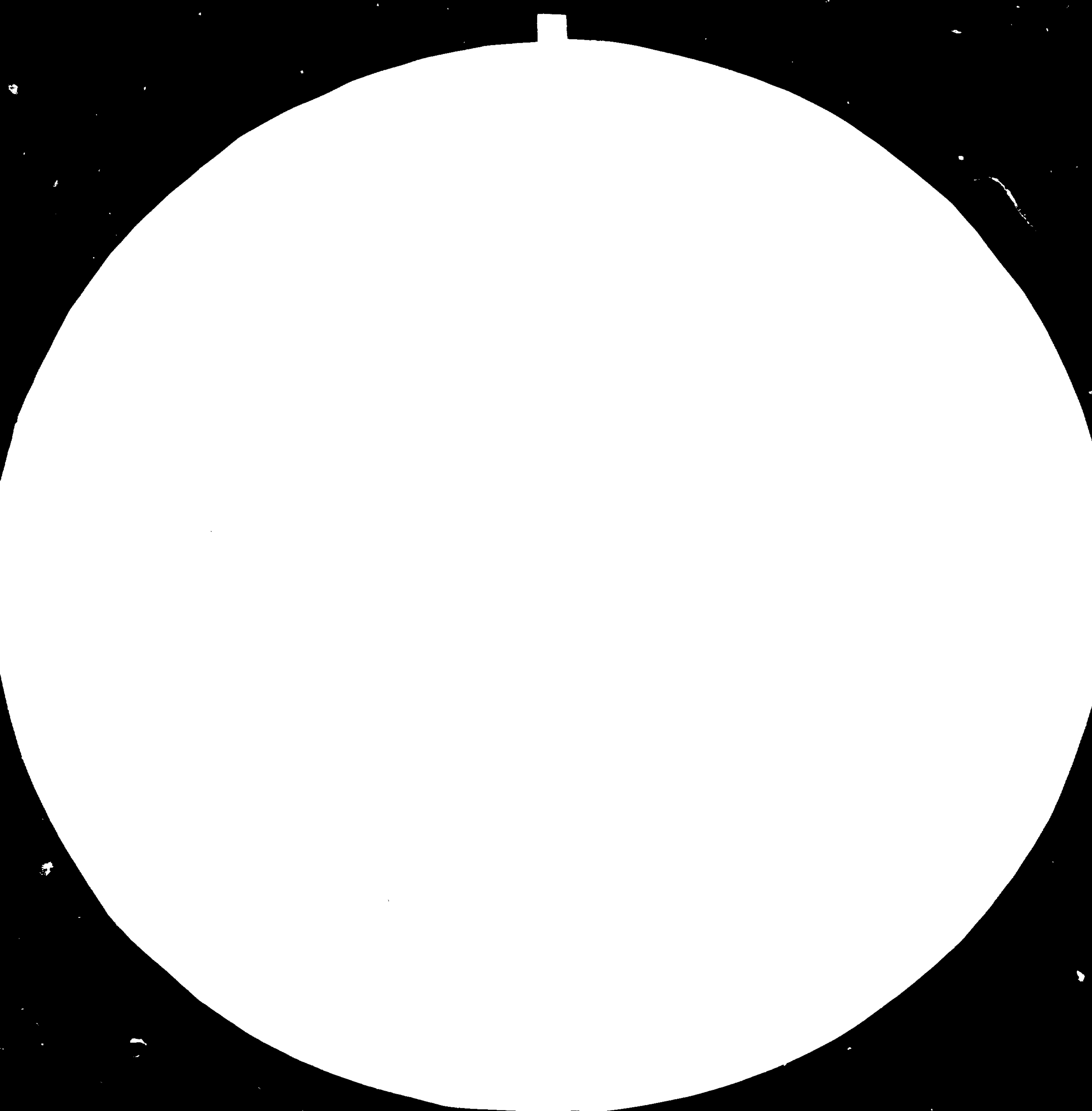

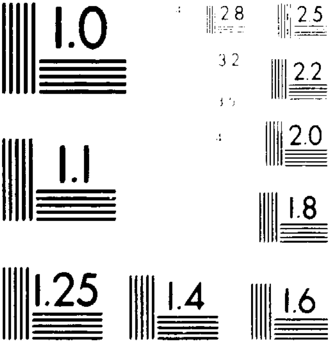

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

August 1984
English

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Niger.

EVALUATION

OF THE PRELIMINARY STUDY

OF THE IRON ORE DEPOSITS

AT SAY REPUBLIC OF NIGER

prepared by

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UNIDO PROJECT DP/IAF/79/067

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IRON ORE DEPOSITS DOGUEL KAINA AND KOLO.

1. Ore reserves.

The iron ore deposits Doguel kaina and kolo, close to SAY, are located 30 to 40 km south-east of NIAMEY, Niger.

Oolothic ore occurs in three horizons:

- Upper horizon with iron oolithes "indurées"

Fe-content average	46...51 %
Thickness average	2,20...2,53 m

- Intercalation with ooloth bearing sands and clays

Fe-content average	24...33 %
Thickness average	1,1 m

- Bottom horizon with iron oolothes "tendres"

Fe-content average	43...46 %
Thickness average	2,0...2,9 m

The average overall thickness of the ore horizons amounts to 6,56 m.

1.1 Doguel Kaina.

The total ore reserves in the Doguel kaina area amounts to	1.009 Mt
Average Fe-content	45,73 %

Assuming a cut-off of 35%Fe for Intercalation horizon, the total ore reserves amount to	937 Mt
with an average Fe-content	47,44 %

1.2 kolo iron ore deposit.

The total ore reserves amount to	207 Mt
with an average Fe-content	40,84 %

Assuming a cut-off of 35% Fe, the total ore reserves amount to 173 Mt
with an average Fe-content 44,67 %

1.3 Advantages of the iron ore deposits Doguel Kaina and Kolo.

- Large ore reserves.
- Iron mineral is goethite which is easy reducible.
- Open pit mining.

1.4 Disadvantages of Doguel Kaina and Kolo ore deposits.

- Relative high ratio overburden/ore.
- High silicious ore, practically without CaO and MgO.
- Due to impurities in the oolithes, this type of ore is possible to concentrate only up to 54 $\pm$1 %Fe.
- Low concentration of iron ore per m^2, i.e.only about 17 t/m^2 and therefore it is always necessary a long internal transport from open pit to beneficiation plant which requires high transport cost.

Remote location, i.e.about 900 km from the sea port which excludes any export possibilities.

1.5 By means of an appropriate, simple and cheap beneficiation method concentrated oolothic ore, could be a very cheap raw material for a domestic steel industry.

2. Project Work Plan - PWP.

The detailed PWP has included all necessary works and tests:

- To identify the quality and quantity of the iron ore reserves.
- To asses techno-economically the beneficiation characteristics of the ore, including iron recovery and quality of concentrates.
- To assess techno-economically the pelletization characteri-

stics of the concentrates and direct reduction characteristics of the pellets.

I have to emphasise that the Contractor - HUMBOLDT WEDAG - has carried out this PWP very carefully and exemplary. All above mentioned problems have been successfully solved and optimal possible results have been obtained.

2.1 Beneficiation tests.

Crushing, grinding and beneficiation tests have surely proved the following:

- Recoverable Fe is concentrated only in oolithes.

- The emphasis has been put on maximum possible concentration of the iron mineral and 50 pure oolithes from each sample have been mannually separated after attrition.
  The chemical analyses of the individual oolithes of
  - sample 1 yielded an Fe-content of 54,21 % and
  - sample 2 yielded an Fe-content of 53,4o %

- Quartz grains are mainly smaller than 0,63mm - see B.4.1 !

- Due to very fine impurity inclusions in the structure of oolithes, the fine grinding of oolithes and HIWMS is not giving a higher concentrate quality in comparison with quality of concentrate /-3 + 0,5/mm, i.e.optimal beneficiation results could be obtained only by liberation of oolithes.

- Screen analyses of the crushed oolithic ore are no doubt an approval for the above mentioned statements.

  The most characteristic are screen analyses for sample 2, i.e.oolothes tendre - see Annex C-4 and C-6:

Fraction	%W	%Fe	%R	$\%SiO_2$	%R
+ 5 mm	23,4	41,9	22,9	18,6	24,6
-5 + 3 mm	3,6	42,6	3,5	18,o	3,7
-3 + 2 mm	10,1	50,1	11,8	8,7	5,o
-2 + 1 mm	31,2	50,1	36,6	7,9	14,2
-1 + 0,5 mm	17,5	43,6	17,9	17,2	17,4
-0,5 mm	14,2	21,6	7,2	43,1 !!	36,1
Feed	100	42,7	100	17,4	100

Grinding results of sample 2 are a proof that beneficiation of oolithic ore - regardless of feed Fe-content - could be successful only by liberation of oolithes, i.e.by grinding on 100% -3mm, resp.according to screen analyses on -2,5mm, including the attrition/abradding of the matrix on the surface of each oolithe.

The above mentioned statement is valid also for oolithic intercalation horizon, with an Fe-content below cut-off limit of 35 %Fe.

Phosphorus problem.

All attempts to separate or to decrease P-content have failed and therefore in the steel plant a dephosphorization of the pig iron should be provided.

2.2 Crushing-grinding-attrition.

For desintegration of the oolithic ore contractor has used
- hammer crusher,
- hammer mill and
- attrition.

Regardless on the type of ore - indurée or tendre - by this equipment is possible to beneficiate the oolithic ore /-3+0,5/mm practically to the limit, i.e.53...54%Fe, what is a good result taking into account that a pure goethite - without impurities in the oolithes - has theoretically a content of 62,8 %Fe.

These results have been obtained only by separation of the soft matrix between oolithic grains by crushing/grinding and
by abradding of the matrix residue from the oolithe surface during attrition process and
by washing the adhering clay particles.

I have no comments concerning above mentioned equipment during beneficiation tests.
Meanwhile taking into account that hammer mill crushing gives considerable quantity of crushed oolithes and
that attrition of oolithes is a very important process phase,
I recommend for fine grinding - instead of a hammer mill - an autogenous mill with peripheral discharge, as it is KRUPP PERIMILL.

An autogenous PERIMILL closed circuit grinding has many advantages:

- Extremely sharp control of size grinding which should be according to screen analyses decreased on 2,5mm.
- During grinding, the attrition of liberated oolithes is continuously present.
- Dry attrition of oolithe grains is optimal.
- Attrition time is prolonged by recycling of the oversize fraction +2,5mm to the mill, i.e.closed circuit grinding.
- Wet attrition by a special attrition cell could be shortened to minimum.
- In the material -2,5mm there will be practically no broken oolithes.
- A PERIMILL will ensure the same liberation conditions for oolithes indurées, oolithes tendres and intercalation, regardless of Fe-content, i.e.cut-off 35 %Fe, taking into account that intercalation consists of iron oolithes bigger than 0,50mm in clayay-sandy matrix.
- No selective mining will be necessary!!

2.3 Desliming.

Contractor has deslimed fraction -0,50mm for HIWMS purposes on +0,020mm.

Meanwhile screen analyses of the fraction -0,50mm have showed that desliming on +0,10mm x) will give practically the same or even better technological results: See Annex C-13!

Fraction		%W	%Fe	%R	%SiO$_2$		%R
-0,50 + 0,30	mm	11,2	34,1	9,2	27,9		17,1
-0,30 + 0,10	mm	11,o	22,2	5,9	41,1		25,1
-0,10 + 0,063	mm	2,4	16,5	1,o	45,7	!!	6,1
-0,063	mm	2,3	18,1	1,o	34,9	!!	4,5

These results are based on a material which was crushed by force by a hammer mill, i.e.the crushing which gives a considerable quantity of crushed oolithes in the fraction -0,50mm. Meanwhile PERIMILL will give practically no broken oolithes!!

x) or even 0,15o mm!!

2.4 Attrition.

Attrition is a very important process phase. By attrition

- clayay matrix between oolithes should be separated and
- clayay oolithe surface shells should be abraded, taking into account that each oolithe has a barren shell of some tenth microns thickness which seems to be of the same hardness as oolithes themselves.
- Attrition of the soft clayay matrix represents no problem, meanwhile attrition of the oolithe shells demands more time and optimal attrition conditions, the conditions which occur only during autogenous grinding.

Conditions of attrition of the fraction -3mm were probably not optimal, concerning the pulp density:

	g/dm^3	dm^3 solid	dm^3 water	Ratio s/w
Sample 1	1100	0,415	0,585	65/35
Sample 2	1300	0,490	0,510	72/28

Taking into account relatively low spec.density of the oolithes - with a bulk density of 1,92 - attrition conditions were acceptable for sample 2, but not for sample 1.

Attrition is namely successful when ratio s/w is about 70/30 to 75/25, depending upon the volume concentration.

2.5 HIWMS.

The only successful process for the beneficiation of deslimed fraction -0,50mm is HI Wet Magnetic Separation.

Oolithic ore crushed by a hammer mill has always a higher percentage of broken oolithes in the fraction -0,5mm.
But oolithic ore milled by a PERIMILL contains practically no broken oolithes.

The fraction-0,10mm is practically pure matrix material, i.e. clayay material which <u>should be deslimed</u> without any deterioration of Fe recovery.
In this case HIWMS will operate under much better conditions!

Dewatering of of any concentrate +0,10mm represents no problem.

Fraction for HIWMS.

All beneficiation tests have been elaborated on the basis of two main fractions:
/-3 + 0,5/mm and fraction -0,50mm.

Taking into account data - se page B 16 I - that quartz grains are mainly in the fraction -0,63mm, I recommend the following fractions:

- fraction /-2,5 + 0,6/mm and
- fraction -0,60mm, the fraction which should be deslimed on ±0,10mm.

Material /-0,6 + 0,1/mm is still a very convenient one for HUMBOLDT JONES HIWMS process.

3. Conception for the exploitation of the iron ore deposits.

All critical remarks about C.6.1 - Treatability of the differend ore horizons - are correct taking into account the proposed beneficiation scheme, i.e.crushing by a hammer mill.

By an autogenous mill with peripheral discharge, desintegration of oolithes will be optimal,
- practically without broken oolithes in the fraction +0,6mm,
- without broken oolithe particles in the fraction -0,60mm
- and with an attrition under optimal conditions.

Evenmore, by introducing a PERIMILL close circuit grinding, the beneficiation conditions of all iron ore horizons, including intercalation, will be equaled, regardless of the Fe-content.

No selective exploitation will be necessary and all three iron ore horizons could be exploited at once.

The quantity of the fraction -0,60mm will be strongly increased:
- partly due to the decreasing of upper size from 3 to 2,5mm,
- partly due to the screen size increasing from 0,5 to 0,6mm and
- mainly due to a strong attrition action during the autogenous milling in closed circuit by a PERIMILL.

By first desliming on ±0,10mm, attrition conditions will be strongly improved.

According to these scheme improvements the following concentrate could be produced:

Fe concentrate	with 53...55 %Fe,	in ignited state	62±1 %Fe
with approx.	2 % P_2O_5	"	2,3 % P_2O_5
with approx.	less than 4 % SiO_2	"	4,5 % SiO_2

Such a concentrate could be a very good raw material for local consumption - Niger and north Nigeria -but due to low basicity and mine remote location, any export possibilities are excluded, taking into account that river Niger is not navigable between Niamey and the river mouth.

4. <u>Pelletizing and Direct Reduction process</u>.

I have no remarks on the pelletizing tests.
Contractor has proved that high quality acid pellets could be produced.
Pellets with a basicity 0,8 could not be produced.

Meanwhile the problem of pelletizing should be treated in connection with the chosen reduction process.
Among the many DR processes, contractor has chosen and recommended KR process, the process which has many advantages, although untill now - August 1984 - no industrial KR plant has been put in operation.

But for the chosen KR process <u>pelletizing is not at all necessary</u>. KORF Engineering claimed that by KR process the following iron ores could be used:
- pellets,
- natural pellets -25mm and
- sinter !!

In our case the concentrate /-2,5 +0,1/mm represents an excellent sinter material and even self-fluxing sinter is not excluded.

Therefore there is no need for the following proposed expensive phases:

- fine grinding of Fe concentrate and
- pelletizing of such a ground Fe concentrate.

The proposed metallurgical KR process - which produces pig iron - enables use of Fe concentrates with over 0,20 %P, taking into account that a dephosphorization process should be provided in the steel plant.

5. Conclusions and proposed scheme.

5.1 Exploitation of iron ore deposits.

Oolithic iron ore will be exploited by riping. A CAT D8H with one-teeth hydraulic riper will be probably sufficient strong, since oolithic ore is strongly bedded.
Ore produced by riping has practically no boulders!

5.2 Crushing.

Ore should be crushed by a primary single-toggle crusher 1000 x 800mm.
Recommended discharge setting 250mm.
Crushed ore will be stocked on a small open pile.

5.3 Grinding.

Crushed ore -250mm is a feed for an autogenous KRUPP PERIMILL, with peripheral openings 5mm, probably without grinding balls.

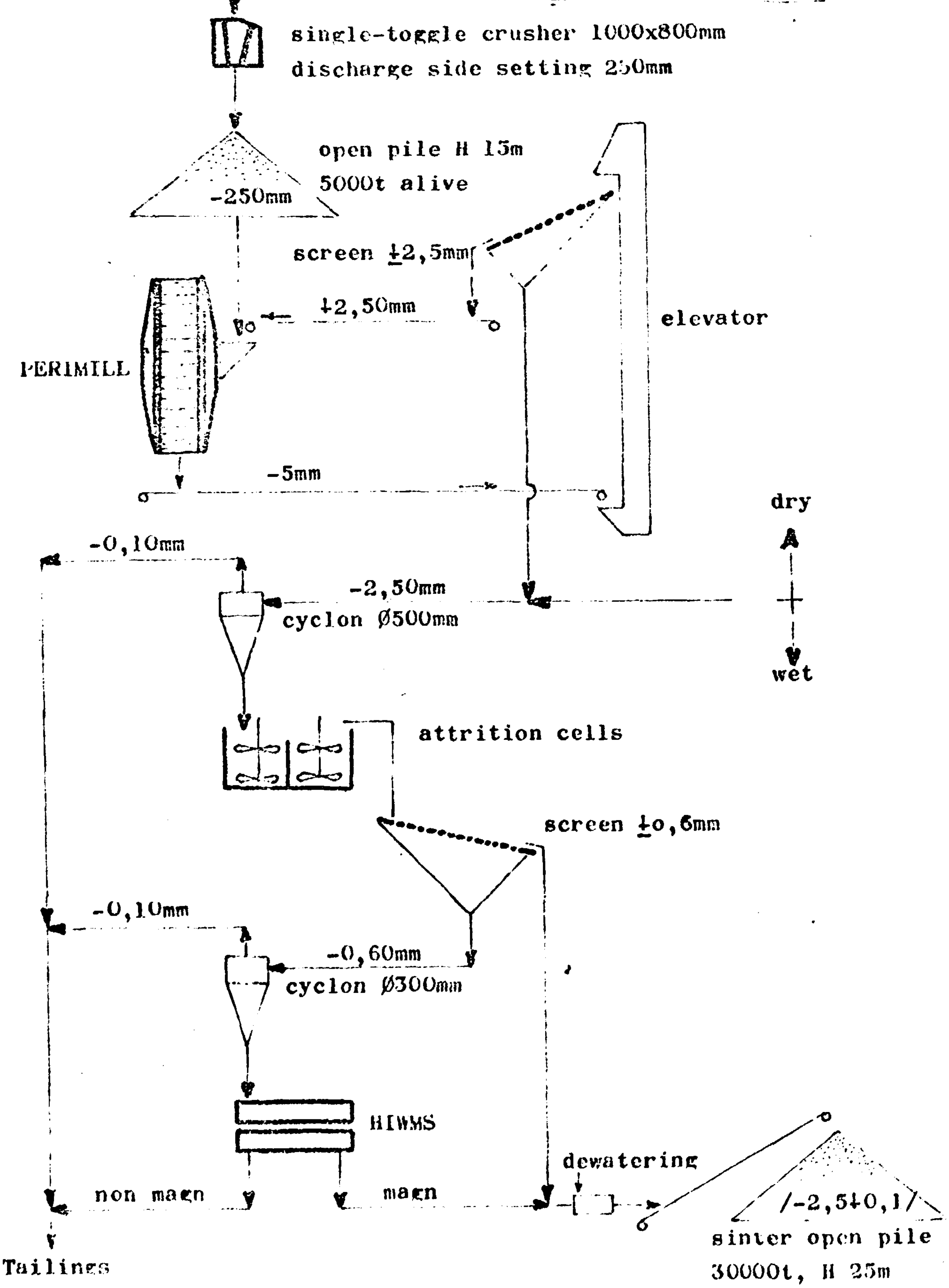
The mill will work in closed circuit with a screen +2,50mm. Oversize +2,5mm will return to the mill.

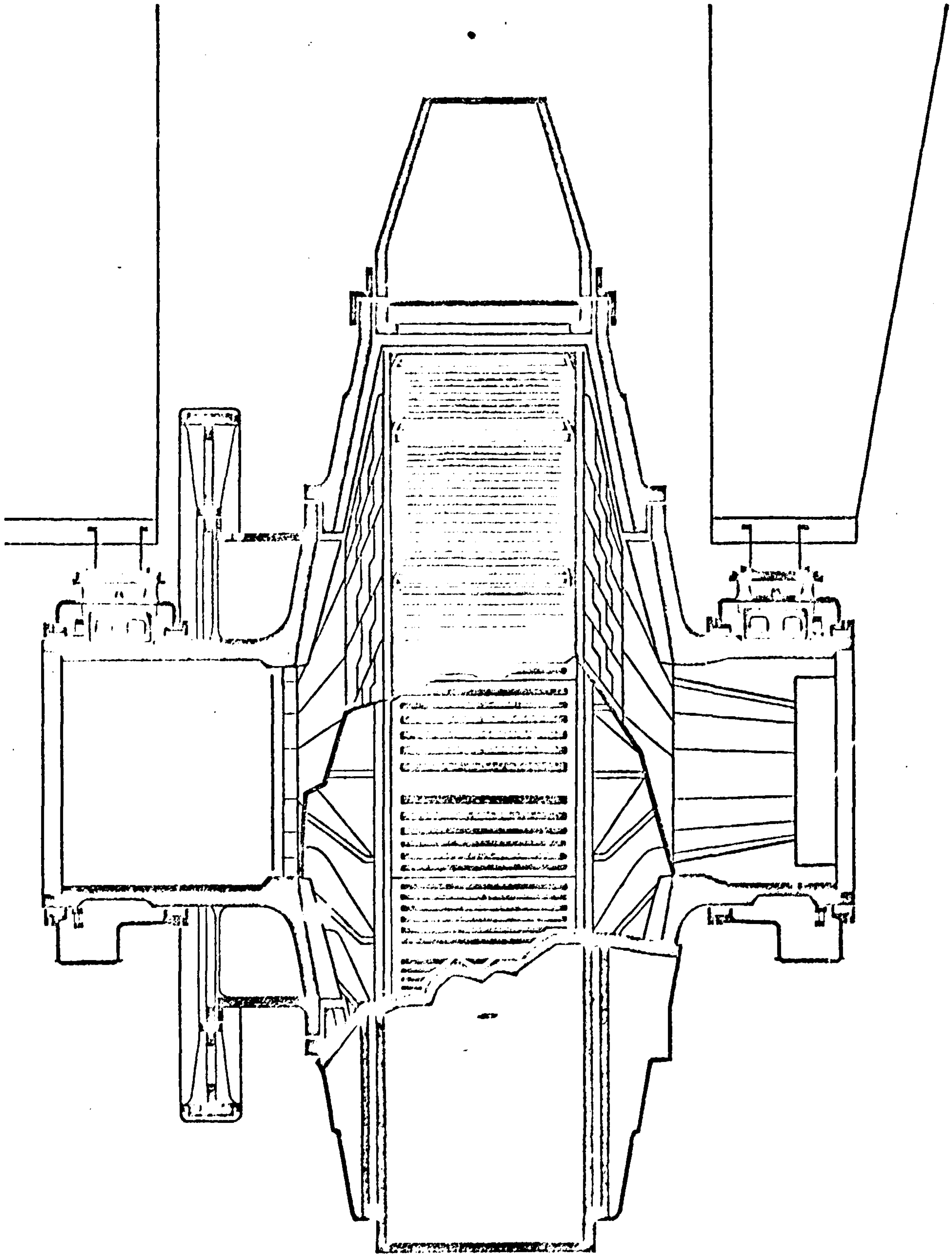
5.4 Desliming.

Undersize material -2,50mm should be deslimed in front of attrition by cyclons: Ø about 500mm, pressure about 0,5 bar.

IRON ORE DEPOSITS S A Y - N I G E R

BENEFICIATION SCHEME





5.5 Attrition of material /-2,5 + 0,1/mm.

Attrition time by an attrition double blade cell will be maximum about 5 min.

5.6 Screening on +0,6mm.

Oversize +0,60mm will be dewatered.
Undersize /-0,6 + 0,1/mm is feed for HIWMS.

5.7 Desliming of fraction -0,60mm.

Fraction -060mm should be deslimed in front of HIWMS.

5.8 HIWMS.

Fraction -0,60mm will be separated by HIWMS and concentrate will be dewatered together with the concentrate +0,60mm.

5.9 Sintering.

Limestone or dolomitised limestone will be added to the Fe concentrate and a self-fluxing sinter will be obtained.

5.10 KR process.

KR process produces a pig iron with phosphorus.
A dephosphorization process - LDAC - in the steel plant will produces Thomas slag - a fertilizer - for local consumption.

5.11 Slag.

Due to high Al_2O_3 content in Fe concentrate, a specific slag with high alumina will be produced with the following analyses:

SiO_2	about	34 ± 4 %	Al_2O_3	about	18 ± 2 % !!
CaO	about	38 ± 3 %	MgO	about	6 ± 1 %

Such a slag - with high alumina content - is today produced

only by some iron work plants like:
- Appleby Frodingham, Great Britain,
- Iron Works Skopje, Yugoslavia and
- some Australian iron works.

Appleby Frodigham is selling this slag
- partly as CALUMITE for glass industry and
- partly is grinding this slag and the product is a valuable cement, marketed as CEMSAVE.
  By adding 20...30% hydrated lime, this cement is used for the construction of water dams.

6. Remark.

Krupp Industrie and Stahlbau, Rheinhausen, FRG, dispose of a pilot plant with a PERIMILL Ø1,9m x 0,9m, which is working in closed circuit with a screen ±2 mm.

Designing of the mill demands in any case a pilot plant grinding test, the test which will prove that a PERIMILL is an ideal device for desintegration of soft oolithic ore,
- without crushing the oolithes and
- that optimal results concerning quality and Fe recovery could be obtained by an autogenous grinding.

Ljubljana, 18th August 1984

Viktor Bo[illegible]c