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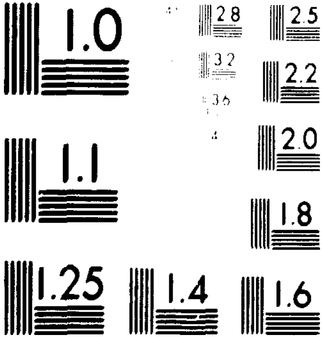

MICROCOPY RESOLUTION TEST CHART

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United Nations Industrial Development Organization

PRE-INVESTMENT STUDY OF THE INDUSTRIALIZATION OF FLUORITE DEPOSITS IN MOZAMBIQUE

VOLUME 1.:

FLUORITE MINING AND BENEFICIATION

FINAL REPORT

ALUTERV-FKI
BUDAPEST/HUNGARY
DECEMBER 1982

446

FLUORITE MINING AND BENEFICIATION IN MOZAMBIQUE

FINAL REPORT

by

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1. SUMMARY

1. SUMMARY

The fluorite deposits of Mozambique are worth considering due to their high CaF_2 content (50-60 %).

Before investment decisions could be made further geological exploration of the ore resources is necessary.

The way of exploitation is underground mining in vertical, thin veins. Beneficiation of the ore is rendered difficult by the disadvantageous mineral composition of the impurities (Djanguire deposit). Lack of infrastructure makes the investment and operational costs high, consequently the as mined ore and even the concentrate can not be marketed economically regarding the current low prices. The start of aluminium smelting in Mozambique or the increase of fluorite prices might turn profitable the fluorite mining. More detailed data and further analysis are needed to prepare a more reliable evaluation.

2. PROJECT BACKGROUND AND HYSTORY

2. PROJECT BACKGROUND AND HISTORY

The study of mining and beneficiation of fluorite in Mozambique, as well as the processing of this ore into fluoride salt was initiated by the UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO).

The geological prospecting carried out in 1960-70 revealed considerable fluorite deposits in Mozambique. The energy available from the hydro-power plant in CABORA-BASSA might be devoted to an aluminium smelter utilizing fluoride salts, i.e. domestic raw material.

Given a product of adequate quality and quantity, the possibilities of marketing should be investigated, too.

The contracted costs of preparing this study had been

135,000 US$

Since fluorite can be sold after beneficiation even if it had not been processed tc fluoride salt required for aluminium smelting, this preliminary elaboration was divided intc two parts:

Volume 1: Fluorite mining and beneficiation
Volume 2: Fluoride salts manufacturing plant

Editing both volumes have been taken into consideration the prescriptions of the "Manual for the Preparation of Industrial Feasibility Studies" (UNIDO) Consequently several repetitions would have occurred in some paragraphs of the two volumes dealing not with the siting and technology itself. To avoid that, some definitions (i.e. characteristics of paved roads etc.) or general describing, explaining parts (i.e. summary, economical evaluation etc.) have been detailed in the Volume 2 only.

3. MARKET AND PLANT CAPACITY

3. MARKET AND PLANT CAPACITY

3.1 NATURAL FLUORINE RESOURCES

Several fluorine bearing minerals are known, only 10 of which contains significant amount of fluorine, however, not more than half of these has commercial importance. The most important minerals are: cryolite with a fluorine content of 54.3 %, fluorite containing 48.8 % F and apatite with 4.0 % F.

Some micas and the sedimentary phosphorite have a fluorine content of a few percentages (max. 9 %).

From the commercial point of view fluorite seems to be the most important ore. The natural cryolite reserves are exhausted and new deposits are scarce. The production of fluorite increased more than fivefold in the last 25 years (860 thousand tons in 1950, while 5,000 thousand tons in 1975). The increase of fluorite demand is due to the rapid development of metallurgy and chemical industry. Thus, the position of these industrial sectors is reflected also in the demand and price of flurite. Between 1975 and 1980 the boom of production stopped, moreover slight cutbacks could be observed.

Fluorite or calcium fluoride (CaF_2) is a frequently occurring mineral. It appears mainly in the pneumatolitic and hydrothermal periods of genesis. In high temperature veins it is present less frequently.

Practical importance can be assigned to the hydrothermal and metasomatic deposits.

3.2 INDUSTRIAL APPLICATION, QUALITY REQUIREMENTS

Depending upon the field of utilization fluorite is generally classified in one of the following groups:

chemical (acid grade)
ceramical
metallurgical.

Some authors count as a fourth independent type fluorite used for optical purposes.

The following commercial specification applies for acid grade concentrates:

CaF_2	92-95 %
SiO_2	max. 1.0 %
$CaCO_3$	max. 1.0-1.25 %
S	0.5 %
humidity	1 %

In certain countries, e.g. in the U.S. the criteria are still more stringent.

Ceramic grade fluorite is normally supplied satisfying the following specifications:

CaF_2	min. 93-95 %
SiO_2	max. 2.5-3 %
$CaCO_3$	max. 1.0 %
Fe_2O_3	max. 0.12 %

Zinc, barium, lead, sulphur and phosphorus can be present only in traces.

Metallurgical fluorite is generally required to contain 80-85 % CaF_2, however, some users accept in average 70-75 % CaF_2, too. (Metallurgical calcium fluoride may also be qualified by the effective fluorite content given as: $CaF_{2eff} = (CaF_2\ \% - SiO_2\ \%) \times 2.5$).

The particle size of metallurgical fluorite can vary from 5 to 60 mm. The percentage of sulphur must not exceed 3 %, that of lead 0.2-0.5 %, that of quartz 5 %, arsenic and barium should remain lower than 0.01 %.

Fluorite being separated into the fourth type, the so called optical grade fluorite is obtained from unique deposits where the crystals or crystal fractions represent well developed, totally transparent pieces free from inclusions and at least 10 mm in diameter.

If a deposit yields low grade material as mined, a common practice is to apply subsequent beneficiation. The limit for industrial utilization is usually set at 30 % CaF_2 content, lower grade ores are rarely extracted, except if they occur as a monomineral or purely quartz-fluoritic deposit.

Diverse uses of fluorite may be envisaged. As an additive it reduces the melting point and the viscosity of slag, therefore, it is widely used in iron metallurgy. In fact, 40-45 % of the total consumption enters this field.

Fluorite is used in most steelmaking processes as a slagforming component.

In the past three decades the demand for fluorite increased proportionally to the growth of steel production, however, recently it diminished or leveled off in consequence of the crisis in steel consumption.

Considerable proportions of fluorite compounds are transformed to aluminium fluoride and cryolite. Since the latter has rather rare natural occurrences and is needed in huge quantities for manufacturing aluminium it is synthethized.

The cryolite fused during electrolysis provides the solvent for alumina.

One could predict that on the long term the fluorite concentrate consumption in the aluminium industry will fall due to the introduction of new technologies as well as to the utilization of fluorine resulting from phosphate processing.

During the last ten years the procedure of briquetting was also introduced for the purposes of metallurgical fluorite.

Enhanced concern of the environment forces the smelters to reduce air pollution. Using dry cleaning the gases are adsorbed by alumina and in this way 18-20 % of the fluorine can be recovered for repeated use.

3.3 FLUORITE DEPOSITS IN MOZAMBIQUE

Two important fluorite deposits are recorded in Mozambique:

- one in the Tete district, near to the village Djanguire at the border with Zimbabwe;
- the other in Sofala district, between the settlements Canxixe and Maringue.

We were able to visit the former one and collect there technological samples. On the other hand our partners in Mozambique deemed not feasible to arrange a trip to the second deposit within the period available in order to collect data there, too. Nevertheless, the acquired geological information can be summarized as follows:

3.31 The Djanguire deposit

Rocks belonging to the base complex, to the carroo and postcarroo are found at the Djanguire-Piroro territory. The lode rocks are of the postcarroo.

The base complex

This is represented by the South and South-East part of the area studied. The constituents are mainly feldspar, biotite, biotite-amphibole gneiss as well as magmatite gneiss, muscuvite and amphibole gneiss. In general these rocks are finely dispersed.

On the South-East edge of the territory a small intrusive garnet block can be found surrounded by gneiss. The

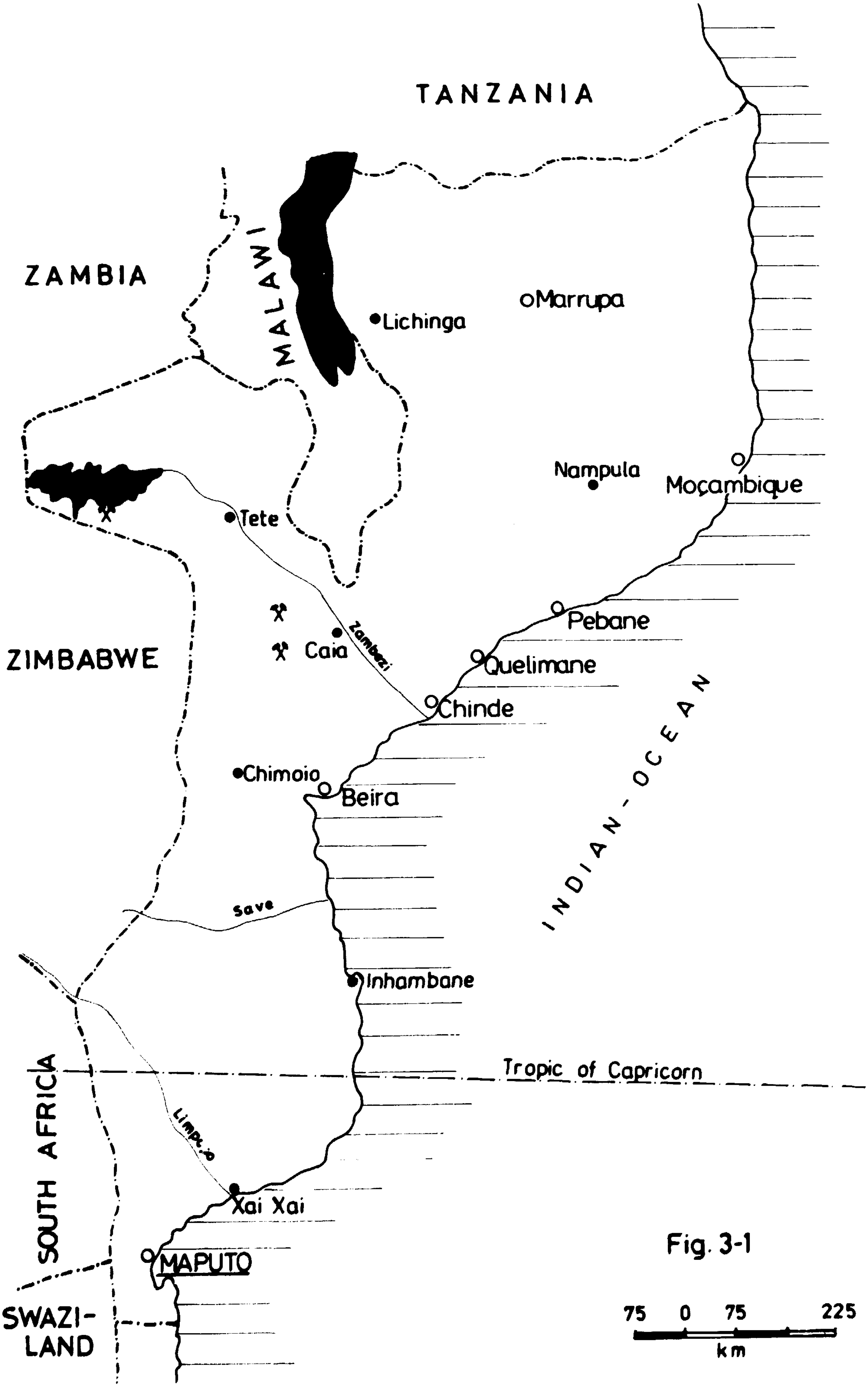

TANZANIA
ZAMBIA
MALAWI
oMarrupa
Lichinga
Nampula
Moçambique
Tete
Pebane
Quelimane
Zambezi
Caia
ZIMBABWE
Chinde
INDIAN - OCEAN
Chimoio
Beira
Save
Inhambane
Tropic of Capricorn
SOUTH AFRICA
Limpopo
Xai Xai
MAPUTO
SWAZI-LAND
75 0 75 225
km

Fig. 3-1

age of this can hardly be identified. The listed formations are intersected by basic and ultrabasic (dolerite) rock-lode quartzitic, quartzporphyryc pegmatite veins, respectively. The dimensions and length of the veins are variable without any characteristic orientation. They are carroo and postcarroo formations.

North and East from the base complex is found a range of sedimentary rocks. Two such spots are qualified as carroo and postcarroo formations, respectively.

These can be separated using litological analogies. The following principal features can support the distinction:

carroo formations

- litologically heterogenous: sandstone is dominant, sandstone with levels of conglomerate, clay or claystone which is locally very hard and has brownish red - greeny colour;
- abundant doleritic veins generally oriented Northwest - Southeast;
- faint morphology

Continental Cretaceous formations

- homogenous, almost exclusively ([illegible]) from soft sandstone;
- with conglomerate impregnations;
- absence of dolerite lodes;
- weak relief, the extended planes are dominant.

Lava rocks

The biggest feature of the extrusive formation can be seen at the Northwest part of the area, on the Inharuala mountain. The rocks are composed from hemicrystalline and porphyrycally textured riolite-trachite and from compact basalt with amygdales. The amygdales are often filled by adult agate, zeolite, quartz and calcite crystals.

Postcarroo lodes of uncertain age

Both the base complex and the postcarroo formations are traversed by porphyric dolerite and quartz veins. The latter contain often fluorite, too. Special interest should be devoted to the fluorite veins, which build up the Danguire deposit.

General data

The site of the exploration area is 4 km Southeast from the village Djanguire within the administrative district of Chioco. The following coordinates delineate the exploration area:

South latitude: 16°21', 45" - 16°24', 34"
East longitude: 32°33', 25" - 32°28', 14"

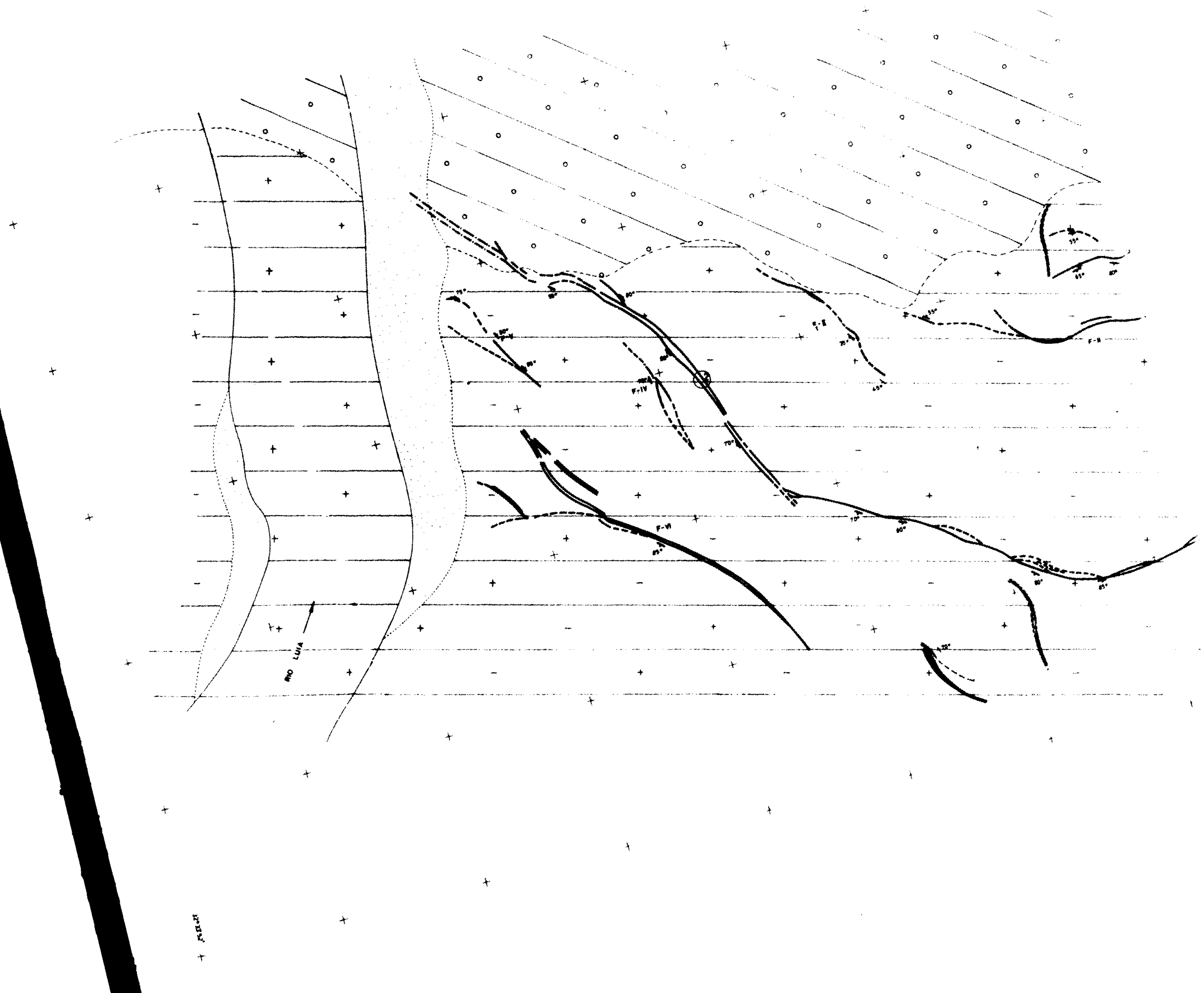
The distance from Tete, the district capital is 154 km including 101 km dirt road.

The highest concentration of veins is South from the large bend of the Rio Luia, confined from three sides by the river. (Despite this fact there seems to be no danger of flood). This bend of the river lends a marked character to the territory. During the rainy season (December-March) the area becomes a marshland due to the flat morphology, transportation by heavy vehicles is impossible and it can not be recommended even with light all-wheel driven cars. No live waterflows remain in the dry season and also the approximately 100 m wide bed of the Luia river gets absolutely desiccated.

Results of the earlier explorations

The fluorite prospecting was carried out by the Geological and Mining Explorer Team No. 3. under the leadership of Luis Celentino de Sousa e Silva in May-November, 1963.

PROSPECTION MAP OF F
OF DJANGUI



SECTION 1

Fig. 3-2

ROSPECTION MAP OF FLUORITE VEINS OF DJANGUIRE

F

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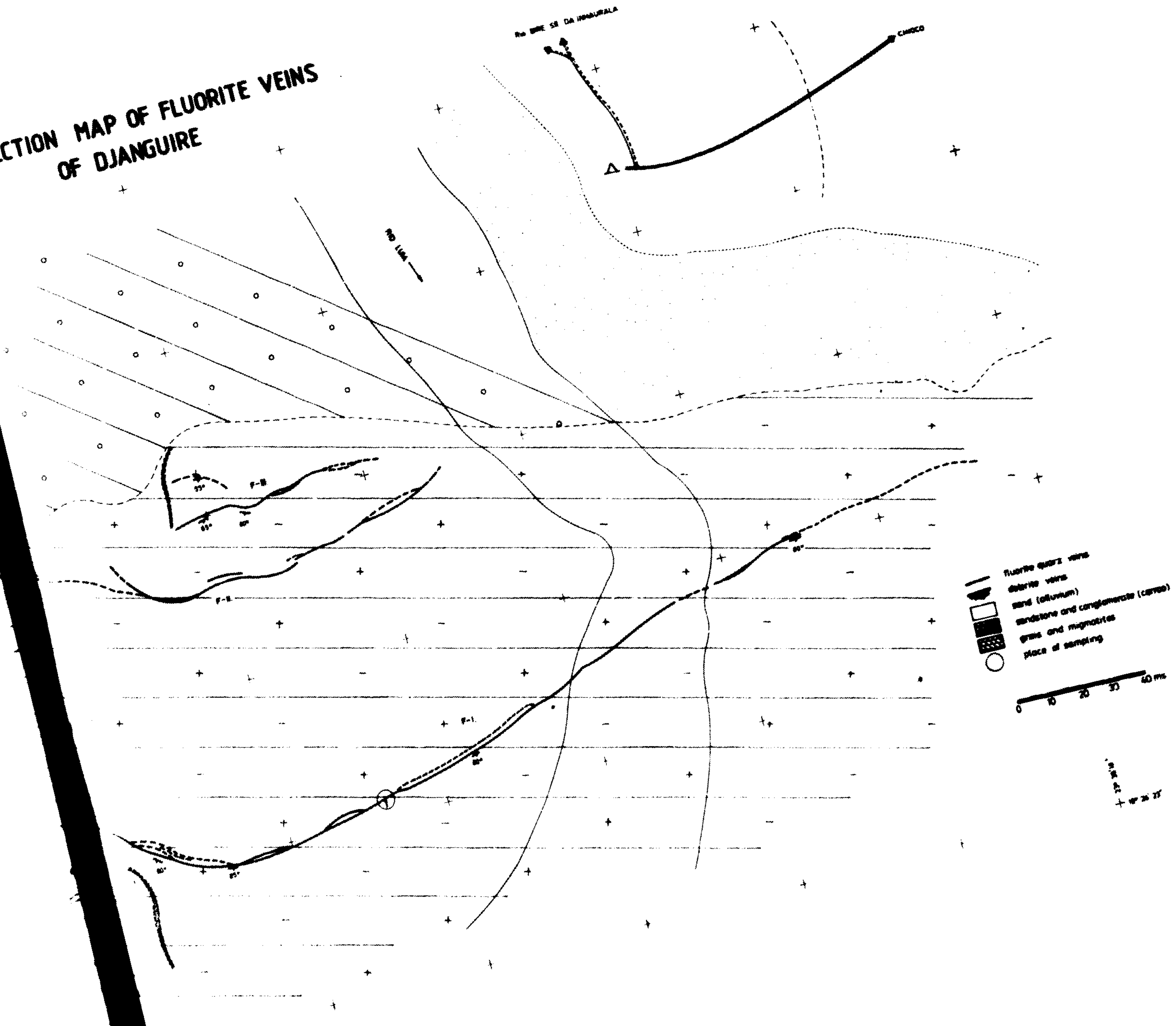


SECTION 2

This prospecting revealed the existence of a group of 6 fluoritic veins. This were followed along the lode line, intersected by ditches and tracked at the intermediate sections based on the outcrops and the detritus.

The results gained show 3 veins as promising for industrial exploitation.

Among these the main vein No. I. has outstanding importance with 1,800 m length. The width is variable between sometimes ten centimeters and 6 m.

Coupled to the 1963 exploration 12 analyses were made for the main vein, 3 for the vein No. II and 1 analysis for the vein No. III. The mineral resource in the deposit was estimated using these data.

The fluorite content changes from 22.7 to 83.8 % the average being 60 %. The material is apparently very pure, the amount of contaminating minerals and secondary sulphides seems to be extreemly low.

The measurement of the secondary phases supports this statement:

	Chemical composition max.	 min.
	%	
SiO_2	57.28	13.74
$CaCO_3$	1.92	0.51
$BaSO_4$	-	-
Fe_2O_3	1.40	0.34
S	less than 0.01 %	

Although the number of analyses is lower than required by European standards, under the given circumstances they are deemed acceptable and suitable for the assessment of resources. At this moment we are not able to present better estimate than that achieved by the 1963 prospecting. Probably the actual reserve is larger and the average quality inferior than the one stated in the report. Sampling of the lode had been accomplished through the ditches collecting material from 10 cm wide and 5 cm deep grooves from the entire width of the fluoritic sections of the veins, including both the fluorite and dead rocks.

2.86 t/m^3 specific weight was used in the calculations taking 90 % of the specific gravity of fluorspar (3.18).

The following basic principles were applied when estimating the reserves:

a) the largest difference in the height of the ditches displaying the vein had been 30 m, within this the quality of the lode did not exhibit important variations, thus the 30 m was recorded as <u>definite</u> reserve. (It is not clear how the variations of level were allowed for.)

b) a further 30 m had been estimated as <u>probable</u> reserve

c) upto a depth of 200 m, supposing uniform evolution, <u>possible</u> reserve was taken into account. Hence:

vein	Definite	Probable	Possible	Total
	mineral resource tons			
I.	61,034	74,382	415,513	550,929
II.	7,569	14,415	81,686	103,670
III.	2,301	6,108	34,777	43,186
	[illegible]90	94,905	[illegible]31,976	697,785

The additio[illegible] less investigated lodes were estimated to [illegible]nd t probable and 60 thousand t possible reserve

The present professional awareness reckons with 600,000 t CaF_2 of 62 % quality in the Djanguire deposit (mainly corresponding to the annually recurring data of the Mining Journal Annual Review).

This approximation is based on the validity of the qualitative and quantitative surface parameters upto a depth of 200 m. However, the fluorite veins change very often irregularly along the rise and it seems indispensable to acquire data about its evolution in depth.

The deposit was found to comply in every respect with the preliminary model of the report. The trenching of the main vein could be easily followed and the formerly used exploration ditsches are well exposed even now. The special location of the veins is fixed well in the report, the data are reliable.

Therefore, besides the confirmation of data our aim at the site had been merely the collection of the samples needed. During sampling the efforts were concentrated on a good approximation of the material to be mined. Thus, samples were collected at two positions from a 0.9 m long and a 5.9 m long section of the lode, respectively, taking care that the sample should represent the mixed material to be worked in the course of mining. Additionally to this sample for technological purposes, trials were made to acquire partial samples along a given line across the vein first of all in order to check the quality and conduct mineralogical investigations. In this manner 25 kg material had been taken for technological and 15 kg for other purposes.

3.32 The Canxixe-Maringue fluorite deposit

Geological environment

Base complex

The formations belonging to the base complex are the dominant formations of the territory. They consist mainly from gneiss, which is intersected by numerous quatzite veins, quartzporphyry ridges and basaltic rock veins. Furthermore pegmatitic and dolerite veins cross it, but these are probably much younger. Macroscopically, the gneiss has rather granatoidic character.

Carroo and postcarroo formations

In fact these are built up from two North/South oriented slabs. According to the exposed contact with the base complex the first is constituted from Ecca and Beaufort faciae. The second includes lava rocks (Lupata formation) which are dominantly basaltic with frequent amygdale cavities. In the latter one can find adult zeolite crystals. The basaltic formation is traversed is several cases by agate lodes.

Mesozoic formations

The 1:2,000,000 scale map of the country published in 1956 dates it back just to the beginning of the postcarroo, but the exploration brought no data concerning this. Its presence is indicated by opening up almost horizontally located conglomerates.

Vein rocks

The base complex is crossed by rock veins filled mainly by quartz. The lodes are most often arranged in a line between 15° and 40°, with a slope near to vertical.

General data

The Canxixe-Maringue deposit is an about 50 km long slab giving indications of fluorite. Morphologically it is flat, slightly wavey area with alluvial river valleys which are, nevertheless, dry in most part of the year. The area had been separated as "zone reserved for mining explorations". It occupies a 30' square between the South latitudes 18°15' and 17°30', respectively and the East longitude 34°30'. Detailed fluorite exploration had been carried out between the Rio Muorodzi and the Rio M'Bahata, parallel to the Maringue-Macossa road.

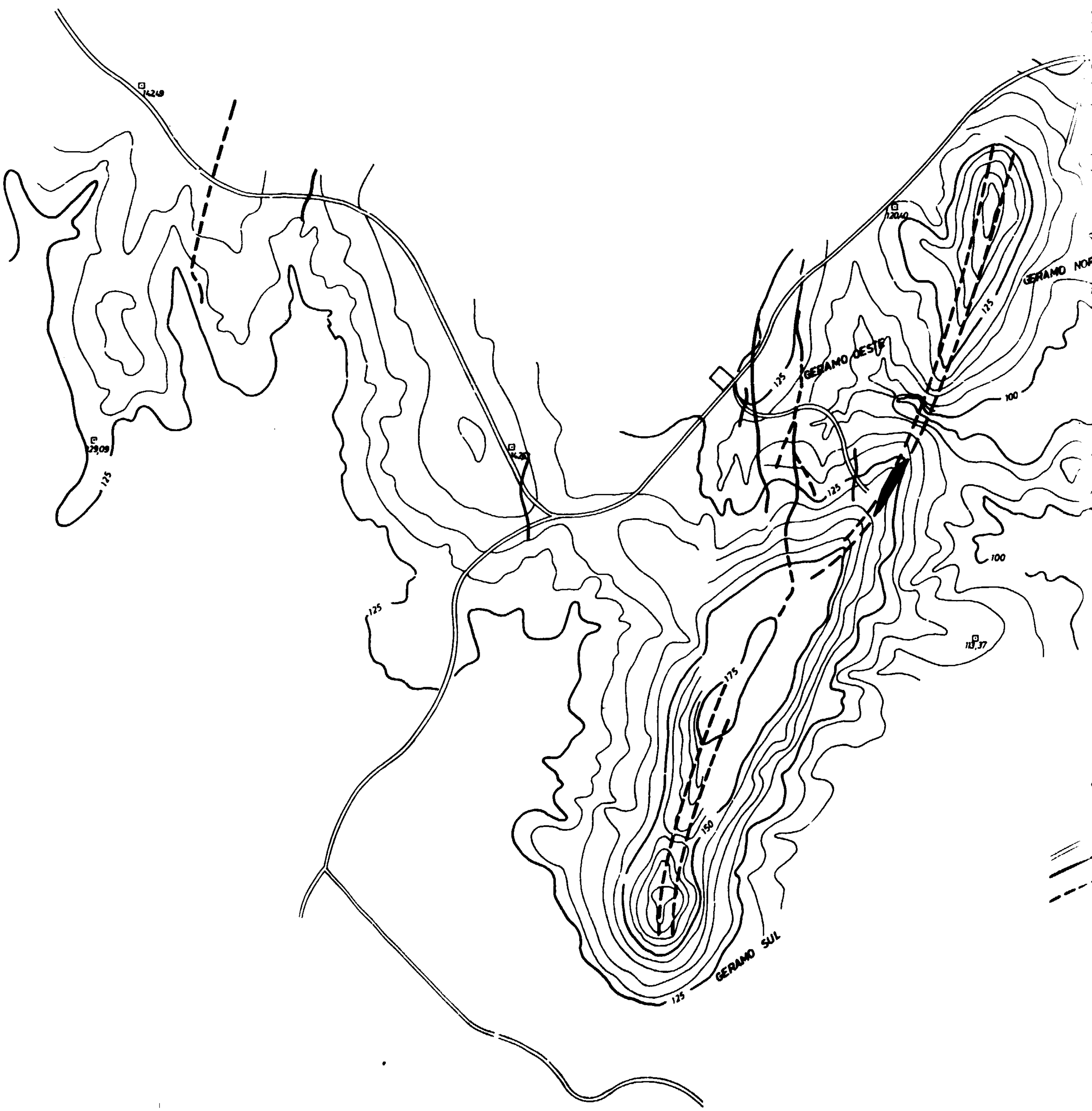
Results of earlier explorations

The fluorite prospecting had been executed by the Geological and Mining Explorer Team No. 4. in 1960 under the leadership of Nuno Mendes Alvez.

The basic method of the exploration was trenching, complemented by field inspection for geological evaluation and mapping of limited areas. Large scale detailed maps and 1:50 scale documentation were prepared from the ditches.

The following main conclusions can be drawn upon the mineralization:

- the deposit is characterized by hydrothermal veins;
- within this frame two types of ore formations can be distinguished:



SKATCH MAP OF
OF FLUORITE VEIN

SECTION 1

Fig. 3-3

SKATCH MAP OF LOCATION
OF FLUORITE VEINS IN MARINGUE

(i) solid, compact fluorite vein, and
(ii) dispersed mineralization, extending into the secondary rock.

The bulk fluorite lode (fluorita individualizada) can be described as striated, having irregular nests, being rarely spotted, roughly dispersed terra sigillata. The colour of fluorite ranges from dark green to light green, at some places turns redish. The weathered layers close to the surface are faded, lighter in shade.

The quartz veins have brecciated texture, they frequently developed streakily. The structure observable and cocarde at some places reflects repeated openings of the vein.

The scattered fluoritization (fluorita diseminada) appears as often hardly recognizable spots or very fine streaks with a breadth of the magnitude of a mm or a tenth of a mm. There are extreemly thin dikes within the lode and sometimes the mineralization continues in the secondary rock, too.

The matrices of the two types of fluorites show evident differences in the form of frequently occurring cryptocrystalline dead rock, often amorphous types of silica: jasper and chalcedony. The sampling was carried out here also in the width of the vein reduced to the fluorite. According to our experience the ratio of pure fluorite to dead rock equals 1:2.

The 1960 report does not include data on the quality and the reserve was neither estimated. In the summary section the report emphasizes:

- the mineralization might extend in the Northeast direction (Palane);
- improved vein quality can be supposed in depth;
- regarding the possible concentrations the data can be qualified as advantageous ones;
- further exploration is recommended.

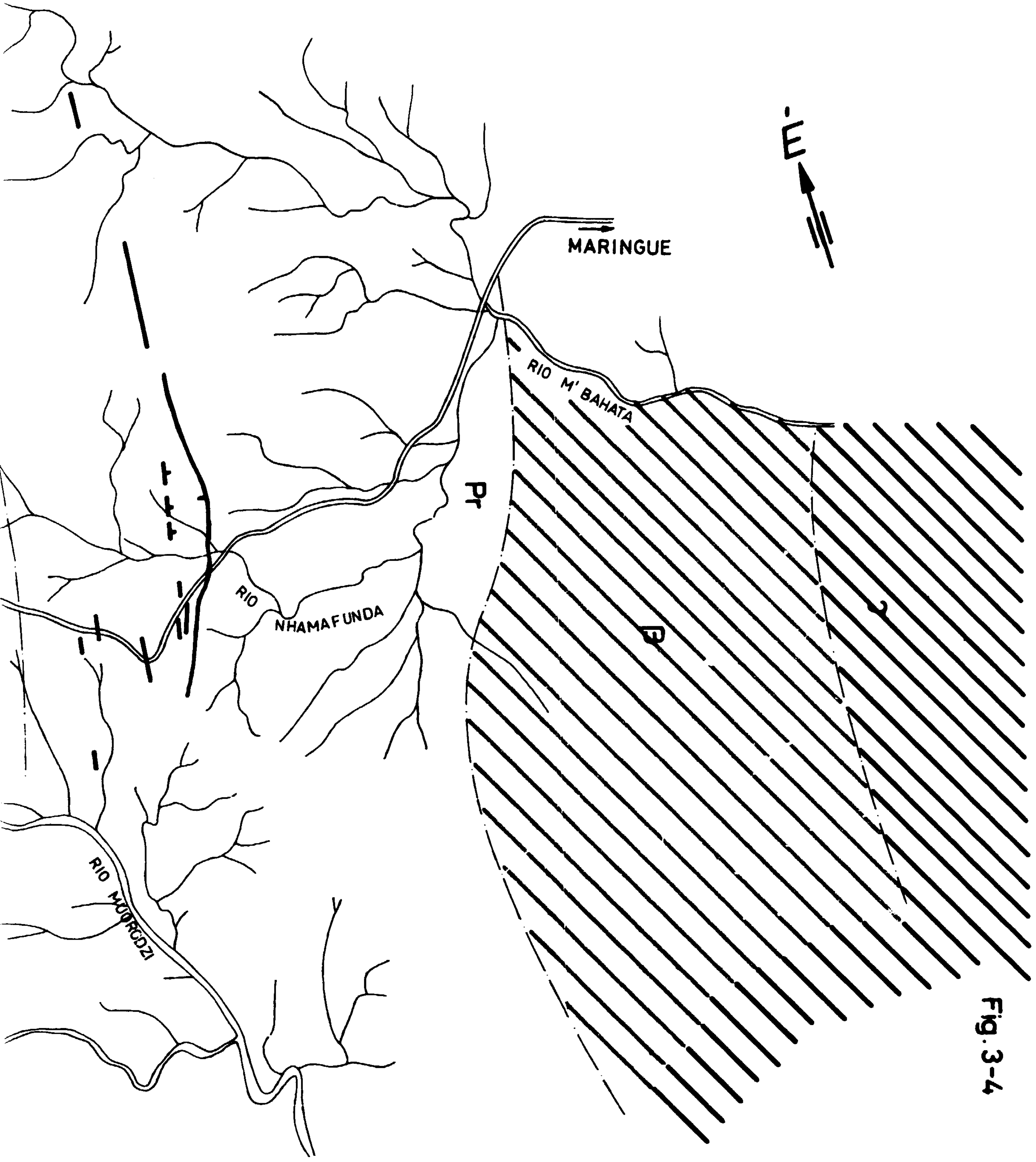
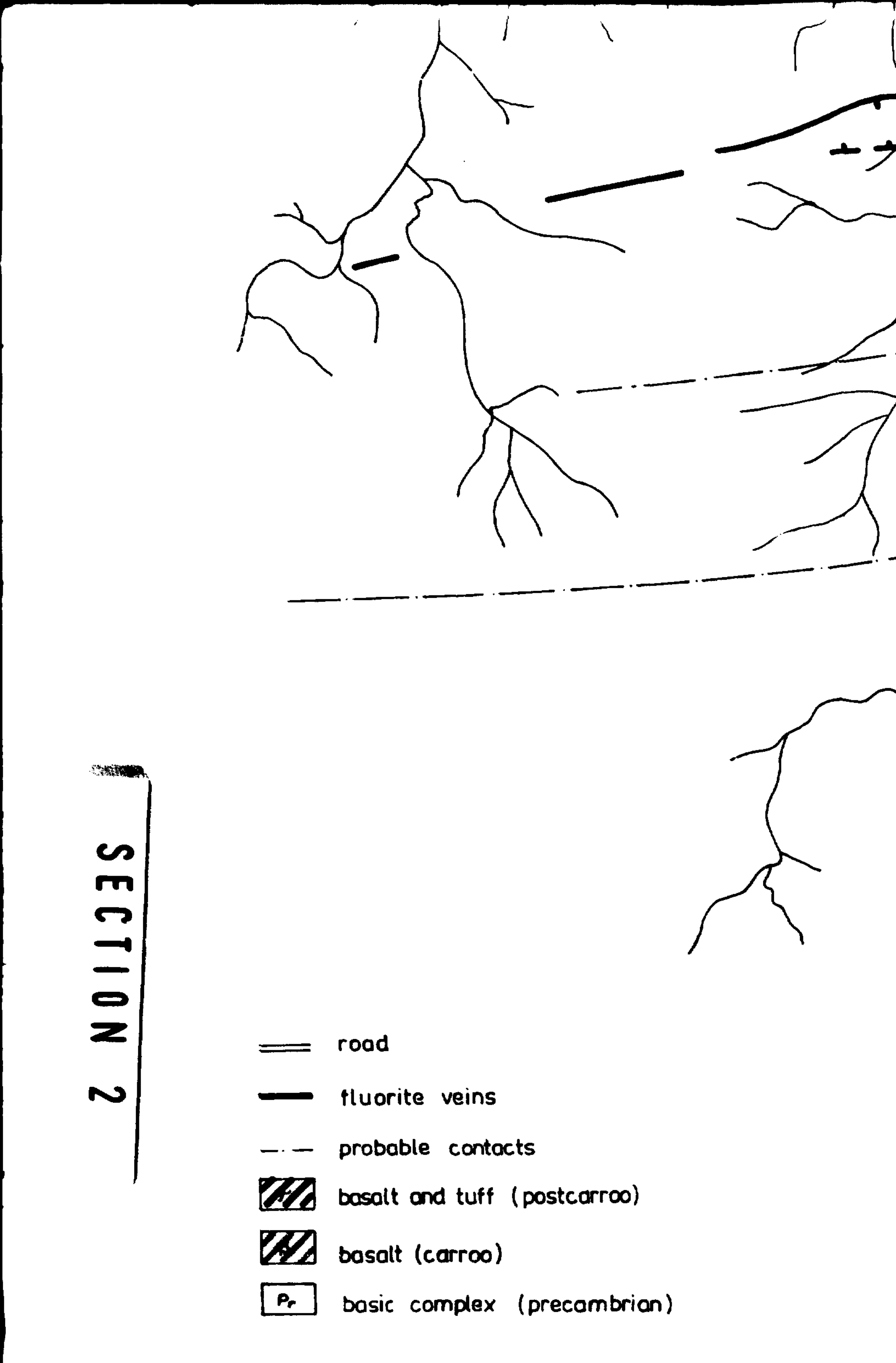
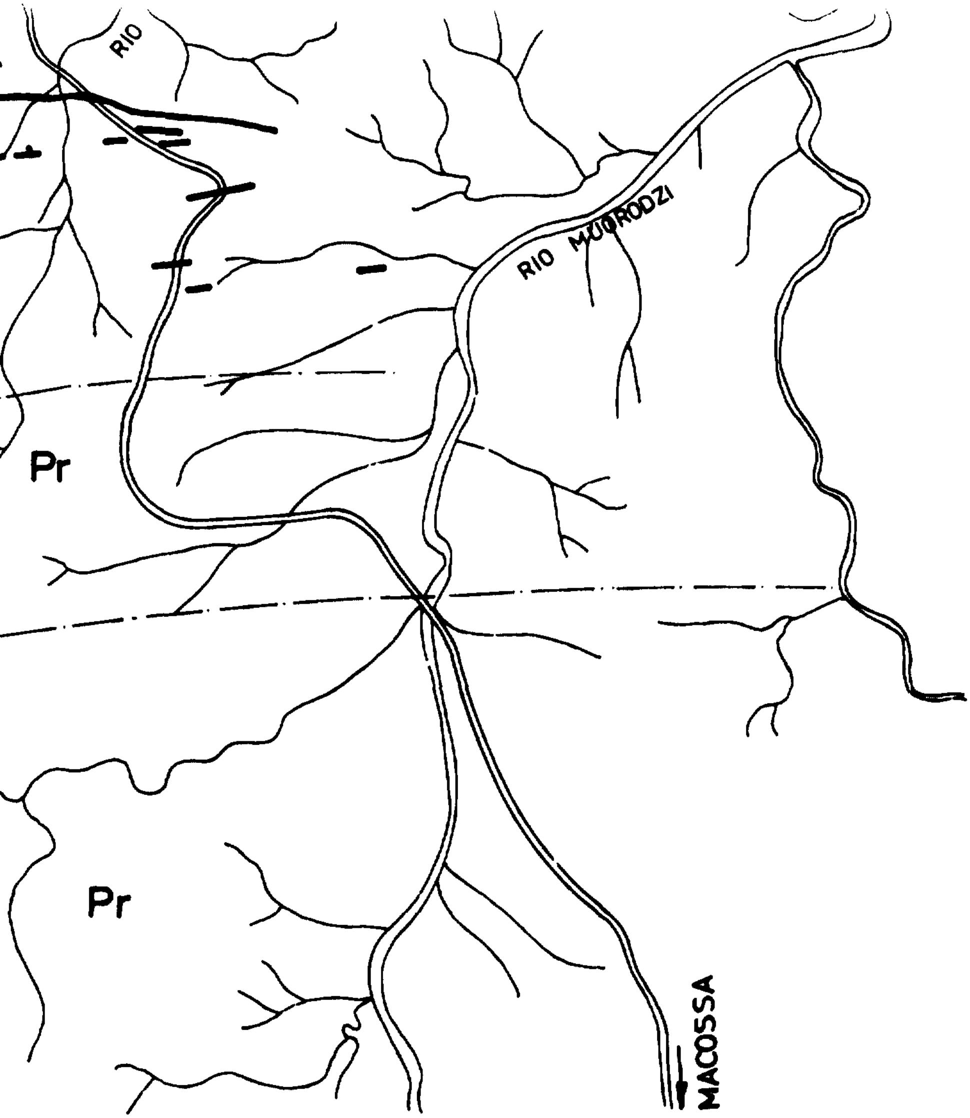
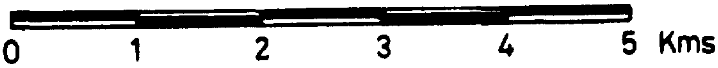


Fig. 3-4


SECTION 2
road
fluorite veins
probable contacts
basalt and tuff (postcarroo)
basalt (carroo)
Pr
basic complex (precambrian)



GEOLOGICAL SKATCH MAP
OF ZONE PLANNED FOR
PROSPECTION OF FLUORITE



As far as we are aware the next prospecting had been accomplished ten years later in 1972. The team was headed by Prof.Real and they carried out drillings and mining prospecting at the Geronimo deposit below Canxixe. No detailed documentation was made available to us in respect of this work. According to the data disclosed, three bores crossed the vein transversally in a depth of 80-90 m.

Thereafter a mining company was formed under the name Interminas Canxixe with participation of the Japanese Mitsubishi Corporation and this began planning and preparation for mining. Production was envisaged at the Geronimo D section and in fact it was started here. The Japanese enterprise predicted at this site 40,000 t commercial reserve (specific weight = 3 t/m^3). Taking advantage from the local topography a horizontal adit was opened and the vein had been worked above this to a height of 15-20 m.

The ore obtained was beneficiated exclusively by means of gravitational methods (crushing vibrational screening, manual selection) and since only those parts of the lode were regarded as usable which contained compact, separable fluorite, very good quality was achived. This material graded "fluorita individualizada" can be taken as representing 60 % CaF_2.

The enterprise Interminas Canxixe went bankrupt in 1979 when the Rodesian army occupied the site and the equipment was damaged in the fights. Then the Governement asked for the assistance of Bulgaria in order to restart the production. The Bulgarian firm GEOMIN contracted to reorganize the fluorite exploration and production at Canxixe-Maringue.

The concept established by the Bulgarians was slightly different from that applied by the Japanese as far as it calls for a drilling program and assures the planning of production and beneficiation technologies besides the repeated geological survey of the entire 50 km indication strip and reambulation prospecting.

The Bulgarian project includes the reinvestigation of about a dozen brecciated quartz veins the 50 km long strip, along the total length of the precambrium/basalt sediment contact.

The program prescribes 1:5,000 scale geological mapping, 1:10,000 scale geochemical sampling within the indication area and especially in the Geronimo area 10,000 m drilling generally to a depth of 40-80 m (eventually 120 m) and, of course, lode exploration by trenching.

At the present the job is in preliminary stage, it will be started in December and finished in the first quarter of 1983. The project will conclude in a report to be presented at the fall of 1983.

The most important deviation of the Bulgarian concept from the Japanese one can be seen in its decision to exploit the entire brecciated zone of the vein (both the compact and the scattered fluorite). Naturally, as a consequence the reserve becomes "diluted". In contrast to the 40,000 tons 60 % CaF_2 taken into account by Mitsubishi, the Bulgarians estimate 100,000 tons of material with 25-40 % CaF_2 content (Geronimo S).

In course of laboratory experiments all three grades of commercial concentrate could be produced successfully. The procedure applied is analoguous to that of separating heavy minerals. Regarding the Japanese production data it seems not impossible to gain a good quality industrial product. The Interminas Canxixe produced from about 30,000 raw ore 7,000 t acid grade material and 6,000 t metallurgical fluorite, while about 16-17 thousand t poor ore was deposited for later flotation.

From the abruptly finished operations of the Japanese firm there was left approx. 2,000 t as mined ore which is of the following quality according to analyses made by the Bulgarians:

CaF_2	65.8 %
SiO_2	21.1 %
$CaCO_3$	1.07 %
Fe_2O_3	0.5 %
$BaSO_4$	0.3 %

Results on the material beneficiated, prepared for transportation but actually also left at the site, are as follows:

CaF_2	91.79 %
SiO_2	5.12 %
$CaCO_3$	1.06 %
Fe_2O_3	0.49 %
$BaSO_4$	0.67 %

It can be seen clearly that the shift in concentration is exclusively due to selection: despite the 75 % decrease in quartz content the amount of calcit and iron changes negligibly and the barite content even increases to some extent.

Finally it should be noted that the Bulgarian exploration concept pointed out the existence of precambrian marble attached to the edge of the area, which might be of extreem importance as a metasomatic mineral trap.

Unfortunately we could not visit the Canxixe-Maringue fluorite deposit. Nevertheless, as a result of our talks with the members of the Bulgarian group we received a collection of samples at the beginning of April, 1982. These were selected samples from Canxixe, but we can only suppose their exact origin as well as the technique used for sampling. We guess they were selected at the Geronimo S site according to colour. Furthermore, the samples were confused during transportation, thus their contribution to our investigations can be only limited.

These unfavourable condition explain why only materials research was made on the Canxixe-Maringue samples.

3.33 Fluorite deposits at Monte Domba, Serra de Manguama, and Monte Bunga, and Lupata, respectively

On these areas the Geological and Mining Explorer Team No. 4 parallelly to their search after other raw materials - in 1963 looked also for fluorite. The following data can be underlined in their report:

Monte Domba

The indication of fluorite can be taken as positive within the following coordinates:

33°5' 28,3"	South latitude and
16°46' 3,8"	East longitude.

The width of the hydrothermal vein at this occurrence varies from 2 cm to 2 m. The line of lode is about 300°, and the slope is variable in direction around Northwest/Southeast.

The vein is filled by quartz, its material is compact. The secondary rock is not mineralized, scattered fluorite is rare.

The most important lode can be found in a line 310-130°, with 55-60° slope. It can be tracked for about 80 m in a width 1.70-2.25 m. The report mentiones also an alluvial zone. According to this fluoritic quartz debris is abundant along the whole area, in the densely scattered material one could find even larger blocks.

The width of the alluvial zone is 1.5 m at the Western slope of the mountain. In the summarizing section the report puts forward the statement, that the quality of compact, solid fluorite considerably surpasses that of the dispersed fluorite and describes the deposit as one having very advatageous characteristics although not even a single analysis is given for fluorite.

We could inspect the deposit of Monte Domba. In the two ditches left from previous explorations a leached out lode of quartz extends in the line 300°. The upright, practically vertical vein can be verified for 50-60 m in a width of 1.0-1.5 m. Doubts arose already during the inspection regarding the fluorite content of this vein and these doubts were confirmed by the optical investigation could detect the presence of fluorite. We face here a gap filled with useless quartz, thus neither the material extracted from the vein nor the scattered litological surroundings (debris) can give rise to optimism.

Serra Manguama and Monte Bunga

The territory is located between the South latitude 33°0'17.2" and the East longitude 16°51'20.1".

This vein is not explored yet but very roughly. Only ditch documentation is given, no map of exploration, site layout or any analysis data. (All available is a 1:50,000 scale sketch with shadowed outline of the prospecting area.)

Lupata

The Lupata deposit is mentioned in the 1964 report of the Geological Explorer Team No. 1.

Authors of this report are: José de Reis F.Rebolo mining engineer and Bernardine Pombo de A.Ferro geologist. Information gained from the latter allow to draw the following picture about the Lupata deposit.

It consists fluorite and barite in hydrothermal quartzitic brecciated veins. According to the arrangement this veins show kindred with the contact of the carroo-postcarroo formation and the crystalline komplex. They are ordered into Northwest-Southeast, and North-Northeast/South-Southwest lines of lode, respectively, close to the contact.

We do not know analytical results or other detailed exploration documentation concerning the area. As far as the available data are regarded only an indication is justified.

The characteristic geology can be summed up as follows:

Recent-pleistocene formations:	alluvium, fluvial, terrace stones
Tertiary formations:	postmiocene ultrabasic intrusions
Mesozoicum:	Lupata series (alternation of lava and sandstone)
Carro:	Stromberg series
	Basalt
	Batonga sandstone
	Beaufort
	Tete sandstone
	Gneiss migmatite complex
	Lode rocks.

Essentialy only the observations of a geological survey mapping are available, thus commercial value assessment is not feasible.

3.4 RELATIONS BETWEEN THE ORE RESERVES AND THE CAPACITY OF THE MINE TO BE OPENED

Before planning mine openings further geological explorations are needed. For the aims of this preliminary study it was supposed that:

- the ore reserve at Canxixe-Maringue is at least identical in size to that estimated in Djanguire;
- the arrangement of the fluorite veins is similar, the veins are narrow, almost vertical;
- referring to the geological conditions the same conditions of mining can be predicted for both fluorite deposits.

The capacity of the plant producing fluoride salts is 10,000 tpy. Taking into account also the technological losses of the beneficiation procedures and processing the mine has to provide 29,000 tpy ore with 50 % fluorite content. Due to the thin veins further 6,000 t rock must be removed from the deep mines,i.e. a mine of 35,000 tpy capacity would be able to supply raw material for the processing plant. If such a rate of production were realized the expected fluorite reserves of the Canxixe-Maringue (or Djanguire) deposit could yield possibilities for mining in a period of 15-20 years.

The economy of mining can not be improved by producing in excess of the demand set by the processing plant. This can be explained as follows:

- because of the thin veins the production can be intensified only by proportional expenditure;
- the fluorite reserves are not well enough known;
- due to transportation difficulties the stock (consisting of auxiliary materials and mined ore) to be deposited will increase;
- the price of fluorite marketed as mined mineral or as concentrate will be augmented by the overhead costs of transportation to the sea;
- there is no skilled labour.

3.5 THE FLUORITE PRODUCTION IN THE NATIONAL ECONOMY AND THE MARKET POSSIBILITIES

The existing industry in Mozambique does not consume fluorite and there is no important fluorite user in the perspectives except the aluminium smelter.

Among the foreign users one could enumerate the metallurgical industry of the African states as well as that of the Arabic countries and India. In the latter states the establishment of smelters - first of aluminium smelters - is intended, and these will consume fluorite and fluoride salts.

If producing 29,000 tpy ore, Mozambique would occupy the 29th position in the list of fluorite producing countries (according to the statistics of 1980 the total fluorite production in 27 countries equals 4.9 million t).

The possible preparation of mined fluorite was analysed in 3 alternatives:

Var. 1: 29,000 tpy raw mined product with 50 % average fluorite content. When extracting the material of the entire fluorite vein caution is necessary during explosions and transportation that the ore should not intermix with the dead rock worked inevitably. The fluorite is comminuted by means of jaw crushers in the mine area and then transported to the site of further processing. The ore containing 50 % fluorite can be transformed into fluoride salts directly, provided adequate technology is applied. The waste is removed from the pit by a light bagger and it is levelled by a doser. The costs of waste handling appear together with those of mining because the stock of ore produced in the rainy season and temporarily undeliverable is deposited using the same equipment.

Var. 2: Crushing the ore twice, selecting manually and screening the finer material one could obtain at the mine a fluorite of metallurgical grade (metspar) with 70 % CaF_2 in a quantity of 21,000 tpy. The separated material fraction has still fluorite content, thus should be stored isolated from the dead. If the technical and/or economic conditions change this mined material will become eventually processable and does not add to the loss of ore resources. The mass of material to be transported diminishes that way by 30 % and the product quality might justify direct marketing.

Var. 3: The raw ore from the mine will be prebeneficiated as described in Var. 2. Further processing is contemplated at a place possessing more advantageous infrastructure (chemical plant, harbour, railway station, etc.). It is not necessary to transport the pre-concentrate in special containers which are inadequate to deliver in reverse direction the material required for mining. Electrical power drawn from the mains costs only one third of that produced by an aggregate. The water needed for wet technology can be provided easier even in the dry season. The flotation plant would not follow the mining centre moving continuously to the locations of the ore. The product gained after flotation is 14,000 tpy acid grade fluorite a CaF_2 content exceeding 97 %. This is the best starting material for a plant producing fluoride salt. The quality would be good enough for immediate selling.

In the technological variant where jet-mills and air-classifiers accomplish the grinding before flotation the different quality ceramic grade fluorite fractions may also be separated. Var. 3 is thus capable to produce from a raw ore with 50 % CaF_2 either metspar or ceramic grade fluorite or acid-spar.

It should be also noted that the Djanguire deposit includes quartz in such a crystalline structure that 30-40 % of the fluorite gets into the waste. The particle size after grinding is, however, in this case very fine and consequently the material can not be stored as an ore reserve.

The anticipated investment and operational costs are very high for the marketable products and if amortisation, interest and transportation fees to the sea must be added it seems impossible in the present economic situation to achieve the rate of profit which would make commercial production reasonable. In case of domestic utilization reasons like interest of industrial development, avoiding import and social benefits might justify the prompt starting of fluorite production and beneficiation.

4. MATERIAL INPUTS

4. MATERIAL INPUTS

4.1 Raw material

The previous analysis data, published in the paragraph 3.31 were not enough to determine the beneficiation technology of the fluorite. The results of our investigations on the samples collected on the site were the following:

Analysis of the chemical compositions

The samples received were analysed in details with the most exact methods for 22 chemical components. A part of these components (9) could be found comparatively greater quantity and in the identifiable mineralogical phases. An other smaller part of the components were less identifiable according to mineralogical components. The behaviour of the latters during the beneficiation procedure were not followed with attention, and they are put in the table only for the sake of completeness.

The chemical compositions of the three raw basic samples shows Table 4-1.

We have to make another comment in connection with the chemical analysis, that we applied a special quick analysis method at the analysis of the enriched fractions. This method made it possible to determine four components in one operation. Beyond the determination of the two main components, i.e. the CaF_2 and the SiO_2, we received the total carbonat content related to $CaCO_3$ and the total amount of the trivalent metal oxides. During the beneficiation process we could follow these, so we analysed in the followings only in this manner. The composition of the two samples from Djanguire are the following according to the above said /see page 27/.

Table 4-1

Place of occurrence		Djanguire		Canxixe-Maringue
Analysed components		sing 2/8/T	1/6/T	3/T
Main components:				
CaF_2	%	41.10	63.80	72.20
CaO (not fluo)	%	1.1	0.2	5.0
MgO	%	0.4	0.05	0.1
K_2O	%	3.1	1.1	0.2
Na_2O	%	0.12	0.08	0.05
SiO_2	%	48.64	29.32	18.00
TiO_2	%	0.3	0.08	0.2
Al_2O_3	%	4.7	1.7	1.3
Fe_2O_3	%	2.5	0.64	0.5
Other components:				
BeO	%	0.06	0.08	0.015
Li_2O	%	0.26	0.22	0.21
P_2O_5	%	0.05	0.03	0.05
V_2O_5	%	0.01	0.01	0.02
ZnO	%	0.014	0.018	0.004
S_{total}	%	0.02	0.03	0.01
Pb	%	0.04	0.04	0.01
Ga	%	0.001	0.001	0.1
Cr	%	0.09	0.09	0.005
Ni	%	0.07	0.07	0.01
Cu	%	0.025	0.025	0.005
Y	%	(1-2 ppm)	(1-2 ppm)	0.01
MnO_2	%	0.01	0.02	0.01

Note: The sulphur content is so small, that it could not have been investigated the distribution in sulphate and in sulphite.

The samples were wery poor in Y!

Components		Sign of samples	
		2/8/T	1/6/T
CaF_2	%	41.10	63.80
SiO_2	%	48.64	29.32
$CaCO_3$	%	3.41	2.12
R_2O_3	%	6.85	4.76
	%	100.00	100.00

Analysis of the mineral composition

In respect of the beneficiation, the mineral composition is at least as important as the chemical one. The examinations were carried out by means of traditional mineral-optical, and by X-ray diffractometry methods. According to the results of the examinations of the thin sections taken from the vein stuffs, the material contains mainly quartz and fluorite. The quartz is observable in two generation in forms of xenomorphic agglomerations and in form of columnar crevice fillings. The former is composed of mosaic-like interlaced agglomerations of entities of 20-200 μ size, the crevice fillings, however, of undulatorily extincted columns of abt. 2,000 μ size of quartz. The fluorite itself is composed of very great - several ten-thousand μ size reaching - entities. It is often interlacing the material as a dense crevasse network. They are spotted by tiny anisotropic inclusions of μ-size diameters, and contaminated by 2-10 μ size crevice filling materials. The country rock which is closing the vein is gneiss, which contains in two generations feldspar (great orthoclases in ten-thousand μ sizes and smaller 150-300 μ size feldspar gatherings of twin lamellar form). There is a frequent occurrence of quartz in form of xenomorphic agglomerations of some hundred µ size entities. As coloured blending parts are mainly muscovite and decomposed biotite present, as well as some unimportant piroxene-needles.

In occurrence the following constituent is the feldspar, in the shape of needle appearance, with crystals of 150-300 µ length and 30-50 µ width. They are often decomposed, into chlorite and ferrous (limonitic) flakes. The third most important constituent is the chlorite. As regards to its composition we deem it to Mg/Fe/Al-silicate conglomerate with a medium iron content in form of pennine-ironprochlorite. On rare occasions as accessory mineral compounds we could find illite and very little quantity of opaque material.

The mineral composition of the three basic samples were, taking into consideration the X-ray diffractometric examinations as follows:

Mineral	Djanguire		Canxixe-Maringue
	2/8/T	1/6/T	3T
feldspar (Or-Mk)	8.1	3.7	0.7
quartz	42.7	25.3	16.8
chlorite	2.0	0.2	-
muscovite, biotite	1.5	0.8	-
milarite	0.2	0.3	-
fluorite	41.7	63.8	76.1
limonite	0.5	0.5	-
ankerite	2.5	0.6	-
calcite	-	-	1.4

In principle the fluorite could be selected well out of this row by specific weight, but the frequent crevassing and the crevase filling ferrous contaminations (ankerite?) as well as the crystal coalescences are hindering this. Taking into account the size of the individual crystals to free the fluorite the material should be ground below the size of 50 µ because the coalescences. The extraction of the contaminations out of the crevasses of the fluorite is practically not possible.

The composition of the sample taken from Canxixe is nearer to the customary pattern. We could find hardly some feldspar in it, which presence in the samples of Djanguire is so disturbing, it appears the kaolinite, which is most probably the decomposition product of the feldspar. We have to point out that it could be rendered probable the presence of many such minerals the concentration of which are below the limit of detection by means of X-ray diffractometry. The presence some of these can be rendered probable beyond the chemical compositions by means of exposures taken from the elementary distributions. Such minerals can be, e.g. on the basis of the phosphor content - the apatite, respectively, the fluor-apatite, some sulphide and sulphate (Magnesium sulphate) lithium mica,and the so-called pearl mica (margerite) and some sorts of granite etc.

In order to define the temperature of the formation of the fluorite we made decrepitation examinations on one sample taken from Djanguire and on one sample taken from Canxixe. The results showed unimportant differences 330 °C (± 5°) and 336 °C (± 7°) as to the relative formation temperatures.

The occurrence of Canxixe-Maringue which was examined in lesser degree seems to differ from the occurrence of Djanguire by its simpler mineral composition and more decomposed, clayey upgrowth.

The examinations of the samples taken from Monte Domba have resulted in all fields and uniformly negative.

Taking into consideration that the previous reports have not mentioned any results of analyses of this occurrence, presently we might presume that such results have never been. We could not trace the presence of fluorite either by chemical or by mineralogical examinations (we made 4 chemical analyses and 7 thin section examinations). The vein of Monte Domba, in the examined two trenches and in the supposed secondary deposits in the gravel were consisting uniformly of waste quartz filled, on some place pale yellow, in feldspar rich aplite-like rocks.

Further examinations with electron ray micro-analyser and beneficiation tests were carried out only on sample from Djanguire, because only these materials could be regarded as mine products. The selected samples taken from the occurrence of Canxixe-Maringue, which were free from harmful contaminating materials could leed to unrealistic technological results.

By the application of the micro-analyser it became possible to study the regional distribution of the most important elements in respect of the enrichment (F, Si, Fe, Ca, etc.).

The attached photos are showing the structure of the individual representative samples. The group of figures showed on the photos are meaning the followings:

10	601	3587	0010.0
exciting voltage in kV	magnification $60x10^1=600x$	serial No. of the photo	the sign corresponds 10 (ten) micrometers

1. Group of photos (3687-3692) vitreous fluorite grain. Its contamination is primarily Si.

2.	Group of photos	(3609-3619) A greater fluorite inclusion in a big field of silicates.
5.	Group of photos	(3643-3650) Dark violet-coloured fluorite with quartz inclusion, the crevasse fillings are mica and feldspar.
11.	Group of photos	(2223-2229) A coalescence of fluorite-quartz - feldspar.
12.	Group of photos	(2238-2239) A coalescence of fluorite and quartz.
13.	Group of photos	(3559-3567) A brown-violet coloured part, richer in fluorite, a fluorite - silica coalescence.

We have ascertained on the basis of our examinations carried out by means of electron-ray micro-analyser the followings:

- The deepening of the colour of the fluorite (colouring) means at the same time the increase of the contaminations. The fluorite tinted to dark-violet colour is the most contaminated.

- The material of the occurrence of Djanguire can be enriched only with rather great difficulties according to the classical preparation methodes, because practically there can not be found a pure phase, respectively, the required purity of the fluorite can be achieved by means of considerable losses in CaF_2. The loss of fluorite is abt. 15-20 % when ground under 200 μ, which can be decreased to 5-10 % if the ore has been ground under 40 μ. Reaching this grain-size there are emerging difficulties in the enrichment, which is caused by the previously mentioned colloidal size hematite, which acts as a toxic agent at the process of the flotation.

Table 4-2

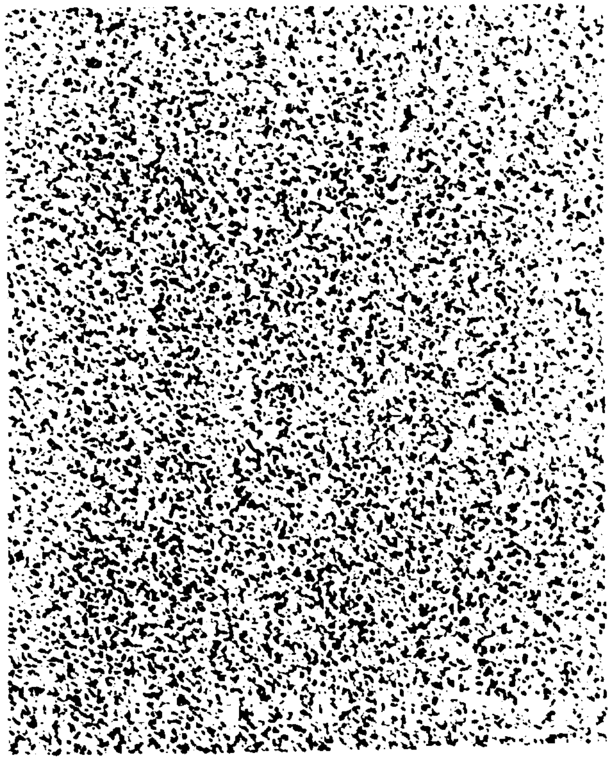
1. GROUP OF PHOTOS /3687-3692/
Vitreous fluorite grain.
Its contamination is primarily Si.

BEI

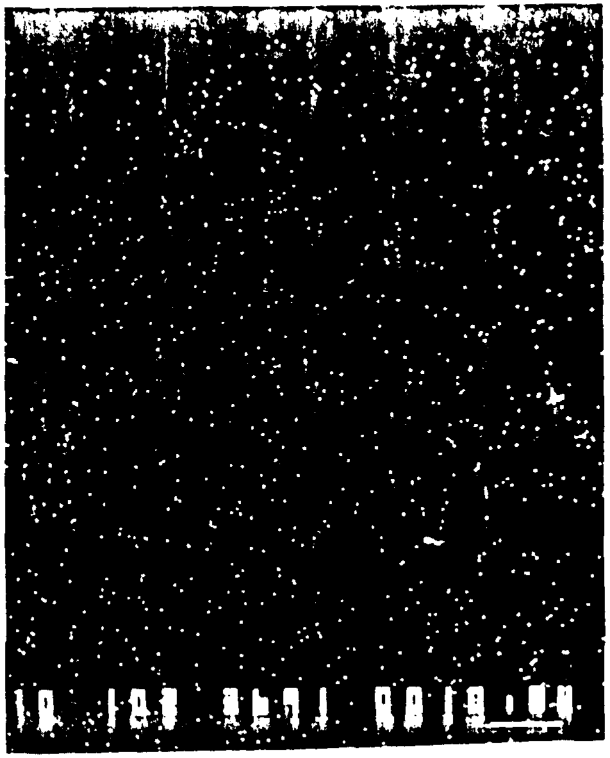
BEI

Table 4-3

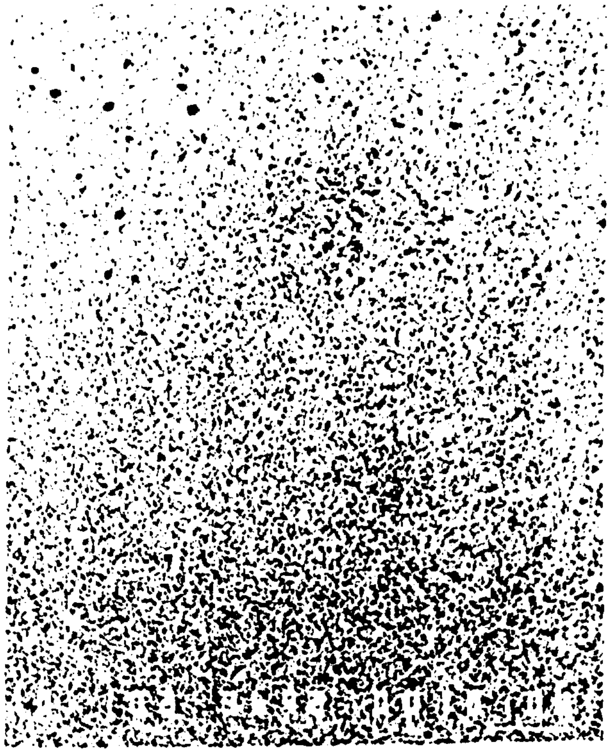
1. GROUP OF PHOTOS /3687-3692/
Vitreous fluorite grain.
Its contamination is primarily Si.



F K_α



Si K_α



Ca K_α

Table 4-4

2. GROUP OF PHOTOS /3609-3619/
A greater fluorite inclusion in a
big field of silicates.

BEI

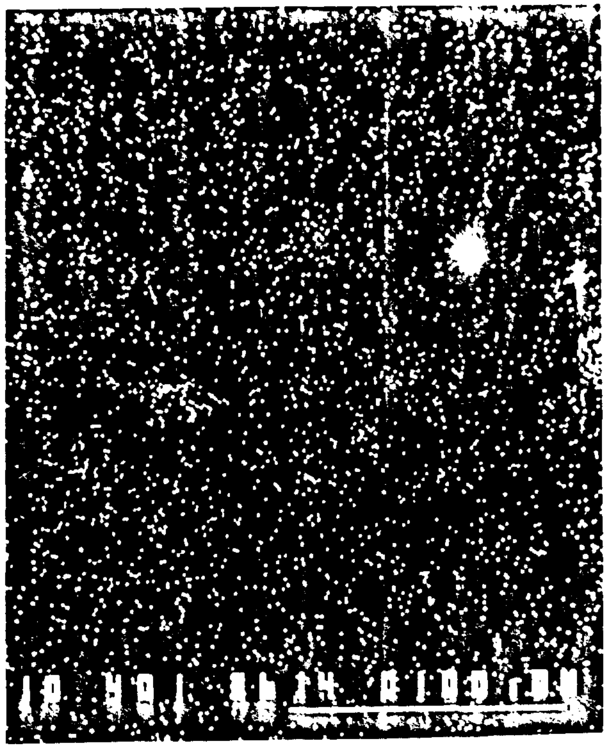
BEI

2. GROUP OF **PHOTOS** /3609-3619/
A greater fluorite inclusion in a
big field of silicates.

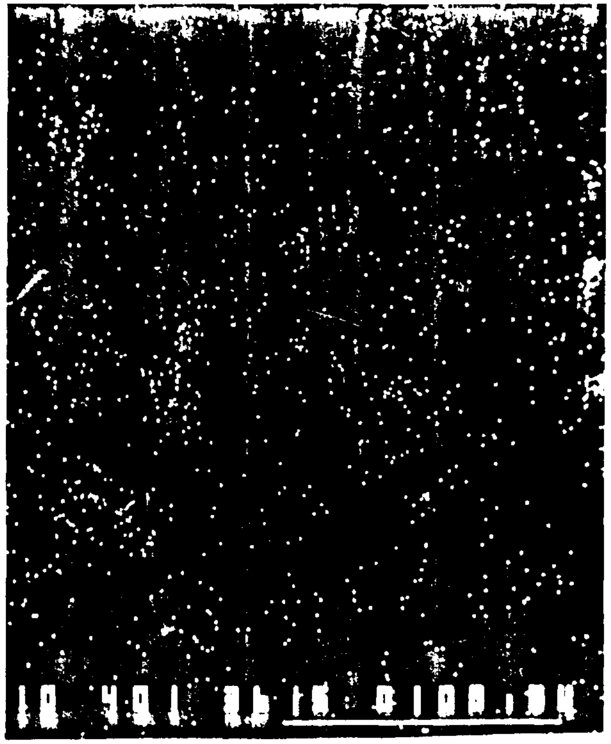
F K_α Si K_α Fe K_α

Table 4-5

2. GROUP OF PHOTOS /3609-3619/
a greater fluorite inclusion in a
big field of silicates.



Na K_α



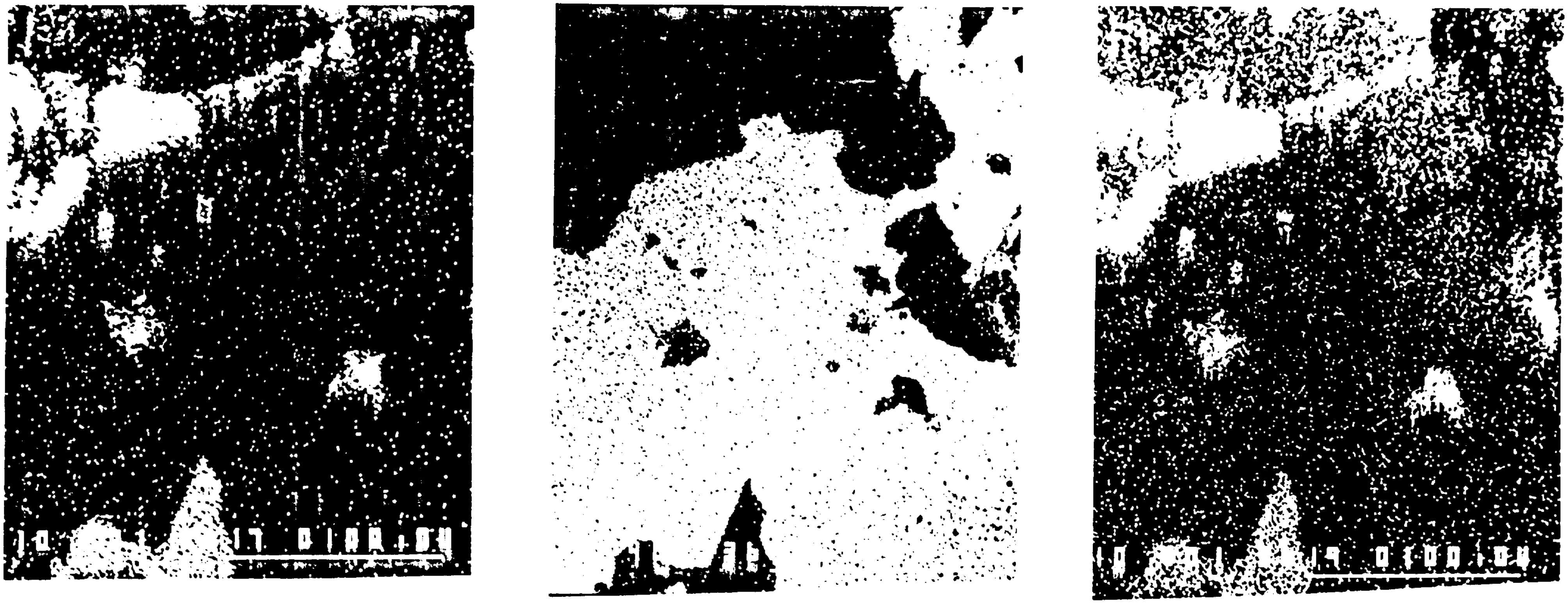
S K_α

Mg K_α

Table 4-6

2. GROUP OF PHOTOS /3609-3619/

A greater fluorite inclusion in a big field of silicates.



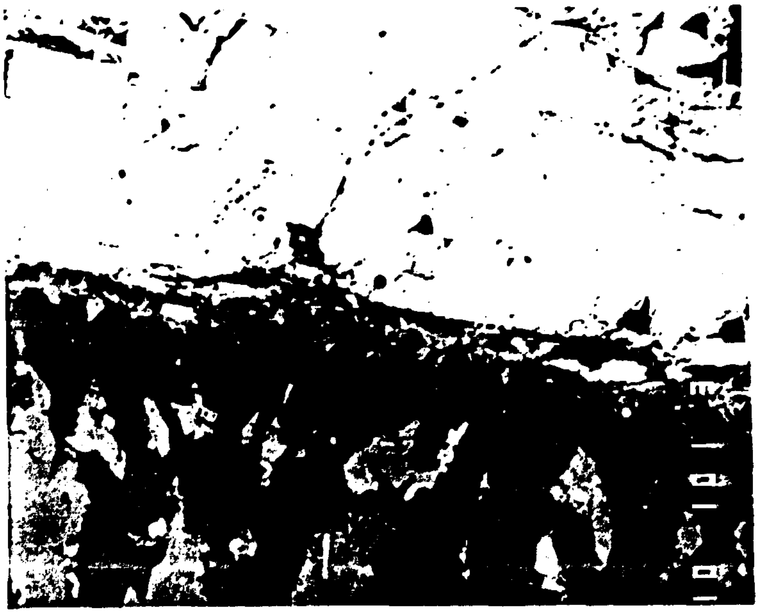
K Kα Ca Kα Al Kα

Table 4-7

Table 4-8

5. GROUP OF PHOTOS /3643-3650/
Dark violet-coloured fluorite with quartz inclusion, the crevasse fillings are mica and feldspar.

BEI

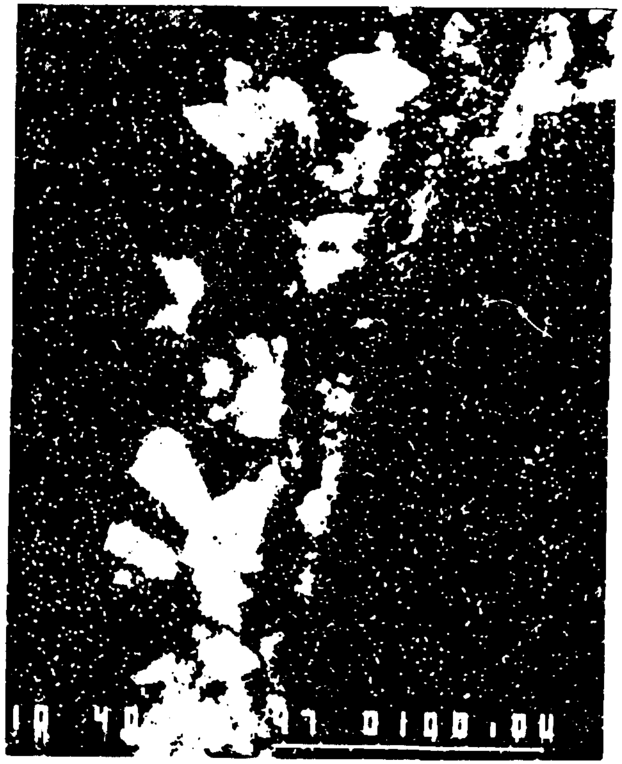


BEI

5. GROUP OF PHOTOS /3643-3650/
Dark violet-coloured fluorite with quartz inclusion, the crevasse fillings are mica and feldspar.

Si Kα

F Kα



K Kα

Table 4-9

5. GROUP OF PHOTOS /3643-3650/
Dark violet-coloured fluorite with quartz inclusion, the crevasse fillings are mica and feldspar.

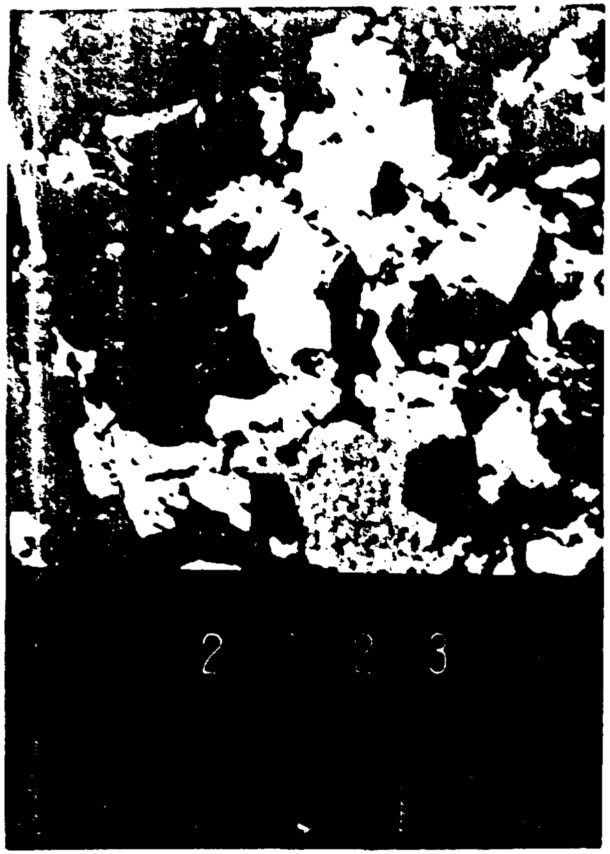
Mg K_α

Ca K_α

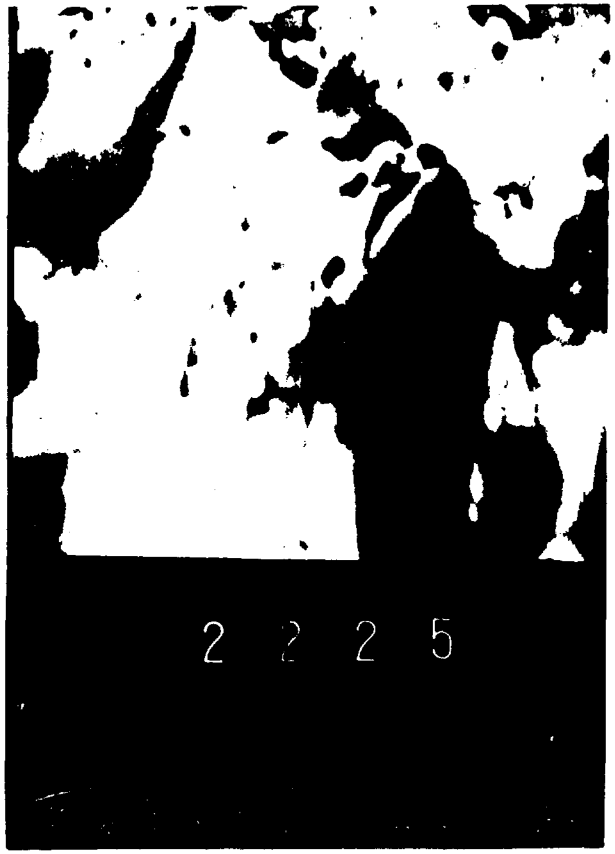
Al K_α

Table 4-10

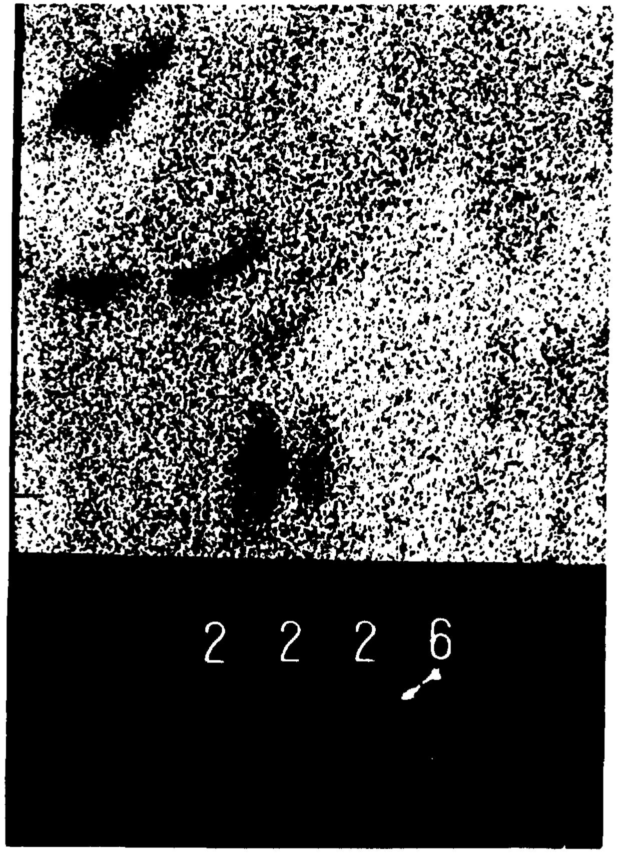
11. GROUP OF PHOTOS /2223-2229/
A coalescence of fluoritequartz - feldspar.



BEI
N ~ 200×



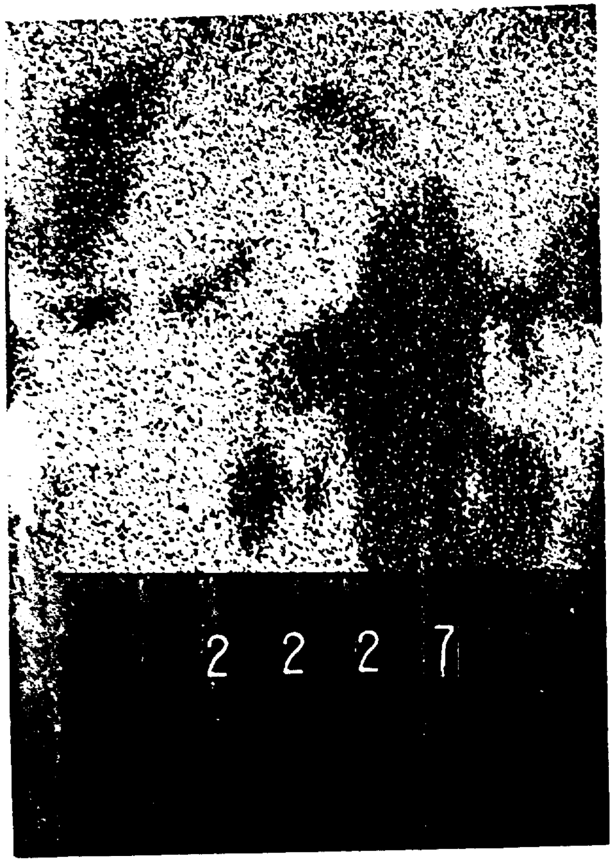
BEI
N ~ 800×



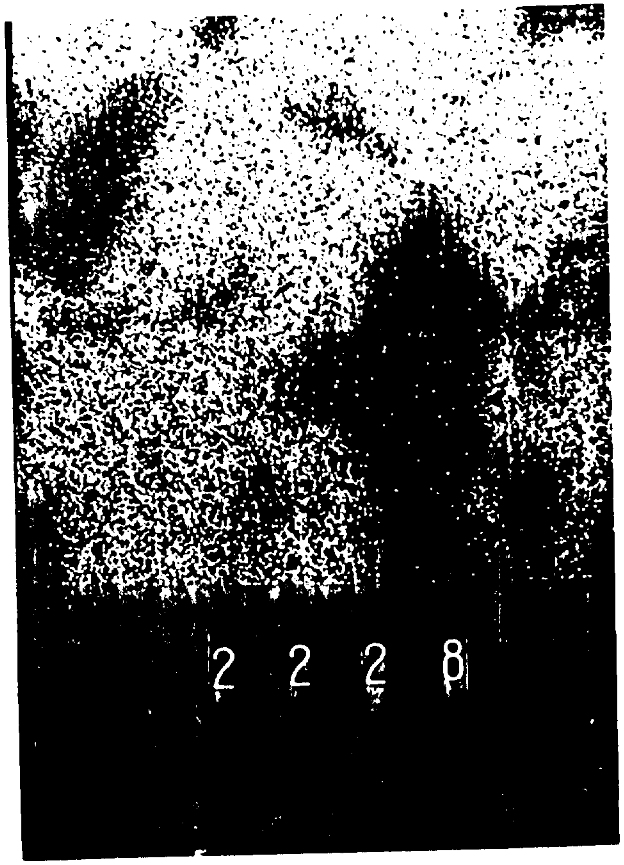
Si Kα
N ~ 800×

Table 4-11

11. GROUP OF PHOTOS /2223-2229/
A coalescence of fluoritequartz - feldspar.

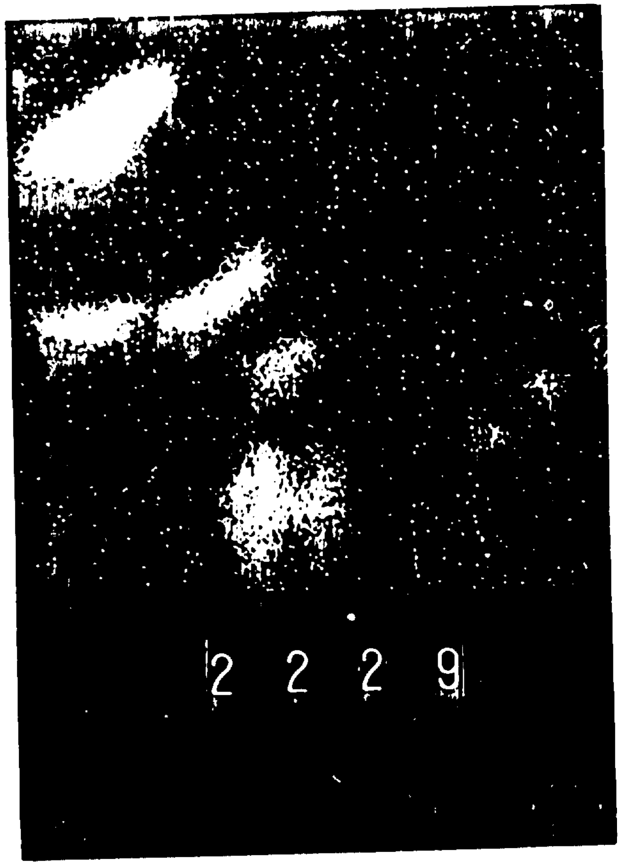


Al Kα



K Kα

N ~ 800x

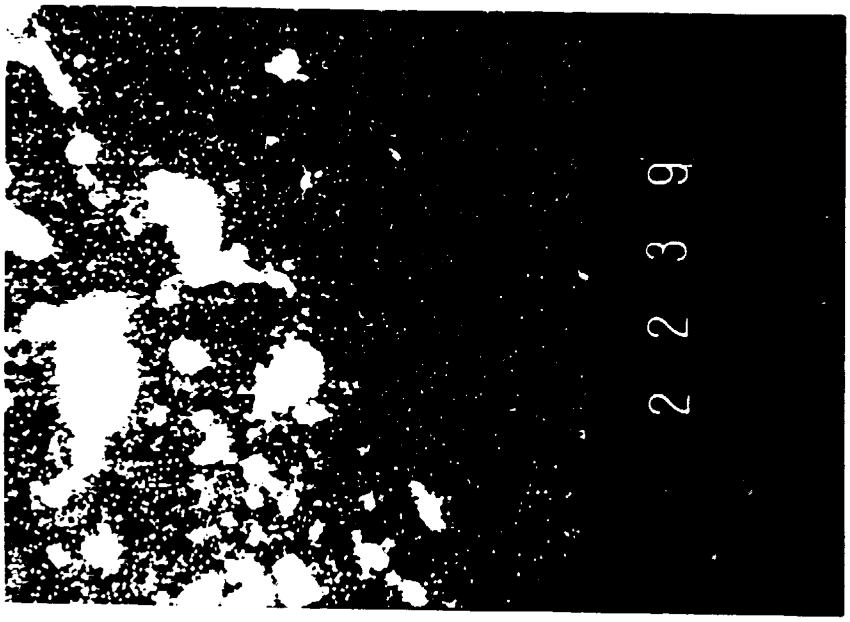


Ca Kα

Table 4-12

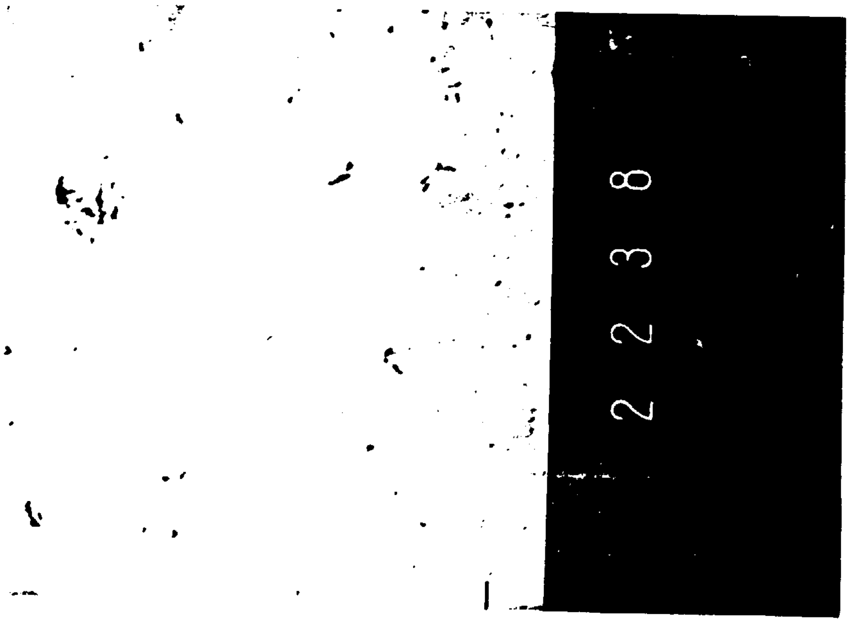
Table 4-13

12. GROUP OF PHOTOS /2238-2239/
A coalescence of fluorite and quartz.



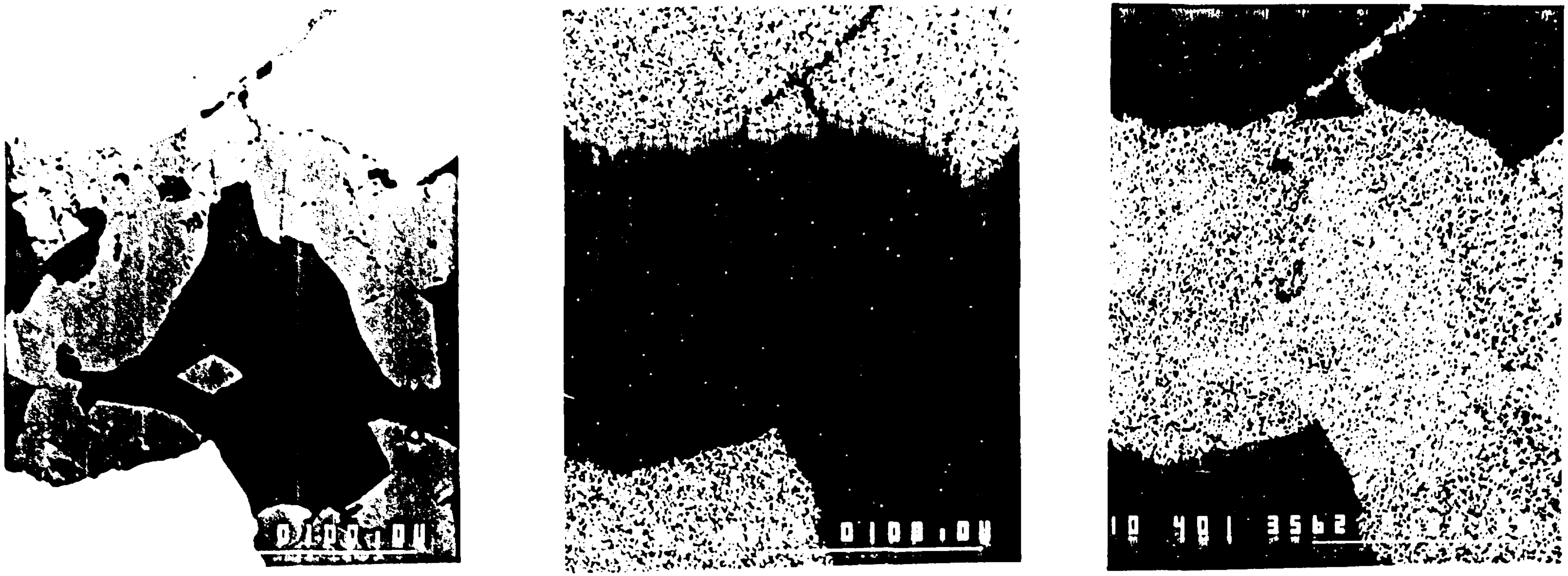
Ca K_α

N ~ 200x



BEI

13. GROUP OF PHOTOS /3559-3567/
A brown-violet coloured part, richer in fluorite, a fluorite - silica coalescence.



BEI

F Kα

Si Kα

Table 4-1

13. GROUP OF PHOTOS /3559-3567/
A brown-violet coloured part, richer in fluorite, a fluorite - silica coalescence.

Mg Kα

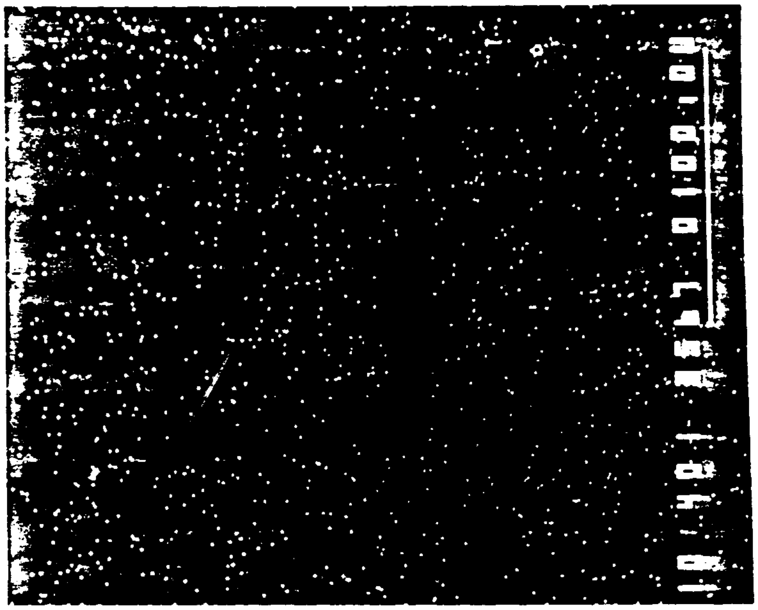
K Kα

Ca Kα

Table 4-15

Table 4-16

13. GROUP OF PHOTOS /3559-3567/
A brown-violet coloured part, richer in fluorite, a fluorite - silica coalescence.



Fe Kα

Al Kα

Examinations of the beneficiation possibilities

The examined alternatives

1. Crushing, classification, manual selection
2. Crushing, classification, selective grinding
3. Curshing, classification, concentration by flotation
4. Crushing, selective grinding, magnetic separation, and concentration by flotation.

Main remarks regarding the tests

- The best selective result of crushing can be achieved in jaw-crushers when it is overcharged.

- The screening off the material at + 3 mm size, after a roll-crusher can separate nearly 20 % of the SiO_2 content by a comparatively small (4-5 %) loss of CaF_2.

- In case the CaF_2 content of the primary ore reaches at least 40 % before crushing, the enrichment by manual selection might reach 70 %.

- The best selection results can be achieved by ores crushed to 15-20 mm size by application of the fluorescent separator of the "ORE SORTERS" equipment. However, this equipment is not mentioned in our technological recommendations, because of its capacity which strongly exceeds the required quantities, and because its high price (1.2 million US$) which could not be justified after the economic and social considerations.

- The advantage of the selective dry milling is, that in the jet-grinder the ore particles are colliding each other and its consequence is the grinding. The samples at hand, however, were not enough to perform such tests, therefore, we tried to define the proper dimensions by an indirect method, fixing the optimal collision-speed.

- In case the ore was ground - after a two step crushing - in a ball mill (i.e. no selective grinding was applied) than we could concentrate the fluorite content - by applying a flotation operation under -200 µ - up to 97 %, but we could not decrease the SiO_2 content to the required limit of the acid grade requirement. In case the grinding was continued (under -40 µ) and then flotated, the loss of CaF_2 rose to an unacceptable size the cause of which were shown on the photos of the micro-analyser (sprincled quartz, colloid forming hematite). The "conventional" technology does not seem optimal in consequence of the above said.

- The minerals containing iron and titanium can be removed satisfactorily by magnetic separation, applying low strength of magnetic field (0.4 Tesla). In such a way just those parts of the SiO_2 containing minerals could be removed, which hamper the most of the selective grinding-classification and the flotation operations.
  The application of the selective grinding- and classification and magnetic separation makes the manual selection unnecessary.

- To select the most effective reagent at the flotation, the carried out tests showed that the oleic acid proved to be the most adequate collective reagent.

4.1 Auxiliary materials

Auxiliary materials and power requirement to the technological processes related to 1 ton of product:

		Var. 1	Var. 2	Var. 3
Security material in the mine	(pcs)	0.03	0.03	0.03
Explosives	(kg)	2.4	2.4	2.4
Fuses	(pcs)	0.4	0.4	0.4
Diesel fuel	(l)	4.52	5.02	5.02
Lubricating material	(kg)	0.15	0.22	0.3
Electric power	(kWh)	-*	4.17	50.27
Water	(m^3)	-	-	0.76
Chemicals to the flotation	(kg)	-	-	1.9

* - It is included to the Diesel fuel which is needed to the operation of the power aggregate.

5. LOCATION AND SITE

5. LOCATION AND SITE

5.1 Location of the Mine

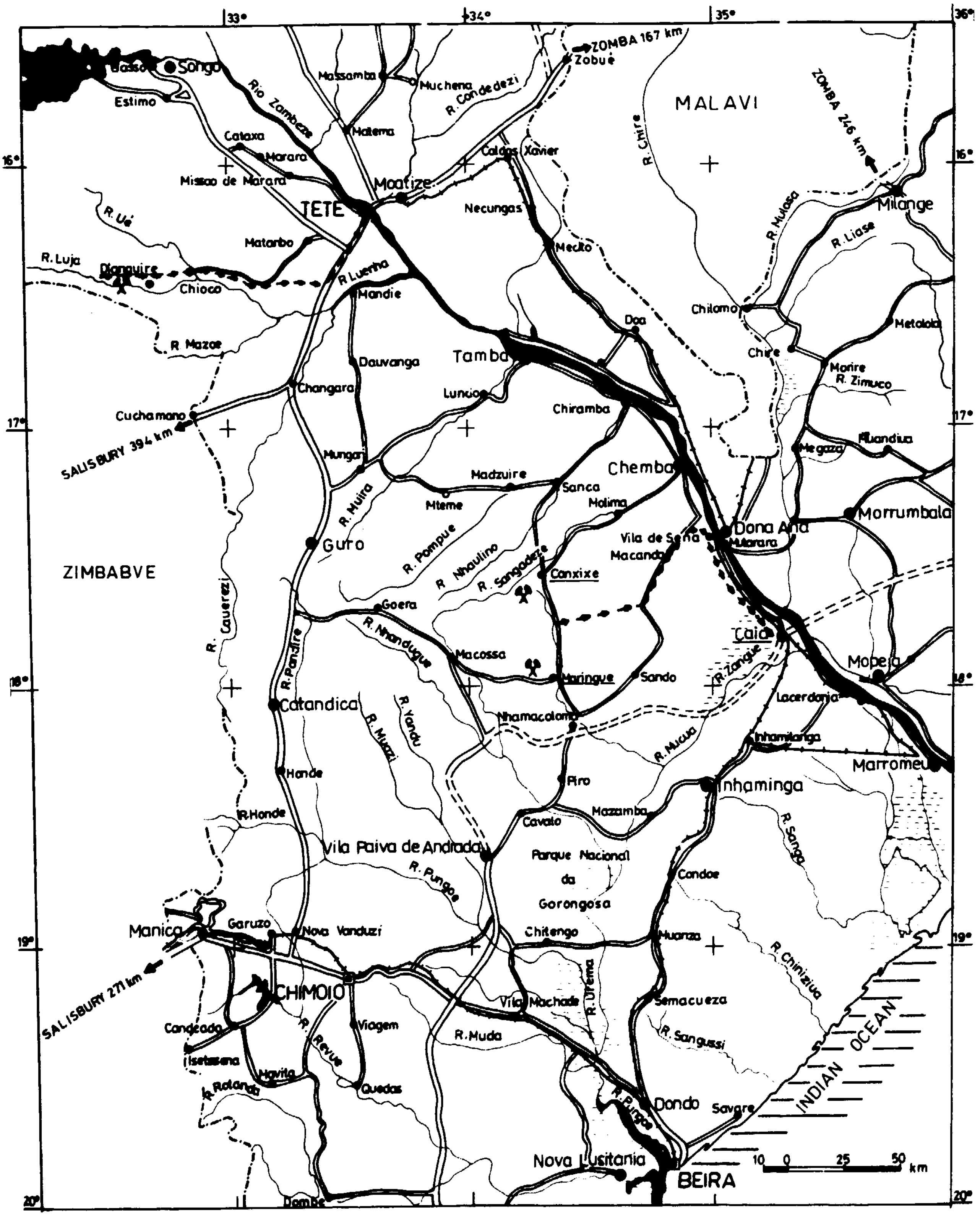
Regarding the location of the mine, the occurrence of the Canxixe-Maringue is more favourable. The ore deposit is at least as big as of the occurrence at Djanguire - according to our estimations. The quality of its fluorite is most probably better.

Djanguire lies 160 km - from the township of Tete (i.e. from the rail station, resp. from the river of Zambezi). Out of this 110 km are dirt road, and 50 km metalled surface road. The centre of the Canxixe-Maringue line lies 101 km from the settlement of Vila de Sena, which has a rail station and which is built at the Zambezi river. The road to this settlement is dirt road entirely. It leads to the township Caia a further dirt road of 58 km.

While the neighbourhood of Djanguire is the one of the least populated areas of the country (the density of population lies under 2 persons/km^2), the vicinity of Canxixe is relatively well populated. Therefore manpower can be secured much more easily. Industrial infrastructure does not exist on any of the two places.

The delivery distance of the equipment and materials supplied from abroad is much less in case of Canxixe. The better conditions are verified by the fact, that this occurrence has been commenced to be exploited already at an earlier date.

The mining plant has to be located - of course - upon the ore deposits. The narrow, almost vertical and streched out in the length veins allow only a wandering exploitation of the mine. We left out of the crushing and classifying equipment only those which can separate about the 30 % of the raw mine product, in order to decrease the quantity to be delivered further. A further point of view is that during the dry season, the mine districts are suffering from the



GENERAL MAP OF AREA
BETWEEN TETE AND BEIRA

Fig. 5-1.

water shortage, while during the rainy season the mine districts can not be approached at all for several months.

Meteorological data from the mining sites were not available. We know only by the traces of water flows and out of the national precipitation data that on the fields and on the dirt roads the traffic is made impossible during the rainy season. We have taken a four months period as a maximum, when no traffic can be effected in respect of the determination of the dumps of the product (fluorite) and for the operations necessary auxiliaries. In case more accurate data will be available, these positions might be decreased.

There is no high voltage power-line in the vicinity of the mining districts. The power generated by the captive aggregates costs about the threefold of the power taken from the network. This fact is justifying the decision, that at the site of the mines only the most indispensable ore-preparation equipment have to be placed.

5.2 Location of the beneficiating plant

The other equipment of the ore beneficiating plant has to be placed suitably at the site of the fluoride salt producing chemical plant. The location of this will be according to our present sutdy Caia. Even in case the marketing of unprocessed fluorite would be decided, the grinding, classifying and flotation plants have to be placed economically on such transfer places (Vila de Sena, or Beira) where there is an industrial infrastructure (electric power from the network, water etc.) already present, or will be available in foreseeable future (see Var. 2. and Var. 3.). On this places it has to be built in any case ore deposits, because of the absence of lorry transport possibilities during the rainy seasons.

The possible locations of the ore beneficiating plants could not be investigated at site by us. We could not receive adequate data, nor detailed maps of the site. At the definition of the locations of the building sites of the plants it has to be taken into consideration the environmental protection against the dust and the noise of these plants especially at the vicinity of inhabited areas.

5.3 Environment

According to the law in Mozambique territory can be obtained for domestic companies from state owned territory without compensation. The mine district is uninhabitated savannah, where the mining operations and the deposition of the ore and the waste as well as the dust from the crusher plant do not contaminate inhabitated areas. There is no harmful industrial sewage output. The abondened areas are not spoiling the landscape; the production of fluorite is generally done by underground working. The trenches, which remain at the outcrops of the veins at the surface, will be filled with the rock-debris from the further operations. The openings of the abandonned underground mines have to be closed to prevent any mishaps.

6. PROJECT ENGINEERING

6. PROJECT ENGINEERING

6.1 TECHNOLOGY OF THE MINING PLANT

The possibilities of the mining operations are determined by the bedding circumstances of the fluorite deposites.

The fluoritic quartz veins are - generally - protruding from the eroded vicinity, because of their more resistant rock-material to the weathering. These protruding veins can be exploited by open pit mining. However, these parts of the narrow vertical veins stretching into the depths are so small, that at the economic calculations we have not taken them into consideration. The machines provided to the underground mining /bulldozers, LHDs, drilling machines etc./ can be utilized to the open pit operations, too.

After ending the open pit operations, where at the bottom of the trench only the vein has been exploited, a covering concrete layer has to be applied, to protect the deep-mining operations.

For a production of 29-30,000 tons per year of ore, supposing an average thickness of the vein 1 m, and taking the bulk density of 3 tons/m^3 into account, round 10,000 m^2 of the vein have to be exploited.

Calculating with economical underground haulage distances - taking into consideration 100-100 m long wings - it would be necessary to mine the fluorite to a depth of 50 m. Until the geological survey has to depend on surface trenchworks it would not be advisable to envisage in the first step greater depth in the exploitation. The intended technology can be applied otherwise without any modifications either repeated in greater depths or continued horizontally, only the shafts have to be sunk further, or new shafts have to be opened.

On the principal sketches the twofold mining systems can be seen.

a) Raise Stoping (Alimac method)
b) Sublevel Stoping

There is no significant difference between the two methods either in technical, or in economical point of views. The requirement of the drift driving is greater in the second case. On the other hand, the drillings for the blasting can be made from a more comfortable position, and the individual bore-holes are shorter.

At both methods of stoping the fluorite blast out of the vein gets by gravitation on the haulage level, where rubber tyred LHD equipment is collecting and hauling to the vertical shaft.

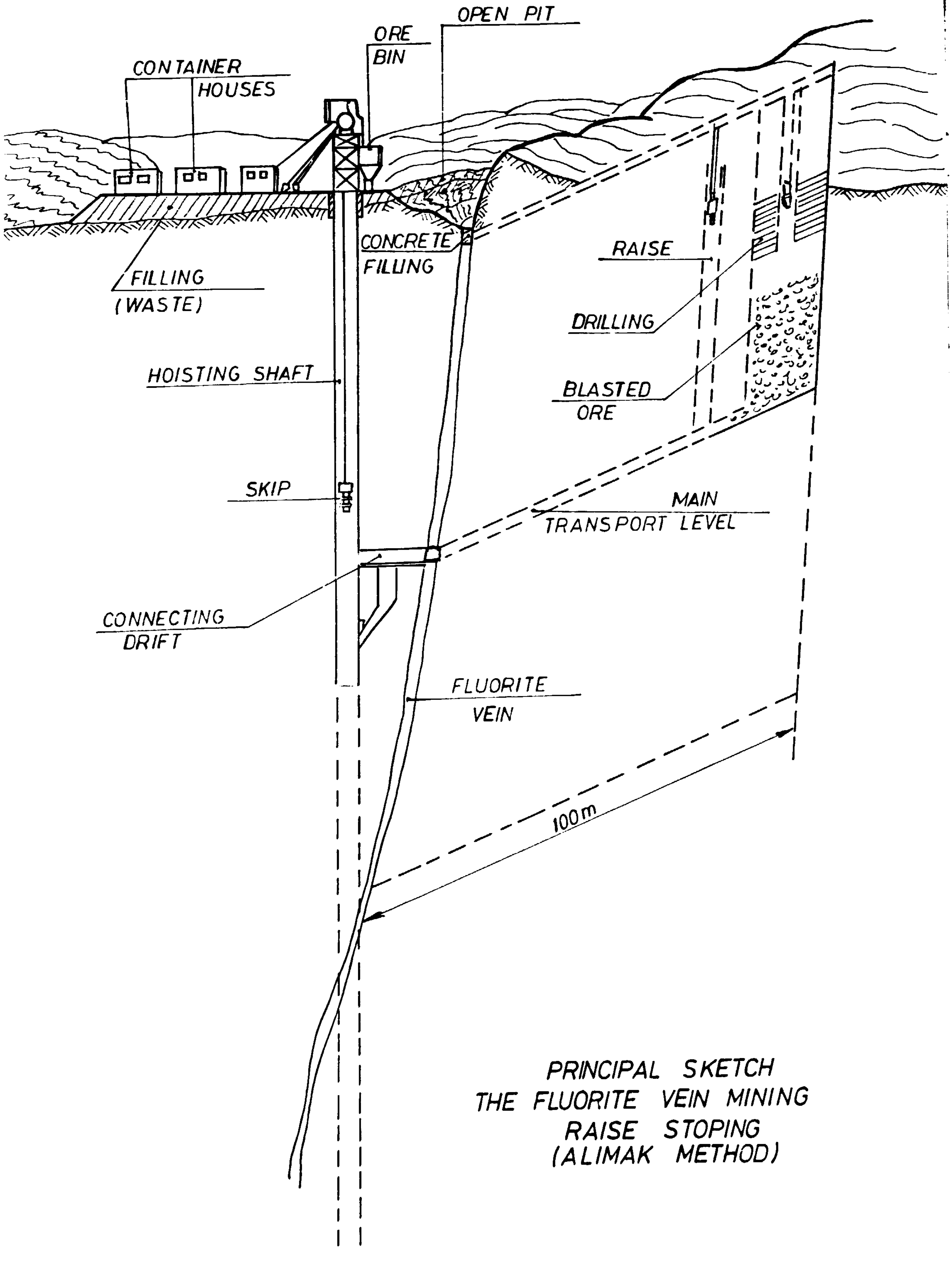
The material hoisted to the surface by a skip-bucket gets in the raw ore bin, then after crushing and grinding either on the transporting equipment or on depots. The dead rock from the drift driving operations will be hoisted on the same way to the surface from time to time and there it will be forwarded to the waste rock pile by belt conveyor.

Only the vertical shaft and the connecting drifts of the alternative b) are cut entirely in barren rocks. The upthrows, sublevels, branch haulageways are protruding from the veins only in such a measure, as it is necessary for the operation of the machinery. The fluorite and the dead rock are in such a case scaled separately and hauled to the surface.

For the purpose of ventilation the concrete closing layer of the vein has to be pierced at right places. The ventilation of the working places will be solved partially by radial flow auxiliary ventilators.

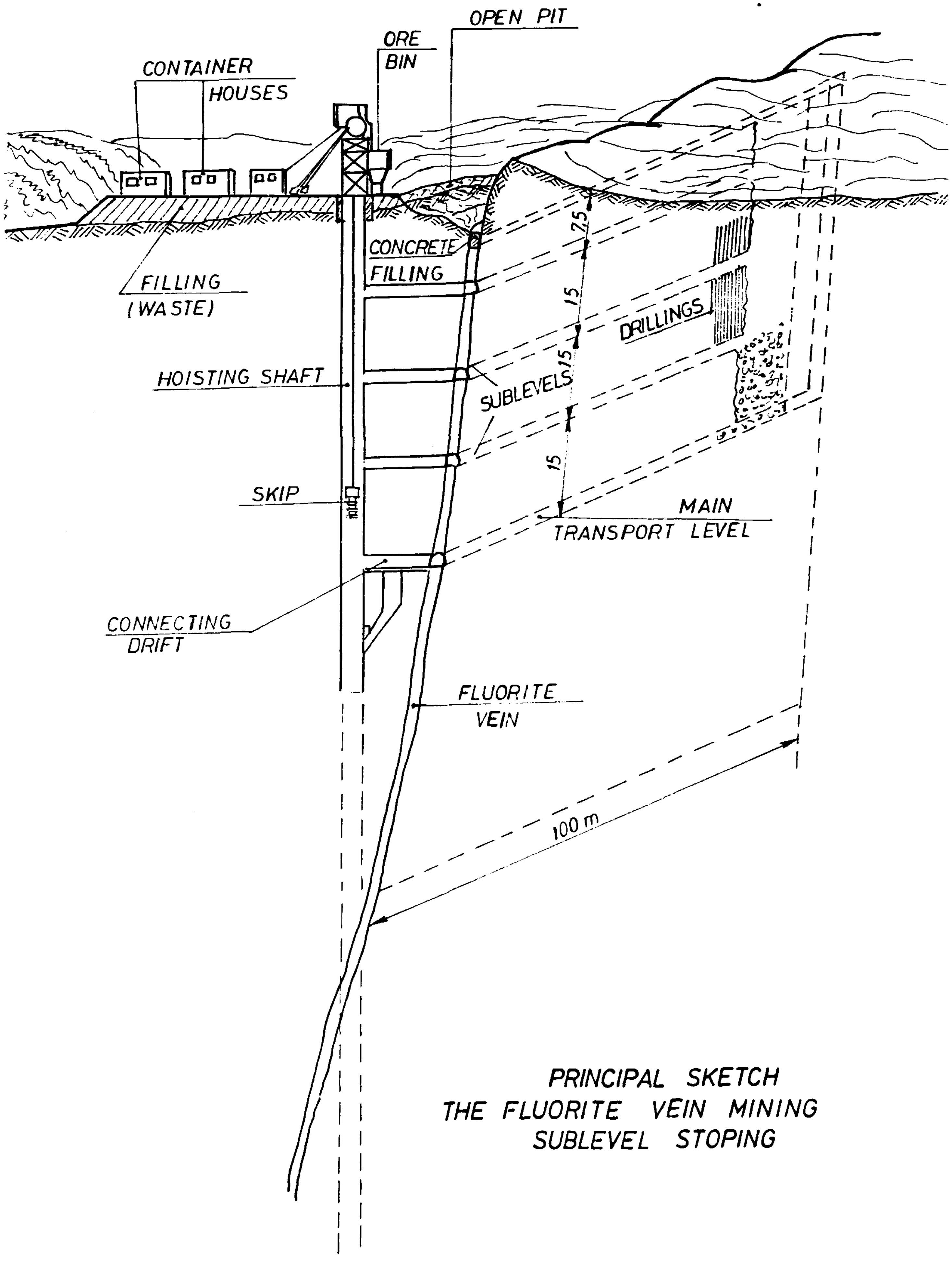
The blasting will be done by slurry ANCO expolsive.

Fig. 6-1



PRINCIPAL SKETCH
THE FLUORITE VEIN MINING
RAISE STOPING
(ALIMAK METHOD)

Fig. 6-2



PRINCIPAL SKETCH
THE FLUORITE VEIN MINING
SUBLEVEL STOPING

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
1.	**MINING** Load-haul -dump EIMCO 911 LHD	1	1	-	Electric powered. 30 HP. Bucket capacity 0,756 m^3	
2.	Raise climber ALIMAK STH SEE	1	1	-	Elektric powered 2x10 HP	
3.	Universal hoist ALIMAK U-500	1	1	-	Hoisting speed 47m/min.	With special cage.
4.	Drilling-truck ALIMAK BT 121	2	2	-	Hydraulic type With robber wheels	
5.	Rock drills ALIDRILL AD 101	4	3	1	Power input 37 kW Weight 115 kg.	
6.	Winches ALIMAK HPG 3000	2	1	1	Power input 29 kW Electric powered	
7.	Bulldoser	1	1	-		
8.	Radial flow auxiliary fan	3	2	1		

Table 6-1

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
9.	Motor-generator-unit	2	1	1	250 kVA capacity	
10.	Submersible pumps Typ. FLYGT 2075	2	1	1	Power input. 4 kW	

Table 6-2

The machinery needed to the mining can be obtained only from foreign sources. In Mozambique there is no production of mining machinery. Because of the narrow veins, for the mining operations among such circumstances the equipment mainly of the ALIMAC Co. - which were developed just for such purposes - can be taken into consideration.

On the list of the machinery the nominal power requirement of the individual machines are shown. At the operation of the mining machinery the simultaneity factor remains under 0.5. The machines and equipment of this small plant can be supplied by power with a single power-generating aggregate. All mining machines are operated electrically, or electro-hydraulically. In such a way it can be devoided the great losses of energy of the compressed air system, and the ventilation system of the mine is not overcharged by the Diesel aggregates fume, vapour and heat.

According to our present knowledge there is no danger of gas, or water in the fluorite mines.

The secondary rocks (quartz veins and gneiss) are solid and stable, and because of this fact we have to count only with minimal support.

For minor reparature and overhaul of the mining machinery an electrical-, a locksmith- and a welding-shop is foreseen in our plans for the site. For reparature of bigger scale and maintenance we could not get information about adequate workshops which would have the necessary equipment and qualified labour-force in a resonable distance from the mining site.

We suppose that the colliery MOATIZE, which has a considerable scale deep-mining capacity, or at BEIRA we might find such workshop. Both of these places can be reached from the rail station of Vila de Sena.

We could provide spare equipment only at the machines of vital importance, because otherwise the mine could not be even near to the limit of the economic operation. By manual labour it can not be achieved any significant saving in machinery at the deep-mining of fluorite (e.g. manual miners-cars could be used at the haulage levels instead of LHDs). The time losses caused by the repairs have to be compensated by the organization of work (2 respectively 3 shifts working) in case it becomes necessary.

For spare of the machinery, 1 % of the total investment cost of the machines is provided.

6.2 TECHNOLOGY OF ORE BENEFICIATION

The successive steps in the ore dressing and beneficiation technology are safeguarding the quality of the fluorite concentration required for different purposes from the raw material received from the mines, where the selectively mined ore has a CaF_2 content of about 50 %.

The capacity of the individual equipment have been chosen in such a way that they can satisfy of the requirements of the chemical plant set down in the material balance of the same.

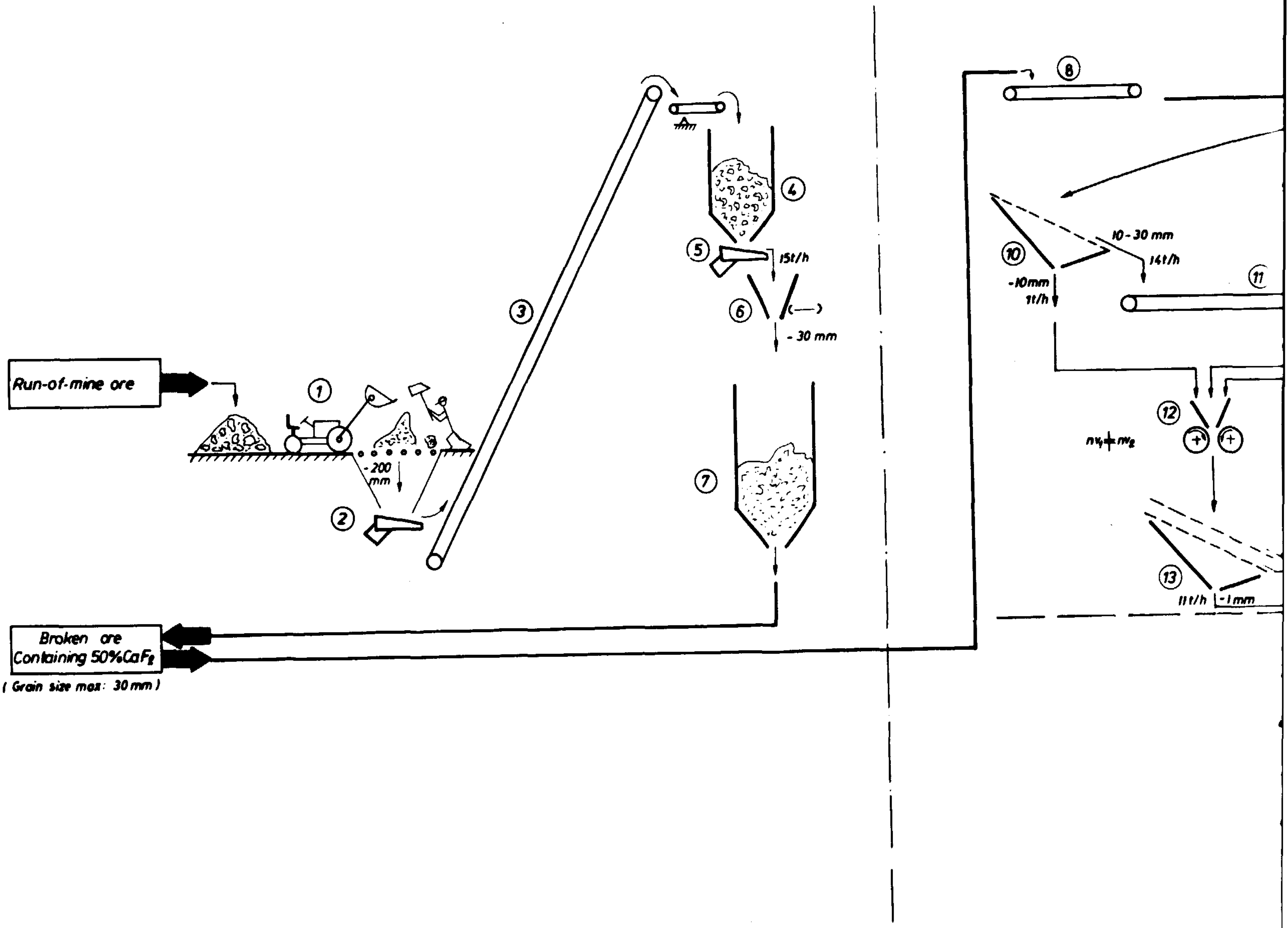
Ore dressing unites can be located at the mining plant (Variant 1)

First technological step securing the raw material with 50 % CaF_2 content to the chemical plant. I.. the mining plant the selectively scaled raw ore has to be crushed with adequate crushers to maximum 30 mm size for the purposes of the chemical plant.

At the dumping place at the mining plant the ore will be loaded by scoop shovel (1.) to the grizzly (2.).

TECHNOLOGICAL FLOW-SHEET OF ORE DRESSING

UNIT LOCATED AT THE MINING SITE



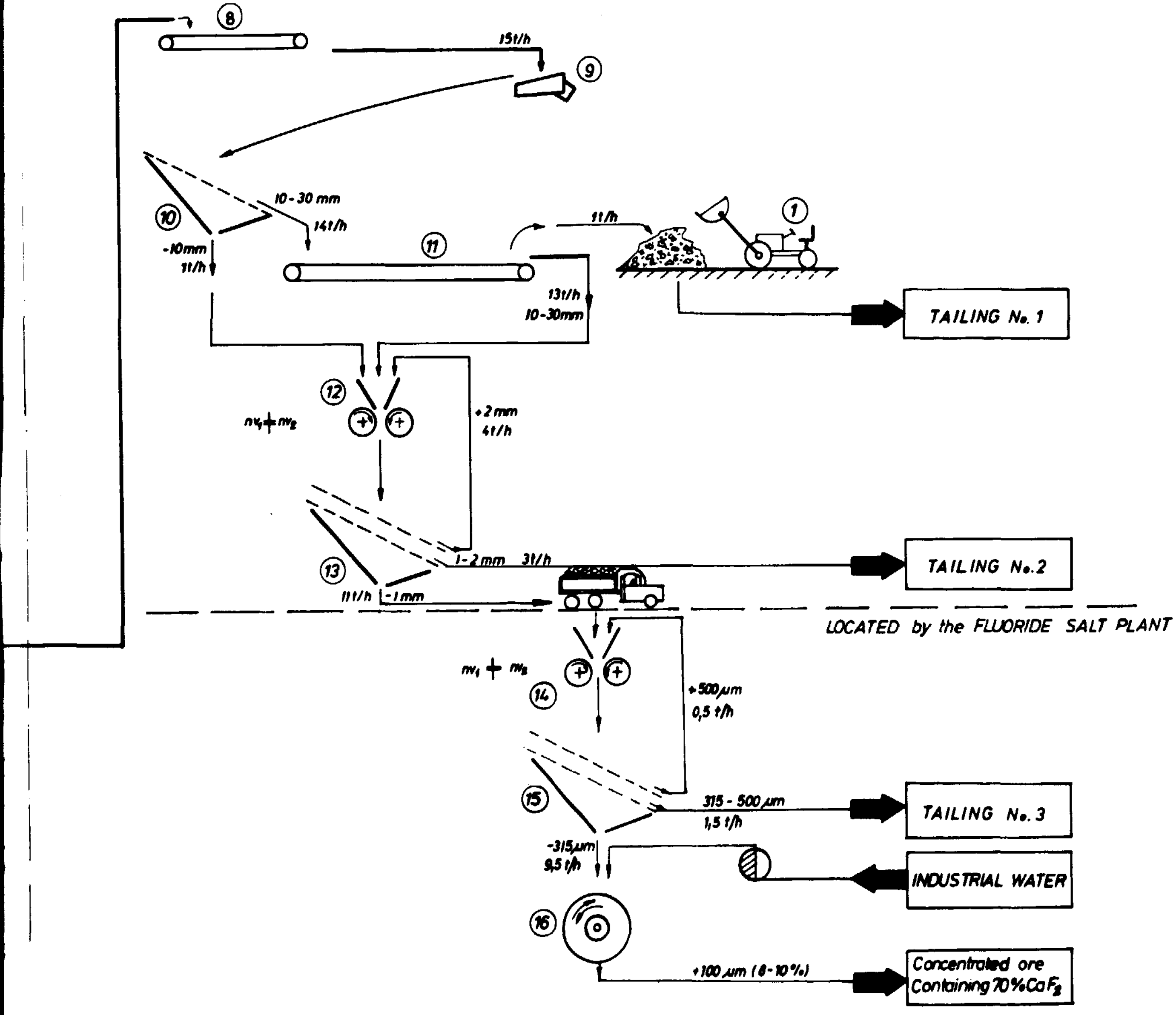
First technological step

SECTION 1

Fig. 6-3

HEET OF ORE DRESSING

MINING SITE



Second technological step

SECTION 2

On the surface of this grizzly the pieces of the ore greater than 200 mm will be crushed. Underneath of the grizzly the ore falls to a conveyor belt of 600 mm width (3.) wich forwards it to a bin (4.) which capacity is 11 m^3. Below the orifice of the bin is a heavy-duty feeder (5.) which can be regulated in such a way, that the jaw-crusher (6.) under it will be operated with steady overcharging. The material crushed to max. 30 mm size gets from the crusher to a storage bin made from steel plates (7.) from where the continuous feeding of the lorries, respectively the transportation can be secured.

Variant 2

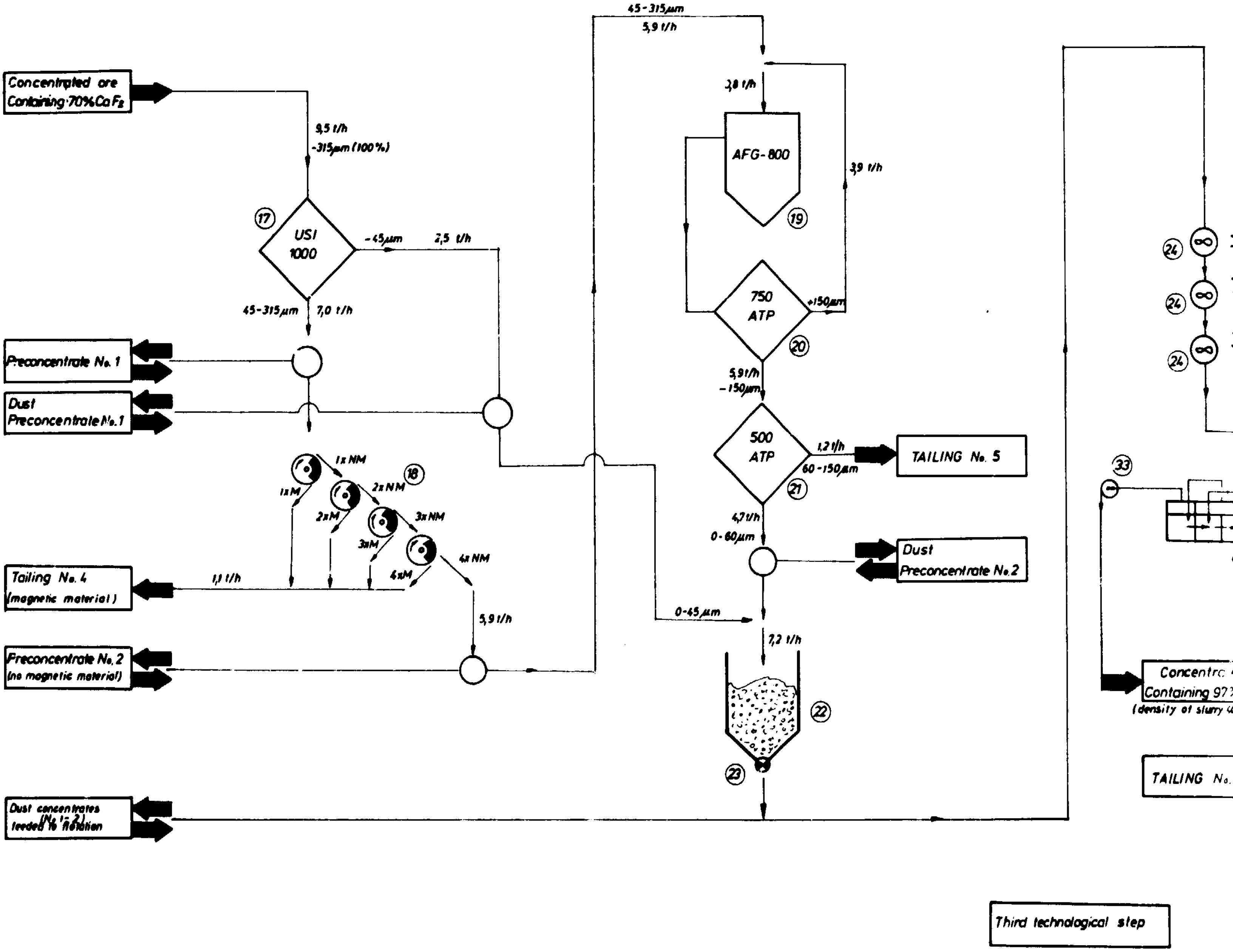
Second technological step. Preparation of raw material with a CaF_2 content of 70 %.

A raw material with higher CaF_2 content can be secured only by manual selection of adequate efficiency.

The material prepared in the 1. technological step gets on a 500 mm broad belt conveyor (8.) to a vibration feeder (9.) and screen (10.). On the screen the dusty fraction below 10 mm is discharged because this cannot be selected manually. The pieces between 10-30 mm are getting on a 20 m long apron belt conveyor (11.) for selection, which is 800 mm broad, where the material well spread can be selected by adequate number of workers who are removing quartzous, barren pieces efficiently. After this selection the ore gets - together with the dusty fraction previously selected on the

TECHNOLOGICAL FLOW-SHEET OF BEN

UNIT LOCATED AT THE CHEMICAL PLANT

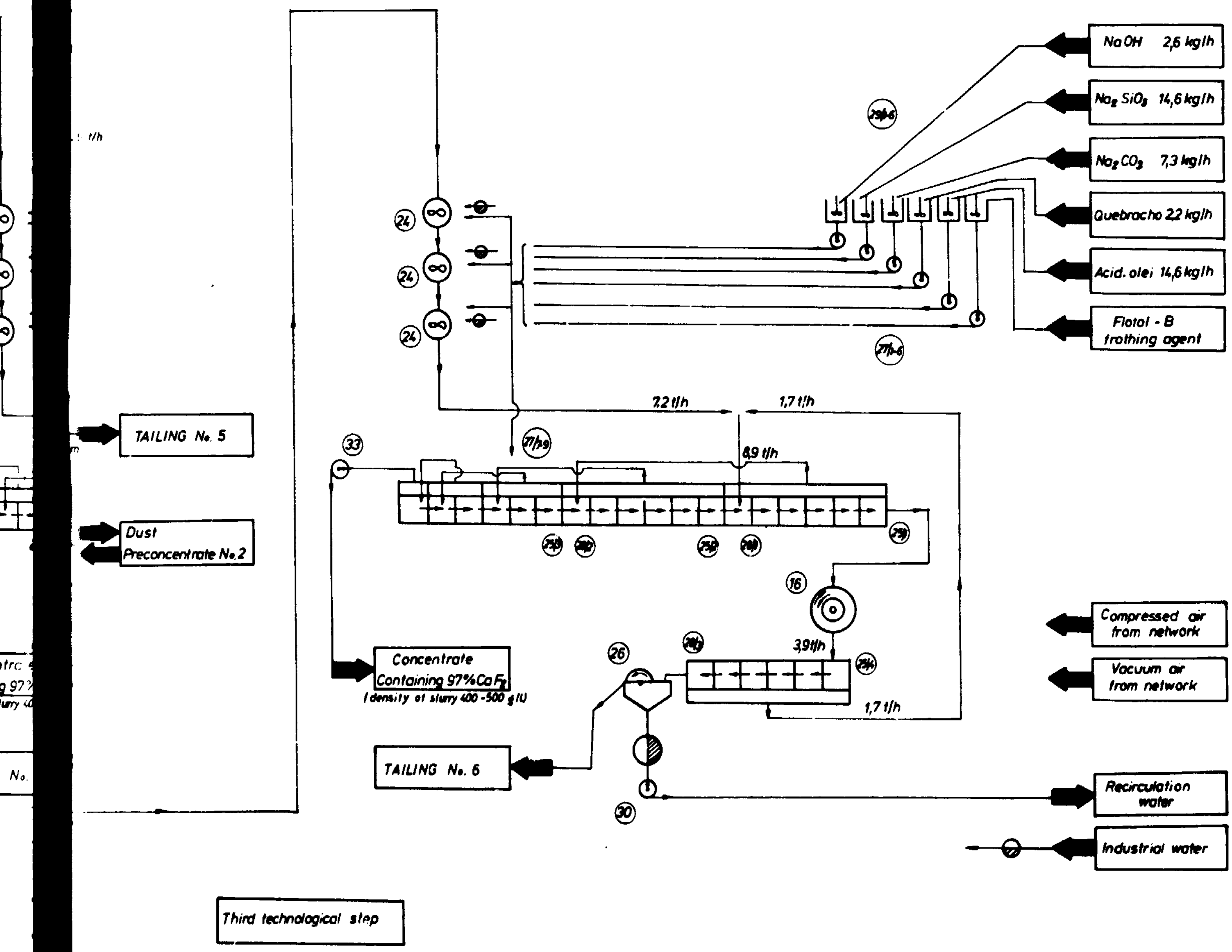


SECTION 1

Fig. 6-4

EN AL FLOW - SHEET OF BENEFICIATION

NT OCATED AT THE CHEMICAL PLANT



SECTION 2

screen - to a ribbed roll-grinder (12.) which will be operated - like the jaw crusher - with overcharging. The different speed of the two rollers of the roll-grinder is securing the intensive grinding. The material falling through the roll-grinder gets to a double screen (13.). On this those fraction - which was defined after previous examinations and which is containing because of its different hardness more barren part - will be discharged. The grinder and classifier are working in a closed circuit.

The enriched ore with about 70 % of CaF_2 content will be delivered from the mining plant to the chemical plant on trucks.

In regard to the fact, that in this technological step the considerable part of the dead rock will be selected by means of the selective grinding - even in the very small grain-size, too - therefore, the ore ground below 1 mm size will be led to a smooth roll grinder (14.) and the coupled double screen system (15.) which is working in a closed circuit with the grinder. The fraction between 315-500 μ, which is richer in barrens will be discharged again and the fraction below 315 μ - as the enriched ore fraction - can be ground further according to the requirements of the chemical plant - in a corundum disc mill (16.) until we reach the + 100 μm 8-10 % grain-size.

We have to remark, that the grain-size produced by the corundum disc mill is suitable to the flotation operations, too. In case in the further acid-, or ceramic grade CaF_2 concentrate with 97 % of CaF_2 content has to be produced it is advisable to place the corundum disc mill into the beneficiating plant, as it is shown on the technological flow-sheet (3. technological step).

Material balance of beneficiat

/ Deposit of [illegible] /

2 nd Technological step:

A. Efficiency of selection by hand /11/

	Grain size μm	Weight percent contentration / % / direct	reduced
Feeded /selective stoped/	ore > 30000	100,0	100,0
Middling No.1.	0-30000	93,5	93,5
Coarse tailing No.1.	10000 - 30000	6,5	6,5

tion.

Chemical composition / % /				Ore recovery / % /	
CaF_2	SiO_2	$CaCO_3$	R_2O_3	CaF_2	SiO_2
50,00	44,00	2,00	4,00,	100,0	100,0
52,53	41,14	2,05	4,28	98,2	87,4
13,5o	85,10	1,20	0,20	1,8	12,6

Table 6-3

2 nd Technological step:

B. Crushing with ribbed roll-grinder /12/ and classification /13/

	Grain size μm	Weight percent contentration / % /		Chemical composition / % /				Ore recovery / % /	
		direct	reduced	CaF_2	SiO_2	$CaCO_3$	R_2O_3	CaF_2	SiO_2
Middling No.1.	0 - 30000	100,0	93,5	52,53	41,14	2,05	4,28	98,2	87,4
Middling No.2.	0 - 1000	78,6	73,5	62,46	30,01	2.24	5,29	91,8	50,1
Small tailings No.2.	1000 - 2000	21,4	26,5	16,05	82,10	1,35	0,50	8,4	37,3

Table 6-4

2 nd <u>Technological step:</u>

C. Crushing with plain roll-grinder /1

	Grain size μm	Weight percent contentration /%/ direct	Weight percent contentration /%/ reduced
Middling No.2.	0 - 1000	100,0	73,5
Contentrated ore	0 - 315	86,4	63,3
Tailings No.3.	315- 500	13,6	10,2

Table 6-5

/ and classification /15/

Chemical composition / % /				Ore recovery / % /	
CaF_2	SiO_2	$CaCO_3$	R_2O_3	CaF_2	SiO_2
62,46	30,01	2,24	5,29	91,8	50,1
70,00	21,50	2,40	6,10	88,6	30,9
15,68	82,77	1,25	0,30	3,2	19,2

A - C Total material balance

	Grain size μm	Weight percent contentration / % /	Chemical composition / % /				Ore recovery /%/	
			CaF_2	SiO_2	$CaCO_3$	R_2O_3	CaF_2	SiO_2
Feeded /selective stoped/ ore	- 30000	100,0	50,00	44,00	2,00	4,00	100,0	100,0
Concentrated ore	0 - 315	63,3	70,00	21,50	2,40	6,10	88,6	30,9
Total tailings /No.1.+2.+3./	- 30000 + 315	36,7	15,50	82,81	1,31	0,38	11,4	69,1

Table 6-6

Material balance of beneficiation.

/ Deposit of [illegible] /

3 rd **Technological step:**

A. Air-classification /17/ and dust-preconcentrate 1. separation

	Grain size μm	Weight percent contentration / % /		Chemical composition / % /				Ore recovery / % /	
		direct	reduced	CaF_2	SiO_2	$CaCo_3$	R_2O_3	CaF_2	SiO_2
Concentrated ore	0 - 315	100,0	63,3	70,00	21,50	2,40	6,10	38,6	30,9
Dust-Preconcentrate No.1	0-45	26,3	16,6	72,88	18,31	2,45	6,36	24,2	6,9
Pre Concentrate No.1.	45 - 315	73,7	46,7	68,95	22,65	2,39	6,01	64,4	24,0

The Dust-preconcentrate No.1. gets in storage-bin /22/ then to flotation.

Table 6-7

3 rd Technological step:

B. Dry magnetic separation /18/

	Grain size µm	Weight percent contentration / % /		Chemical composition / % /				Ore recovery / % /	
		direct	reduced	CaF_2	SiO_2	$CaCo_3$	R_2O_3	CaF_2	SiO_2
Preconcentrate No.1.	45 - 315	100,0	46,7	68,95	22,65	2,39	6,01	64,4	24,0
Preconcentrate No.2. /non magnetizable/	45 - 315	84,3	39,4	76,68	19,95	1,85	1,52	60,4	17,8
Tailings No.4. /with magnetic separating/	45 - 315	15,7	7,3	27,33	37,10	5,44	30,13	4,0	6,2

Table 6-8

3 rd Technological step:

C. Selective fine grinding with jet-mill /19/ and air classification /20,21/

	Grain size μm	Weight percent concentration / % /		Chemical composition / % /				Ore recovery / % /	
		direct	reduced	CaF_2	SiO_2	$CaCo_3$	R_2O_3	CaF_2	SiO_2
Preconcentrate No.2. /non magnetisable/	45 - 315	100,0	39,4	76,68	19,95	1,85	1,52	60,4	17,8
Dust-preconcentrate No.2.	0 - 60	79,7	31,4	86,10	10,65	1,80	1,45	54,1	7,6
Tailings No.5.	60 - 150	20,3	8,0	39,63	56,61	1,88	1,88	6,3	10,2

Table 6-9

D. Flotation

In the storage bins /22/ stored dus
flotation after being converted to s

Calculation of feeded

	Grain size μm	Weight percent concentration /%/	
		direct	reduced
Dust-preconcentrate No.1.	0 - 45	-	16,6
Dust-preconcentrate No.2.	0 - 60	-	31,4
Feeded to flotation	0 - 60	-	48,0

t-preconcentrates /No. 1+2/ come to slurry and conditioned.

Chemical composition /%/				Ore recovery /%/	
CaF_2	SiO_2	$CaCO_3$	R_2O_3	CaF_2	SiO_2
72,88	18,31	2,45	6,36	24,2	6,9
86,10	10,65	1,80	1,45	54,1	7,6
81,54	13,29	2,02	3,15	78,3	14,5

Table 6-10

Material balance of beneficiation.

/ Deposit of DJANGUIRE /

	Grain size µm	Weight percent concentration / % /		Che
		direct	reduced	CaF_2
Feed to flotation	0 - 60	100,0	48,0	81,54
Concentrate	0 - 60	80,6	38,7	97,00
Tailings No.6. /tailings of flotation/	0 - 60	19,4	9,3	17,20

CaF_2 recovery in concentrate /apply to flotation/

Table 6-11

mical composition / % /			Ore recovery / % /	
SiO_2	$CaCO_3$	R_2O_3	CaF_2	SiO_2
15,29	2,02	3,15	78,3	14,5
1,50	1,10	0,40	75,1	1,3
62,37	5,81	14,62	3,2	13,2

: 95,9 %

Material balance of beneficiation.

/ Deposit of [illegible]/

A - D Total material balance

	Grain size µm	Weight percent concentration / % /		Chemical composition / % /				Ore recovery / % /	
		direct	reduced	CaF_2	SiO_2	$CaCo_3$	Al_2O_3	CaF_2	SiO_2
Concentrated ore /feeded/	0 - 315	100,0	63,3	70,00	21,50	2,40	6,10	88,6	30,9
Concentrate	0 - 60	61,1	38,7	97,00	1,50	1,10	0,40	75,1	1,3
Total tailings /No. 4+5+6/	0 - 315	38,9	24,6	27,52	52,97	4,43	15,08	13,5	29,6

Table 6-12

83.08.11

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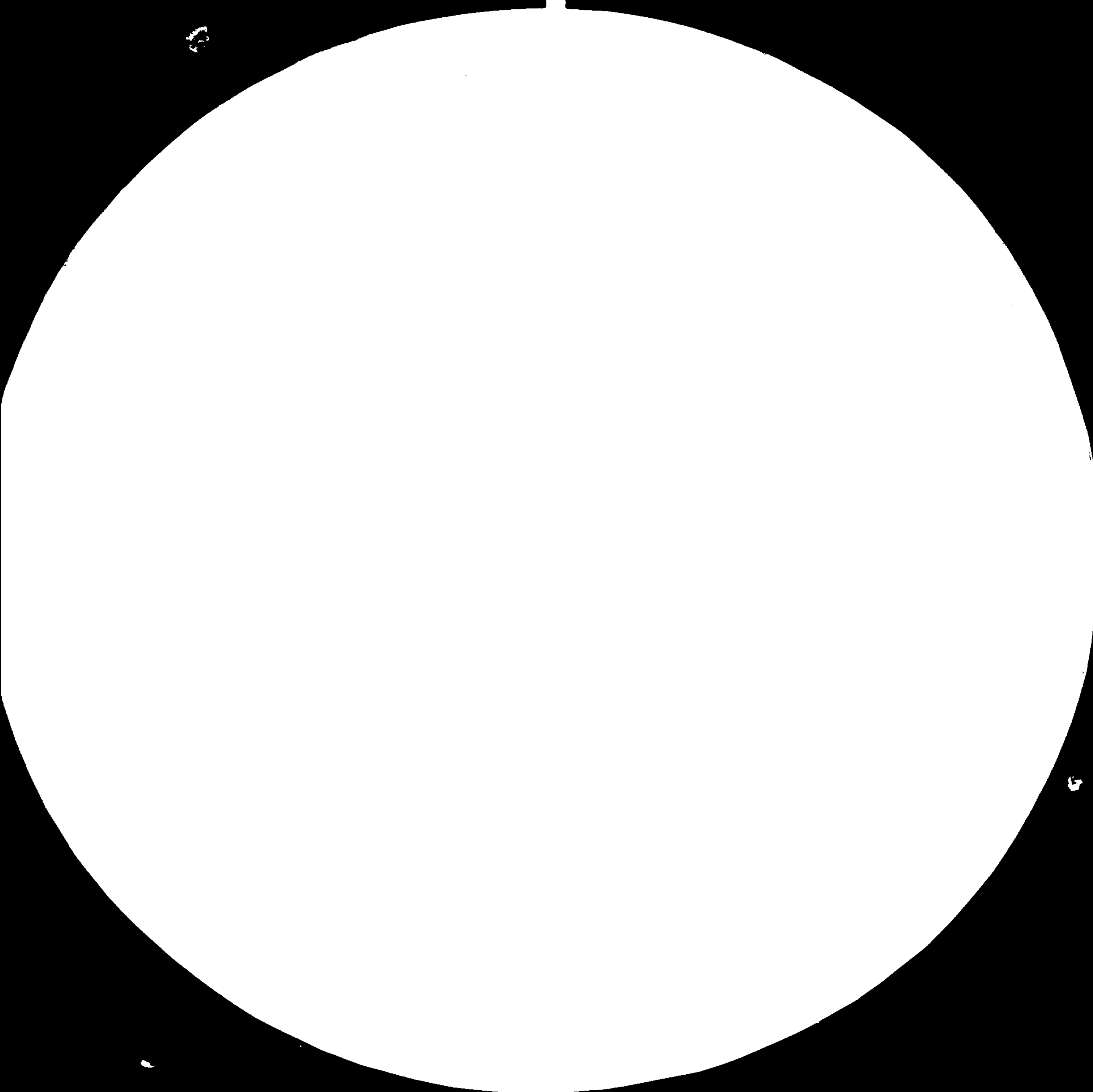

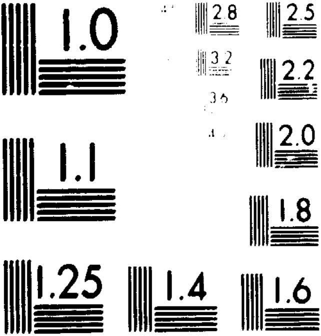

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

Ore beneficiation up to min 97 % CaF_2 and max 1,5 % SiO_2 /Variant 3/

Third technological step to produce a concentration of 97 % CaF_2 content.

First of all the fraction ground below 315 µ, containing 70 % of CaF_2 has to be dedusted, because the operation of the magnetic separation can be made with adequate efficiency only by this means. In our planes we provided to the classification in the range of the finest grain fractions an up-to-date great capacity air-classifier equipment. The air-classifier (17.) is discharging the fraction below 45 µ to a bin (22.) where it is stored as a fraction which is suitable for flotation.

The grains between 45-315 µ size will be led to the magnetic separators. The two double barelled magnetic separators (18.) - in case the intensity of their magnetic field is properly adjusted - select the magneticable ferrous and titanium containing minerals, which is important in respect of the flotation, because - according to our examinations - effective flotation cannot be envisaged without the removal of these impurities. The non-magnetic, in fluorite rich preconcentrate 2. product has to be ground further. For this purpose a great capacity, high efficiency jet-mill (19.) has been selected. To this jet-mill belongs a high capacity, high pressure special compressor, too.

The ore ground in the jet-mill will be classified twice in the air-classifier. The application of the air-classifier is making possible to separate sharply the different grain-size fractions, and so - according to our tests - the fraction of 60-150 µ which is enriched in barren materials can be discharged. The two air-classifier equipment (20. and 21.) will be supplied with special accessories, the duty of which is to collect the product and to avoid the harmful dust formation at the working place.

After the second air-classifier the received preconcentrate 2. product which is - 60 μm dust size, will be stored in the dust bin (22.). The dust-concentrates which are suitable for the flotation between the grain-size of 45-60 μm are getting to blending tanks with mixers (24.) where industrial-, and recirculated water will be added to make a slurry. This slurry will be fed into the DENVER typ flotation cells (25.) where the flotation-enrichment will be done.

The scheme of the connections of the cells are shown on the technological flow-sheet. The reagents needed to the flotation enrichment, will be prepared in 0.5 m^3 size tanks (29.) and will be fed to the optimal feeding points through pipelines, by micro-feeder pumps (27.). The control and regulation of the pH-value during the flotation will be secured by 3 electronic units (28.). The final refuse, produced by the flotation beneficiating operation will be dehydrated by means of a drum filter /26./ and the filtrated water will be recirculated to the system. By the help of the use of this system a saving in the reagent material and in the quantity of the usage of water can be achieved.

For material forwarding in form of solid- and in slurry phases belt conveyors of 400 mm width (31.) bucket elevators (32.), resp., piston type- (33.) and rubber lined centrifugal slurry pumps (30.) have been provided in our plans.

We deem it suitable to the purpose to place this beneficiating plant into a workshop with a ground size of 10 m x 36 m near to the fluoride salt plant. To the operation of the flotation cells, and the vacuum drum filter, the necessary compressed air, resp., vacuum will be secured by the fluoride salt plant.

At the drawing up the cost calculation of the flotation plant we have taken into consideration beyond the cost of the hall structures for the flotation, the costs of pipeline system, valves, steel structures, electric equipment and cables as well as the costs of the dust controlling system, too.

Preparatory unit located at
the mining site
1 - 2 - Technological steps

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
1.	Scoop shovel	2			KNA-250 Typ. With Diesel engine Size of the shovel: 1,0 m^3	
2.	Piece selecting grizzly	1			200x200 mm size steel grid	
3.	Rubber belt conveyor	1			Belt width: 600 mm Motor output: 8,0 kW Conveyor length: 21 m	With steel construction complete
4.	Raw ore bin	1			11 m^3 holding capacity	With steel construction compl.
5.	Heavy duty feeder	1			URA-400/600 Typ. Motor output:2,4 kW; With variable stroke	
6.	Single swing jaw-crusher	1			500x350 mm size of muzzle Motor output: 22 kW	
7.	Buffer bin	1			30 m^3 holding capacity	With steel construction compl.
8.	Rubber belt conveyor	2			Belt width: 500 mm Motor output: 7,5 kW Conveyor length: 15 m	With steel construction complete
9.	Vibating feeder	1			VA-10 Typ. Motor output: 2,0 kW	
10.	Vibrating screen clssifier	1			Binder Type single screen for removal of 10mmsize parts. K-1-2000x800 Type	Motor output: 5,5 kW

Table 6-13

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
11.	Apron typ selecting conveyor	1			Width:800mm, Motor outp:15,0kW Length:20 m	With magnetic iron separator. With metal detector
12.	Ribbed roll-grinder	1			MERTZ WBP-8/4 Type. Motor:10 kW R.p.m.of the rolls variable separately.	
13.	Vibrating screen classifier	1			Binder system;double screen for selection of grains of +2 and +1 mm sizes. SS 1600/6000 Type.	Motor output: 8,0 kW
14.	Plain roll-grinder	2			MERTZ WBP-5/10 Type. R.p.m.of the rolls variable separately. Motor output: 8 kW	Located to the fluoride salt plant
15.	Classifier screen /sieve/	4			Binder system; double screen for selection of grains of +500 µm and+315 µm sizes. MERTZ Type	Motor output: 15,0 kW
16.	Corundum disc-mill	1			Wet finish grinder,with special grinding surfaces FRYMA MK 180 Type	Motor output: 25 kW

Table 6-14

Preparatory unit located
at the chemical plant
3.Technological step

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER TOT.	OP.	SP.	TECHNICAL DATA	REMARK
17.	Air classifier	1			Uplex separator ALPINE-USI-1000. Type. Complete Motor output:87,0 kW.	Accessories: 1 pc.cell type conveyor ZS-I type. 1 pc.cell type conveyor 300-K 12 type. 1 pc. dust cyclone KAZ-1000 type
18.	Magnetic separator	2			Double barelled, dry BOX-MAG-RAPID DHR 750.2 Type Motor output: 15,2 kW	
19.	Selective fine grinding jet-mill	1			ALPINE-AFG-800. Type. Complete motor output: 55,0 kW	Accessories: 1 pc. special compressor with automatic regulatio and switchgear unit
20.	Air classifier	1			ALPINE -TURBOFLEX - 750 ATP Type Complete motor output: 163,0 kW	Accessories: 2 pcs.cell type conveyor 300 - K 12 Type. 1 pc.dust cyclone KAZ140
21.	Air classifier	1			ALPINE-TURBOFLEX-550 ATP Type. Complete motor output: 71 kW	Accessories: 2pcs.cell type conveyor 300-K 12 type. 1 pc.dustcyclone KAZ-100
22.	Storage bin	2			30 m^3 holding capacity, for storage of the semiproducts	With steel construction complete
23.	Cell type conveyor	2			ALPINE 300-K12 Type Mounted under the semiproduct storage bins Motor output 0,75 kW	

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
24.	Mixing container	3			EKA 150/160 Type 3 m^3 holding capacity for conditioning purposes. Motor:3 kW	
25.	Flotation cell	3			Units consisting 6 members DENVER-18 type with mechanical mixing, cast rubber diffuser Motor output per unit: 22 kW	
26.	Vacuum drum-filter	1			50 m^2 filtering surface, DORR-OLIVER type. Motor output:2 kW	
27.	Chemicalies and reagents feeder	9			Micro-feeder pumps to feed variable quantities MASZ-5 type.	Motor outp:0,25 kW
28.	pH regulating controler	3			pH adjusting and regulating electronic device. RADELKIS type	
29.	Reagent solution	6			2x0,5 m^3 capacity with twin containers and mixers, acid- and lye-resistant. Motor: 0,75 kW	
30.	Slurry pump	1			Warman type with rubber lined stator and rotor, for slurry pumping. Motor output: 20 kW	
31.	Rubber belt conveyor	4			Belt width: 400 mm Length: 15 m Motor output: 5,0 kW	Complete with steel construction. To convey different grain size milling products

Table 6-16

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
32.	Bucket elevator	3			Hoisting height: 12 m Bucket size: 12 x 12 cm Motor output: 2,5 kW	With steel structure complete. To hoist different size milling products.
33.	Slurry pump	8			Diaphragm type pulsating pump To forward different slurries /concentrates/ at the flotation concentration. Motor output: 3 kW	
34.	Dust exhaust system	1			For protection of the workers complete Motor output: 7,5 kW	Wet type dust-separator

Table 6-17

6.3 CIVIL WORKS

The building in the vicinity of the mining plant has to be reduced to the principal vital investments, because the location of the production shaft will alter in every second year. The areas needed to the building up of the plant shops and for the transportation and dumping of the materials might be developed at the time, when the vein outcrops has been stripped off, for the surface mining. The costs of the terrain correction and the building of the service roads of the mining plant are recurring expenses which are charging the account of the mining plant.

Those buildings, which have to serve as buro, shower, store-room and workshops have to be built expediently as - of heat insulated-steel, or aluminium containers, to make possible the easy shifting to an other location.

The explosives have to be stored according to the local safety prescriptions.

The water supply of the mining work have to be solved by captive water-work. We have taken into consideration at our cost calculation a shallow well, pump, pipe-network and the erection of an aquaglobus (water-tower). In case a deep drilled well would be necessary these costs will be increased.

Industrial sewage will not be produced at the mine. The communal sewage has to be settled,clarified and disinfected.

The transportation of the fluorite will be done on dirt-roads. The road network of the country consist mainly of dirt-roads so between Canxixe-Maringue and Caia are only the same.

We made provisions for the expenses which are needed to make passable the temporary water-flows, by cutting the slope of the steep banks and paving it.

At the end of every rainy season repeated corrections will be needed, which will represent a recurrent costfactor, too. The informations received on the site are showing that the lorry park of Mozambique is rather run down and overladen. The transportation of fluorite can be solved only in case the necessary vehicles will be imported. These vehicles could be utilized elsewhere during the decreased or entirely stopped ore transportation periods of the rainy seasons. Such incomes might decrease the expenditures but we could not take them into account. The transportation season of the fluorite has been taken - with safety - to 8 months. According to this supposition have been determined the necessary number of the vehicles, too. The maintenance and running expenses have been calculated in such a way, that we took the costs according to the received transport charges sheet. These approaching have to be pointed out, because one of the key questions of the economic production of fluorite in Mozambique is the transportation. (These costs are representing nearly the 30 % of the running costs.) Beyond this it is influencing strongly the necessary quantity of the stored fluorite and auxiliary materials, too.

To calculate the costs of the civil works, we used the unit prices received in Mozambique. The data received from different sources are reflecting the peculiar characteristics of the local price and value system, and even in their own proportions are not matching the international scale of values. A further difficulty is caused in making up a realistic view, the not value-proportionate conversion of the local currency (Metica) to the US$. In this respect we have applied the conversion factor (1 US$ = 36 Metica) which was used by the branch office of UNIDO at Maputo at November 1981. (It was the same in the Study of the Aluminium Finished goods). For this purpose the local cost positions of our Study are contianing more uncertainities than the import positions.

The costs of the buildings of the fluorite crushing, classification, dumping are figuring at the mine-plant. The same of the fine grinding, flotation (Var. 2 and 3.) are shown separately, but there are shown only the expenses inside the fence of the plant. The fluorite beneficiation plant has an economic chance only in case - by the present prices - when the connecting road network, longer electric connection to the existing grid and captive water-work, i.e. the lack of an industrial infrastructure are not burdening the investment.

Cost estimation for civil, and mine establishing works:

Var. 1:

		Thousand US$
a)	Mining plant above ground	
	Terrain correction	14,4
	Terrain paving	125,0
	Inner service roads	27,4
	Drinking water supply	170,5
	Foundations	12,6
	Canalization, sewage treatment	69,4
	Shade construction for power aggregate	8,9
	Steel constructions	15,8
	Living container-quarters	295,3
	Fuel storage	16,0
	Fences	56,3
	Terrain lighting	10,9
b)	Mining plant sublevel building	
	Vertical shaft 70 m	994,0
	Skip bay and pull hole	7,9
	Connecting drift from the shaft	10,0
	Other mine areas	12,1

		Thousand US$
c)	Electrical equipment	
	Signal and power cables	0,9
	Power supply for the mine and machinery	63,8
d)	Fluorite crushing, dumping, transportation	
	Raw ore bin	20,3
	Steel screen for piece separation (grizzly)	5,2
	Buffer container	13,0
	Steel structures	13,0
	Dirt-road corrections in 120 km length	500,0
Var. 2	Additional charges for this variation:	
	Terrain correction	7,2
	Terrain paving	37,5
Var. 3	Additional charges for this variation:	
	Workshop 10 x 36 m ground-space	85,0
	Pipelines	79,0
	Steel podests and scales	39,5
	Inner electric network	65,8

7. PLANT ORGANIZATION AND OVERHEAD COSTS

7. PLANT ORGANIZATION AND OVERHEAD COSTS

According to the text put down in the Chapter 5.2 the fluorite plant is divided in two plants located separately.

a) Mine and crushing plant
b) Grinding and flotation plant

This latter is consisting of - in the case of the Variant 2 - a dumping place with the stockpile, which is securing the continual working possibilities during the rainy season, and some machines which are belonging to the fluoride salt plant.

In case of the Variant 3 when the beneficiation of the fluorite ore is ending with the flotation, there is quite a considerable apparatus working to attach it as a separate plant unit to the fluoride salt plant.

Telecommunication between the two sites will be solved by wireless system.

The costs of the organization and the overhead are contained in the economic calculation (Volume 2).

8. MANPOWER

8. MANPOWER

The labour requirement to the 3 variations of the technology are shown in the tables below:

Semi-skilled and unskilled workers can be secured without difficulties. In the category of skilled worker, we have to recon with much greater difficulties. There are no skilled workers to the sublevel mining nor to the ore beneficiting plant. In the categories of the mining technician, and mining engineer - the locally received information - did not consist any payment category in Metica, only in US$, because at these levels there are no domestic skilled people. In such a way the monthly fees of a mining engineer or technician - converted to Metica by the application of the official conversion factor - will amount to the fourfold - to fivefold of those native engineers or technicians who are working in the same categories of the building industry. At the mining plant in respect of the difficulties of the labour market, it is essential to keep the foreseen minimal size of machinery.

PERSONNEL REQUIREMENTS

Category	Persons for Var 1.	Persons for Var 2.	Persons for Var 3.
Engineer	1	1	1
Technician	2	4	7
Skilled worker	34	29	41
Semi skilled worker	12	21	35
Unskilled worker	18	42	48
Administrator	1	1	2
	68	98	134

Table 8-1

9. IMPLEMENTATION AND COST ESTIMATES

9. IMPLEMENTATION AND COST ESTIMATES

The fluorite mine and ore beneficiation plant have been examined in three variations (see p.22-23). According to the there variants are given cost estimates based on a two years long period of realization. On the following schedules all costs are given in thousand US$

Examining the yearly operating costs only it is self explanatory, that the expenditures on one ton of mined, or beneficiated ore are very near to the present prices of the relevant ore qualities.

Rough comparison between costs and prices

	Var. 1	Var. 2	Var. 3
Output/year	29000 t (below commertial grade)	21000 t	14000 t
Costs/t at Caia	45.78 $	60.50 $	130.92 $
Depreciation		18.-	44.-
Railway transp. and port		23.-	23.-
Tentative costs at Beira without interest		102 $/t	198 $/t
F.O.B. prices of relevant quality fluorite (July, 1982) at the world market		80-90 $/t	182-195 $/t

CAPITAL COST SHEDULE

	Var 1.			Var 2.			Var 3.		
Years	1 st	2 nd	Total	1 st	2 nd	Total	1 st	2 nd	Total
Mine opening Civil eng. works Structures Buildings	1204,7	1259,3	2464,0	1699,4	809,5	2508,9	1804,4	973,8	2778,2
Machinery and equipment /Incl.transportation and erection/	997,9	677,2	1675,1	997,9	985,9	1983,8	997,9	3197,5	4195,4
Vechicles	177,0	168,0	345,0	177,0	100,8	277,8	177,0	100,8	277,8
Indirect costs	267,0	311,6	578,6	284,2	331,6	615,8	433,1	505,2	938,3
	2646,6	2416,1	5062,7	3158,5	2227,8	5386,3	3412,4	4777,3	8189,7

Table 9-1

OPERATING COSTS
000 US $/year

	Var 1.	Var 2.	Var 3.
Auxiliary metarials	230,3	241,8	489,6
Spare parts	16,5	19,6	41,7
Semi fixed assets	10,5	11,1	24,4
Other materials	42,5	51,5	96,0
Total expenditure for materials:	299,8	324,0	649,7
Salaries	221,1	302,7	447,6
Transportation costs	700,0	532,0	532,0
Fluorite prospecting	29,0	29,0	29,0
Cash on hand	77,7	82,9	174,1

Table 9-2

10. ANNEX

10. ANNEX

The DRAFT FINAL REPORT for fluorite exploitation in Mozambique was discussed in Maputo, 15-23. December, 1982.

In the meantime, the proper government authority, the GABINETE DO PROJECTO DE ALUMINIO received the Feasibility Study for the smelter, prepared by the Italian New Hunters Co. This smelter study influences our fluorite study in that it estimates fluoride consumption of the new 150,000 tpy smelter at 4,000 tpy and suggests two alternatives for the location (Beira or Tete). Related data of the Soviet-made smelter study (VAMI) are not yet known. There is also no known Mozambique decision re location; all our questions in this topic have remained unanswered.

Production and ore concentration costs of fluorite - extraction of which can only be reckoned with as underground operation on the long run - do not make, at least presently, the product marketable.

The smelter, as foreseen in the Italian study, needs the lesser half of the production on what we had to base our study, i.e. it necessitates a mine with a very small capacity of about 16,000 tpy. As mining operations are determined by geological conditions, they should remain - independently from capacities - as concepted, but with a minimized mechanization rate. The newer technology of fluoride salts production (see Volume II.) would possibilitate the elimination of variant 3. (flotation concentration), i.e. a solution according to variant 2.

The specialists who took part in discussing the Study in Maputo reached an understanding stating that technical-economical aspects of a future fluorite industry in Mozambique could and should only be estimated in a next Feasibility Study that shall be based on accurate starting data suggested and changed by the smelter studies and decided on by the authorities proper.

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(2 of 2)

United Nations Industrial Development Organization

PRE-INVESTMENT STUDY OF THE INDUSTRIALIZATION OF FLUORITE DEPOSITS IN MOZAMBIQUE

VOLUME 2.

FLUORIDE SALTS MANUFACTURING PLANT

FINAL REPORT

ALUTERV-FKI
BUDAPEST/HUNGARY
DECEMBER 1982

FLUORIDE SALTS MANUFACTURING PLANT
FINAL REPORT

by

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1. SUMMARY

1. SUMMARY

The Government of the People's Republic of Mozambique intends to establish an aluminium industry (smelting and processing) to be based on the exploitation of the available hydroelectric power and other natural resources of the country. These plans are presently in the stage of feasibility studies. The purpose of the present Report is to assist the National Energy Direction's Cabinet of Aluminium and the National Planning Commission in the realization of the manufacturing of two important auxiliary materials of aluminium smelting, aluminium fluoride and cryolite, based on the processing of domestic raw materials.

The Report deals with the use and market background of aluminium fluoride and cryolite, with various manufacturing technologies and their comparative evaluation, with the examination of plant siting variants. It contains the specific material and energy consumptions required for the manufacturing process, manpower requirements, capital and operating costs, and a proposed implementation schedule. Finally it discusses the economy of the project.

As a result of the general recession felt in the aluminium industry the markets of both aluminium fluoride and cryolite are presently supersaturated. Since the projected fluoride salt manufacturing plant is first of all destined for satisfying the requirements of the aluminium smelter to be established in Mozambique, the world market situation has only a diminished influence on the justification of the establishment of a fluoride salt manufacturing plant. However, the aluminium smelters projected for Africa and nearby areas (Zaire, Libya, India, The Cameroons, Republic of South Africa) can be taken into consideration as potential customers over and above the domestic requirements.

Manufacturing capacity of the plant has been set at 10,000 tpy final product, composed of 3,000 tpy aluminium fluoride and 7,000 tpy cryolite. The desirable proportion of the two products may be significantly influenced by the type of the prospective aluminium smelter to be determined at a later stage, and by other, presently unknown economic and market factors.

It has been taken into consideration at the development of the manufacturing technology that the basic material can be extracted in three different qualities for the chemical processing according to its CaF_2 content (50, 70 and 97 per cent CaF_2, resp.) from the available raw ore by applying different beneficiation methods. The comparative economic evaluation of the manufacturing technologies suitable for the processing of the above basic material qualities has shown that there is no significant difference between the economy of the processing of the three basic material qualities. However, the processing of the basic material beneficiated by flotation and containing 97 per cent CaF_2 shows a slightly better economy than the other variants do. As a result of these insignificant differences it does not seem to be expedient at the present stage to select the manufacturing technology to be applied. The selection should be carried out on the basis of more accurate and reliable data when preparing a feasibility study. Having emphasized these reservations the details of the present Report have been worked out for the processing of the basic material containing 97 per cent CaF_2.

The areas of Tete, Caia and Beira have been taken into consideration for the siting of the plant, first of all from the point of view of the costs of transportation. No detailed data were available for other important points of view (geographical, meteorological, infrastructural, etc.), therefore, the influence of the latter could not be taken into consideration. The siting of the plant at Beira has turned out to be the most advantageous from the point of view of the transportation costs of the direct technological materials. Taking the transportation costs of this siting variant for 100 per cent, the transportation costs of the Caia siting variant are higher by 18 per cent and those of the Tete siting variant by 30 per cent. However, in order to reduce the costs of infrastructure and the operating costs it seems to be expedient to site the plant first of all in the vicinity of the aluminium smelter to be established, or else in the vicinity of another, possibly already existing industrial establishment. Since according to our informations Caia is favoured as the site of the aluminium smelter, the same site has been selected for the fluoride salt manufacturing plant. However, it has to be emphasized that since the siting has a significant influence on the economy of the plant, a complex study has to be carried out during the next stage, taking into consideration the siting of the smelter, too.

The fluorite mine, the ore beneficiation facilities and the fluoride salt manufacturing plant have been economically evaluated as a single unit. Cash payment has been presumed for the financing of the capital costs. According to our calculations the sales income of the plant attainable at the present prices of aluminium fluoride and cryolite would probably only cover the operating costs but not assure the return of the capital invested. However, the higher prices prognosticated on the basis of an anticipated upturn in the world economy could increase the profitability of the project and may in the long run even result in the return of the total investment.

It must be emphasized that several factors influencing the economical feasibility of the project could only have been investigated in a very broad sense; in some cases only hypothetical local data had been available to start with during preparation of the pre-investment study.

The only statement valid in connection with economical efficiency is that efficient realization could not hoped for as a direct consequence of adversely influencing local conditions, such as high transport rates, high imported material rate, etc. But this in no way excludes the necessity of the project for meeting local demands. The answer to this could be given by a next preparatory phase (feasibility study) that has to be based - in close connection with the aluminium smelter - on exact starting data.

The DRAFT FINAL REPORT was mutually evaluated in Maputo between 16-22. December, 1982.

During the discussions, the Mozambique Client informed us about the recently prepared Feasibility Study of the aluminium smelter. According to the Study, fluoride demand of the smelter planned would be not more than 4,000 tpy. Since fluorides will most possibly be not exportable because of the present prices, establishing the above production capacity can only be justified. But in case of such a small capacity, manufacture of two kinds of product (cryolite and aluminium fluoride) would most certainly be uneconomical. The means that one of the fluorides, cryolite would have to be produced since it was the one that would be used in greater quantities.

In this case, i.e. with only cryolite production, the technology would also be simpler. The starting material may contain 5-10 % of SiO_2 and of the auxiliary materials sodium can be substituted by the definitely cheaper industrial NaCl. These possibilities can make economical feasibility more advantageous.

2. MARKET AND PLANT CAPACITY

2. MARKET AND PLANT CAPACITY

2.1 GENERAL DESCRIPTION OF THE MARKET BACKGROUND

Aluminium is the non-ferrous metal presently produced in the largest amount,the production capacity of which is continuously expanded in order to satisfy the demands of the future. The present recession is viewed in professional circles as a temporary phenomenon. The January, 1982 copy of MINING MAGAZINE published the following figures for the yearly rates of expansion of the aluminium production capacity of the world:

1955 to 1974	8.2 per cent
1975 to 1980	2.8 per cent
1981 to 1990	3.2 per cent (estimated)

Two of the most important auxiliary materials of the aluminium smelting are cryolite - Na_3AlF_6 - and aluminium fluoride - AlF_3 - subsequently called fluoride salts in short. Consequently the consumption of these two materials will also increase, although at a lesser rate than that of the aluminium production since the newly constructed modern electrolysis cells operate with lower fluorine losses. Depending on the cell type the consumption of fluoride salts is 20 to 40 kg of cryolite and 10 to 20 kg of aluminium fluoride per tonne of aluminium metal produced. The consumption of the up-to-date electrolysis cells fitted with prebaked anodes and dry scrubbing systems for the retention of the fluorine content of the cell gases varies around the lower limits of the above ranges.

Over and above the existing aluminium smelters of Africa and of the geographical area adjoining it first of all new smelters to be established in the near future may be taken into consideration as export markets for the products of the projected fluoride salt manufacturing plant in Mozambique, since these will secure their supplies only in the future.

According to the relevant publications the establishment of the following aluminium smelting capacities may be counted upon within the area in question:

- Zaire (Banana)
  Initial capacity of the smelter will be 200,000 tpy. Construction will begin in 1983-84, the smelter will be commissioned in 1988-89.
  (Revue de l'Aluminium No. 509, September 1981.)

- Libya (Zuwara, Nigat Al-Khams zone)
  Projected capacity of the smelter is 120,000 tpy.
  (Erzmetall, October 1981.)

- India (Orissa State)
  The smelter will be established near Talcher with a capacity of about 220,000 tpy within the framework of the NALCO-PECHINEY aluminium complex. The commissioning of the smelter is due in 1987.
  (Mining Journal No. 7587, January 16th, 1981.)

- Indonesia (Asahan project)
  A 75,000 tpy potline was commissioned early in 1982. Two further potlines are under construction. These will be commissioned in 1983 and 1984, resp. The final capacity of 225,000 tpy will be attained in 1985.
  (Mining Journal No. 7641, January 29th, 1982.)

- Cameroons (Edea)
  The existing 50,000 tpy smelter will be expanded to 120,000 tpy by 1986.
  (Aluminium, Vol. 57. No. 12., 1981.)

- Republic of South Africa (Richards Bay)
  A 86,000 tpy existing smelter is under expansion to double its capacity by 1983-84.
  (Aluminium, Vol. 57. No. 1., 1981.)

The main reason behind the establishment of the present project is to supply the required fluoride salts for the projected aluminium smelter in Mozambique as the raw material (fluor-spar) required for its manufacturing is domestically available. The projected capacity of this smelter is 150,000 tpy.

The world market prices of the fluoride salts are showing a declining tendency because of the present state of the aluminium market. The usual prices of US$ 950 to 1,000 per tonne of aluminium fluoride and US$ 650 to 700 per tonne of cryolite characteristic of the periods of nonrestricted aluminium production vary presently around US$ 750 to 800 and US$ 550 to 600 per tonne, resp.

2.2 DETERMINATION OF PLANT CAPACITY

The following points have been considered when determining the capacity of the project:

- requirements of the projected domestic smelter,
- export possibilities,
- available raw material reserves.

Preparations for the establishment of a domestic smelter are in a very preliminary stage, no information is, therefore, available on the type to be applied. Consequently, the consumption of fluoride salts depending very much on the technical solution applied can only be roughly estimated. An up-to-date 150,000 tpy smelter requires 20 to 30 kg of cryolite and 10 to 15 kg of aluminium fluoride per tonne of metal produced. The expected annual fluoride salt requirements are as follows:

	Annual requirements	
	lower estimate	higher estimate
Aluminium fluoride	1,500 t	2,250 t
Cryolite	3,000 t	4,500 t
Total of fluoride salts	4,500 t	6,750 t

It can be seen in the table above that the expected total annual fluoride salt consumption of the projected aluminium smelter will be in the range of 5,000 to 7,000 tonnes depending on the technical solutions applied. This is one of the points considered when determining the capacity limits of the fluorite processing plant.

The 200,000 tpy new smelter in Zaire offers perhaps the best export potentials. Fluoride salt requirements of this smelter will be at least 5,000 tpy by the same calculation method.

Expected domestic demand and export potentials may this way support the production of an annual total of some 10,000 tonnes of fluoride salts. The expected distribution of this amount between the two products is 3,000 tpy aluminium fluoride and 7,000 tpy cryolite. It has to be noted, however, that the ratio of the two salts also varies very much among various smelters, so the most likely distribution may be determined only after selecting the type of the domestic smelter.

According to the presently available information the total (proven and possible) fluor-spar reserves of the Djanguirre and Canxixe deposits amount to 700 to 750 thousand tonnes with an average CaF_2 content of 50 to 60 per cent. Taking 20 to 40 per cent beneficiation losses into account this corresponds to some 300,000 tonnes of basic material with a CaF_2 content of 97 per cent. Some 14,000 tpy of basic material is required for the manufacturing of

10,000 tpy of fluoride salts, consequently the presently known deposits are sufficient for 20 to 25 years at the envisaged rate of consumption. This justifies the selection of a 10,000 tpy capacity from the supply side, too.

2.3 PRODUCT SPECIFICATION

The specifications of the fluoride salts used in aluminium smelting are as follows:

Cryolite:

Adhesive moisture + loss on ignition	max. 1.5 per cent
Na_3AlF_6	min. 97.6 per cent
F	min. 53.0 per cent
Al	min. 13.0 per cent
$Fe_2O_3 + SiO_2$	max. 0.45 per cent
SO_4	max. 1.0 per cent
NaF/AlF_3 molar ratio	2.9 to 3.0

Aluminium fluoride:

Adhesive moisture + loss on ignition	max. 1.5 per cent
AlF_3	min. 92.0 per cent
F	min. 60.0 per cent
Al	min. 30.0 per cent
$Fe_2O_3 + SiO_2$	max. 0.5 per cent
SO_4	max. 1.0 per cent

3. DEVELOPMENT OF THE TECHNOLOGY

3. DEVELOPMENT OF THE TECHNOLOGY

3.1 BASIC MATERIAL

Since the report dealing with geology and mining contains the detailed description of the basic material, it is referred to at this place only to such an extent as necessary for the development of the manufacturing technology of the fluoride salts.

The average CaF_2 content of the presently known fluorspar reserves of the various deposits is about 50 to 60 per cent. A basic material containing 68 to 72 per cent CaF_2 may be obtained by manual sorting or dry beneficiation of this ore, whereas beneficiation by flotation may yield a concentrate containing some 97.0 per cent CaF_2. The three possible basic materials can be processed by different technologies, consequently with different manufacturing costs.

The following three basic material compositions have been used for the development of the processing technology:

		Unbeneficiated	Beneficiated by dry process	Beneficiated by flotation
CaF_2	per cent	50	70.0	97.0
SiO_2	per cent	44	21.5	1.5
$CaCO_3$	per cent	2	2.4	1.1
Fe_2O_3 + Al_2O_3	per cent	4	6.1	0.4

3.2 DESCRIPTION OF THE TECHNOLOGICAL VARIANTS

Four different technological solutions have been taken into consideration for the processing of the three possible basic material qualities described in Chapter 3.1.

Variant A (Block Diagram No. 1.)

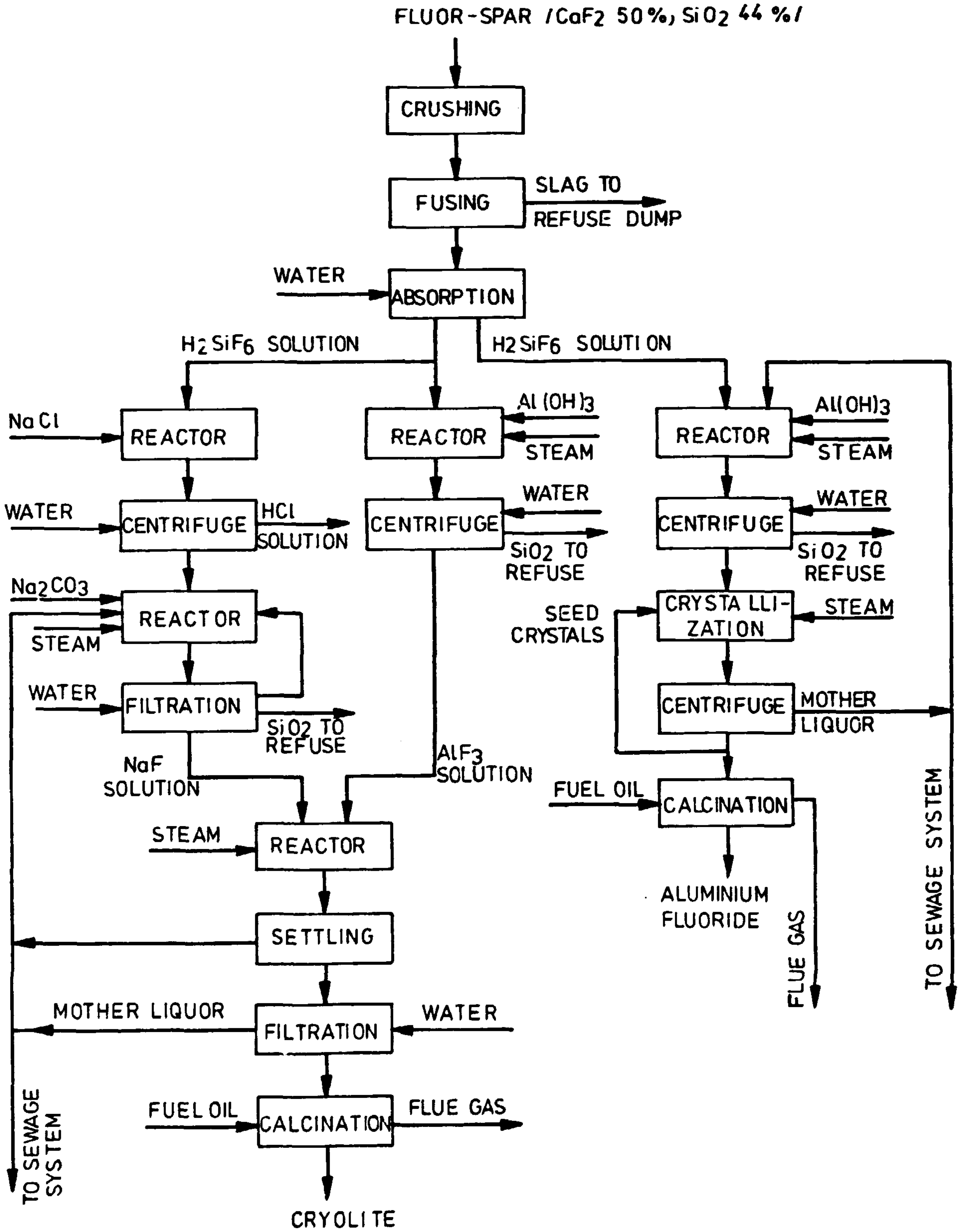
The raw material corresponding to the average ore quality and containing about 50 per cent CaF_2 can be processed by this technology. The ore is crushed to a size of minus 30 mm and subsequently fused at 1,300 °C in an electric arc furnace. During this process silica, the other main component of the ore, acting as an acid anhydride displaces the more volatile fluorine in its calcium salt. The fluorine gas set free reacts with the silica content of the ore forming silicon fluoride (SiF_4) and the latter leaves continuously the fused material as a gas. The remaining slag mainly consists of dicalcium silicate ($2CaO.SiO_2$). The ore should preferably contain as much silica as required stoichiometrically for forming $2CaO.SiO_2$ and SiF_4. When absorbing in water the silicon tetrafluoride gas set free in the furnace a solution of hexafluorosilicic acid (H_2SiF_6) is formed, with the simultaneous precipitation of silicic acid. The hexafluorosilicic acid solution serves as an intermediate product for the manufacturing of both cryolite and aluminium fluoride.

The hexafluorosilicic acid solution required for the production of cryolite is divided into two parts before further processing. One part is transformed at room temperature into sodium hexafluoro silicate (Na_2SiF_6) by adding sodium chloride (NaCl) to it. The sodium hexafluoro silicate crystals precipitated during this reaction are separated by centrifuging from the mother liquor containing hydrochloric acid (HCl). The mother liquor is discharged into the sewage

BLOCK DIAGRAM No. 1.

CRYOLITE AND ALUMINIUM FLUORIDE PRODUCTION

/VARIANT A/



system, whereas the sodium hexafluoro silicate is transformed at 60 °C by a sodium carbonate (Na_2CO_3) solution into a sodium fluoride (NaF) solution. The silicic acid precipitated during these reactions is removed by filtration.

The other part of the hexafluorosilicic acid is used for dissolving alumina hydrate ($Al/OH/_3$) at 100 °C to produce an aluminium fluoride solution. The silicic acid precipitated during this production step is removed from the solution by centrifuging. The silica-free sodium fluoride and aluminium fluoride solutions are mixed in such a ratio that the NaF to AlF_3 molar ratio should be 3. In this case cryolite precipitates at 60 °C. After the reaction is completed, the resulting slurry is concentrated by thickening and the cryolite is filtered on a drum filter. The wet cryolite cake is dried and subsequently calcined at a temperature of 650 to 700 °C.

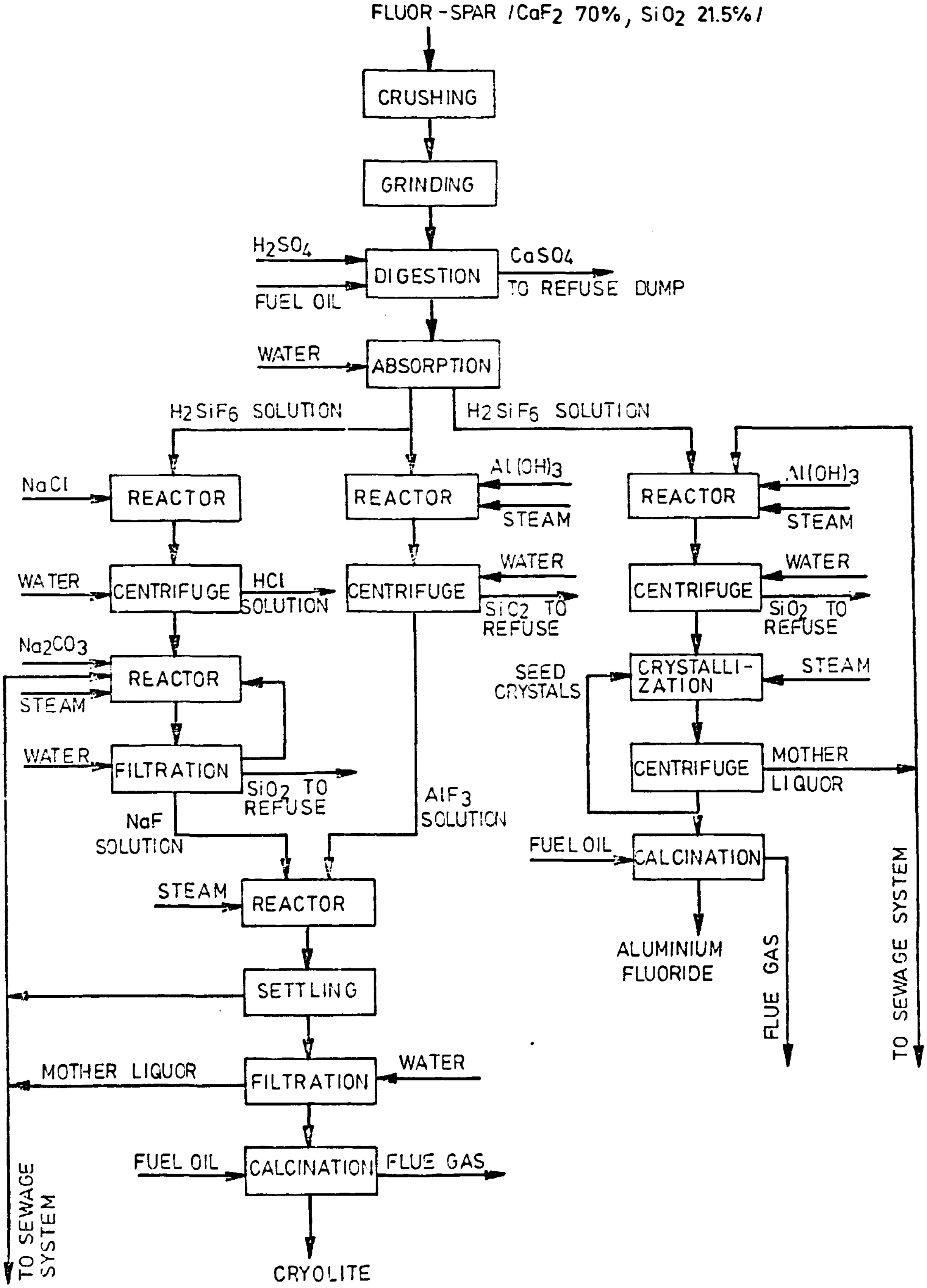
The hexafluorosilicic acid solution required for the production of aluminium fluoride is also used for dissolving alumina hydrate in a stoichiometric proportion. After removing the silicic acid precipitate by centrifuging the aluminium fluoride solution is fed into a crystallizer in which $AlF_3.3H_2O$ crystals precipitate at a temperature of 90 to 93 °C. Seed crystals are added in order to accelerate the crystallization. The product crystals separated by centrifuging are dried and subsequently calcined at a temperature of 650 °C.

Variant B (Block Diagram No. 2.)

This variant has been worked out for the processing of a basic material containing some 70 per cent CaF_2 obtained by manual sorting or dry beneficiation of the ore. The beneficiated ore is crushed and ground to such an extent that the + 100 µm grain-size fraction should not exceed 8 to 10 per cent. The ground basic material is digested in concentrated

BLOCK DIAGRAM No. 2.

CRYOLITE AND ALUMINIUM FLUORIDE PRODUCTION
/ VARIANT B /



sulphuric acid in a rotating tube reactor at a temperature of 240 to 280 °C. The greater part of the fluorine content of the basic material is transformed into silicon tetrafluoride (SiF_4) and the smaller part of it into hexafluorosilicic acid (H_2SiF_6) during digestion. When absorbing these gases in water a solution of hexafluorosilicic acid is forming with the simultaneous precipitation of silicic acid. The residue of the digestion mainly consisting of calcium sulphate ($CaSO_4$) is dumped.

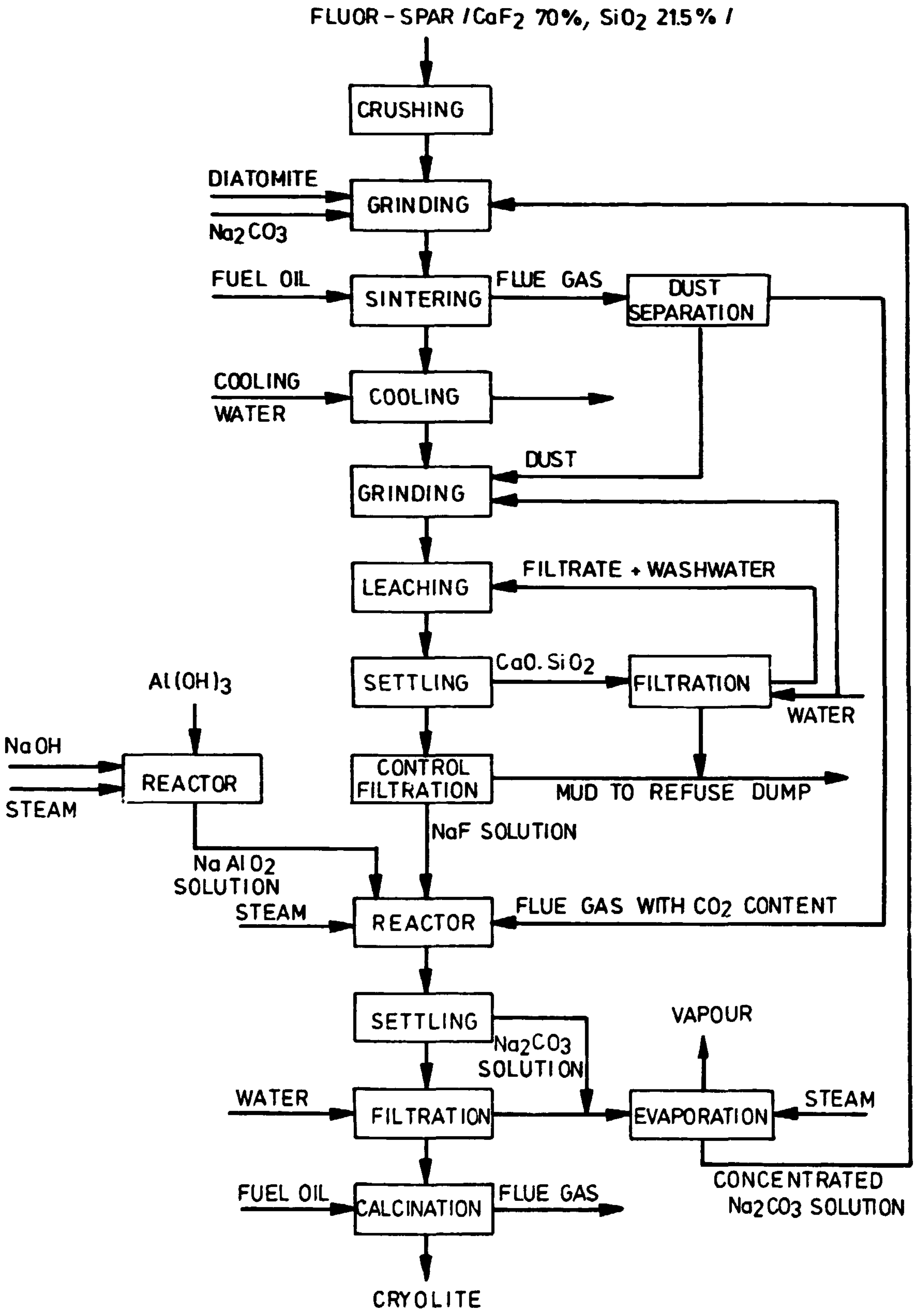
Cryolite and aluminium fluoride are manufactured from the hexafluorosilicic acid solution according to the process described under Variant A.

Variant C (Block Diagram No. 3.)

This technology has also been worked out for the processing of the basic material containing some 70 per cent CaF_2 obtained by manual sorting or dry beneficiation of the ore, but it uses alkaline digestion instead of the acidic one. The beneficiated ore is ground to minus 200 µm in a wet process after mixing it with soda ash (Na_2CO_3) and diatomite (mainly SiO_2) in the necessary ratios. The ground material (adhesive moisture 46 per cent) is sintered in a rotary kiln at a temperature of 825 to 875 °C. Sodium fluoride (NaF) and calcium silicate ($CaO.SiO_2$) are forming in this process step. Precondition for a high-yield transformation is that the required amount of silica (SiO_2) is introduced in the form of amorphous (i.e. chemically active) diatomite into the process, and not as much less active quartz sand. The required amounts of sodium carbonate and silica are determined by the following molar ratios:

$$CaO:SiO_2 = 1 \quad \text{and} \quad Na_2CO_3.CaF_2 = 1.1$$

CRYOLITE PRODUCTION
/VARIANT C/



The sinter product is ground to a grain-size of 0.5 to 1 mm and subsequently leached by water at a temperature of 50 to 55 °C. The resulting slurry containing some 10 to 15 gpl dissolved sodium fluoride is concentrated by thickening and subsequently filtered. The filter cake mainly consisting of calcium silicate is dumped. The sodium fluoride solution can only be used for the manufacturing of cryolite.

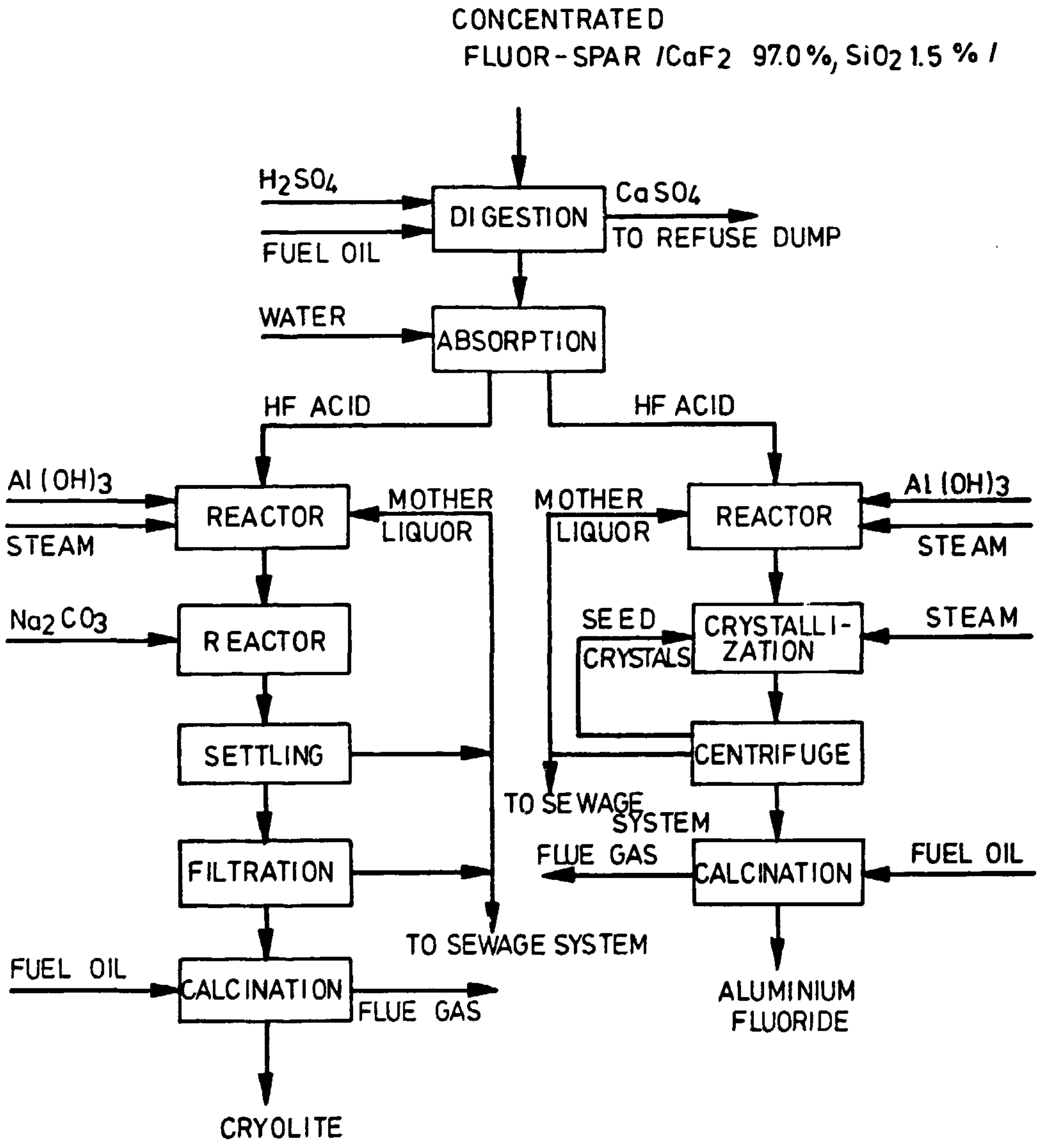
Cryolite is precipitated by means of a sodium aluminate solution at 70 to 75 °C and a simultaneous introduction of carbon dioxide (CO_2) gas. The flue gases of the sintering kiln previously cleaned of dust may be used for the purpose of this carbonization process. The sodium aluminate solution required for the precipitation of cryolite is prepared by dissolving alumina hydrate ($Al/OH/_3$) in sodium hydroxide (NaOH) at a temperature of 100 to 105 °C. The precipitated cryolite is separated by filtration from the mother liquor (sodium carbonate solution), dried and calcined at a temperature of 650 to 700 °C. The mother liquor is concentrated by evaporation to some 430 to 440 gpl Na_2CO_3 and recycled to the beginning of the process.

Variant D (Block Diagram No. 4.)

Basic material beneficiated by flotation is processed by this technological variant. The most important requirement for this material is that its SiO_2 content should not exceed 1.5 per cent. The beneficiated ore already ground to minus 100 µm before flotation is digested by concentrated sulphuric acid at a temperature of 240 to 280 °C in a rotating tube reactor. The fluorine content of the basic material is tranformed to hydrogen fluoride (H_2F_2) gas during digestion. The latter is cleaned of dust and absorbed in water to form a hydrofluoric acid solution. The digestion residue mainly consisting of calcium sulphate ($CaSO_4$) is dump-

BLOCK DIAGRAM No.4.

CRYOLITE AND ALUMINIUM FLUORIDE PRODUCTION
/VARIANT D/



ed. The hydrofluoric acid solution serves as an intermediate product for the manufacturing of both cryolite and aluminium fluoride.

The stoichiometrically required amount of alumina hydrate ($Al/OH/_3$) is dissolved at a temperature of 95 to 100 °C in the hydrofluoric acid solution required for the manufacturing of cryolite to form hexafluoroaluminic acid (H_3AlF_6). By neutralizing the latter with sodium carbonate (Na_2CO_3) cryolite precipitates at 60 °C. The cryolite slurry is thickened in a settler and subsequently filtered on a vacuum drum filter. Most of the mother liquor is recycled to the alumina hydrate dissolution step, a smaller part of it is led into the drainage system. The wet cryolite filter cake is dried and subsequently calcined at a temperature of 650 to 700 °C.

The stoichiometrically required amount of alumina hydrate ($Al/OH/_3$) is similarly dissolved in the hydrofluoric acid solution required for the manufacturing of aluminium fluoride (AlF_3). The latter is crystallized in the form of $AlF_3.3H_2O$ crystals at a temperature of 90 to 93 °C after adding seed crystals of the same composition. The crystals are separated by centrifuging from the mother liquor, dried and subsequently calcined at a temperature of 650 °C. Most of the mother liquor is recycled to the alumina hydrate dissolution step, a smaller part of it is led into the drainage system.

3.3 AUXILIARY MATERIALS AND ENERGY SUPPLIES

The manufacturing of cryolite and aluminium fluoride requires a great variety of auxiliary materials and energy supplies. Depending on the technological variant to be selected even the type of the required auxiliary materials differs, too. Table 3-1. shows the annual basic material, auxiliary material and energy requirements of the variants described in Chapter 3.2.

Table 3-1.

ANNUAL MATERIAL AND ENERGY CONSUMPTION

Denomination	Unit	Annual consumption Variant A	Variant B	Variant C	Variant D
Fluor-spar (50% CaF_2)	tonne	28960	-	-	-
(70% CaF_2)	tonne	-	20646	19000	-
(97.0% CaF_2)	tonne	-	-	-	13770
Sulphuric acid (98% H_2SO_4)	tonne	-	23660	-	18126
Diatomite (90% SiO_2)	tonne	-	-	7000	-
Soda ash (98% Na_2CO_3)	tonne	3906	3906	9500	5341
Alumina hydrate (dry)	tonne	5810	5810	4000	5449
Caustic soda (98% NaOH)	tonne	-	-	2500	-
Rock-salt, technical (95% NaCl)	tonne	4200	4200	-	-
Hydrated lime (90% Ca/OH/$_2$)	tonne	3067	3302	-	1278
Graphite electrodes	tonne	180	-	-	-
Flocculant	tonne	-	-	2	-
Industrial water	1000 m^3	330	300	300	230
Compressed air (0.3 MPa)	1000 St.m^3	16100	16100	16100	16000
Coal (20 MJ/kg)	tonne	4200	4200	23830	2040
Fuel oil (42 MJ/kg)	tonne	877	2567	4152	2274
Power	MWh	50860	2950	4350	2644

PRODUCT QUANTITIES

In Variants A, B and D:	7,000 tpy cryolite and 3,000 tpy aluminium fluoride
In Variant C:	10,000 tpy cryolite

According to the informations available to us the auxiliary materials required for the manufacturing of the fluoride salts are not produced in Mozambique, therefore, their importation has been taken into consideration in the present study. Presumably a large proportion of the auxiliary materials (sulphuric acid, soda ash, caustic soda, alumina hydrate) will have to be imported from continents other than Africa. It seems to be expedient to import alumina hydrate from the same source that will supply the alumina required by the projected smelter. The imported materials will be unloaded in the harbour of Beira, wherefrom they can be transported by train since both plant locations taken into consideration by the authorities of Mozambique (Caia and Tete) are situated along a railway line. Though the regulation of the river Zambezi in order to make it navigable is included in the long-range plans, river transportation is presently left out of the calculations.

Fuel oil will also be imported and unloaded in the harbour of Beira and transported by rail to the plant site. Coal requirements will be met by domestic production. Coal deposits are in the vicinity of Moatize. It will also be transported by rail. Domestic hydropower will be used since Mozambique has a power generation capacity exceeding its demands.

There are some specific quality requirements to be met by some auxiliary materials:

- Sulphuric acid

  The sulphuric acid containing about 98 per cent H_2SO_4 but the accuracy of the blending of the reacting materials requires a consistent concentration, therefore, the variation of the latter should not exceed 0.5 per cent at the place of its use.

H_2SO_4 content:	98.0 to 98.5 per cent
Fe content:	max. 0.005 per cent

- Alumina hydrate

  Both dry and filter-wet materials are suitable. When using the latter it is important that the variation of its adhesive moisture should not exceed 1 per cent at the place of its use.

Fe content:	max. 0.015 per cent
SiO_2 content:	max. 0.010 per cent

- Soda ash

Loss on ignition (at 300 °C):	max. 4 per cent
Na_2CO_3*:	min.98 per cent
NaCl*:	max. 0.5 per cent
Na_2SO_4:	max. 0.2 per cent
Insolubles:	max. 0.2 per cent

*relative to the ignited material

3.4 COMPARATIVE EVALUATION OF THE TECHNOLOGICAL VARIANTS

3.41 Specific characteristics of the variants

Some specific characteristics of various variants influencing the selection of the best technology are pointed out in order to make the comparison more realistic. These characteristics have to be evaluated simultaneously with the economic data shown later when selecting the technological solution to be applied.

Variant A

The average quality of the known ore reserves corresponds to requirements of this technology, so the costs of the basic material are probably the lowest in this variant. No chemicals (neither sulphuric acid nor soda ash) are required for the digestion of the fluorine content of the ore, since this variant is based on an electrothermic process. The above chemicals required by the other digestion processes have to be imported, whereas the electric energy required for the digestion in this variant is locally available as a relatively inexpensive hydropower. The heat requirement of the digestion is also covered by hydropower instead of imported fuel oil.

On the other hand, the excess transportation costs resulting from the fact that the raw material contains large amounts of materials other than calcium fluoride significantly reduce the advantages of this variant. The transportation costs of the basic material are relatively high in any case, since the processing plant can only be established quite far from the ore deposits, so the basic material has to be transported to a distance of at least 150 km on public roads being in a very poor shape.

Variant B

This variant has no specific characteristics except for the quality of the basic material. But it has to be mentioned that starting with the processing of the hexafluorosilicic acid solution cryolite is manufactured in this variant according to a process patented and applied on a commercial scale in Hungary.

Variant C

This variant eliminates the corrosion risks associated with the technologies using acid digestion, so it makes unnecessary the use of more expensive corrosion-resisting structural materials. As a result of the alkaline digestion no fluorine-containing gases harmful for health and environment are set free. Large amounts of water have, however, to be evaporated from the sodium carbonate solution requiring very large amounts of steam for this purpose.

A very important characteristic of this variant is that only cryolite, but no aluminium fluoride can be produced with it.

Variant D

As a result of the low amount of contaminants present in the beneficiated ore the processing technology is much simpler and both the number and variety of the necessary equipment are less than those in the previous variants. On the other hand, this variant entails significant capital and operating costs at the ore beneficiation stage.

3.42 Sequence of the technological variants

The technological variants described in the previous chapter require different basic material qualities. Therefore, the capital and operating costs of the preparation of the basic material are different, too. For this reason the capital and operating costs of mining, beneficiation and fluoride salt manufacturing have to be examined together when comparing the economies of the technological variants. The variant yielding the smallest sum of the two costs is the most economical. Since the capital costs are invested only once, but operating costs are incurred year by year, the two types of costs can not be simply added. The original costs have to be transformed into yearly average capital costs distributed for n years by taking into consideration the expected life of the plants and mines established and a calculative interest rate. This method is known as "annuity calculation" in the technical literature.

The original capital costs can be transformed into yearly average capital costs by using the following formula:

$$K = B\,\frac{\frac{i}{100}\left(1 + \frac{i}{100}\right)^{n}}{\left(1 + \frac{i}{100}\right)^{n} - 1}$$

K - yearly average capital costs, US$ per year
B - original capital costs, US$
i - calculative interest rate, per cent
n - expected life of the plants and mines, year

According to the calculations described in Vol. 1. the costs of the mines and beneficiation plants are the following for the three basic material qualities:

	Basic material quality		
	50 % CaF_2	70 % CaF_2	97 % CaF_2
Capital costs, thousand US$	5062,7	5386,3	8189,7
Variable operating costs, thousand US$ per year	1298,6	1241,6	1803,4

The capital and operating costs of the four technological variants described in the previous chapter are shown in Table 3-2.

When carrying out the annuity calculations for the technological variants with the help of the formula described before, supposing a 12 per cent calculative interest rate and a plant and mine life of 20 years the figures shown in Table 3-3 can be arrived at.

Table 3-2.

VARIABLE OPERATING COSTS

Denomination	Unit price US$/t (US$/MWh)	Annual costs, thousand US$ Var. A	Var. B	Var. C	Var. D
Sulphuric acid ($98\ \%\ H_2SO_4$)	45	-	1064.7	-	815.7
Diatomite ($90\ \%\ SiO_2$)	60	-	-	420.0	-
Soda ash ($98\ \%\ Na_2CO_3$)	120	468.7	468.7	1140.0	640.9
Alumina hydrate (dry)	128	743.7	743.7	512.0	697.5
Caustic soda (98 % NaOH)	370	-	-	925.0	-
Rock-salt, technical (95 % NaCl)	9	37.8	37.8	-	-
Hydrated lime ($90\ \%\ Ca/OH/_2$)	37	113.5	122.2	-	47.3
Graphite electrodes	1910	343.8	-	-	-
Flocculant	4000	-	-	8.0	-
Coal (20 MJ/kg)	20	84.0	84.0	476.6	40.8
Fuel oil (42 MJ/kg)	200	175.4	513.4	830.4	454.8
Power	(25)	1271.5	73.7	108.7	66.1
Total direct materials		3238.4	3108.2	4420.7	2763.1
Wages, salaries and fringe benefits		254.8	254.8	211.6	225.1
Maintenance materials		564.0	570.0	513.0	460.0
Inland freight		146.2	270.9	313.6	197.3
Port charges		172.2	300.4	247.0	222.2
TOTAL		4375.6	4504.3	5705.9	3867.7

CAPITAL COSTS

	Variant A	Variant B	Variant C	Variant D
Thousand US$	23200	23300	21200	18900

Table 3-3.

RESULTS OF THE ANNUITY CALCULATIONS

	Specific costs, US$ per tonne			
	Var. A	Var. B	Var. C	Var. D
MINING AND BENEFICIATION				
Transformed (yearly average) capital costs	67.8	72.1	72.1	109.7
Variable operating costs	129.9	124.2	124.2	180.3
FLUORIDE SALT MANUFACTURING PLANT				
Transformed (yearly average) capital costs	310.6	312.0	283.9	253.1
Variable operating costs	437.6	450.4	570.6	386.7
TOTAL	945.9	958.7	1050.8	929.8

The economical sequence of the technological variants is (in the order of increasing sum of the variable cost elements used for the purpose of comparison) the following:

1.	Variant D	929.8 US$ per tonne	100.0 per cent
2.	Variant A	945.9 US$ per tonne	101.8 per cent
3.	Variant B	958.7 US$ per tonne	103.1 per cent
4.	Variant C	1050.8 US$ per tonne	113.1 per cent

The annuity calculations do not show significant differences between the costs of Variants D, A and B. In such cases usually those variants are favoured (especially in developing countries) the capital costs of which are the lowest. The sequence of the capital costs of these three variants are (in increasing order) the following:

1.	Variant D	27090 thousand US$	100.0 per cent
2.	Variant A	28263 thousand US$	104.3 per cent
3.	Variant B	28686 thousand US$	105.9 per cent

Both sequences favour Variant D (sulphuric acid digestion of the flotated ore) from two different economical points of view. Nevertheless, it has to be emphasized, that even Variant B occupying the third place in both sequences costs only 3.1 and 5.9 per cent more than Variant A, the differences being much lower than the accepted error margins of estimates made in a preinvestment study. Therefore, Variants D, A and B can be considered to be nearly equivalent from the point of view of economy at the present level of the study. Only Variant C can be left out from the further calculations on the basis of the present comparison since its costs significantly exceed those of the other variants. The technological variant most suitable for realization can be selected from the remaining three variants only when local data more accurate and wideranging than those at present are available. These corrections should be made when a feasibility study is prepared.

When evaluating the technological variants the effect of the quality of the raw material has to be specially emphasized since it exerts a significant influence on both the beneficiation and the further processing. The present evaluation has been made on the basis of the Djanguirre ore having an inferior chemical and mineralogical composition from the point of view of processing, because the samples from the Canxixe deposit arrived late and they can not be considered to be representative (see Vol. 1.). The processing of the Canxixe ore (expected to have a better composition) may involve reduced capital and operating costs - first of all at the flotation stage - and so the difference between the variants may be modified.

The details of the project have been worked out in further parts of the study for Variant D, however, the competitiveness of Variants A and B also has to be emphasized. It seems to be specially justified to submit Variant A to an intensive examination in the stage of preparing the feasibility study, since this variant uses domestic electric power instead of auxiliary materials to be imported (sulphuric acid, fuel oil).

4. PLANT SITING

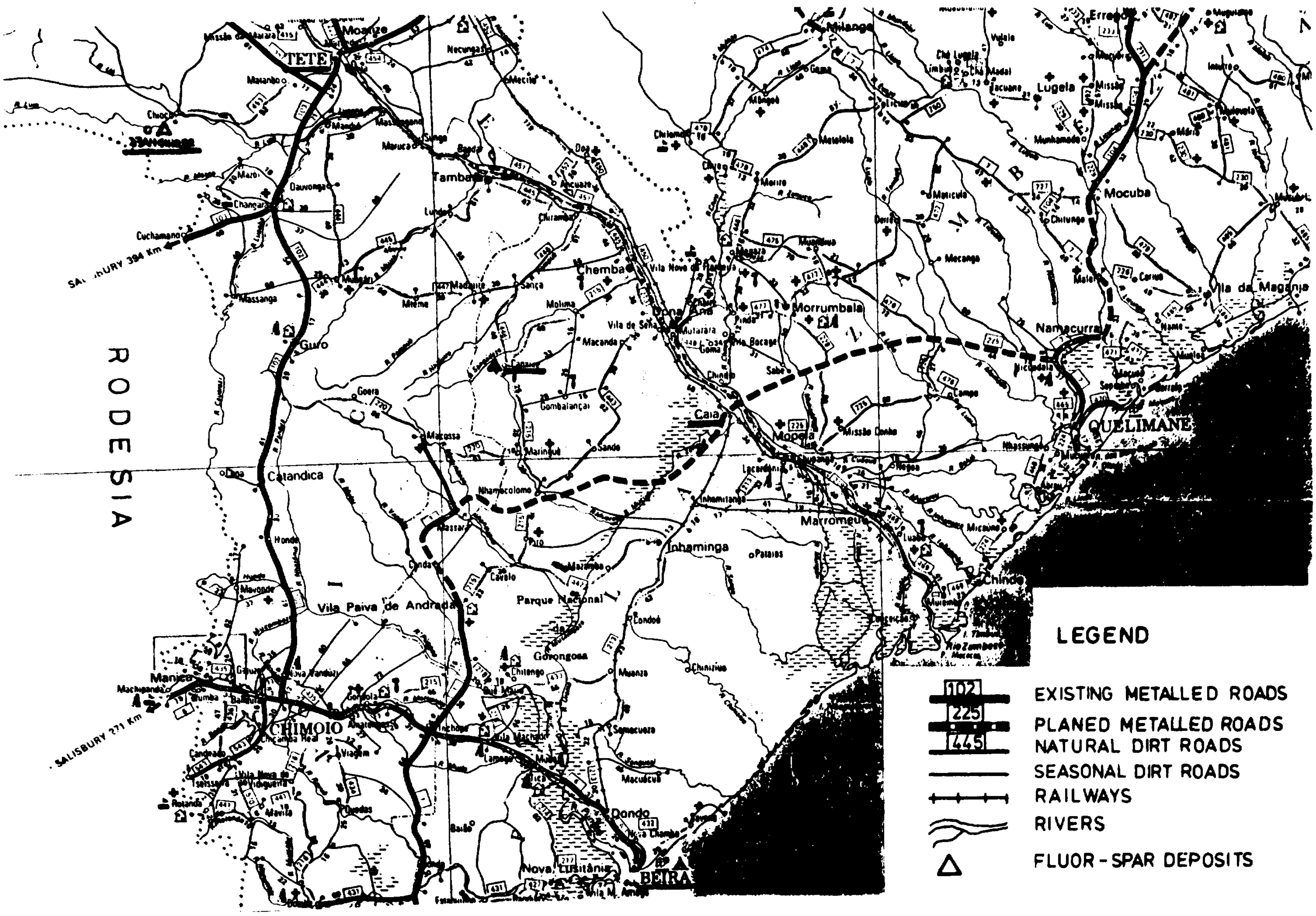
4. PLANT SITING

The authorities of Mozambique have not made a concrete decision concerning the siting of the plant by the time of the collecting of the study's basic data. Therefore, the following variants have been considered for the siting:

- in the vicinity of the raw material deposits,
- in the vicinity of the aluminium smelter using the products,
- in the area of the harbour (Beira) where the auxiliary materials will be unloaded.

Fig. 4-1. outlines the siting conceptions.

Most of the raw material - as previously mentioned - is located in two deposits, in the areas of Canxixe and Djanguirre, some 300 to 400 km from each other. Both deposits are at distances of some 150 km from the railway line and can only be reached by trucks on unmetalled roads. Traffic is impossible on the unmetalled roads during the rainy season. There is no natural water source in the vicinity of the deposits during most of the year. Power is not available either, and the extension of the power grid to these areas is not included in the development plans for the time being. On the basis of these arguments there is no realistic possibility for the siting of the plant in the vicinity of any of the ore deposits. Attention is drawn at this place to the fact that as a result of the above reasons the flotation plant can not be sited to the deposits either. According to the mining conception a flotation plant will be constructed in the area of either Tete or Caia - advantageously in the vicinity of the fluoride salt manufacturing plant - and it will



GENERAL LAYOUT

Fig. 4-1

be relocated to the other area by the time the deposit closer to the plant site to be selected is exhausted and the mining of the other deposit gets under way.

The relatively small capacity of the fluoride salt manufacturing plant and the low profitability of the products can probably not support the infrastructural and other additional expenditures necessary if the plant is realized as an independent project. Therefore, a siting making possible the connection to the infrastructure of another industrial project seems to be advantageous. From this point of view first of all the siting of the plant to the projected aluminium smelter may come into consideration, but the siting to a fertilizer plant to be possibly constructed may offer some advantages, too. The authorities of Mozambique have mentioned during the collecting of the data that some plans exist for the construction of a fertilizer plant in the vicinity of Beira.

The greater part of the cryolite and aluminium fluoride to be produced will be consumed by the aluminium smelter to be constructed. Two conceptions are presently known for the siting of the smelter: Caia and Tete. The siting of the fluoride salt manufacturing plant to the smelter has additional advantages over and above those resulting from the local consumption of the products. A number of plant units serving both the smelter and the fluoride salt manufacturing plant may be constructed as common units significantly reducing both the capital and operating costs. Such common service units may be the followings:

- railway siding and rail traction,
- substation receiving,and distributing electric power,
- fuel oil receiving storage and handling,
- industrial water works, water cooling system,
- repair and maintenance shop,

- laboratory,
- management and administration building,
- welfare establishments (change room, canteen, medical facilities, etc.).

The selection of Caia or Tete for the establishment of the fluoride salt manufacturing plant has an influence on the domestic transportation costs of the auxiliary materials. The transportation costs of the basic materials are more or less the same for both siting variants, since the deposits are approximately at the same distance from both Caia and Tete. The validity of the above statement may be slightly influenced by the magnitude of the reserves of the two main deposits but since these are only estimates for the magnitude of the reserves, their influence has not been taken into consideration.

Table 4-1. contains the domestic transportation costs of the basic and auxiliary materials to the two possible plant locations taken into consideration. The tariffs shown in US$/t in Table 4-1. are calculated by the use of an exchange rate of 36 MT per US$ from the tariffs given by the authorities of Mozambique. It has to be mentioned that the tariffs given by the authorities refer to other materials except for those of fuel oil and fluor-spar, therefore, tariffs given for other, similar materials have been used in the calculations. The authorities of Mozambique have given the railway tariffs for the Beira-Caia distance only, except for fuel oil, for which the Beira-Tete (Moatize) tariff has also been disclosed. Since the Beira-Tete tariff for fuel oil is 1.46 times as much as the Beira-Caia tariff for the same, this figure has been used as a correction factor for the tariffs of every other materials. Road transportation costs have also been calculated for the distance between the mine and the flotation plant. The latter was supposed to be 150 km for both the Caia and the Tete plant locations. Road

Table 4-1.

DOMESTIC TRANSPORTATION COSTS OF THE BASIC AND AUXILIARY MATERIALS

DENOMINATION	Caia siting		Tete siting	
	Tariff US$/t	Annual costs 1000 US$/yr.	Tariff US$/t	Annual costs 1000 US$/yr.
Sulphuric acid	4.6	83.4	6.7	121.4
Soda ash	6.6	35.2	9.7	51.8
Alumina hydrate (10 % adhesive moisture)	6.6	39.4	9.7	58.7
Hydrated lime	6.6	8.4	9.7	12.4
Coal	2.6	5.3	-	-
Fuel oil	9.2	20.9	13.3	30.2
Total without fluor-spar		192.6		274.5
Fluor-spar (by rail*)	4.9	33.7	4.9	33.7
Fluor-spar (by road)	26.5	547.1	26.5	547.1
TOTAL		773.4		855.3

* Rail transportation costs have been calculated for both siting variants for only half of the fluor-spar reserves since the basic material produced only at one or the other deposit has to be transported by rail in both cases.

transportation costs have been calculated for 20,646 tpy ore beneficiated by the dry process (70 % CaF_2), rail transportation costs for 13,770 tpy ore beneficiated by flotation (97.0 % CaF_2), since flotation can not be carried out at the mines.

Two important conclusions can be drawn from Table 4-1:

- Total transportation costs of the basic and auxiliary materials are less by US$ 81,900 in the case of a Caia siting of the plant than in the case of a Tete siting. For a total of 10,000 tpy output this amounts to a difference of US$ 8.2 in manufacturing costs, i.e. to about 1 per cent of the average selling price of the product. So the cost difference between the two locations is not very significant and can not play a decisive role in itself in the selection of the plant site.

- The greater part of the total domestic transportation costs are due to the transportation of the basic material. The transportation costs of fluor-spar amount to the following per cents of the total domestic transportation costs:

	Caia siting	Tete siting
Rail transportation	4.3 %	3.9 %
Road transportation	70.7 %	64.0 %
Total	75.0 %	67.9 %

The total transportation costs of the fluor-spar amount to US$ 58.1 per tonne of final product, i.e. to nearly 9 per cent of the average selling price of the products. The aim of such a detailed discussion of the transportation costs is to draw attention to the fact that they have an important influence on the economy of the plant and, therefore, they should later be repeated on the basis of detailed local data.

The reason for raising the possibility of siting the plant to the harbour (Beira) where the auxiliary materials will be unloaded lies first of all in the fact that the imported auxiliary materials have not to be transported to a great distance in this case and so, domestic transportation costs arise only for fluor-spar and coal. As previously mentioned, this siting variant may have some reality first of all if the fluoride salt manufacturing plant can be combined with another, existing chemical plant in the area of Beira utilizing the existing infrastructure of the latter, since there are similar advantages in this case as described for the case of siting the plant to the aluminium smelter.

For the siting of the plant to Beira the domestic transportation costs of the basic and auxiliary materials are shown in the following table:

	Tariff US$/t	Annual costs '000 US$/yr.
Coal	4.7	9.6
Fluor-spar (by rail*)	7.1	97.8
Fluor-spar (by road)	26.5	547.1
Total		654.5

*Transportation costs are calculated for an ore beneficiated by flotation since in the case of this siting variant it is advantageous to carry out the flotation before rail transportation.

When comparing the above transportation costs with those in Table 4-1., it can be found that the Beira siting seems to be the most advantageous among the variants examined, as far as the transportation costs are concerned.

Should we take the transportation costs of this variant for 100 per cent, those of the Caia variant amount to 118.1 per cent and those of the Tete variant to 130.7 per cent.

There are differences between the plant locations taken into consideration as far as the availability of manpower is concerned. According to some informations given by the authorities of Mozambique a long-range excess of manpower is available in the areas of Caia and Tete whereas a future manpower shortage has to be calculated with in the area of Beira.

The above considerations take only one aspect into account for the selection of the plant site, i.e. that of the transportation costs. There was no possibility of carry out studies on a wider scale since no detailed data were available for the locations taken into consideration. The sequence of the variants according to the transportation costs can naturally not be the basis but only an important aspect of the selection of the plant site. As a consequence of the above reasons no properly supported suggestions can be given in the present Prefeasibility Study for the siting of the fluoride salt manufacturing plant. However, it can be expected that this plant can be well fitted to the projected aluminium smelter from the point of view of infrastructure, transportation, public works and other services, therefore, a siting to the smelter has been supposed in the area of Caia. Manpower supply is also advantageous for this site.

5. DETAILED DESCRIPTION OF THE MANUFACTURING TECHNOLOGY

5. DETAILED DESCRIPTION OF THE MANUFACTURING TECHNOLOGY

5.1 RECEIVING AND HANDLING OF THE BASIC AND AUXILIARY MATERIALS

Fluor-spar

No storage of fluor-spar is projected in the fluoride salt manufacturing plant, since it will be supplied continuously in the form of a slurry from the adjoining beneficiation plant unit. The required amount of unbeneficiated fluorspar will be stockpiled in the beneficiation plant unit.

Alumina hydrate, soda ash, hydrated lime

Transportation of these auxiliary technological materials is projected in one-way plastic containers. These materials will arrive by rail to the plant site. Since these are imported materials, stockpiles sufficient for a quarter-year should be stored of them. They can be stored in containers in an open-air storage area surfaced with concrete and provided with rain-water drainage. Fork-lift barrows will be used for the unloading of the containers from the waggons, for their transportation within the plant and for the feeding of their content into the feeding hopper of the plant.

Sulphuric acid

Sulphuric acid will be supplied in rail tankers. It will be transferred by pump from the tankers into the storage tanks. These can hold a 30-day stock. They will be placed into concrete basins constructed according to the relevant safety standards. The sulphuric acid can be homogenized in the tanks by circulating it by pumps.

Coal

Coal will be supplied in railway waggons to the plant site. A 15-day supply can be stockpiled in the storage area. A crane will be used for the unloading of the waggons and for the feeding of the coal.

Fuel oil

No fuel oil unloading and storage has been projected to the fluoride salt manufacturing plant. The fuel oil requirements of the smelter and the anode plant belonging to it will be several times as much as those of the fluoride salt manufacturing plant, therefore, it is advantageous to establish a common fuel oil storage at the smelter. Fuel oil will be transported from the common storage tanks by a pipeline to the fluoride salt manufacturing plant.

5.2 DESCRIPTION OF THE TECHNOLOGY

5.21 Digestion of fluorite by sulphuric acid

The flow-sheet of the process is shown in Fig. 5-1. Beneficiated fluorite will be fed as a slurry from the flotation plant unit to filter No. 001. The flow-rate of the slurry to be filtered will be 4.35 m^3/h. The filtrate will be recycled to the flotation by pump No. 003, whereas the wet cake will fall into hopper No. 004.

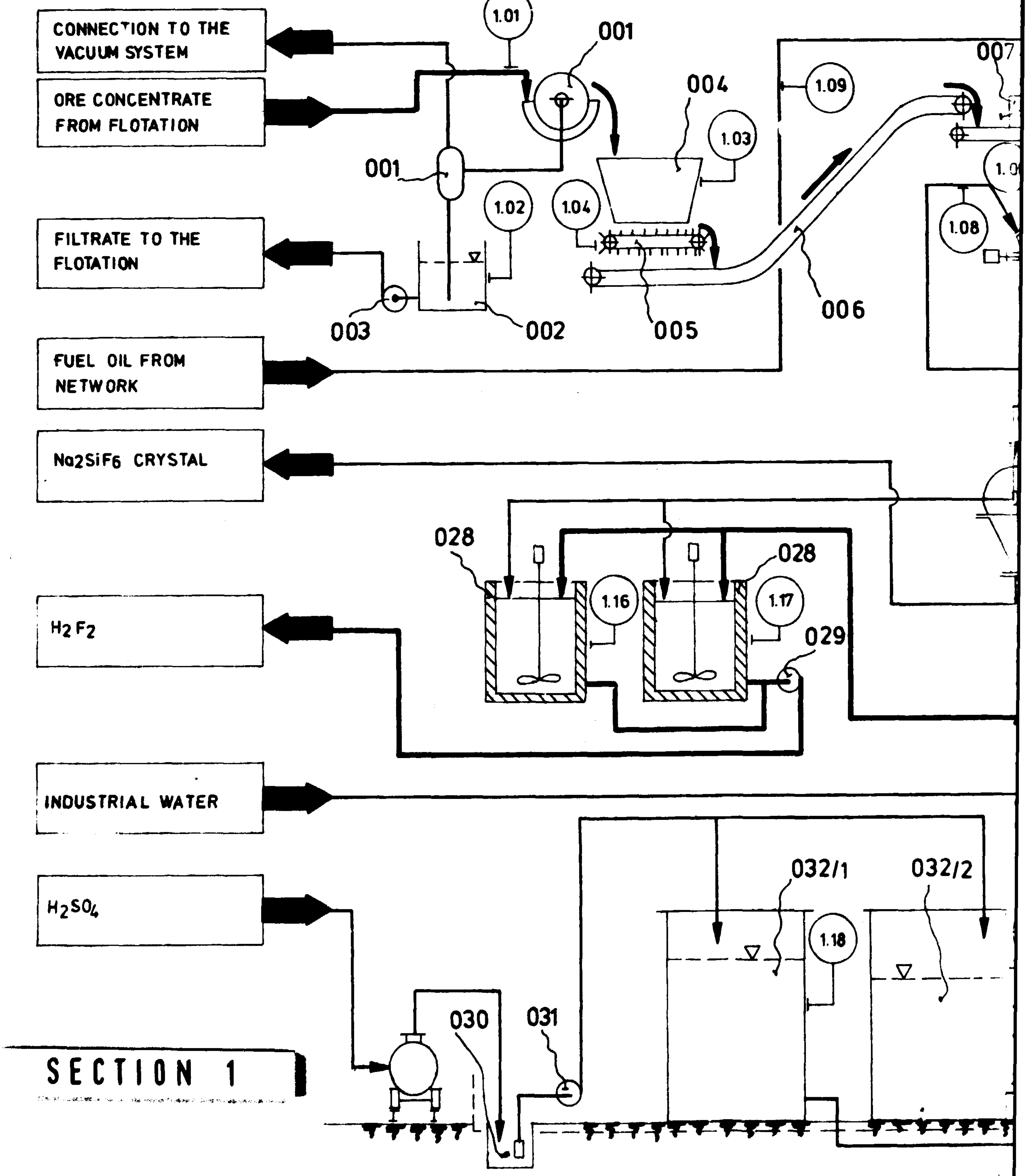
Fluorite will be digested at 300 °C by indirect heating in rotary kiln No. 011. Fuel oil will be supplied from the central storage by a pipeline. 1.887 t/h of fluorite (with an adhesive moisture of about 8 per cent) and 2.333 t/h sulphuric acid will have to be fed continuously into the kiln. The flow of the fluorite will be controlled by conveyor No. 005 and measured by weighing belt No. 007. A gaseous product and a solid residue will be produced in the course of the digestion process. These will be separated in chamber No. 012. The 3.207 t/h residue will be slurried by water in tank No. 016, its acid content will be neutralized by lime milk, and it will be pumped to a dump.

The gaseous phase will be led through dust precipitator No. 014 into absorber No. 022 where hydrogen fluoride (H_2F_2) will be absorbed by water. The resulting 1.33 m^3/h hydrofluoric acid will be collected in tank No. 023. If necessary, soda ash will be added into this tank to precipitate any silica contaminant. The slurry containing sodium hexafluorosilicate (Na_2SiF_6) will be fed into thickener No. 025. The solids-free hydrofluoric acid will overflow into holding tanks No. 028, whereas the underflow of the thickener will be led to centrifuge No. 027. The liquor will flow into tanks No. 028 from the centrifuge, the sodium hexafluorosilicate crystals will be packed in bags. The latter is a useful by-product, it can by used in the leather and rubber industries and as a rodent poison.

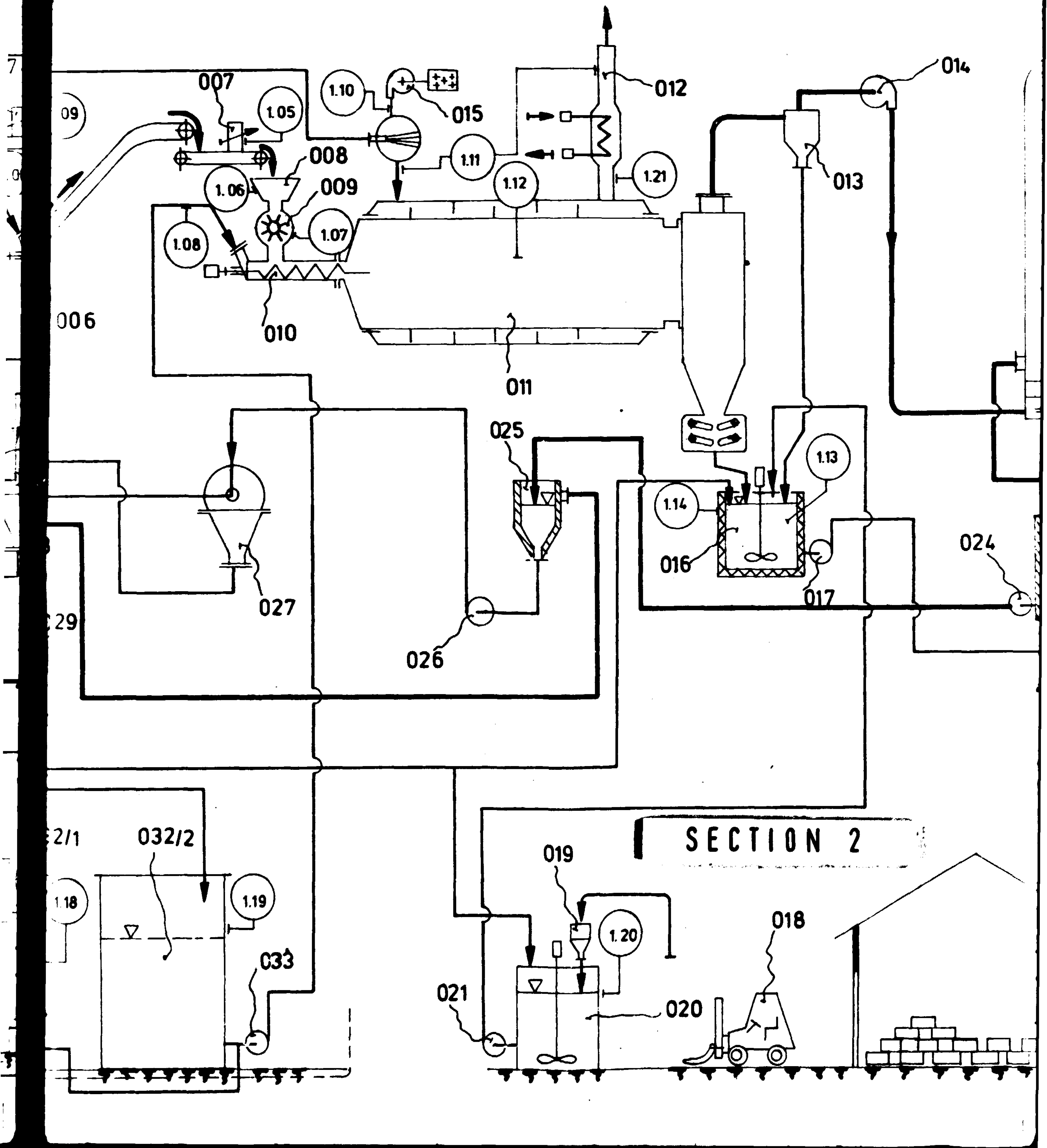
5.22 Aluminium fluoride manufacturing

The principal flow-sheet of the process is shown in Fig. 5-2. The product will be manufactured by dissolving alumina hydrate in hydrofluoric acid and crystallizing it subsequently. The dissolving will be carried out batchwise, the crystallization in a continuous process. 16 m^3 of mother liquor will have to be fed into tank No. 040 at a

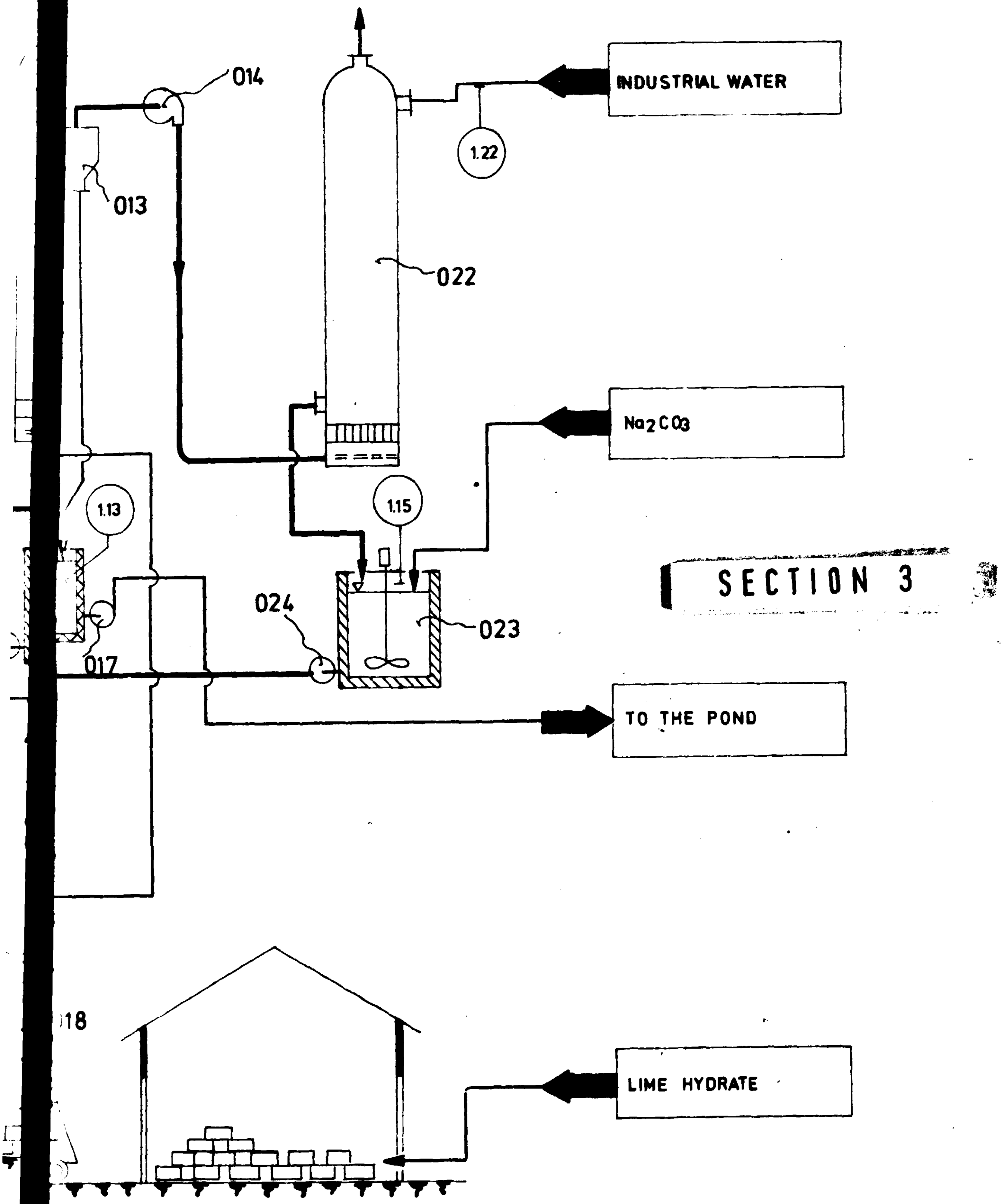
CONCEPTUAL PROCESS FLOW-



CESS FLOW-SHEET OF FLUORITE DIGESTION BY SULPHURIC ACID



PHURIC ACID


014
013
022
INDUSTRIAL WATER
1.22
Na2CO3
1.13
1.15
SECTION 3
024
023
017
TO THE POND
18
LIME HYDRATE

flow-rate of 25 m^3/h and at the same time 2.07 t of alumina hydrate containing 10 per cent adhesive moisture at a rate of 2 to 4 t/h, too. The hydrate will be fed from hopper No. 035 by belt conveyor No. 036 and it will be measured by weighing belt No. 038. 2.46 m^3 50 per cent hydrofluoric acid required for the dissolving of the hydrate will be pumped from tanks No. 028 at a flow-rate of max. 4 m^3/h. After transferring the required amounts of the various components the feedings will automatically stop. The prescribed temperature of the dissolution is 95 to 100 °C. This will be provided by direct steam heating.

After concluding the dissolution the liquor will be pumped into tank No. 042, wherefrom it will be continuously fed into crystallizing tank line No. 045 at a flow-rate of 3.72 m^3/h. A constant feeding rate will be ensured by an orifice applied after hydrostatic vessel No. 044. Seed crystals will be continuously fed into the first crystallizing tank of the line at a rate of 0.25 t/h. The temperature of the crystallizing tank line will be kept at 95 to 100 °C by direct steam heating. The slurry leaving the last tank of the crystallizing line at a flow-rate of about 4 m^3/h will be fed to centrifuge No. 048. The mother liquor will flow from the centrifuge into tank No. 063, the separated solids will be further used partly as seed crystals, partly as product crystals. The latter, amounting to some 0.9 t/h in wet form, will be transported by belt conveyor No. 050 into hopper No. 051 wherefrom it will be continuously fed into drying and calcining equipment No. 053 through charger No. 052.

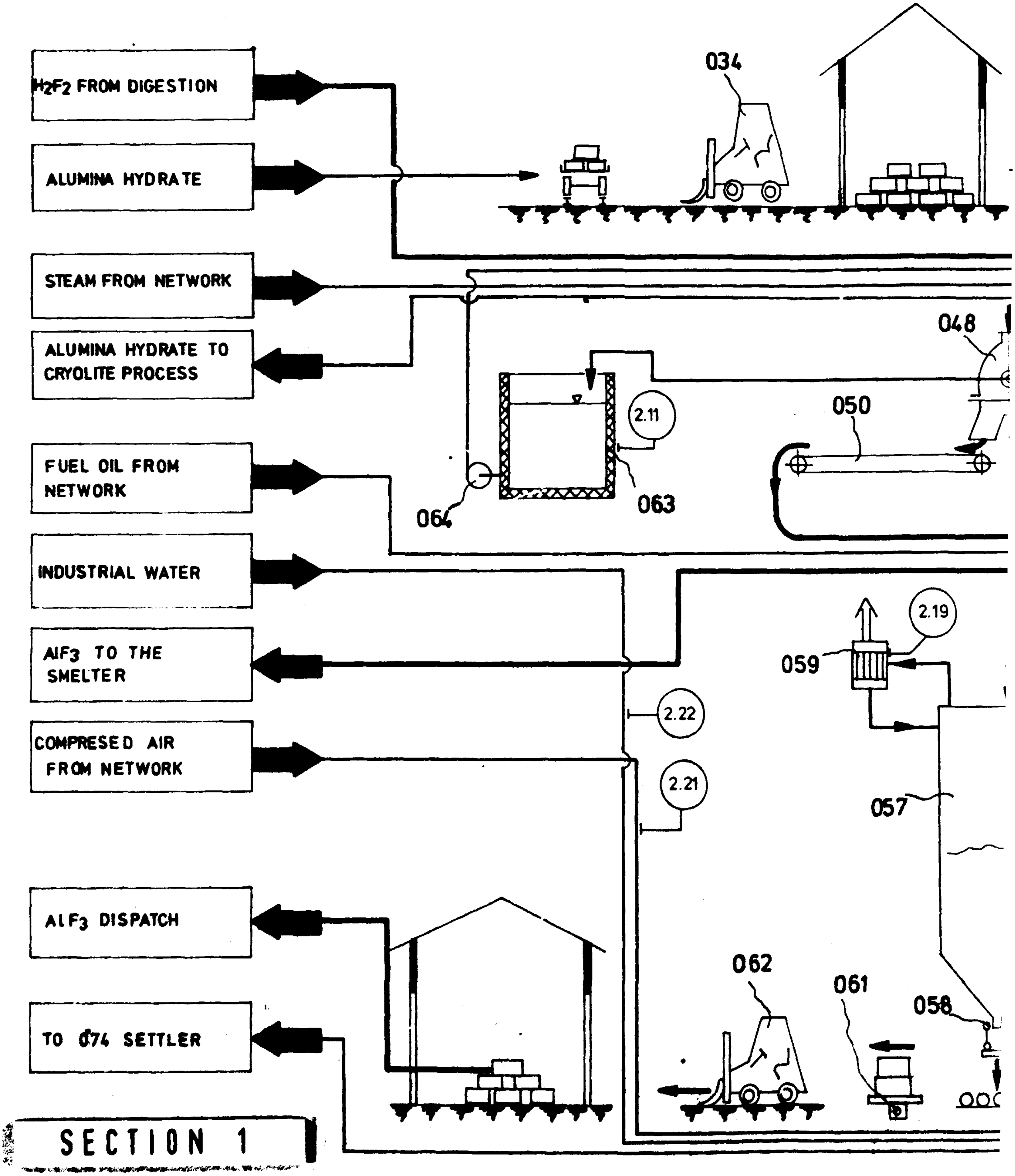
The calcination temperature of 600 °C will be provided by fuel oil firing. The dust content of the flue gases will be precipitated by wet scrubbing. The calcined product will leave the calciner through discharger No. 054 and it will get through fluid bed transporting channel No. 055 and air lifting tank No. 056 into storage hopper No. 057. The amount of the calcined product will be 0.38 t/h. One part of the aluminium fluoride can be packed into bags by means of sack filling machine No. 058, the other part will be transferred immediately into the aluminium smelter.

5.23 Cryolite manufacturing

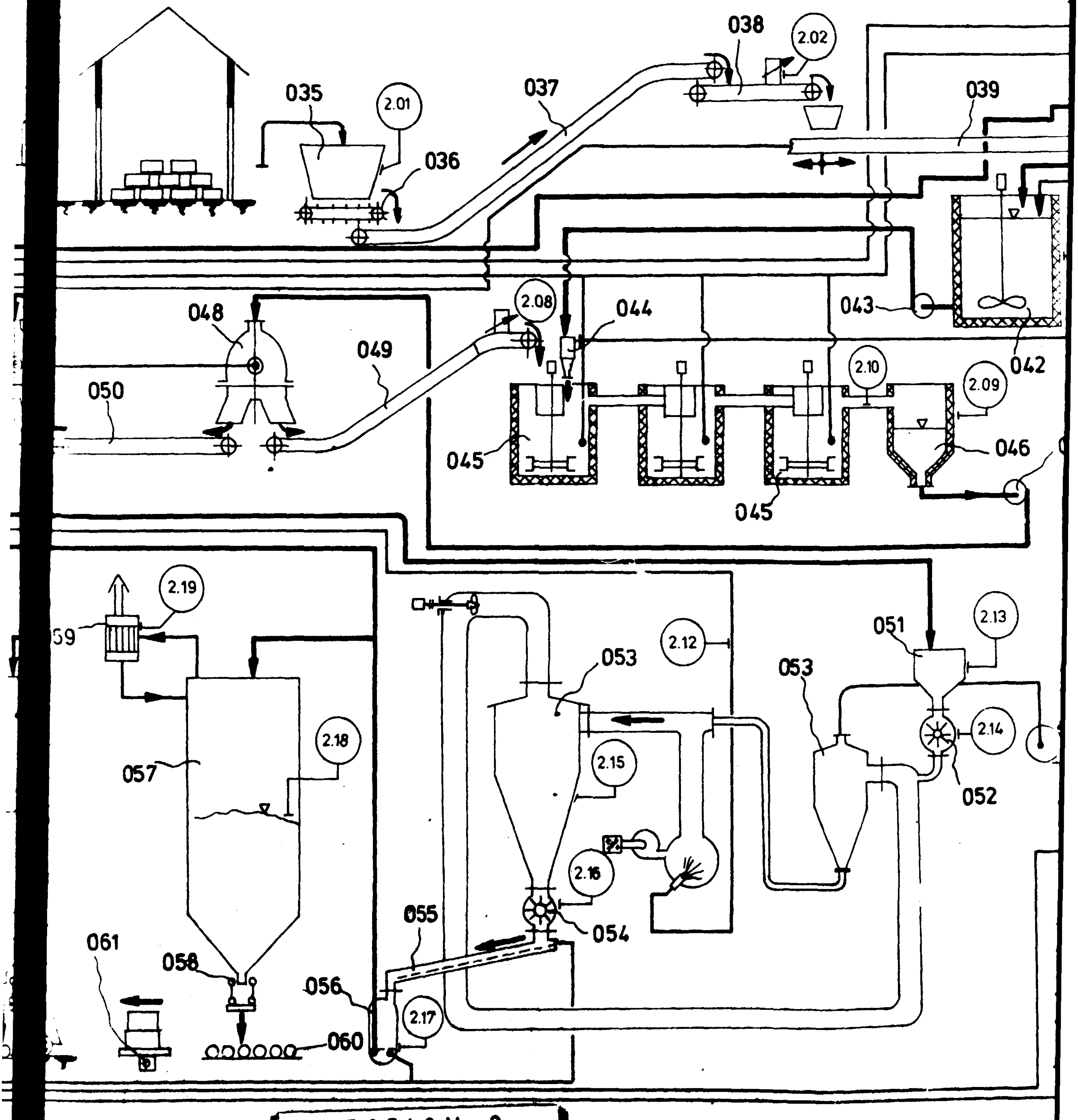
The principal flow-sheet of this process is shown in Fig. 5-3. 16 m^3 of mother liquor will be fed from tank No. 078 into tank No. 080/1 for hydrate slurrying. 1.66 t alumina hydrate containing 10 per cent adhesive moisture will be weighed into it by weighing belt No. 038 at a rate of 2 to 3 t/h. 3.92 m^3 50 per cent hydrofluoric acid required for its dissolving will be pumped from tanks No. 028 at a flow-rate of max. 8 m^3/h. After transferring the required amounts of the various components the feedings will automatically stop. The prescribed temperature of the dissolving is 95 to 100 ^{o}C. This will be provided by direct steam heating.

After concluding the dissolution the liquor will be pumped into tank No. 080/2, wherefrom it will be continuously fed into the first tank of the cryolite precipitation tank line No. 071 at a rate of 4.7 m^3/h. A constant feeding rate will be ensured by an orifice applied after hydrostatic vessel No. 070. 12.5 m^3/h of mother liquor will also be fed continuously into the first precipitation tank from tank No. 078. Cryolite will be precipitated by the continuous addition of 0.672 t/h soda ash. The latter will be fed from hopper No. 066 through vibrating feeder No. 067 and weighing belt No. 069 into the first tank of tank line No. 071. The prescribed temperature of cryolite precipitation is 50 to 55 ^{o}C. This will be provided by direct steam heating.

CONCEPTUAL PROCESS FLOW



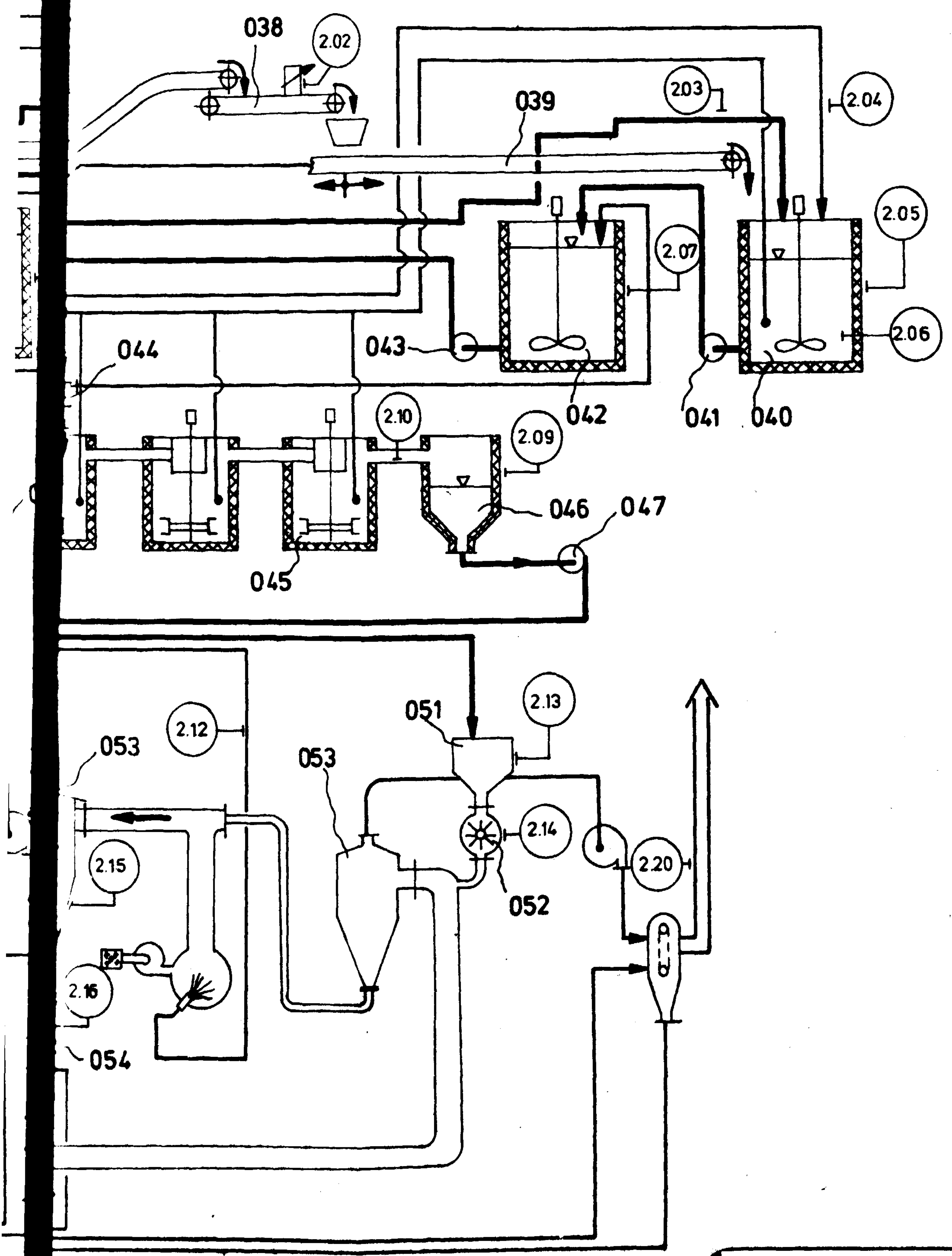
ROCESS FLOW-SHEET OF ALUMINIUM FLUORIDE PRODUCTION



SECTION 2

FLUORIDE PRODUCTION

Fig. 5-2



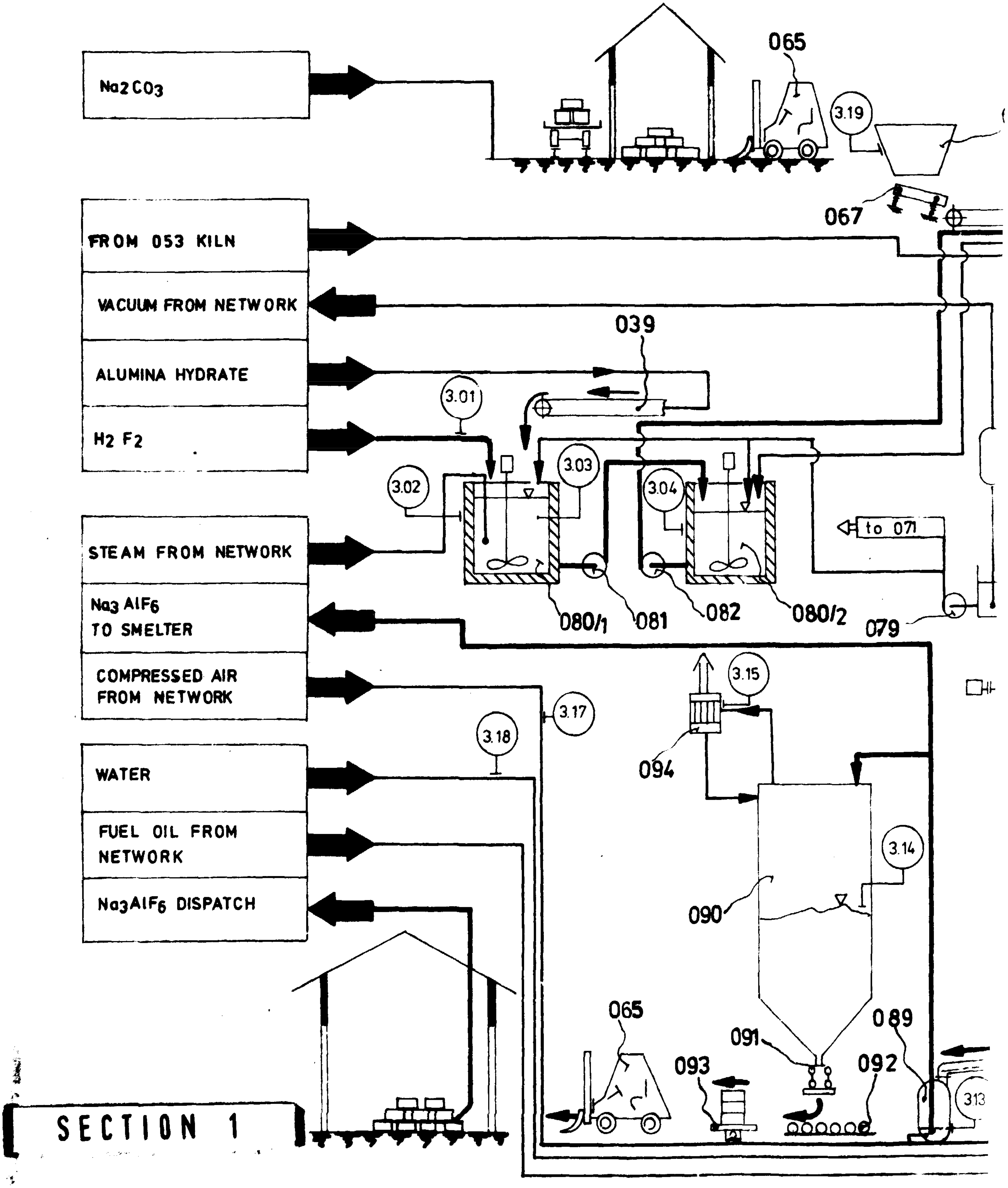
SECTION 3

The slurry containing some 50 gpl solids and leaving the precipitation tanks will be buffered in tank No. 072, and thickener No. 074 will be fed from the latter. The overflow of the thickener will flow into mother liquor tank No. 078, its underflow will be fed through tank No. 075 to vacuum drum filter No. 077. The filtrate will also flow into mother liquor tank No. 078 through a filtrate receiver. The filtered cryolite crystals - their amount will be 1.037 t/h with an adhesive moisture of 15 per cent - are transferred by belt conveyor No. 083 into hopper No. 084, and from there into drying and calcining equipment No. 086 through charger No. 085.

The calcination temperature of 650 to 700 °C will be provided by fuel oil firing. The dust content of the flue gases will be precipitated by wet scrubbing. The calcined product will leave the calciner through discharger No. 087 and will get through fluid bed transporting channel No. 088 and air lifting tank No. 089 either into silo No. 090 or immediately into the aluminium smelter. The amount of the calcined product will be 0.88 t/h. The cryolite can be packed into bags from the silo by means of sack filling machine No. 091.

The equipment list of the three technological processes are shown in Table 5-1.

CONCEPTUAL PROCESS FLOW-S



FLOW-SHEET OF CRYOLITE PRODUCTION

Fig. 5-3

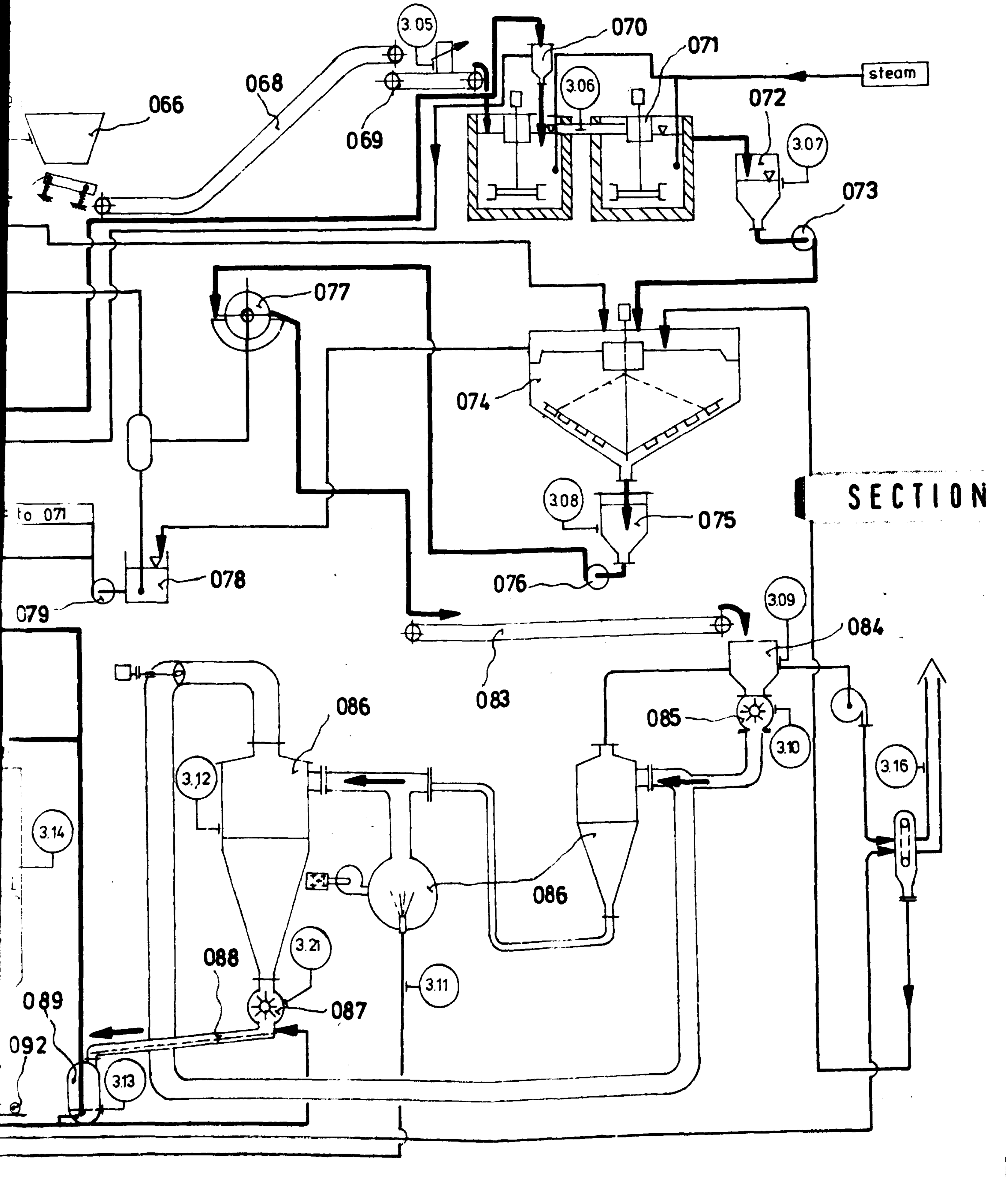


Table 5-1.

EQUIPMENT LIST

Serial No	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
	FLUORITE DIGESTION					
001	Vacuum drum filter	2	1	1	$A = 4\ m^2$	incl.: filtrate receivers
002	Tank	1	1	0	2.0 m dia - 2.0 m height $V = 6\ m^3$, flat bottom	
003	Pump	1	1	0	$Q = 5\ m^3/h$	
004	Hopper	1	1	0	$V = 6\ m^3$	
005	Apron belt	1	1	0	W = 400 mm L = 3.0 m Cap. = 2.6 t/h	r.p.m. regulation
006	Belt conveyor	1	1	0	W = 400 mm L = 8.0 m Cap. = 2.6 t/h	
007	Weighing belt	1	1	0	W = 400 mm L = 2.5 m Cap. = 1-3 t/h	

EQUIPMENT LIST

Table 5-1. (cont.)

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
008	Hopper	1	1	0	$V = 1\ m^3$	
009	Charger	1	1	0	Cap. = 1-3 t/h	r.p.m. regulation
010	Screw feeder	1	1	0	Cap. = 3 t/h	
011	Rotary kiln	1	1	0	Cap. = 65 t/day, wet fluorite	incl.: slag separator
012	Heat exchanger	1	1	0	to be specified later	
013	Dust precipitator cyclone	1	1	0	0.8 m dia - 1.2 m long	acid resistant execution
014	Ventilator	1	1	0	$Q = 2,000\ m^3/h$	acid resistant execution
015	Ventilators	2	1	1	$Q = 4,000\ m^3/h$	
016	Tank	1	1	0	3.15 m dia - 3.15 m height $V = 25\ m^3$, covered, flat bottom, agitated, lined with P.V.D.F.	
017	Pumps	2	1	1	$Q = 15\ m^3/h$	wear resistant execution

EQUIPMENT LIST

Table 5-1. (cont.)

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
018	Electric truck with fork	1	1	0	Cap. = 2 t	
019	Hopper	1	1	0	V = 1 m^3	
020	Tank	1	1	0	3.15 m dia - 3.15 m height V = 25 m^3, covered, flat bottom, agitated	
021	Pump	1	1	0	Q = 15 m^3/h	
022	Absorber	1	1	0	1.6 m dia - 8.0 m height	
023	Tank	1	1	0	3.15 m dia - 3.15 m height V = 25 m3, covered, flat bottom, agitated, lined with P.V.D.F.	
024	Pump	1	1	0	Q = 4 m^3/h	acid resistant execution
025	Thickener	1	1	0	1.8 m dia - 3.0 m height V = 4 m^3, covered, cone bottom, lined with P.V.D.F.	
026	Pump	1	1	0	Q = 4 m^3/h	acid resistant execution

EQUIPMENT LIST

Table 5-1. (cont.)

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
027	Centrifuge	1	1	0	Cap. = 2 m^3/h	acid resistant execution
028	Tanks	2	2	0	3.15 m dia - 3.15 m height V = 25 m^3, covered, flat bottom, agitated, lined with P.V.D.F.	
029	Pump	1	1	0	Q = 10 m^3/h	acid resistant execution
030	Tank	1	1	0	2.0 m dia - 2.0 m height V = 6 m^3, covered, flat bottom	
031	Pump	1	1	0	Q = 30 m^3/h	
032	Tanks	2	2	0	10.0 m dia - 6.0 m height V = 500 m^3, covered, flat bottom	
033	Pumps	2	1	1	Q = 2 m^3/h	

EQUIPMENT LIST

Table 5-1. (cont.)

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
	ALUMINIUM FLUORIDE PRODUCTION					
034	Electric truck with fork	1	1	0	Cap. = 2 t	
035	Hopper	1	1	0	V = 6 m^3	
036	Apron belt	1	1	0	W = 400 mm L = 3.0 m Cap. = 3 t/h	
037	Belt conveyor	1	1	0	W = 400 mm L = 20.0 m Cap. = 3 t/h	
038	Weighing belt	1	1	0	W = 400 mm L = 2.8 m Cap. = 1-4 t/h	
039	Reversible belt conveyor	1	1	0	W = 400 mm L = 10.0 m Cap. = 2.6 t/h	

EQUIPMENT LIST

Table 5-1. (cont.)

Serial No.	AREA EQUIPMENT	NUMBER TOT.	OP.	SP.	TECHNICAL DATA	REMARK
040	Tank	1	1	0	3.15 m dia - 3.15 m height $V = 25\ m^3$, covered, flat bottom, agitated, lined with P.V.D.F.	
041	Pump	1	1	0	$Q = 25\ m^3/h$	rubber coated
042	Tank	1	1	0	3.15 m dia - 3.15 m height $V = 25\ m^3$, covered, flat bottom, agitated, lined with P.V.D.F.	
043	Pump	1	1	0	$Q = 4\ m^3/h$	rubber coated
044	Hopper	1	1	0	$V = 1\ m^3$, lined with P.V.D.F.	
045	Tanks	3	3	0	2.0 m dia - 3.0 m height $V = 9\ m^3$, covered, flat bottom, agitated, lined with P.V.D.F.	
046	Tank	1	1	0	2.0 m dia - 3.0 m height $V = 8\ m^3$, covered, cone bottom, lined with P.V.D.F.	
047	Pump	1	1	0	$Q = 4\ m^3/h$	rubber coated
048	Centrifuge	1	1	0	$Q = 4\ m^3/h$	acid resistant execution

Table 5-1. (cont.)

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
049	Belt conveyor	1	1	0	W = 400 mm L = 15.0 m Cap. = 0.5 t/h	
050	Belt conveyor	1	1	0	W = 400 mm L = 18.0 m Cap. = 1.0 t/h	
051	Hopper	1	1	0	V = 1 m^3, lined with P.V.D.F.	
052	Charger	1	1	0	Cap. = 0.5 - 1.0 t/h	r.p.m. regulation
053	Kiln	1	1	0	Cap. = 1.0 t/h, wet aluminium fluoride	incl.: dust precipitator system
054	Discharger	1	1	0	Cap. = 0.2 - 0.6 t/h	r.p.m. regulation
055	Fluid bed transporting channel	1	1	0	Cap. = 0.6 t/h	
056	Air lifting tanks	2	2	0	Cap. = 0.6 t/h	wear resistant execution
057	Aluminium fluoride silo	1	1	0	V = 50 m^3, covered, cone bottom	

Table 5-1. (cont.)

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
058	Sack filling machine	1	-	-	Cap. = 0.5 t/h	incl.: weighing and sack-closing devices
059	Bag filter	1	1	0	A = 10 m^2 Cap. = 3,000 m^3/h	
060	Roller conveyor	1	-	-	W = 400 mm L = 5.0 m	
061	Hydraulic platform hoist	1	-	-	Cap. = 1.5 t	
062	Electric truck with fork	1	1	0	Cap. = 2.0 t	
063	Tank	1	1	0	3.15 m dia - 3.15 m height V = 25 m^3, covered, flat bottom, lined with P.V.D.F.	
064	Pump	1	1	0	Q = 40 m^3/h	rubber coated

Table 5-1. (cont.)

EQUIPMENT LIST

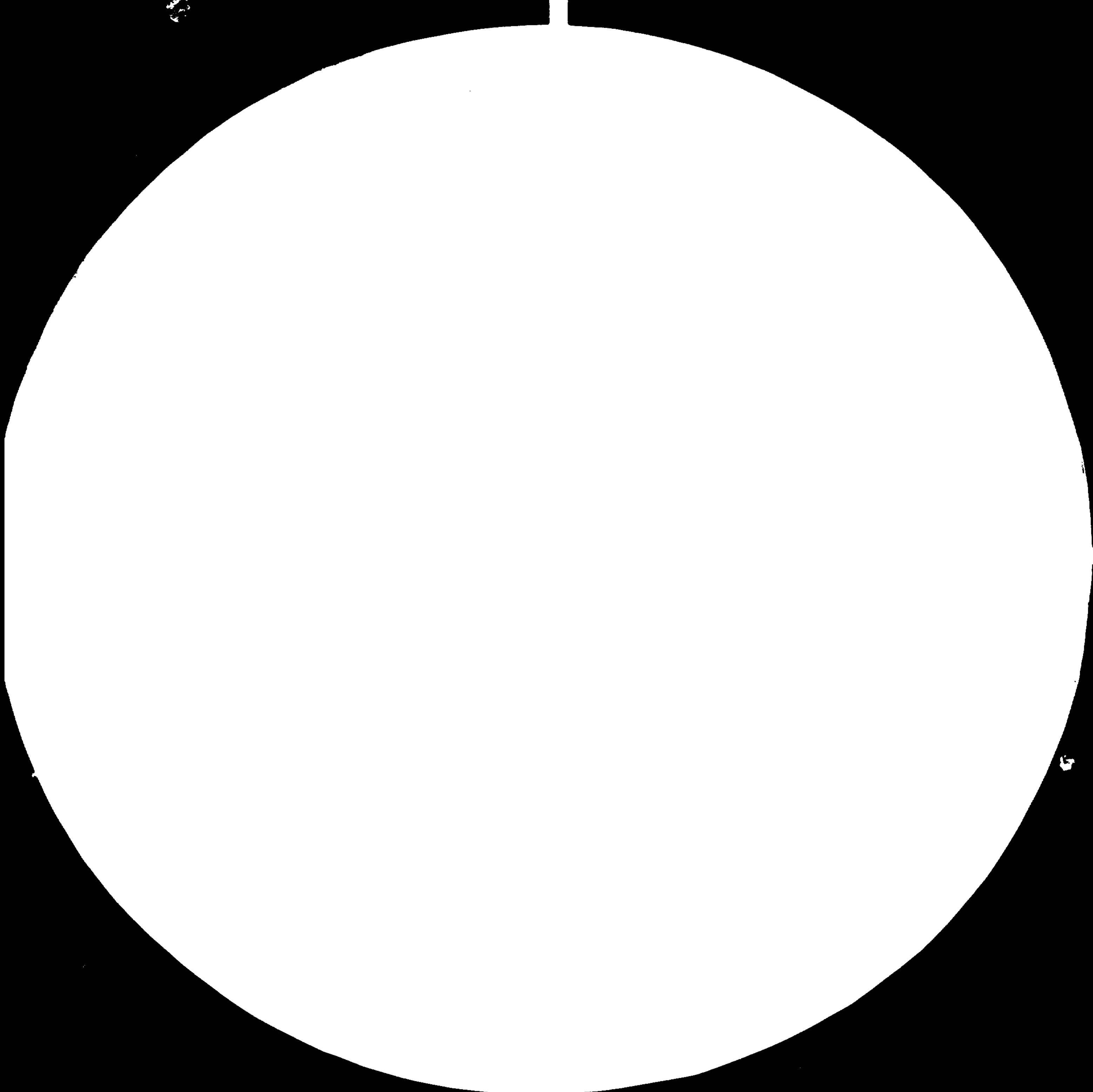
Serial No.	AREA EQUIPMENT	NUMBER TOT.	OP.	SP.	TECHNICAL DATA	REMARK
	CRYOLITE PRODUCTION					
065	Electric truck with fork	1	1	0	Cap. = 2 t	
066	Hopper	1	1	0	$V = 1\ m^3$	
067	Vibro charger	1	1	0	L = 1.2 m Cap. = 0.5 - 0.9 t/h	
068	Belt conveyor	1	1	0	W = 400 mm L = 12.0 m Cap. = 1.2 t/h	
069	Weighing belt	1	1	0	W = 400 mm L = 2.5 m Cap. = 0.7 - 1.4 t/h	
070	Tank	1	1	0	0.5 m dia - 1.0 m height $V = 0.2\ m^3$, covered, cone bottom	
071	Tanks	2	2	0	4.0 m dia - 4.0 m height $V = 50\ m^3$, covered, flat bottom, agitated, lined with P.V.D.F.	special double stream agitator

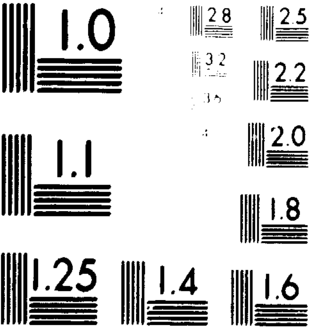
EQUIPMENT LIST

Table 5-1. (cont.)

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
072	Tank	1	1	0	2.0 m dia - 2.0 m height V = 5 m^3, covered, cone bottom	
073	Pump	1	1	0	Q = 20 m^3/h	rubber coated
074	Settler	1	1	0	7.0 m dia - 2.2 m height V = 100 m^3, covered, 1:3 slope bottom, with rake mechanism	
075	Tank	1	1	0	2.0 m dia - 2.2 m height V = 6 m^3, covered, cone bottom	
076	Pump	1	1	0	Q = 5 m^3/h	
077	Vacuum drum filters	2	1	1	A = 5 m^2	incl.: filtrate receivers
078	Tank	1	1	0	3.15 m dia - 3.15 m height V = 25 m^3, flat bottom	
079	Pump	1	1	0	Q = 30 m3/h	
080	Tanks	2	2	0	3.15 m dia - 3.15 m height V = 25 m^3, covered, flat bottom, agitated, lined with P.V.D.F.	

83.08.11





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

EQUIPMENT LIST

Table 5-1. (cont.)

Serial No.	AREA EQUIPMENT	NUMBER TOT.	NUMBER OP.	NUMBER SP.	TECHNICAL DATA	REMARK
081	Pump	1	1	0	$Q = 25\ m^3/h$	rubber coated
082	Pump	1	1	0	$Q = 10\ m^3/h$	rubber coated
083	Belt conveyor	1	1	0	W = 400 mm L = 10.0 m Cap. = 1.3 t/h	
084	Hopper	1	1	0	$V = 1\ m^3$	
085	Charger	1	1	0	Cap. = 0.5 - 1.5 t/h	r.p.m. regulation
086	Kiln	1	1	0	Cap. = 1.3 t/h, wet cryolite	incl.: dust precipitator system
087	Discharger	1	1	0	Cap. = 0.5 - 1.0 t/h	r.p.m. regulation
088	Fluid bed transporting channel	1	1	0	Cap. = 1.0 t/h	
089	Air lifting tanks	2	2	0	Cap. = 1.0 t/h	wear resistant execution
090	Cryolite silo	1	1	0	$V = 50\ m^3$	

Table 5-1. (cont.)

EQUIPMENT LIST

Serial No.	AREA EQUIPMENT	NUMBER			TECHNICAL DATA	REMARK
		TOT.	OP.	SP.		
091	Sack filling machines	2	-	-	Cap. = 0.5 t/h	incl.: weighing and sack closing device
092	Roller conveyor	1	-	-	W = 400 mm L = 5.0 m	
093	Hydraulic platform hoist	1	-	-	Cap. = 1.5 t/h	
094	Bag filter	1	1	0	A = 10 m^2 Cap. = 3,000 m^3/h	
	PIPE RACKS					

5.3 MATERIAL BALANCE, SPECIFIC AND ANNUAL CONSUMPTIONS

The basic parameters used for the designing have been the followings:

Annual production: 3,000 tonnes of aluminium fluoride,
7,000 tonnes of cryolite.

Annual operating time: 8,000 hours.

Composition of the beneficiated fluor-spar:

CaF_2	97.0 per cent
SiO_2	1.5 per cent
$CaCO_3$	1.1 per cent
$Fe_2O_3 + Al_2O_3$	0.4 per cent

Overall fluorine recovery: 88.0 per cent

Tables 5-2. and 5-3. contain the material balances for the production of 1 tonne of aluminium fluoride and 1 tonne of cryolite. Specific and annual consumption figures are shown in Table 5-4.

Table 5-2.

MATERIAL BALANCE FOR THE PRODUCTION OF 1 TONNE OF ALUMINIUM FLUORIDE

FLUOR-SPAR DIGESTION

IN					OUT				
		Fluor-spar	Sulphuric acid	Total			Residue	Gas	Total
CaF_2	kg/t	1553.1	-	1553.1	H_2F_2	kg/t	41.7	711.9	753.6
SiO_2	kg/t	24.0	-	24.0	CaF_2	kg/t	81.5	-	81.5
H_2SO_4	kg/t	-	2065.5	2065.5	H_2SO_4	kg/t	77.4	20.0	97.4
Others	kg/t	23.9	-	23.9	Others	kg/t	2725.4	8.6	2734.0
Dry material	kg/t	1601.0	2065.5	3666.5	Dry material	kg/t	2926.0	740.5	3666.5
Moisture	kg/t	-	42.1	42.1	Moisture	kg/t	-	42.1	42.1
Total	kg/t	1601.0	2107.6	3708.6	Total	kg/t	2926.0	782.6	3708.6

HYDROGEN FLUORIDE ABSORPTION

		Gas	Water	Total			Hydrofluoric acid	Exhaust gas	Total
H_2F_2	kg/t	711.9	-	711.9	H_2F_2	kg/t	705.5	6.4	711.9
H_2SO_4	kg/t	20.0	-	20.0	H_2SO_4	kg/t	20.0	-	20.0
Others	kg/t	8.6	-	8.6	Others	kg/t	-	8.6	8.6
Dry material	kg/t	740.5	-	740.5	Dry material	kg/t	725.5	15.0	740.5
Moisture	kg/t	42.1	641.2	683.3	Moisture	kg/t	683.3	-	683.3
Total	kg/t	782.6	641.2	1423.8	Total	kg/t	1408.8	15.0	1423.8

ALUMINIUM FLUORIDE REACTOR

		Hydrofluoric acid	Alumina hydrate	Mother liquor	Total			Aluminium fluoride solution	Total
H_2F_2	kg/t	705.5	-	-	705.5	AlF_3	kg/t	1032.0	1032.0
H_2SO_4	kg/t	20.0	-	-	20.0	$Al_2(SO_4)_3$	kg/t	23.2	23.2
$Al(OH)_3$	kg/t	-	927.8	-	927.8	Others	kg/t	24.3	24.3
AlF_3	kg/t	-	-	44.3	44.3				
Others	kg/t	-	3.7	20.6	24.3				
Dry material	kg/t	725.5	931.5	64.9	1721.9	Dry material	kg/t	1079.5	1079.5
Moisture	kg/t	683.3	103.5	8037.4	8824.2	Moisture	kg/t	9466.6	9466.6
Total	kg/t	1408.8	1035.0	8102.3	10546.1	Total	kg/t	10546.1	10546.1

ALUMINIUM FLUORIDE CRYSTALLIZING AND CENTRIFUGING

		AlF_3 solution	Seed crystals	Wash water	Total			Product crystals	Dust losses	Seed crystals	Mother liquor	Total
AlF_3	kg/t	1032.0	250.0	-	1282.0	AlF_3	kg/t	980.0	2.2	250.0	49.8	1282.0
Crystal water	kg/t	-	160.0	-	160.0	Crystal water	kg/t	630.0	1.4	160.0	-	791.0
Others	kg/t	47.5	5.1	-	52.6	Others	kg/t	20.0	0.1	5.1	27.4	52.6
Dry material	kg/t	1079.5	415.1	-	1494.6	Dry material	kg/t	1630.0	3.7	415.1	77.2	2126.0
Moisture	kg/t	9466.6	177.9	700.0	10344.5	Moisture	kg/t	698.6	1.6	177.9	8835.0	9713.1
Total	kg/t	10546.1	593.0	700.0	11839.1	Total	kg/t	2328.6	5.3	593.0	8912.2	11839.1

Table 5-3.

MATERIAL BALANCE FOR THE PRODUCTION OF 1 TONNE OF CRYOLITE

FLUOR-SPAR DIGESTION

IN					OUT				
		Fluor-spar	Sulphuric acid	Total			Residue	Gas	Total
CaF_2	kg/t	1242.5	-	1242.5	H_2F_2	kg/t	33.4	569.5	602.9
SiO_2	kg/t	19.2	-	19.2	CaF_2	kg/t	65.2	-	65.2
H_2SO_4	kg/t	-	1652.3	1652.3	H_2SO_4	kg/t	57.9	20.0	77.9
Others	kg/t	19.3	-	19.3	Others	kg/t	2180.4	6.9	2187.3
Dry material	kg/t	1281.0	1652.3	2933.3	Dry material	kg/t	2336.9	596.4	2933.3
Moisture	kg/t	-	33.7	33.7	Moisture	kg/t	-	33.7	33.7
Total	kg/t	1281.0	1686.0	2967.0	Total	kg/t	2336.9	630.1	2967.0

HYDROGEN FLUORIDE ABSORPTION

		Gas	Water	Total			Hydrofluoric acid	Exhaust gas	Total
H_2F_2	kg/t	569.5	-	569.5	H_2F_2	kg/t	564.4	5.1	569.5
H_2SO_4	kg/t	20.0	-	20.0	H_2SO_4	kg/t	20.0	-	20.0
Others	kg/t	6.9	-	6.9	Others	kg/t	-	6.9	6.9
Dry material	kg/t	596.4	-	596.4	Dry material	kg/t	584.4	12.0	596.4
Moisture	kg/t	33.7	508.9	542.6	Moisture	kg/t	542.6	-	542.6
Total	kg/t	630.1	508.9	1139.0	Total	kg/t	1127.0	12.0	1139.0

HEXAFLUOROALUMINIC ACID REACTOR

		Hydrofluoric acid	Alumina hydrate	Mother liquor	Total			Hexafluoroaluminic acid solution	Total
H_2F_2	kg/t	564.4	-	-	564.4	H_3AlF_6	kg/t	677.3	677.3
H_2SO_4	kg/t	20.0	-	-	20.0				
$Al(OH)_3$	kg/t	-	377.5	-	377.5				
Na_3AlF_6	kg/t	-	-	56.7	56.7	Na_3AlF_6	kg/t	56.7	56.7
Others	kg/t	-	1.5	36.7	38.2	Others	kg/t	61.5	61.5
Dry material	kg/t	584.4	379.0	93.4	1056.8	Dry material	kg/t	795.5	795.5
Moisture	kg/t	542.6	42.1	17886.6	18471.3	Moisture	kg/t	18732.6	18732.6
Total	kg/t	1127.0	421.1	17980.0	19528.1	Total	kg/t	19528.1	19528.1

CRYOLITE PRECIPITATION AND FILTRATION

		H_3AlF_6 solution	Soda ash	Wash water	Total			Product crystals	Dust losses	Mother liquor	Gas	Total
Na_3AlF_6	kg/t	56.7	-	-	56.7	Na_3AlF_6	kg/t	980.0	2.2	62.2	-	1044.4
H_3AlF_6	kg/t	677.3	-	-	677.3	CO_2	kg/t	-	-	-	310.4	310.4
Na_2CO_3	kg/t	-	747.8	-	747.8							
Others	kg/t	61.5	15.5	-	77.0	Others	kg/t	20.0	0.1	56.9	-	77.0
Dry material	kg/t	795.5	763.3	-	1558.8	Dry mat.	kg/t	1000.0	2.3	119.1	310.4	1431.8
Moisture	kg/t	18732.6	-	700.0	19432.6	Moisture	kg/t	176.5	0.4	19382.7	-	19559.6
Total	kg/t	19528.1	763.3	700.0	20991.4	Total	kg/t	1176.5	2.7	19501.8	310.4	20991.4

Table 5-4.

SPECIFIC AND ANNUAL CONSUMPTIONS

DENOMINATION	Unit	Aluminium fluoride		Cryolite	
		Specific (per tonne)	Annual (per year)	Specific (per tonne)	Annual (per year)
Fluor-spar (97.0 % CaF_2)	t	1.601	4803	1.281	8967
Sulphuric acid (98 % H_2SO_4)	t	2.108	6324	1.686	11802
Alumina hydrate (dry)	t	0.932	2796	0.379	2653
Soda ash (98 % Na_2CO_3)	t	-	-	0.763	5341
Hydrated lime (90 % $Ca/OH/_2$)	t	0.150	438	0.120	840
Coal (20 MJ/kg)	t	0.098	295	0.249	1745
Fuel oil (42 MJ/kg)	t	0.324	972	0.186	1302
Power	MWh	0.214	642	0.286	2002
Industrial water	m^3	30.0	90000	20.000	140000

6. PROCESS CONTROL SYSTEM

6. PROCESS CONTROL SYSTEM

INSTRUMENTATION

6.1 GENERAL

Instruments were specified to fulfill the demands of technology and to overcome the difficulties induced by the nature of process fluids to be handled. Control panels will be located on each technological unit containing the central devices of measuring and control loops.

Alarm system provides the warning signals in case of process failure.

Special control loops were designed to charge the required amount of materials into reactors.

Continuous measuring and controlling loops are provided to check the amount of materials to be used and to help to make material and energy balance calculations.

6.2 FIELD INSTRUMENTS

Level measurements

For measuring solids' level in silos, in bunkers or bins ultrasonic level transmitters are considered to provide alarm signals at given levels.

Level switches are used to measure liquid levels in open tanks. Wetted parts of instruments are lined with materials chemically resistant against the materials to be measured.

Flow measurements

For water, steam and compressed air services pressure differential generating orifice plates are used. For metering various liquor and slurry flows magnetic type flow-meters are specified.

For releasing preset quantities into reactors automatic batch metering devices are used. Rotameter type flowmeters were designed into oil pipelines.

Weighing belt conveyors are used to measure the quantity of solids equipped with automatic batch metering devices where necessary.

Temperature measurements

For temperature measurements the electrical resistance type instruments are used. Thermowells are used to protect the sensing elements. Thermowells should be made of the same material as the pipeline or tank.

Final control elements

Double seated globe valves are used in compressed air services while single seated ones in oil pipelines. Special control valves were designed to handle the acid flows.

To modify the quantity of solids discharged from bins, bunkers, RPM modifying loops are provided.

6.3 CENTRAL DEVICES

Indicators, controllers, recorders are mounted into central panels along with signal lamps, push buttons and potentio-meters for remote control of the processes.

6.4 ENVIRONMENT PROTECTION

Sensors and detectors are provided at technological points where technology could pollute the environment, e.g. dust separation, flue gases.

6.5 LIST OF MEASURING AND CONTROL LOOPS

6.51 Fluorite digestion

1.01 Fluorite slurry flow measurement
1.02 Filtrate tank level alarm
1.03 Fluorite bin level alarm
1.04 Apron belt RPM remote setting
1.05 Fluorite flowmeter
1.06 Fluorite bin level alarm
1.07 Fluorite charger RPM remote setting
1.08 Fluorite/sulphuric acid ratio control
1.09 Fuel flow control
1.10 Air flow control
1.11 Flue gas temperature measurement
1.12 Kiln temperature measurement
1.13 pH control at tank No. 016
1.14 Level alarm at tank No. 016
1.15 Level alarm at tank No. 023
1.16 Level alarm at tank No. 028/1
1.17 Level alarm at tank No. 028/2
1.18 Sulphuric acid tank level measurement
1.19 Sulphuric acid tank level measurement
1.20 Lime slurry tank level alarm
1.21 Flue gas control
1.22 Flow control of industrial water

6.52 Aluminium fluoride production

2.01 Hydrate bunker level alarm
2.02 Hydrate flow charging
2.03 Hydrogen fluoride flow charging
2.04 Mother liquor flow charging
2.05 Level alarm at tank No. 040
2.06 Temperature measurement at tank No. 040

2.07 Level alarm at tank No. 042
2.08 Seed flowmeter
2.09 Level alarm at tank No. 046
2.10 Temperature measurement at tank No. 045/3
2.11 Mother liquor tank level alarm
2.12 Fuel flow control
2.13 Level alarm at bunker No. 051
2.14 RPM remote setting at charger No. 052
2.15 Heating cyclone level alarm
2.16 RPM remote setting of discharger No. 054
2.17 Level control of air lifting tank
2.18 Product silo level alarm
2.19 Air separator dp measurement
2.20 Flue gas control
2.21 Compressed air flow measurement
2.22 Industrial water flowmeter

6.53 Cryolite production

3.01 Hydrogen fluoride flow charging
3.02 Hydrogen fluoride tank level alarm
3.03 Temperature measurement on tank No. 080/1
3.04 Level alarm on tank No. 080/2
3.05 Sodium carbonate flow control
3.06 Cryolite temperature measurement
3.07 Level alarm on tank No. 072
3.08 Underflow tank level alarm
3.09 Cryolite bunker level alarm
3.10 RPM remote setting of charger No. 085
3.11 Fuel flow control
3.12 Heating cyclone level alarm
3.13 Level control of air lifting tank
3.14 Product silo level alarm
3.15 Air separator dp measurement

3.16 Flue gas control
3.17 Compressed air flowmeter
3.18 Industrial water flowmeter
3.19 Sodium carbonate bunker level alarm
3.20 Vibration discharger performance control
3.21 RPM remote setting of discharger No. 087

7. NON-TECHNOLOGICAL UNITS

7. NON-TECHNOLOGICAL UNITS

7.1 SUPPLY OF ELECTRIC POWER

7.11 General description

Electric power demand of the consumers built in the plant including the consumers of the auxiliary units and of the lighting system is 580 kW. Average electric power demand is 400 kW.

The plant network will be fed by medium voltage line. One sectioned, single busbar, plate clad system distributor is considered for reception and for distribution of the medium voltage level electric power. This distributor contains two feed sections, two branching and one measuring section as it is shown in Fig. 7.1.

Two tropicalized, dry transformers were designed for the supply of the average 400 kW power on a voltage level of 0.4 kV. Continuous supply of the plant can be ensured by one of these transformers.

7.12 Electric power distribution

One single busbar, plate clad system central switchgear station is provided for the power supply of the 0.4 kV consumers. Branching line, protecting and operating equipment of the technological consumers will be located in the central switchgear station.

One plate clad system distributor fed from the central switchgear station is provided for both, the plant maintenance shop and the administration building. Consumers will be connected to the power supply system by junction boxes and safety push-button stations are required in the plant for their operation. From these push-button stations, the supply for the consumers can be switched on-off and isolated from the site. The control desks will be provided with indicator lamps only. Cabling throughout the plant area will consist of an overhead system with cable racks mounted on poles or possibly mounted on technological pipeline supporting systems. Power factor correction is necessary to reduce losses within the plant area. Power factor correction will be carried out by capacitors linked to the central switchgear station. Without correction the power factor will be about 0.65.

7.13 Illumination

Main illumination distributor would be located in the central switchgear station. This main illumination distributor will be fed from the 0.4 kV switchgear.

Open areas will be illuminated uniformly by mercury vapor lamps, while normal bulbs and fluorescent lamps will be used for illumination of closed areas.

The average intensity of illuminations considered is 10 lx for open areas and roads, 25 lx for technological equipment located out-door, and 150 lx for closed areas.

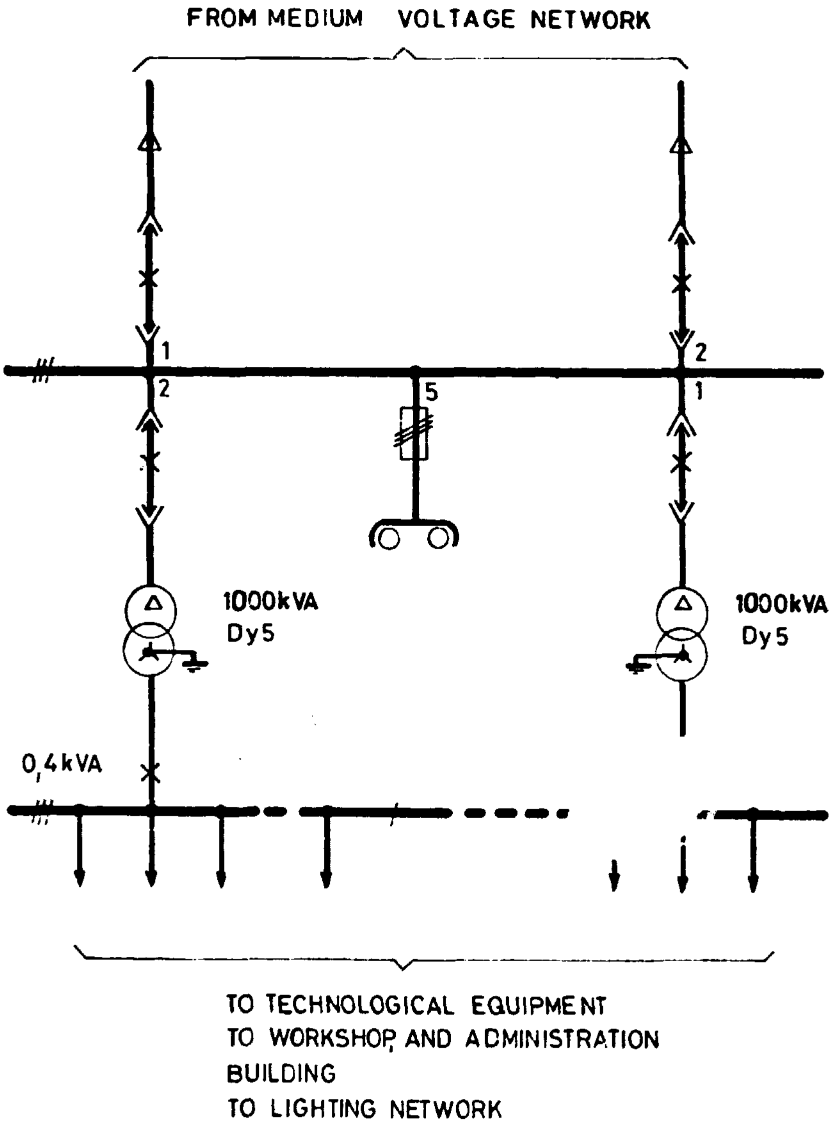
7.14 Electric shock protection and lighting protection

Electric shock protection is neutral earthing complemented with the protective earthing network.

All metallic equipment, structures of the plant, which are normally not under tension, are to be linked with a common earthing network.

All out-door steel tanks, steel structured columns, technological pipeline systems, steel structures of buildings will be connected to the protective earthing electrodes at the joining points of arresters and earthing network. It is expedient to locate dip pipe earthing electrodes at the joining points of arresters and earthing network for ensuring safe leakage of the direct lighting flash.

Fig. 7-1.



SINGLE LINE DIAGRAM OF POWER SUPPLY

7.2 WATER SUPPLY

Because of the low water requirement of the fluoride salt plant and of the reasons mentioned in Chapter 4 it was not considered to install separate water intake and water treatment plant for this project. Water required for the plant should be supplied either from one of the existing water supply systems, or from the water system of a later project - such as the smelter - considered to be built in the future.

The fluoride salt plant will require the following types of water:

- drinking water
- industrial water

7.21 Drinking water

The quality of the drinking water has to meet the local regulations, and because of the Public Health regulations drinking water generally needs separate piping.

According to the Hungarian Regulations domestic water demand has to be calculated as per the following norms:

average: 0.15 m^3/day, head
maximum: 0.22 m^3/day, head

Taking into account these norms domestic water demand of the fluoride salt plant will amount to 0.8 to 1.3 m^3/h.

7.22 Industrial water

Industrial water will be used:

- as process water
- as cooling water
- for boiler feed water preparation
- as fire-fighting water

Separate piping system is considered for industrial water supply.

The quality of the industrial water has to meet the following:

Hardness in German degrees:	7°
Solids content:	max. 100 mg/l

Process water

Industrial water will be consumed in the technological process:

- for H_2F_2 acid preparation
- for lime slaking and lime milk preparation
- for dust control of different gases generated in the process
- for washing of precipitates and end products
- for repulping of digestion residue and different precipitates to obtain slurry with solids concentration sufficient for pumping it to the pond

It is expected, that free water accumulated in the pond can be recirculated and used for repulping of digestion residue and different precipitates. In this case a significant reduction in fresh make up water consumption can be achieved.

Cooling water

Industrial water will be used for cooling ot technological and non-technological equipment.

Major part of this water will be used for cooling of the technological equipment in which heat with be generated by chemical reaction. This part of the cooling water will be recirculated to the water works.

Minor part of this water will be used for cooling of the equipment in which heat will be generated due to mechanical operation. This part of the cooling water will be led to the slurry disposal tank through the drainage system.

Boiler feed water

Feed water of the boiler will be prepared from industrial water by ion exchangers provided for desalination. The quality of the feed water has to meet the specification of the boiler supplier.

Fire-fighting water

Fire-fighting water will be ensured by the industrial water system provided with necessary branchings and hydrants for the whole area of the plant. According to the existing Hungarian regulations, which generally are identical with International Standards, the piping system has to ensure 50 l/sec water for a period of 3 hours at a pressure of 50 m water column at the most disadvantageous farthest hydrant.

The hourly industrial water demand

	Industrial water demand		Make up water	
	Average m^3/h	Max. m^3/h	Average m^3/h	Max. m^3/h
Process water	15.3	18.0	12.3	13.0
Cooling water	146.0	151.0	15.0	16.0
Boiler feed water	1.5	2.0	1.5	2.0
Total:	162.8	171.0	28.8	31.0

7.3 COMPRESSOR AND VACUUM PUMP STATION

Compressed air demand of the plant will be met by one container system turbocompressor of 2,500 m^3/h intake air. Compressed air will be supplied at an absolute pressure of 0.45 MPa.

One vacuum pump will be provided to ensure vacuum in the plant. The capacity of the vacuum pump is 700 m^3/h at an absolute pressure of 0.02 MPa.

7.4 STEAM PLANT

Steam demand of the plant will be met by one coal fired boiler. The boiler will be provided with the necessary auxiliary equipment such as controlling and regulating instruments, control panel, coal feeding and slag disposal equipment.

Main characteristics of the boiler are as follows:

Steam production:	max. 2 t/h
Operating pressure:	3 bar
Steam temperature:	140 °C

7.5 LABORATORY

Basic pre-condition of proper running of the fluoride salt plant is the up-to-date control of the process circuit. The function of this department is to advise operators whenever exact and extensive analyses of raw and auxiliary materials are required and also if the intermittent and final products are not in accordance with technological specifications.

Listed hereunder are the responsibilities of the laboratory:

- To collect representative samples from given places in adequate quantity and frequency.
- To prepare samples, and to eliminate conditions which may falsify test results.
- To perform specified physical and chemical investigations of the samples.
- To record the results on laboratory log-sheets.
- To preserve checked samples of raw material and final product.
- To carry out several controlling technological jobs connected to, or resulting from running the plant.

The floor area required for the accommodation of the laboratory equipment and staff is about 100 sq.m.

Main equipment required for laboratory work are the following:

- drying oven
- ignition furnace
- laboratory fine crushing equipment
- fine grinding (powdering) equipment
- vibrating machines with a set of sieves
- analytical balance
- spectroph
- thermoquant
- pH-meters
- calorimete
- magnetic ag

7.6 PLANT MAINTENANCE SHOP AND STORES

Because of the reasons mentioned in Chapter 4 common maintenance activities, for instance spare parts fabrication, machining, etc. should be carried out in a maintenance shop provided for a larger project such as the aluminium smelter.

The maintenance activities required at the plant site and special maintenance requirements due to the acidic process will be met by the plant maintenance shop located in the area of the fluoride salt plant. This plant maintenance shop will be provided with pedestal grinding machines, table drilling machines, portable welding machines, vice benches, hand tools and vulcanizer sets.

One store provided with shelf stands is considered for the special spare parts of machines, electrical and process control equipment.

7.7 SAFETY PROVISIONS

There will be adequate safety equipment installed throughout the plant. In addition, staircases and guardrails have to be installed in such a manner that speedy exits from certain areas are not impeded.

Equipment which will be installed are

(a) Safety showers with pull chain foot valves,
(b) Eyewash fountains with foot and/or hand operated valves,
(c) Stretchers properly stored in damage proof cylindrical containers at easily accessible locations.

Water for the eyewash fountains and showers will be connected to the plant drinking water system, and adequate hydraulic pressure shall be maintained at all times, to ensure that the showers and eyewashers which are located at high points in the plant are always supplied with adequate quantities and pressure of water.

8. CIVIL AND ARCHITECTURAL WORKS

8. CIVIL AND ARCHITECTURAL WORKS

8.1 PLANT SETTLEMENT

The fluoride salt plant can be located in an area of about 18,400 sq.m (4.55 acres). Flat ground, main ordinary soil and soil conditions were considered for civil works such as terrain correction, laying equipment and building foundations etc.

For the final plant layout the actual plant site possibilities to the existing railway lines and to the national electric grid, water sources, personnel traffic and the main wind direction have to be considered.

The estimated costs of the civil and architectural works do not include the building costs of the items mentioned in Chapter 4.

8.2 RAILWAY

Raw materials (total amount of about 30,000 tpy) and the products (total amount of 10,000 tpy) will be transported by railway. Therefore, factory siding has to be constructed from the existing 1,067 mm gauge railway line to the plant. The length of the siding within the plant fence, the weighing of the materials and the required transport facilities were calculated on the basis of the storage capacities envisaged.

8.3 INNER ROAD SYSTEM AND PAVING

The task of the inner road system is:

- to ensure the accessibility of the plant units
- to satisfy the requirements of fire protection
- to provide for pedestrian traffic inside the fence

For the construction-erection period only construction roads should be constructed. The final road network should be built after construction-erection works with a flexible pavement (30 cm thick marl base) and asphalt wearing course (5 cm thick). A width of 4.0 m for one-way and 6.0 m for two-way traffic is considered, respectively. Major part of the roads is considered for one-way traffic.

Paving area of the open air plant units will be constructed in the same manner as the roads except the areas contaminated through acidic fluids, where a concrete layer has to be built with different type of special acid resistant wearing course in compliance with the acid concentration of the leaking fluids.

8.4 DRAINAGE SYSTEMS

Non-contaminated rain water form the inner plant area will be collected and led to the recipient by an open channel system.

Sewage has to be collected and led to the sewage treatment plant by a separate closed drainage system.

All the leakages and rain water contaminated by acid will flow through a separated acidic water channel to the slurry disposal tank, from where it will be pumped to the pond after neutralization.

8.5 BUILDINGS AND CONSTRUCTIONS

Because of the favourable climate most plant units can be located in the open. The supports for the different tanks will be built from r.c.c. or steel depending on economy. Naturally all the light structures which are supported by bigger tanks or equipment together with staircases, footwalks and platforms connecting them, will be manufactured from steel.

Belt conveyor bridges will be made of steel provided with protecting cover against rain and wind.

The technological buildings will be constructed from steel-structured frames, their roofs and claddings might be made of corrugated steel with surface protection, or asbestos cement sheet. This type of roofing is made only as a protection against wind and rain. Doors and windows will be constructed from steel. It is very important to ensure good natural ventilation and suitable natural illumination. Some technological buildings will be provided with offices, lavatories, electric switchgear rooms etc.

As regards corrosion the most important aspect is the protection against the effects of the acids and salts.

The buildings of the auxiliary plant units (e.g. boiler plant, transformer and main switchgear station, plant maintenance shop and store, administration and welfare building etc.) will be of r.c.c. structure with bricks or sandwich-panels and will be partly supplied with air-conditioned rooms where necessary.

8.6 MUD POND

Mud is generated during the neutralization of the digestion residues and other vastes. This mud with a solids content of 200 to 300 g/l is pumped to the mud pond located outside the plant fence. From technological data the yearly digestion residue generated is about 26,400 tons, which amounts to a volume of about 20,000 m^3 considering 40 to 50 per cent bound water in the mud and the recirculation of the free water from the pond to the plant.

The environment and the soil have to be protected from the pollutants by proper sealing. The sealing of the pond should be in accordance with the soil conditions. Therefore, detailed soil and hydrogeological investigations have to be carried out at the proposed site of the pond.

For the cost estimation a mud pond was considered with a capacity suitable for an 8 year operation period of the fluoride salt plant.

9. GENERAL EQUIPMENT LAYOUT

9. GENERAL EQUIPMENT LAYOUT

The general equipment layout of the fluoride salt manufacturing plant is shown in Fig. 9-1.

Because of the favourable climate most of the plant equipment are located in the open. Buildings were considered where the characteristics of the work and the protection of the materials against the wind and the rain make them necessary.

For the arrangement of the plant units and equipment the following were considered:

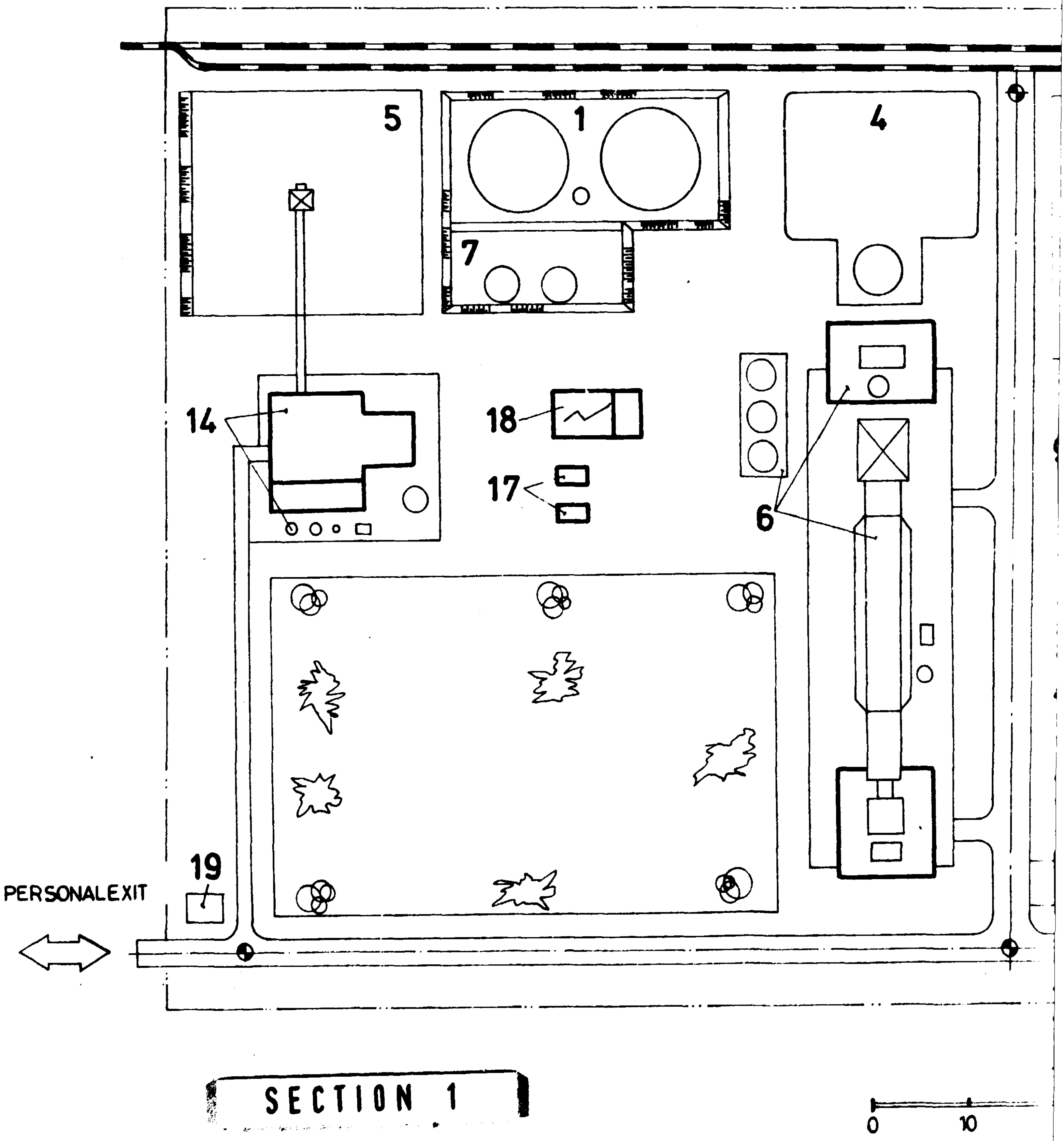
- the technological connection of the plant units and equipment,
- the material transportation among the units,
- the possible separation of the administration and welfare building,
- the transportation of raw and auxiliary materials, as well as of end products,
- the way of personnel traffic.

The plant can be divided into the following main units:

- raw and auxiliary materials handling,
- fluorite digestion,
- aluminium fluoride production,
- cryolite production,
- non-technological units.

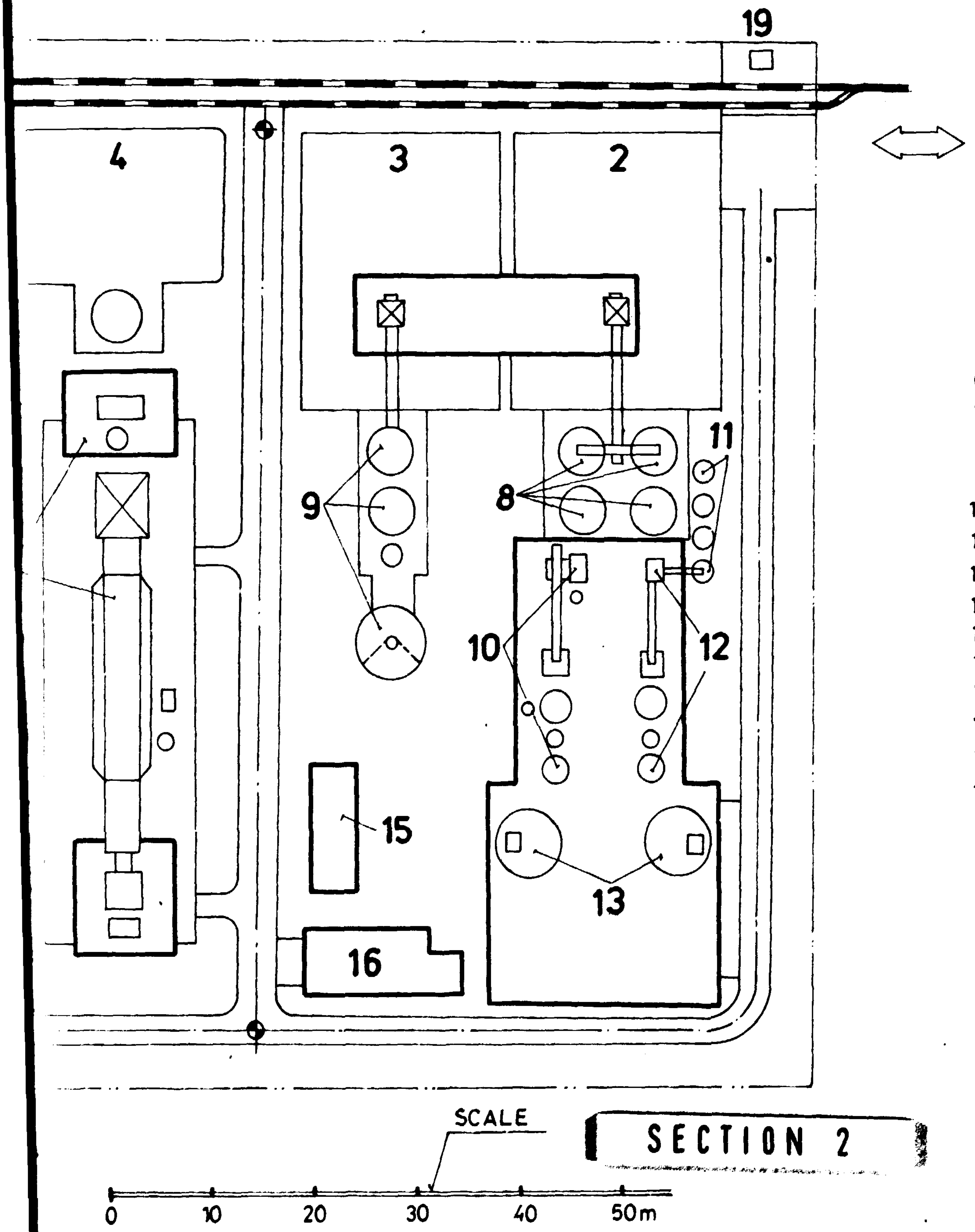
The fluorite beneficiation plant (described in the Mining and Beneficiation Volume) will be located next to the fluoride salt manufacturing plant.

GENERAL EQUIPMENT LAY



SECTION 1

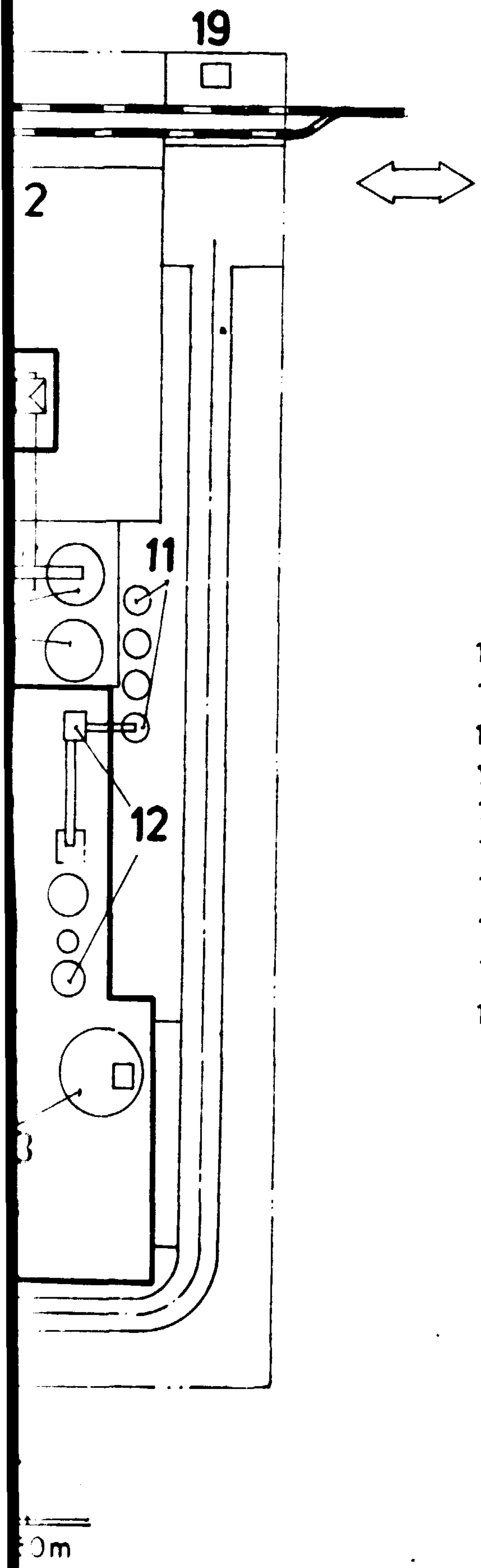
EQUIPMENT LAYOUT



1. SULPHURIC ACID
2. HYDRATE HANDLI
3. SODA ASH HAN
4. LIME HYDRATE H
5. COAL HANDLING
6. FLUORITE DIGEST
7. HYDROFLUORIC A
8. HYDRATE DISSOL
9. CRYOLITE RECOV
10. CRYOLITE FILTR
11. ALUMINIUM FLUO
12. ALUMINIUM FLUO
13. PRODUCT STORAG
14. BOILER PLANT A
15. PLANT MAINTENA
16. ADMINISTRATION
17. COMPRESSOR AN
18. 6 kV DISTRIBUTO
19. GATES

SECTION 2

Fig. 9-1.



1. SULPHURIC ACID HANDLING
2. HYDRATE HANDLING
3. SODA ASH HANDLING
4. LIME HYDRATE HANDLING
5. COAL HANDLING
6. FLUORITE DIGESTION
7. HYDROFLUORIC ACID STORAGE
8. HYDRATE DISSOLVING
9. CRYOLITE RECOVERING
10. CRYOLITE FILTRATION AND CALCINATION
11. ALUMINIUM FLUORIDE CRYSTALLIZATION
12. ALUMINIUM FLUORIDE CENTRIFUGING AND CALCINATION
13. PRODUCT STORAGE
14. BOILER PLANT AND FEED-WATER PREPARATION
15. PLANT MAINTENANCE SHOP AND STORE
16. ADMINISTRATION AND WELFARE BUILDING
17. COMPRESSOR AND VACUUM STATION
18. 6 kV DISTRIBUTOR AND TRANSFORMERS
19. GATES

10. INFRASTRUCTURE

10. INFRASTRUCTURE

The members of the Hungarian delegation have not visited any possible plant site of the fluoride salt manufacturing plant during their short stay in Mozambique. At the same time the Mozambique Party could not give sufficient information about the possibilities of the plant location. Therefore, the Hungarian experts were not in the position to study the infrastructural problems in details.

Beside that, due to the relatively low capacity of the fluoride salt manufacturing plant it can not bear high infrastructural investments. Therefore, a siting making possible the connection to the infrastructure of another industrial project seems to be advantageous. From this point of view first of all the siting of the plant to the projected aluminium smelter may come into consideration. Assuming this possibibility, the following infrastructural investments were considered in the cost calculation:

within the plant fence:

- 300 m long factory siding,
- inner road system,
- drainage system,

outside the plant fence:

- 6 pcs. tank waggons each with a capacity of 30 m^3,
- 1 pc. sulphuric acid storage tank with a volume of 1500 m^3 in the port,
- mud pond construction.

11. ENVIRONMENT PROTECTION

11. ENVIRONMENT PROTECTION

The process units, the non-technological units and the administration and welfare building of the fluoride salt manufacturing plant can be located in a fenced area.

The process plant units include mostly outdoor chemical equipment. The fluoride salt production is a closed process.

The fluoride salt manufacturing plant, from the viewpoint of environmental control, can be classified as follows:

11.1 WATER AND SOIL PROTECTION

The most important task is to protect water of the underground reserves, near-by water courses against contaminating materials originating in the plant.

All the waste liquids, including contaminated rain water originating in the process units will be led through a proper channel system to the mud disposal tank, from where it will be pumped to the pond after neutralization.

The mud pond has to be provided with adequate sealing. Free water accumulated in the pond will be recirculated to the plant in order to reduce the fresh make-up water consumption.

Sewages have to be led through sewage treatment to a recipient.

11.2 AIR PROTECTION

To limit air contamination the prevailing wind has to be taken into consideration when the siting of the plant will finally be decided.

At the favoured technological variant the harmful raw material, the fluor spar will be pumped to the plant in slurry form, in consequence of which fluor spar dust pollution can be neglected.

The interim product of the process, H_2F_2 is the most harmful material to be handled. The equipment and the pipelines, in which H_2F_2 gas will occur, will be operated under vacuum, therefore, this gas can not get into the air in case of proper operation and maintenance.

At the plant units, where dusting may occur, different types of dust collectors were considered to be installed (cyclones, bag and electrostatic dust separators, etc.).

The composition of the stack gases generated in the calciners and in the boiler plant will mostly depend on the quality of the fuels. No accurate data is available relative to the burning system of the boiler and the calciners and so only estimated data on stack gas generation can be given at present.

The air polluting effect of the SO_2 gas formed from the sulphur content of the fuels can be minimized by optimizing chimney heights.

Summary of the stack gas generation and possible other pollution sources is given together with the most important data in Table 11-1.

Table 11-1.

SUMMARY OF STACK GAS GENERATION AND POSSIBLE OTHER POLLUTION SOURCES

	Quantity of the stack gas (m^3/kg fuel oil)	Dust emission (mg/m^3)	Composition of the stack gas (in percentage)		Note
			CO_2	SO_2	
Fluorite digestion tube reactor chimney	11-12	60	15	0.18	monitored by instrument 1.21
Neutralized mud to pond	-	-	-	-	monitored by instrument 1.13
Aluminium fluoride calcining kiln chimney	11-12	30	15	0.18	monitored by instrument 2.20
Aluminium fluoride storage silo	-	60	-	-	monitored by instrument 2.19
Cryolite calcining kiln chimney	11-12	30	15	0.18	monitored by instrument 3.16
Cryolite storage silo	-	60	-	-	monitored by instrument 3.15
Steam boiler chimney	9	20	15	0.18	

12. ORGANIZATION AND PERSONNEL REQUIREMENT

12. ORGANIZATION AND PERSONNEL REQUIREMENT

12.1 PROJECT ORGANIZATION FRAMEWORK

Objectives

The present study deals essentially with the establishment of a modern fluoride salt manufacturing plant, with related facilities. The capacity of the plant will be 10,000 metric tons per year of fluoride salts, which are to be produced from fluor-spar mined within the deposits. This chapter of the report deals with the Project Organization in great outlines and gives a rough idea about the organization from the time a final investment decision is taken for the project's realization and the operation of the plant. While the other chapters are based on definite basic data, technical and economic calculations, the findings of this chapter are more or less depending on the outside conditions such as the content of the contracts to be concluded later and the real financing possibilities available at that time. For this reason this chapter does not deal with the details and does not give concrete suggestions, only a framework as presented.

Project team

It will be necessary for the relevant authorities of Mozambique to establish a Project Team task force. This task force will be responsible for the overall efficient development, control and execution of the Project. It will be the responsibility of the Project Team to co-ordinate the activities of, and provide support services for the contractors (designers, construction and erection firms, etc.) to ensure the efficient execution of the Project.

Technology and Engineering Services Contractor

The Technology and Engineering Services to implement this Project would be the responsibility of Technology and Engineering Services Contractor. Duties of this Contractor would include the setting of the process parameters and the process design; establishment of the plant regulations and codes including safety facilities; plant design; selection of plant machinery and equipment; designers' supervision of erection, supervision during start-up and commissioning of the plant.

Technology and Engineering Services Contractor will also be responsible for setting training programmes so that the technology and know-how will be transferred and so that the local labour force will be capable of taking over and operating the plant when the Contractor's assignments are completed.

12.2 PERSONNEL REQUIREMENT

Personnel requirements have been determined on the basis of experiences gained in other plants and projects.

The following basic data have been assumed:

- 268 working days per year,
- 40 working hours per week,
- 3 per cent sick leave allowance.

Over-all personnel requirements for the fluoride salt production operations are given in summary categories in Table 12-1.

Table 12-1.

PERSONNEL REQUIREMENT DURING OPERATIONS
STAFFING SUMMARY CATEGORIES

		Persons
Category I.	Technical and financial management	5
Category II.	Design engineer	1
	Maintenance foreman	1
	Spare parts administrator	1
	Administrators	2
	Operation foremen	4
Category III.	Laboratory assistants	7
	Operators	45
	Truck drivers	2
	Fitters	10
	Welders	6
	Electricians	12
	Electronic technicians	7
Category IV.	Packers	2
	Unskilled workers	31
	TOTAL:	126

During the initial running period of the plant (5 years) it is advisable to employ expatriate staff for the plant operation and maintenance to train the local staff.

Staffing summary for the initial running period of the plant are given in the following table:

Year	Foreign staff	Local staff	Total
1	18	126	144
2	14	126	140
3	8	126	134
4	5	126	131
5	2	126	128
6	-	126	126

13. IMPLEMENTATION TIME SCHEDULE

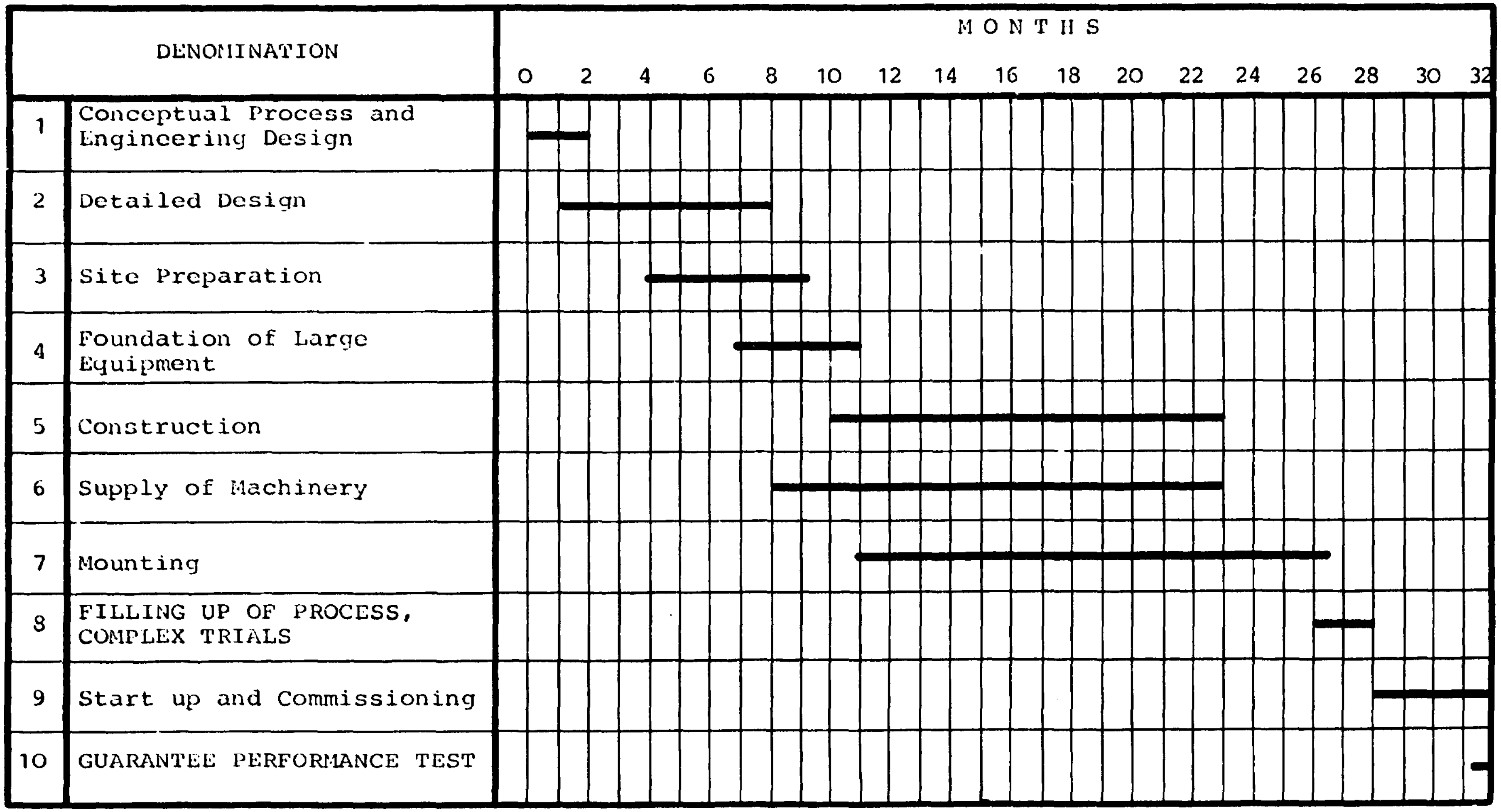
13. IMPLEMENTATION TIME SCHEDULE

The most important activities necessary to establish the 10,000 mtpy capacity fluoride salt manufacturing plant are summarized in Fig. 13-1.

Time requirement of the implementation of the project is about 32 months. From the starting point to the 28th month the following main activities have to be carried out to meet the proposed schedule:

- detailed technological engineering
- detailed civil architectural, mechanical, electrical and process control engineering
- setting up the project organization
- terrain correction
- equipment procurement
- temporary energy and water supply for the construction period
- road and factory siding construction
- foundation work for buildings and equipment
- erection of building structures
- erection and installation of equipment
- fitting of the pipeline system
- fitting of the electrical and process control systems

The start-up period will commence from the 28th month. Full capacity of the plant can be achieved in the 32nd month.



IMPLEMENTATION SCHEDULE

Fig. 13-1.

14. CAPITAL COST ESTIMATE

14. CAPITAL COST ESTIMATE

The capital costs are composed of the following main parts:

- Direct costs,
- Indirect costs,
- Working capital.

All costs are given in thousand US$.

14.1 DIRECT COSTS

Direct costs include the following:

Site Development	20
Fencing, Inner Roads, Preparatory Works of Investment	47
Industrial Waste Water Treatment, Sanitary Sewers	15
Auxiliary Material Reception and Storage	1,172
Fluorite Digestion	4,937
Cryolite Plant Unit	3,162
Aluminium Fluoride Plant Unit	2,982
Power Plant and Distribution	240
Fresh Water Treatment	200
Compressor and Vacuum Pump Station	50
Yard Piping	35
Machinery of the Central Workshop and Store	140
Fork Lift Trucks, Railroad, Rail Tank Cars, Storage Tank in the Port	500
Administration and Service Building	40
Slag and Mud Ponds	26
Spare Parts	28

Auxiliary Materials for Erection and Mounting	85
Freight from Overseas Ports to Beira	952
Freight from Beira Port to the Plant Site	180
Safety Equipment	2
Office Equipment	20
Contingency	500
Total Direct Capital Costs:	15,333

14.2 INDIRECT COSTS

Indirect costs include the following:

Project Management	180
Management of Erection and Mounting	389
Engineering and Know-how	1,167
Manufacturer's Supervision	340
Training	100
Plant Settlement and Provisories	538
Start-up and Commissioning	178
Contingency	100
Total Indirect Capital Costs:	2,992

14.3 WORKING CAPITAL

Working capital includes the following:

	Unit Price	Stock level day	Quantity tonne	Value of Stock '000 US$
Sulphuric acid	45	28	1,580	71.1
Soda ash	120	28	459	55.1
Alumina hydrate (dry)	128	28	450	57.6
Hydrated lime	37	28	103	3.8
Coal	20	10	61	1.2
Fuel oil	200	28	191	38.2
In the process				
- aluminium fluoride			8	3.9
- cryolite			11	4.5
Final product				
- aluminium fluoride		20	180	135.0
- cryolite		20	420	231.0
Spare parts				100.0
Cash on hand				61.0
Total				762.4
Receivables		15		254.2
Payables		30		-441.6
Working Capital				575.0

14.4 SUMMARY OF THE CAPITAL COST ESTIMATE

(1982 prices in thousand US$)

Direct Capital Costs	
Construction	1,781
Machinery and Equipment	7,351
Electrical Equipment	1,160
Steel Structures	697
Process Control	863
Erection and Mounting	1,849
Transportation and Insurance	1,132
Contingency	500
Total Direct Capital Costs	15,333
Total Indirect Capital Costs	2,992
Working Capital	575
Total Capital Cost	18,900

The implementation time of the project is 32 months in accordance with Chapter 13. The Capital Cost Schedule of the fluoride salt manufacturing plant derived from the Implementation Schedule is shown in Table 14-1.

Table 14-1.

CAPITAL COST SCHEDULE

Figures given in thousand US$

Month	1-6	7-12	13-18	19-24	25-30	31-32	Total
Construction, Steel Structures	248	744	867	496	123	-	2,478
Machinery and Equipment, Transportation	-	1,050	2,100	3,679	3,152	525	10,506
Erection and Mounting	-	-	274	740	740	95	1,849
DIRECT CAPITAL COSTS	248	1,794	3,241	4,915	4,015	620	14,833
INDIRECT CAPITAL COSTS	578	723	723	290	433	145	2,892
CONTINGENCY	30	85	134	175	150	26	600
TOTAL DIRECT & INDIRECT CAPITAL COSTS	856	2,602	4,098	5,380	4,598	791	18,325

15. PROJECT ECONOMY

15. PROJECT ECONOMY

The joint economic calculations of the fluor-spar mine and beneficiation facilities and of the fluoride salt manufacturing plant have been carried out for Variant D processing a basic material containing 97 per cent CaF_2 after beneficiation by flotation.

15.1 TOTAL CAPITAL COSTS

Since no informations are available on the financing of the capital costs and the working capital, cash payment has been presumed, therefore, no interests are included in the total capital costs. The estimated total capital costs of the mine and the processing plant expressed in thousand US$ are as follows:

	Mine and Beneficiation	Fluoride Salt Manufacturing Plant	Total
Capital Costs	8189.7	18325.0	26514.7
Working Capital	174.1	575.0	749.1
Total Capital Costs	8363.8	18900.0	27263.8

15.2 OPERATING COSTS

Since the mine and the processing plant would operate as a common enterprise, both their total capital requirements and their profitabilities appear jointly. Therefore, the mine supplies the basic material at production costs, the latter contains neither depreciation, nor interest.

The material costs include both the transportation and handling costs of the auxiliary materials and the port charges.

The annual costs of the maintenance materials have been estimated to reach 3 per cent of the direct capital costs.

An up-to-date technological level of the plant has been taken into consideration when determining the manpower requirement. It has been further presumed that some expatriate labour would be required for the first five years of operation, but in diminishing numbers as the local workforce is trained to take over their jobs. Therefore, the costs of wages and salaries exceed in the first year by US$ 349,200 and in the fifth year by US$ 46,200 those of the sixth year of operation. Fringe benefits amounting to 7 per cent of the wages and salaries have also been taken into consideration.

The following wages and salaries have been calculated with for various job categories:

Local workforce:			
Chief technical:	US$	400	per month
Other technical:	US$	270	per month
Administration:	US$	140	per month
Skilled labour:	US$	140	per month
Unskilled labour:	US$	70	per month
Expatriates:			
Chief technical:	US$	1,800	per month
Other technical:	US$	1,600	per month
Skilled labour:	US$	900	per month

Administration costs have been estimated to reach 3 per cent of the sales income.

The operating costs (for a period when the plant is already well run in) are shown in Table 15-1.

Table 15-1.

OPERATING COSTS

Production: aluminium fluoride 3,000 tpy
cryolite 7,000 tpy

Item	Unit	Unit Price US$	Aluminium fluoride Annual Consumption	Aluminium fluoride Annual Cost 1,000 US$	Cryolite Annual Consumption	Cryolite Annual Cost 1,000 US$	Total Annual Consumption	Total Annual Cost 1,000 US$
Basic material (fluorite concentrate)	t	120	4803	578,4	8967	1079,9	13770	1658,3
Sulphuric acid	t	45	6324	284,6	11802	531,1	18126	815,7
Alumina hydrate (dry)	t	128	2796	357,9	2653	339,6	5449	697,5
Soda ash	t	120	-	-	5341	640,9	5341	640,9
Hydrated lime	t	37	438	16,2	840	31,1	1278	47,3
Coal	t	20	295	5,9	1745	34,9	2040	40,8
Fuel oil	t	200	972	194,4	1302	260,4	2274	454,8
Power	MWh	25	642	16,0	2002	50,0	2644	66,0
Total Direct Material				1453,4		2967,9		4421,3
Maintenance Material								460,0
Transportation and Other Charges								419,5
Material Costs								5300,8
Wages and Salaries*								225,1
Administration Costs								180,7
Production Cost**								5706,6

Note: * Without expatriate labour
** Without interest and depreciation

15.3 PROFITABILITY

The price of aluminium fluoride is at present around US$ 750 per tonne, that of cryolite around US$ 550 per tonne. These would add up to an annual sales income of US$ 6,100,000 for 3,000 tpy aluminium fluoride and 7,000 tpy of cryolite.

According to our calculations the sales income attainable at the present prices would only cover the operating costs but not assure the return of the capital invested. However, higher prices can be expected after an upturn in the presently depressed world economy.

According to the estimates of Hungarian experts the prices of aluminium fluoride and cryolite will develop in the next four years as follows:

US$ per tonne

Years	Aluminium fluoride	Cryolite
1983	750 to 770	550 to 570
1984	780 to 830	580 to 600
1985	840 to 900	620 to 650
1986	900 to 960	670 to 700

When calculating with the mean values of the prognosticated price ranges the sales income would develop for 10,000 tpy product as follows:

	1983	1984	1985	1986
US$ per year	6,200	6,545	7,055	7,855

The higher prices could, consequently, assure an increase of the profitability and in to long run even result in the return of the total investment.

The operating costs shown in Table 15-1. would increase as a result of including depreciation and possible interests paid after the capital costs. In order to improve the profitability it seems to be advisable to reconsider the expediency and necessity of producing two products, i.e. aluminium fluoride and cryolite at the same time. The raising of this question is justified on the one hand by the fact that the proportion of the consumption of the fluoride salts can be influenced by the selection of the type of the aluminium smelter, and on the other by the possibility, that the capital costs of a single-product processing plant may be significantly lower than those of a two product one. First of all the production of aluminium fluoride seems to be more economical, since its production costs are only slightly higher than those of cryolite, but its world market price exceeds that of the latter by about US$ 200 per tonne. Another argument favouring the production of aluminium fluoride is that in Mozambique this product requires less imported auxiliary materials. At the present world market prices the value of imported materials amounts to 46 per cent of the selling price of cryolite, but only to 37 per cent of that of aluminium fluoride.

The important effect of the transportation costs exerted on the manufacturing costs have to be repeatedly underlined. It can be seen in Table 15-1. that the inland transportation costs and port charges of only the auxiliary materials amount to 7.3 per cent of the manufacturing costs. The transportation costs of the raw material are in the same order of magnitude. (They are included in the price of the basic material.) The transportation costs depend very much on the siting of the plant (see Chapter 4.), it seems to be advisable to examine this question in detail together with the siting of the smelter. The transportation costs could possibly be reduced if river barges could be used instead of railway transportation (Zambezi river).

For a detailed examination of the above ideas a more exhaustive knowledge of the economic circumstances of Mozambique, of the local and world market situation, of the conceptions about the establishment of the aluminium smelter, etc. would be required. Therefore, they serve only the purpose of generating new conceptions for improving the profitability of the project. They might be examined in details in the course of the preparation of a feasibility study.