OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

Restricted

08791

DP/ID/SER.B/170
11 April 1978
English

(R) ASBESTOS PROCESSING IN ANDHRA PRADESH.
DP/IND/74/038.
INDIA.

Terminal report .

Prepared for the Government of India
by the United Nations Industrial Development Organisation,
executing agency for the United Nations Development Programme

Based on the work of A. N. Madjanovic,
adviser on asbestos processing

United Nations Industrial Development Organisation

Vienna

id. 78-1961

Explanatory notes

A comma (,) is used to distinguish thousands and millions.

A full stop (.) is used to indicate decimals.

References to "tons" are to metric tons, unless otherwise specified.

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in India is the rupee (Rs). During the period covered by the report, the value of the rupee in relation to the United States dollar was $US 1 = 8.00.

Totals may not add precisely because of rounding.

APMC refers to the Andhra Pradesh Mining Corporation.

The following technical abbreviations are used in this publication:

' foot

" inch

ABSTRACT

The project entitled "Asbestos Processing in Andhra Pradesh" (DP/IND/74/038) arose from a request submitted in June 1974 by the Government of India to United Nations Development Programme (UNDP) for assistance in the development of processing techniques for the asbestos deposits of the Pulivendla belt. The request was approved in July 1975, with the United Nations Industrial Development Organization (UNIDO) designated as executing agency, and the Ministry of Mines and Steel as government co-operating agency. A preparatory three-month mission took place in 1976, and the two-month mission covered by this report began early in February 1978.

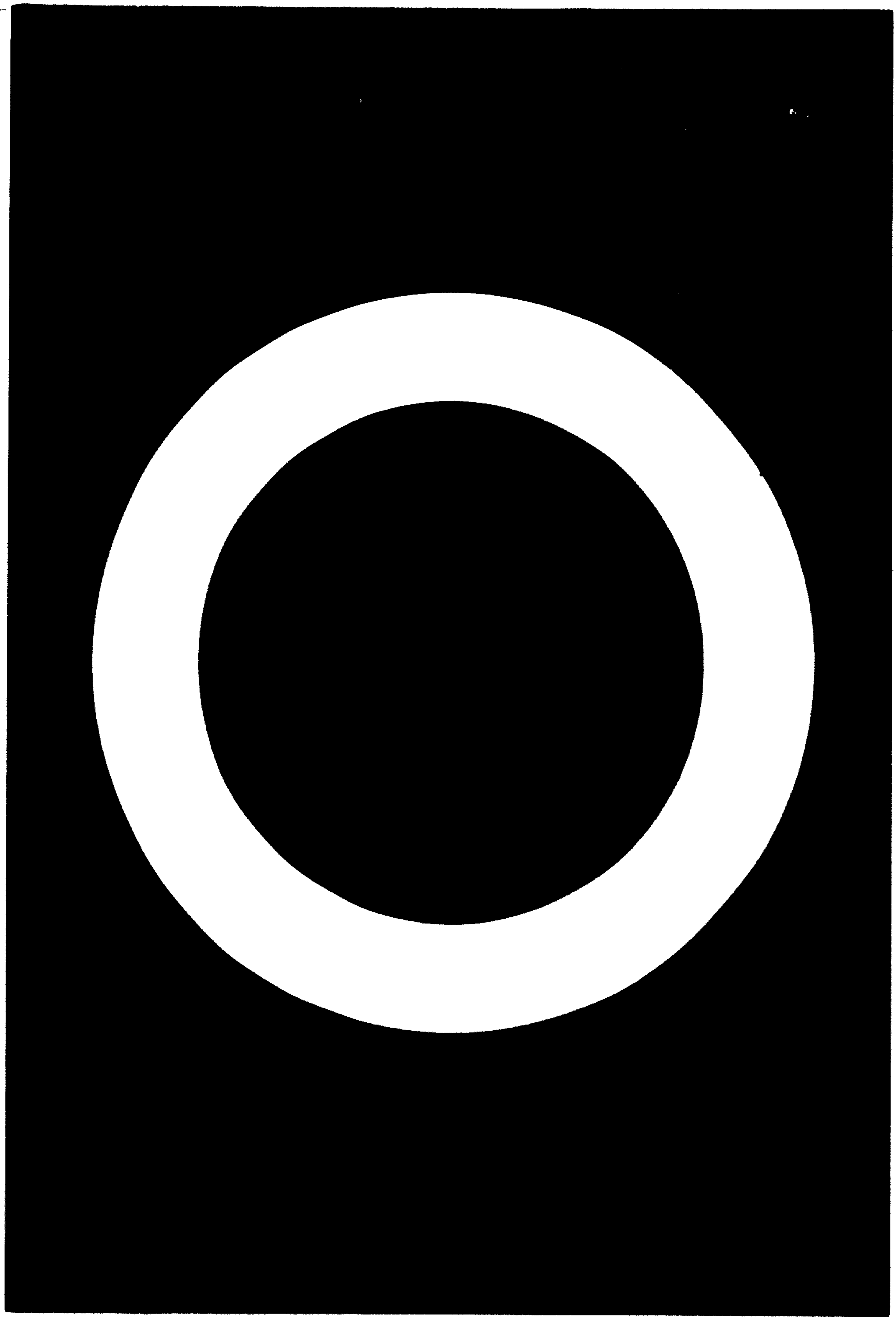
The main conclusions of the report include the following:

(a) The semi-industrial asbestos ore processing tests have given satisfactory results. The flow-sheet of the semi-industrial tests, with the necessary modifications and adaptations, could form a basis for evolving the industrial flow-sheet;

(b) Among the major requirements of the proposed new asbestos plant are a substantial increase in run of mine production, the installation of essential equipment, and adequately trained staff.

The following recommendation is noteworthy:

The Andhra Pradesh Mining Corporation should give close consideration to the preparation of data on the following essential matters: site of the new plant, procuring equipment from Indian manufacturers, supply of basic machinery by foreign firms, estimated engineering and utilities investments, the final plant project.



Contents

Annexes

Tables

Page

I. INTRODUCTION

India is heavily dependent on imports for its industrial requirements of chrysotile asbestos fibre. One of the major deposits in the country are those of Andhra Pradesh. The processing of fibre obtained from these deposits has however given rise to considerable problems. The processing techniques used have resulted, for example, in some of the fibre being left behind in the tailings and a substantial amount of rock dust being left in the processed fibre. It was therefore considered necessary to bring about improvements in processing techniques, so as to reduce processing costs and to optimize asbestos production, thus making it possible to limit dependence on imports and to ensure a continuous supply of minerals to various asbestos-consuming industries. With this end in view, the Government of India submitted a request to United Nations Development Programme (UNDP) in June 1974 for assistance in the development of processing techniques for the asbestos deposits of the Pulivendla belt in the State of Andhra Pradesh. The request was approved in July 1975, with the United Nations Industrial Development Organization (UNIDO) designated as executing agency, and the Ministry of Mines and Steel as Government co-operating agency. A preparatory three-month mission took place in 1976, and the two-month mission covered by this report began early in February 1978. The project budget included a UNDP input of $65,422 and a government contribution of Rs 87,600.

The project was implemented through the Department of Mines and Geology, Government of Andhra Pradesh, and the Andhra Pradesh Mining Corporation (APMC), the major asbestos-producing undertaking in the State. The duties of the expert on the mission covered by this report included the following:

(a) Preparing a techno-economic study to revamp or expand and modernize existing asbestos processing industry with accepted international standards for processing, environmental protection and health codes in accordance with the results obtained from semi-industrial tests;

(b) Preparing the technical specification for bidding on an interantional or national level for the establishment of selected production capacity;

(c) Assessing the need for technical assistance to implement the above-mentioned plan and on formulation of related requests.

The expert's programme of activities was as follows:

14 February to 24 February: Visits to the mines to study new prooessing innovations made during the last two years;

Laboratory testing of ten different samples;

Study of the possible site of the new plant.

27 February to 4 March:	Detailed examination of tailings and middlings, weighing approximately 11 tons, obtained from the semi-industrial tests.
6 March to 10 March:	Processing tests of eight representative samples in the Regional Research Laboratory, Hyderabad.
13 March to 21 March:	Conceptual design of the new asbestos plant at Pulivendla.
22 March to 29 March	Completion of the text of the final report on the project.

II. FINDINGS

The present methodology of processing asbestos ore at the APMC mines at Pulivendla shows significant changes compared with what it was two years ago. There is considerable improvement in asbestos processing, with ore value increased by 28%. Damage of the asbestos fibre due to excessive milling is now avoided or controlled. In the first stage of milling, the running time of the mills is fixed for 2 minutes, and in the second stage a time interval of 1½ minutes is fixed. The introduction of screening before extraction avoids mixing of different grades of asbestos fibre. At present the APMC engineers are developing a systematic processing sequence beginning with application of the jaw-crusher, then going to the first sieving (with an eccentric mechanically-operated screen), first stage extraction (chatas and jigging stage), first stage of milling etc. Improvement in working conditions can be achieved after completing the building of four halls. If these halls are connected to one simple system of dust aspiration, the working conditions will improve considerably. This was discussed with APMC engineers.

Compared with what it was two years ago the dust content in fibre has been reduced significantly by the processing innovation. The dust found by wash test in the end product fibre is shown in table 1 below. These results are to be compared with the 1976 figures of 71% and 74% for 200 mesh.

Table 1. Results of dust analysis

Year	Fibre type	Dust analysis (percentage)
1977 (October)	C1B	50 to 62
	C1R	30 to 44
	D2B	32 to 66
	D3B	46 to 56
1978 (February)	C1B	20 to 51
	C1R	22 to 42
	D2B	32 to 53
	D3B	34 to 55

The improvement can be attributed to the following: the practical experience gained by sending an APMC engineer on a study tour of asbestos plants in Europe; recommendations made by the expert during his visit to the APMC mines in 1976; and the fact that the Indian consumers are demanding improved fibre quality.

Based on recommendations comtained in the expert's technical report of April 1976, construction of a small-size laboratory at the mine site for control of the production of quality fibre is now under consideration. It is now possible to conduct rotap grain size analysis by using Indian laboratory machinery and to wash test at the mine site laboratory. The drying is also carried out by electrical heaters. In the report on the first month of his assignment the expert suggested that aid should be granted this laboratory for the supply of suitable laboratory equipment. Such aid would be most welcome and go a long way towards equipping the laboratory adequately for effective quality control of asbestos fibre production.

A detailed study of various questions concerning the location of the new asbestos plant was made on the spot. Comments on this subject are presented in chapter IV, section B, of this report.

A quantity of 10,803 kg preserved in 42 drums and obtained from the semi-industrial tests was further systematically sampled and tests were carried out. Eight representative samples were processed at the Regional Research Laboratory, Hyderabad. Completion of this work required two full weeks. The following findings are noteworthy:

(a) The semi-industrial processing involved asbestos ore containing 8.95% asbestos;

(b) Total loss of asbestos in the semi-industrial tests of all the reject materials were estimated at 2.94% of the asbestos fibre consisting of long fibre (0.072%), medium fibre (0.200%) and short fibre (2.670%). The recovery ratio from semi-industrial processing for long and medium fibre is 94.8% and for all the asbestos in the ore 67.5%.

Details concerning the analysis of the tailing samples are given in annex I of the preliminary project report. Any additional data which the test operators wish to submit for consideration in the final technological projections may be sent directly to UNIDO.

The semi-industrial asbestos ore processing tests have given satisfactory results. The flow-sheet of the semi-industrial tests, with the necessary modifications and adaptations, could form a basis for evolving the industrial flow-sheet.

The evolution of the flow-sheet of the new asbestos plant is worked out in chapter IV of this report. It would be very useful if UNIDO assisted in the planning of the final technological project for the new asbestos processing plant. A proposal in this regard was made by the expert in his first report. Layout designs and data for inviting offers are given in chapter IV of this report.

The process and asbestos fibre control laboratory at the mine is now under construction on the basis of the expert's design. UNIDO assistance with the supply of part of the equipment to the laboratory is also proposed.

III. RECOMMENDATIONS

1. The entire output of the different mines located on the Pulivendla asbestos deposit belt should supply the feed material to the asbestos processing plant.

2. Run of mine production should be increased threefold through plant rationalization and mechanized underground exploitation. This is the most fundamental requirement of the new asbestos plant.

3. The most important activities in the underground mining of asbestos from the point of view of processing are blasting and the damage it causes to the long fibre. The underground blasting operation must be carried out with the least possible damage to the longer fibre.

4. The asbestos ore in the Pulivendla belt of asbestos deposits consists of long and medium fibre, the value contributed by the longer fibre being 70% while that of the medium fibre is 30%. There are some deposits where only medium and short fibres are present. The values are included in the milled fibre values. The flow-sheet of the new asbestos processing plant should make it possible to extract the asbestos fibre of different groups in the order of their values.

5. The proposed flow-sheet and diagrammatic layout of a modern asbestos processing plant should form the basis for the final project to be worked out by a consulting firm with long experience in asbestos ore processing. As suggested in the first report of the expert, a new UNIDO project could be formulated to give assistance in this regard.

6. The new asbestos processing plant at Pulivendla requires adequately experienced staff in the setting up of the special asbestos machines and also in their maintenance. It is necessary to train an adequate number of staff in the specialized professional line. A three-week training programme proposed by the expert in his first report should be organized. The training could be arranged at asbestos mines in Cyprus, Italy or Yugoslavia.

7. With regard to the improvement of existing processing methodology at the APMC Brahmanapally Asbestos Mines, Pulivendla, the best course of action would be to install some of the special asbestos ore-dressing machines listed in the essential equipment list for the new plant (see annex IV). The machines would include the following: two de-dusters, one for preparing the feed ore before chata/jigging operations, the other for final asbestos de-dusting; one complete set of fibre extraction machinery; one gyratory screen complete with screen cloth frame, one rotary aspirator; and one cyclone collector.

Pending the construction of the new plant, these machines should be installed and worked in the old milling hall in the Brahmanapally mines. The reasons for investing in this special equipment are as follows:

(a) Production will increase by about 30% or more depending on the quantity of run of mine ore;

(b) The quality of the end product will be more constant and uniform as far as the dust content is concerned;

(c) Working conditions will improve immediately after installation of these machines;

(d) The installation and operation of these machines would be very useful for training staff members who would later ensure the operation of the new plant;

(e) The machines mentioned above will in any case be required in the new plant.

8. The small-size processing and asbestos fibre control laboratory now under construction at Brahmanapally mines must be equipped with laboratory test machines. In his first report the expert recommended assistance in the acquisition of some of the laboratory equipment. Other equipment and machines will have to be acquired by the APMC, which should obtain detailed quotations for the supply of essential machines from foreign countries, and also give close consideration to the possibilities of processing equipment from Indian manufacturers.

9. The APMC should conduct studies to determine the most suitable site for the new asbestos processing plant, and prepare preliminary estimates of required utilities, equipment and engineering investment.

IV. PRELIMINARY TECHNO-ECONOMIC STUDY

A. Basic data

Plant capacity

The run of mine ore contains 4% to 5% asbestos fibre belonging to Canadian Standard Groups 3 to 6. The plant has 23 effective production days per month, 276 days per year, and six effective production hours per shift. This is reflected in table 2.

Table 2. Total effective production hours

Number of shifts	Effective production hours per unit of time		
	Day	Month	Year
One	6	138	1,656
Two	12	276	3,312
Three	18	414	4,968

The asbestos plant is expected to recover about 85% of the available fibre in the run of mine ore. The plant is designed to produce 3,000 tons of fibre annually. Total monthly and daily asbestos fibre production will be, respectively, 250 tons and 10,870 kg, and daily production per shift will be 3,623 kg. To achieve these results, the required output of run of mine ore each year must be 3,000/(a% x 85%). Where a = 4% ore, the required output is 88,400 tons, and where a = 5% ore, it is 70,500 tons. As 88,400 + 70,500 = 158,900, this gives an average annual run of mine of 79,450 tons, or monthly and daily averages of, respectively, 6,630 tons and 289 tons. Based on daily run of mine ore production of 300 tons, monthly and yearly production levels would be, respectively, 6,900 tons and 82,800 tons.

At present daily production of run of mine ore is of the order of 100 to 120 tons in two APMC mines (70 to 80 tons) and three other small private mines (30 to 40 tons).

During the next five years when the asbestos plant should be in operation, the daily production of run of mine ore from the present and new mines would be a minimum of 150 tons. During the next 10 years daily run of mine production could reach the level of 300 tons, due to the efforts of the APMC in ore exploration and the development of new mines.

In the design of the new plant consideration must be given to the fact that it will run for some years at 50% of its installed capacity. The supply of machinery and equipment should accordingly be phased out in two stages. Some of the essential machinery (one item from each processing phase) and all the equipment for the plant transport system must be acquired in the first phase of investment. The processing cost per ton for the first stage (involving a capacity of 150 tons per day) will be approximately 20% to 25% higher than the second stage cost at the full installed capacity of 300 tons per day.

Run of mine ore grain size analysis

The Pulivendla asbestos mines are underground mines. The size of run of mine ore for these mines is smaller than the opencast mines and is governed by the underground methods of blasting.

The larger run of mine ore, which varies from 1' to 1½' (457 mm), is 3.3% of the total, while 96.7% of run of mine ore is less than 1' (305 mm). Observation of the bulk lump ore stacked at the surface of the mines indicates that the form of the lump ore is like sedimentary blocks with a prismatic shape or sheet blocks 250 mm to 450 mm long, 150 mm to 300 mm wide, and 100 mm to 150 mm thick. It consists mostly of the lumps of dolomite rock with asbestos veins. The first size control of run of mine ore by grizzly requires a rectangular opening with dimensions of 350 mm x 280 mm.

The average grain size distribution of 53.3 tons of run of mine ore based on screening data of 13 sample points are shown in table 3.

Other details concerning grain size curves are given in the expert's technical report of April 1976.

Table 3. Grain size distribution

Minimum grain size Inches	Millimetres	Percentage less than minimum grain size	Minimum and maximum grain sizes (inches)	Percentage of total sample
12	304.8	96.7	12 (min.)	3.3
8	202.8	91.1	8 to 12	5.6
4	101.4	76.2	4 to 8	14.9
2	50.7	51.0	2 to 4	25.2
1	25.4	26.4	1 to 2	24.6
½	12.7	15.3	0 to 1	26.4

Petrological data

According to an APMC geologist, the main rocks and minerals in the run of mine ore are as follows:

Type of rock	Approximate percentage in run of mine ore
Dolomite	54
Serpentine	35
Dolerite	5
Chrysotile asbestos	5
Other accessory minerals	1
Total	100

The serpentine present in the ore is of three shades: dark green and black (approximately 15% to 25%); yelow-green (approximately 10% to 20%); and yellow (approximately 5% to 10%).

The other accessory minerals are pyrite, chalcopyrite, talc, calcite and magnetite. The weakest mineral of the ore aggregate is the yellow serpentine and consequently, in the process of crushing, it constitutes the major portion of the first fine sand tailings. The dolomite is a compact stone but somewhat more fragile than the yellow-green and dark green and black serpentine. As a result, the yellow-green and dark green and black serpentine are more concentrated in middle size fractions of the coarse tailings.

The grain size analysis of the mineral contents and the foregoing observations provide the main guidelines for identifying the sources of various processing products in the flow sheet.

Run of mine ore hand-sorting study

The fraction size of less than 1" in the run of mine ore is termed fine ore. This fraction after first screening is fed to the drier with no hand-sorting. It is on an average 26.4% of the run of mine ore with variations as follows:

Percentage of fine ore in run of mine ore	Frequency of occurrence (percentage)
15 to 20	8
20 to 25	38
25 to 30	31
over 30	23

The remaining 73.6% of run of mine ore falls between 1" and 1½'. This is to be subjected to hand-sorting. A quantity of 40.7 tons of this type of ore was divided in two fractions, one less than 1½' and greater than 4", and the other less than 4" and greater than 1". The fraction size between 1½' and 4" was 13.15 tons and is 23.8% of run of mine ore. It was hand-crushed to middle-size ore between 4" and 2" (100 mm and 50 mm), and after hand-sorting, the small fraction of less than 1" from this crushing was collected and added to fine ore. The sorting results are given below.

Material	Amount (in tons)
Sorted ore	7.53
Waste	5.62
Total	13.15

The sorted ore coefficient is 7.53/13.15, or approximately 573 kg of sorted ore per ton of feed material. The waste coefficient is 5.62/13.15, or approximately 427 kg of waste per ton of feed material.

The study of variation in the sorted ore coefficient indicates maximum and minimum values of, respectively, 648 kg and 460 kg, and is related to the sample quantity.

The fraction size between 4" and 1" (100 mm and 25 mm) was 27.6 tons and is 49.8% of the run of mine ore. It was tested and hand-sorted. The results are shown in table 4.

Table 4. Sorting of material

Material	Amount (in tons)	Percentage of total
Sorted ore	7.00	25.4
Waste rock	20.56	74.6
Total	27.56	100.0

The sorted ore coefficient for this fraction is 254 kg of sorted ore per one ton of feed material. The waste coefficient for the same fraction is 746 kg of waste per ton feed material.

The variation in sorted ore coefficient is observed to be from 150 to 400 kg per ton of feed material.

The net results of the hand-sorting are presented in table 5.

Table 5. Results of hand-sorting

Material	Primary lump ore sorting for 4" to 1½" fractions (in tons)	Small-size ore sorting for 1" to 4" fractions (in tons)	Total
Sorted ore	7.53	7.00	14.53
Waste	5.62	20.56	26.18
Total	13.15	27.56	40.71

The average sorted ore coefficient is 358 kg of sorted ore/one ton of feed material, and the average waste coefficient is 642 kg of waste/one ton of feed material.

In conclusion, the hand-sorting study showed that in big-size sorting (50 mm to 100 mm) it is preferable to pick out the reject stone pieces, and small-size sorting (25 mm to 50 mm) to pick out the ore bearing pieces.

All the data are based on the results of a study of run of mine ore done in April 1976 and dealt with in the technical report prepared by the expert at that time.

Asbestos ore content and distribution of asbestos fibre in processing and production samples

The run of mine ore coming from the mine is not directly processed. It is always required to be prepared by screening and hand-sorting before milling. The account of the asbestos content in the run of mine ore is worked out on the basis of processing data.

The bulk sample from 13 faces of the three mines was divided into two parts. It was prepared by screening, sorting and crushing to the size of less than 1". The first part of the prepared sample was processed by existing methods. The second part of the prepared sample was treated in the pilot plant. Data concerning bulk sample preparation, drawn from the expert's technical report of 1976, are presented in tables 6 to 10.

Table 6. Bulk sampling

Material	Amount involved (in kg)			
	2" to 1½" fraction	1" to 2" fraction	Fraction of less than 1"	Total
(a) Barren rock	6,550	21,048		27,598
(b) Sorted ore	6,604	6,504	14,633	27,741
(c) Total	13,154	27,552	14,633	55,339
Ratio (a):(b)	0.99	3.23		1.00
Ratio (c):(b)	1.90	4.23		2.00

Table 7. Production

Material	Amount involved (in kg)			
	2" to 1½" fraction	1" to 2" fraction	Fraction of less than 1"	Total
(a) Barren rock	4,242	9,865		14,107
(b) Sorted ore	2,310	3,906	7,288	13,504
(c) Total	6,552	13,771	7,288	27,611
Ratio (a):(b)	1.83	2.52		1.03
Ratio (c):(b)	2.83	3.53		2.04

Table 8. Semi-industrial testing

Material		Amount involved (in kg)			
		2" to 1½" fraction	1" to 2" fraction	Fraction of less than 1"	Total
(a)	Barren rock	2,308	11,183		13,491
(b)	Sorted ore	4,294	2,598	7,345	14,237
(c)	Total	6,602	13,781	7,345	27,728
	Ratio (a):(b)	0.54	4.31		0.95
	Ratio (c):(b)	1.54	5.30		1.95

Table 9. Quantity of prepared ore and concentration ratios

Application	Quantity (in kg)	Ratio
Bulk sampling	27,741	2.00
Production	13,504	2.04
Semi-industrial testing	14,237	1.95

The production sample was better concentrated. For better hand-sorting results, a granulator instead of hammer crusher has to be used after the jaw-crusher.

The asbestos content for semi-industrial testing sample (annex I) in the prepared ore is 8.95%, and in the run of mine ore is 4.53%.

The asbestos content for the production sample is as follows:

Material	Amount involved (in kg)
Fibre product	2,130
Excess dust (25% x 2,130)	-532
	1,598
Short fibre from rejects	+237
Total	1,835

The asbestos content in prepared ore is therefore 13.5%; and in run of mine ore, 6.6%.

The average figure for both samples is 11.2% for the prepared ore, and 5.6% for run of mine ore.

The representative sample of 50 kg of the semi-industrial test sample of fine ore feed was treated. Its asbestos content was 11.09%. The crushed ore for a 1" to 1½" fraction has an asbestos content of 6.8%. The crushed ore asbestos content is always less than the asbestos content in fine ore. The difference here is 2.2%, or 75% of the fine ore.

Table 10. Distribution of asbestos fibre (annex I)

Group	Semi-industrial test sample (%)	Laboratory test sample (%)	Projection sample (%)
3	16.2	22.2	15.00
4	51.8	46.6	55.00
5	12.9	31.2	15.00
6	7.5		5.00
7	11.6		10.00

Data on associated minerals of the asbestos ore and processed products

The specific gravity of associated minerals and asbestos is given below:

Mineral	Specific gravity
Dolomite	2.75
Serpentine	2.55
Dolerite	2.65
Asbestos	2.41

The specific gravity of associated minerals in the run of mine ore is given below:

Mineral (run of mine ore)	Specific gravity
Dolomite with asbestos vein	2.65
Serpentine with asbestos vein	2.52
Dolerite with asbestos vein	2.60

Further bulk density data are given in table 11.

Table 11. Weight/volume ratio or bulk density

Material	Maximum size (in mm)	Tons/m^3
Run of mine ore	400	1.40
Prepared ore	25	1.47
Milled ore with 5% to 7% fibre	2	1.10
Milled ore with 2% to 3% fibre	2	1.25
Milled ore with fibre less than 2%	2	1.35
Coarse tailings	5	1.48
Fine tailings	1.2	1.33
Cyclone dust	0.40	0.51

The data are tentative. The APMC will do systematic measurement of present ore types and processed products with reference to grain size analysis. They will also carry out tests in the regional research laboratory, on which a report will be available for final technological projections.

Review of the semi-industrial processing test results, samples, flow-sheets and technological data

The semi-industrial test sample is a prepared ore sample weighing 12,456 kg, divided into three parts and processed on the basis of two different flow-sheets. The processing of 3,000 kg is based on the first flow-sheet, that of 2,915 kg on the second flow-sheet, and that of 6,541 kg also on the second flow-sheet.

The results obtained with the second flow-sheet were better than those obtained with the first flow-sheet. As far as the recovery ratio is concerned it improved by 16.2% compared to the level achieved with the first flow-sheet. The total fibre strength unit value also improved by 10.93%.

The main characteristics of the flow-sheet are outlined below. In the rock circuit of the first flow-sheet, there are five steps of primary screening with aspiration of asbestos fibre combined with four stages of fiberization for undersized products of the two deck screens. Further, there are five steps of secondary screening with aspiration of asbestos fibre.

With the second flow-sheet, there are six steps of primary screening with asbestos fibre aspiration combined with five stages of fiberization, and there are only two steps of secondary screening with asbestos fibre aspiration.

In the fibre circuit of the first flow-sheet there are four lines and in the second flow-sheet there are only three lines. The processing of middlings in the fibre circuit of both the flow-sheets has one step of fiberization by turbo-fiberizer and in the end there are two steps of fiberization by a vertical type of fiberizer. The final cleaning of the fibre is done by one air-separator.

The semi-industrial test plant is only a laboratory scale model. Only one type of fiberizer unit is used in the rock circuit and the fibre circuit. The screen cloth used on all the screens were stated to be 20 and 30 mesh (British Standard). It was further stated that a three-foot de-duster and an air-separator four feet in diameter were used for cleaning.

The data about the quantitative schedules were stated to be as outlined in table 12.

Table 12. Flow-sheet data

Material	First flow-sheet		Second flow-sheet	
	Kg	%	Kg	%
Total sample	3,000	100	2,915	100
Tailings-1	2,333	78	2,122	73
Tailings-2	58	2	75	2.6
Tailings-3	269	9	370	12.7
Rejects	10	0.3	22	0.7
Dust	108.4	3.6	83.9	2.9
Losses	60.9	2	60.7	2.1
Fibre	160.7	5.4	181.4	6.2

Tailings-1 consists of oversized and undersized reject products from both rock circuit and fibre circuit. Tailings-2 consists of undersized screen rejects from cleaning of the asbestos concentrates. Tailings-3 consists of undersized rejects of the de-duster and undersized rejects of its single-decked screen. The rejects represent the heavier fraction from the air-separator used for final fibre cleaning. The dust is a cyclone product. It appears from the data indicated that the aspirated production was about 25% of the feed ore quantity.

It is not possible to account for or to estimate any ratio between the oversized (coarse) tailings and the undersized (fine) tailings because the tailings-1 figure represents a complete mixture of data of different tailings from different places.

Table 13. Yields of fibre in the semi-industrial test

Run	Yield (%)		Ratio of yields		Total yield		Yield in strength units	
	Group 3	Group 4	3 to 4	Relative to run 1	(%)	Relative to run 1	Yield (%) x FSU[a]	Relative to run 1
1	1.813	3.543	0.51	100	5.356	100	717,993	100
2	1.338	4.884	0.27	53	6.222	116	797,012	111
3	1.535	4.723	0.32	63	6.258	117	754,760	105

Note: Yield (%) = tons of fibre per 100 tons of ore.

a/ FSU = fibre strength unit.

The end product is clean. The dust content for less than 200 mesh as determined by the Bauer-Mcnett test ranges between 20% and 30%. The degree of fiberization is found to be adequate for the cement sheet industry. The degree of surface opening in the first part is 3,200 to 4,700 cm^2/g, in the second part, 3,000 to 4,900 cm^2/g, and in the third part, 3,600 to 6,100 cm^2/g.

The percentage of crudes in the first part ranges between 30% and 48%, in the second part between 38% and 44%, and in the third part between 10% and 25%. The comparison with the box test of the Canadian standard indicates that the process of grading is not yet complete.

The semi-industrial test report does not contain any data regarding the percentage of asbestos in processed ore, asbestos content in the tailings, or milling.

Examination of the semi-industrial test tailings and middling products

The tailings of the semi-industrial test were preserved in 40 drums and the total quantity so preserved was only 10,803 kg. The original test sample was 12,456 kg. Therefore, the quantity of tailings preserved is only 86.7% of the total.

The results of the examination of these tailings are given in annex I.

The oversized tailings are indicated in table 14.

Table 14. Oversized tailings

Material	Mesh number	Quantity (kg)
Coarse tailing	20	4.184
Yellow coarse tailings	20	0.270
	Total	4.454

Oversized tailings are therefore 41.2% of the total rejects of 10.8 kg.

The undersized tailings are given below.

Undersized tailings	Kg
Sand tailings-I	1.541
Sand tailings-II	2.211
Middlings-II	1.210
Middlings-I	1.095
Total	6.057

The percentage of undersized tailings in the total is 56.1% (6.057 : 10.803).

Fine dust

The fine dust is a cyclone product weighing 204 kg. The processing ratio worked out on the basis of the quantity of fine dust, as reflected in the total quantity of tailings rejects of 10.803 kg, is only 1.89%. However, data furnished earlier by the semi-industrial test operators indicates that the processing ratio in the case of fine dust should be around 3%. This shows that not all the fine dust is made available.

The weight-volume ratio of this dust is 0.51 tons/m^3. The grain size analysis of the fine dust is shown in table 15.

Table 15. Grain size analysis

Size group (mesh)		Minimum particle size	
Rejected by	Passing through	(µm)	Percentage
14		>1,204	>8
16	14	1,003	4
22	16	710	2
25	22	600	4
30	25	500	26
36	30	420	25.2
52	36	300	2.8
100	52	150	8.4
150	100	105	5.6
200	150	75	2.8
300	200	53	2.8
	300		8.4
			100.0

The conclusions of the review of the semi-industrial processing test results may be summed up as follows:

1. The oversized and undersized tailings are respectively 41% and 56% of the total tailings, and there are up to 3% of dust products. The foregoing data regarding the grain-size analysis of the coarse tailing from various stages of milling show that the asbestos fibre is opening between grain sizes of 8 mm and 2 mm. The various milling stages could be as shown in table 16.

Table 16. Tailings analysis for various milling stages

Stages	Maximum input size (in mm)	Maximum output size (in mm)
First	25	12
Second	12	6
Third	6	4
Fourth	4	3
Fifth	3	2

2. The average asbestos contained in all the tailings is 2.94%, of which long fibre accounts for 0.072%, medium fibre for 0.20% and short fibre for 2.67%.

3. Coarse tailings are well processed and always contain short fibre less than 1%.

4. All undersized tailings contain short fibre ranging between 2% and 3%. The main losses of short fibre are in the undersized tailings.

5. Ore prepared for semi-industrial testing contains 8.95% asbestos.

6. In semi-industrial testing, the recovery ratio for long and medium fibre was 94.8%, while the recovery ratio for all asbestos fibre was 67.5%.

B. General review of the Pulivendla Asbestos Processing Plant

Current processing methodology

The methods currently employed at the APMC mines are quite different from those previously used. The change for the better in the processing methods can be attributed to the first part of the UNIDO project completed two years ago.

The separation of the free fibre which is fiberized during the underground production is given first priority in the present processing methods.

There are two lines in the rock circuit: the jaw-crusher line (hand-sorting and crushing of the ore up to the size of 1"); the other fine-ore line treating the ore which is less than 1" coming directly from the mine.

The improved working screens of 5' x 3' size with a screen cloth of 24 mesh is used for de-dusting the ore of less than 1". This gives a cleaner end product, as it makes the extraction of fibre by ohata (due to less dust content) easier.

The milling time is controlled. In the first milling by the edge-runners, the time limit of 2 minutes interval is given. In the second milling the time interval is 1½ minutes. This improves the quality of the end product due to lesser damage of the fibre.

Before extraction of the fibre from the milled ore there are four steps of separating the different sizes of namely 8, 16, 24 and 32 mesh. In extraction, the long fibre is not allowed to be mixed with the short fibre. However, the extraction of the fibre is also done by the end jigging (i.e. by ohatas).

The cleaning of the fibre concentrate is done in four steps by using successively 40, 32, 24 and 16 mesh screens.

At present different halls are under construction. The halls are designed on the logical concept of housing of different activities, such as jaw-crushing, first screening extraction, and milling and packing. The innovations in asbestos processing briefly described above represent a significant advance in the end processing. This is however only an interium solution to the problem pending the commissioning of the new modern plant.

Location of the asbestos plant

A location map showing the Pulivendla asbestos deposit belt for a running length of 15 miles is given in annex II (section A). The wind direction is also marked on the map. Two important lines on the map attract attention when the problem of the location of the asbestos processing plant is to be considered. These are the following: the tar road running almost parallel to the asbestos deposit belt, and the zone in the vicinity of the mineralized surface contact. These two lines naturally suggest that the asbestos processing plant could be located in the vicinity of either of them.

The location in the vicinity of the main tar road will have both advantages and disadvantages. From the point of view of transport and communication, this region would provide a favourable location. At the same time, as the area in the vicinity of this road is mainly agricultural and cultivated land, it will be difficult to find a suitable waste dumping yard. Many villages and hamlets are located on both sides of the road within a mile or so. From the point of view of fine asbestos dust causing air pollution, despite the best type of bag filter installation, the location of a processing plant in this region may not be advisable. At the same time the wind direction as shown in the wind rose in the map included in annex II suggests that it will be possible to find a suitable location between Lingala and Chinnaranga-Puram which will not be affected by the flying dust. However, a detailed survey has to be done before the most suitable location in the region could be suggested. A location in the vicinity of the mineralized belt also has some advantages, as it would be close to the main deposit and the cost of ore transportation to the plant could be kept to the minimum. It would be easier to locate a suitable waste dumping yard. It would be necessary, however, to oonstruct a good road for easy approach and access to the plant and for general communications.

It has been estimated that nearly 55% of all the known ore reserves of the asbestos belt would be very close to location No. 1. However, at the rated full capacity of the plant, the available reserves at best can last for only six years. In case future exploration establishes the presence of better ore reserves in the north-west part of the asbestos belt from A.R. to A.V. (all annex II, section A), the location of the plant at this point may prove wrong.

Site No. 2 shown on the map is looated in front of three small private mines where the known reserves are only 44% of the estimated total reserves of the belt. This quantity of ore deposit should last for only about five years at the rated full capacity of the plant. This site, however, has a strong point in its favour, as it is located in the oentre of the region between A.R. and M. In addition to this, if the mines in this region will go into production in the joint sector and the reserves in the other areas are further explored to establish new reserves, this site may prove to have the best conditions. There are vast non-agricultural areas surrounding this site and no villages, hills or any other establishment in the vicinity to cause any obstruction for the looation of plant.

Site No. 3 is almost at the oentre of the asbestos deposit belt. There would be every reason to consider this site provided new reserves are established by exploration from point M. to A.V. The known available ore reserves are about 1% of the entire belt reserves. The reserves, however, oan last for about two years at the estimated full plant oapacity.

The above observations show that it is not possible to come to any definite conclusion at this stage regarding the most suitable site for the plant. The choice of such a site should be governed by the following factors: the estimated reserves to be established during the next five years for the entire belt; the location of new mines in the belt; a realistic estimate of the development of mining activity in the belt during the next five years; the study of wind directions; availabitily of ore from the belt at different points and from different mines during the next five years; and ore transportation costs and other relevant economic factors.

The APMC should conduct a separate and detailed plant location study, taking into account the guidelines mentioned above, and come to a conclusion regarding location of the plant at a site where it would be sure of being fed for at least twenty years with an adequate quantity of ore.

Essential departments of the processing plant

The main governing principles for the new plant are as follows:

(a) The asbestos milling, that is the extraction of the fibre from the concentrates, the de-dusting, the cleaning, grading and the mixing, must be fully maximized with up-to-date equipment;

(b) The installed capacity of run of mine ore of 300 tons per day makes it necessary to install only one single line of workable conveyor system as the main transport line connecting various departments of improved technological plant;

(c) The preparation of run of mine ore has to be carried out with maximum economy in the hand-sorting, combined with one successive crushing system coupled with one semi-mechanized drier to ensure a high quality of well-dried feed ore for milling;

(d) It is advisable to install as few fiberizer units as possible and to avoid unnecessary investment in such units by using silos with adequate capacities. Material could be re-cycled through the few fiberizer units by keeping only a reasonable number of fiberizers and by fully utilizing already installed capacity.

This preliminary technological project envisages two main departments in the new processing plant. The first department is called the Hand-sorting Department. In this department, the three stages are crushing, screen-drying and hand-sorting. This represents the complete preparatory phase before the run of mine ore is sent for milling. The second department is the Milling Department. This will have a uniform type of feed ore and consist of two mills which have to work in two cycles accomplishing four stages of fiberization. There will be only two fibre lines, one for long fibre and another for short fibre.

The final mixing of the fibre is done by one machine, namely the blender. There will be an asbestos container system to feed the blender with appropriate qualities of different grades of fibre before mixing in the blender.

It is important to bear in mind that the flow-sheets and the projections above are only schematic and provided so as to give a general conceptual idea of the new asbestos plant at Pulivendla. The schematic flow-sheets were drawn up by the expert in only two weeks, and no department drawings or layouts are included. About 20 section drawings are necessary for construction of the various departments and the rigorous and detailed study of such sections would easily take many months. After such a study, many changes and viable alternatives suggesting cheaper solutions to design problems may emerge.

C. Hand-sorting Department

Evolution of flow-sheet and probable modifications

The new processing plant at Pulivendla is expected to process asbestos ore from various mines. The feed ore, in some cases, could be in semi-processed condition or in a properly concentrated form as it comes to the plant. The plant must provide for suitable modifications to accommodate this factor. Another factor which would call for appropriate modifications is the high moisture content in the ore. This could be provided for in the plant by a drying line.

The rated input of the new plant is 300 tons/day of run of mine ore. In order to feed the plant regularly, the production capacity of the mine has to be trebbled from the present capacity of 100-120 tons per day. With such a great increase in the production of the run of mine ore, its quality will certainly fall compared to the quality of the present run of mine production. Adjustments in the plant flow-sheet therefore have to be made so that any inferior quality of run of mine material can also be properly treated in the plant. This is expected to be achieved by introducing proper stages of operations in the Hand-sorting Department to ensure that only the proper quality material is fed to the Milling Department. At present about 200 female workers are engaged in the processing. Due to lack of facilities, the productivity of the workers is very poor. In the new plant, the same workers will be employed in the Hand-sorting Department with provision of adequate facilities and better and scientific working methods to promote increased productivity. The Hand-sorting Department engaging the female workers will have to be worked only in the day shift, as required by statute.

In the Hand-sorting Department, the input of run of mine ore of various sizes, all consisting of 4% to 5% asbestos, will be treated to produce an output in sizes of less than 25 mm consisting of 7% to 8% of asbestos. The treatment process involves the stages outlined below.

1. First screening, scalping, three-deck screening (grain size 100/40/25 mm)
2. Primary crushing:

   Feed size: 350 mm

   Output size: less then 80 mm
3. Hand-sorting of the ore fractions greater than 40 mm and 25 mm
4. Drying in a rotary dryer with lignite coal fueling
5. Secondary crushing, 100/40 mm, and tertiary crushing, 50/20 mm.

The long-cycle flow-sheet is useful for treatment of ore of different physical characteristics, including size, moisture content, ore with clean surface, ore with free fibre sticking on its surface lumps in a soiled condition. This method will be useful for ores coming from different mines as it can be expected that different mines will send feed ore having different physical characteristics. This long-cycle flow-sheet will have to be used for about 50% to 60% of the production days. The long-cycle flow-sheet can be switched into operation by removing the 25 mm perforated sheet on the first screen. The flow-sheet is given in annex III, section A.

The short-cycle flow-sheet is useful for treatment of ore which is more homogeneous in nature. Ore containing low moisture and without wide variations in the moisture content can be best treated by this method. Moreover, ore which is cleaner on the surface and ore with small amounts of sticking free fibre can also be treated on the basis of this flow-sheet. This short-cycle flow-sheet can be put into operation by introducing the third screen of 25 mm perforated sheet in the first screen, and also by setting the second and third crusher to give an output of less than 20 mm. The short-cycle flow-sheet will have to be operated for about 30% to 40% of the production days.

For both the long and the short cycle, only fine ore is sent to the drier for controlled drying, and the hand-sorting operation will be carried out in one cycle only.

While operating the short-cycle flow-sheet, it is advisable to switch over to the long-cycle flow-sheet at periodic intervals to cross-check whether input feed material is amenable to short-cycle flow-sheet or requires operation on the basis of the long-cycle flow-sheet. This would ensure prevention of costly processing mistakes.

A flow-sheet for higher moisture run of mine ore will have to be used during the rainy season, possibly a few weeks each year. The ore from the silos will be fed to a screen which will separate sizes greater than 100 mm from those of less than 100 mm. The material of greater than 100 mm will be sent to a crusher to reduce it to less than 100 mm. The initial material of less than 100 mm and the crusher output of less than 100 mm will together go to the drier. The drying will be carried out at the full rated capacity of the drier. It is estimated that only 5% to 10% of the annual production will have to be treated in this way. The drier must be operated for at least two shifts per day during this period to ensure availability of an adequate quantity of dry material for further processing.

The flow sheet is suitable for adaptation to treat fully prepared ore for direct milling without passing through the Hand-sorting Department. This is as indicated in annex III, section D, at point III-1.

Machine capacities and layout analysis

The rated capacity of the input of run of mine ore feed for the hand-sorting is 300 tons/day, or 50 tons per six effective hours per shift.

The first and the second screens of this department however must have a capacity of 70 tons per hour each, as they have to handle re-cycled material of greater than 100 mm in the first screen and of greater than 40 mm in the second screen.

Both the granulators are of the same type, with a capacity of 20 tons per hour, the input size being less than 100 mm, and the output size greater than 20 mm.

The rotary drier has to have a capacity of 30 tons per hour and be designed for treatment of ore with a moisture content of 5%. The moisture will be reduced to 2% in the drier.

The width of the hand-sorting conveyor belt would be 1,000 mm. The APMC should carry out a systematic study of the height of the female workers and the reach of their hands. This would enable revision of the conveyor belt's width, and may prove it necessary for the width to be 1,200 mm. At the same time, the study should reveal data for design of a special seat with back support, to enable the workers to remove the material comfortably. The female workers may work for some time sitting as well as standing.

The quantity of feed ore of less than 100 mm and greater than 40 mm for the first sorting should be 120 to 160 tons per six-hour shift, or 20 to 27 tons per hour. The output per female worker in this size is 1.6 tons per shift of picked material. It is approximately equal to 3.6 tons of feed ore. The daily work programme of 160 tons will require about 50 workers.

In the secondary hand-sorting for the material from the granulators the feed ore of less than 40 mm and greater than 25 mm will be about 60 to 80 tons per day, or 10 to 14 tons per hour. The output of one worker for this size of material is only 450 kg of the picked material, which is equal to 0.9 tons of feed ore. The number of female workers required for the output of 80 tons per shift will be 90.

At the north end of the hall, work place for 20 female workers engaged in the production of long fibre belonging to crudes Nos. 1 and 2 is also provided. The total number of workers thus will be 50 + 90 + 20 = 160. However, a place for 220 workers is provided on the following basis.

The maximum number of working places at one sorting belt is (20 : 0.8) x 2 (sides) = 50; for four belts it is 4 x 50 = 200; with the addition of 20 long-fibre workers, the total comes to 220.

The schematic layout of the department is given in annex III, section D. It does not go into the details of the transport system or all the points of the bypass, which are always essential parts of the hand-sorting installations. The analysis of the department shows the following technological phases as one line, namely jaw-crushing, drying, hand-sorting, arrangement, storage, transport of dried ore etc. The solution given in annex III, section D, is arrived at by application of vector geometry in the ore drying plant.

Meteorological data

The APMC collected detailed data on the climate at Pulivendla over a thirty-year period. A brief review of the data is given in annex II. In the months of April and December, there are two to three rainy days. In the months of June and November, there are four to five rainly days. During the period from July to November, there are six to seven rainy days in each month. Rainfall during the rainly season from July to October is 100 to 150 mm each month. During the months of May and Deoember, the rainfall is between 50 and 80 mm per month. In other months it does not exceed 2 mm. The average annual rainfall is 740 mm. Relative air humidity is always 10% to 20% lower in the evening than in the morning. In the dry season, the relative air humidity is 40% to 50% in the evening, and in the morning it is between 50% and 65%. In the rainy season, the humidity in the evening is between 60% and 70%. In the morning it is 70% to 80%.

Wind data is summarized in annex II, section B, and annex III, section D, and is based on 30 years of observation. The details of wind during day and night are given in the wind rose. The wind rose is the guide to the best ground layout of different departments of the plant based on the wind rose data.

Drying

The drier is of a horizontal rotary type. All details of the drying system as well as the thermodynamic acoount for the furnace, the oontrol instruments and the ooal fuel supply are to be worked out in the final project. The expert estimates that the drier's tentative dimensions would be 1.8 m in diameter and 16 to 18 m in length, using lignite coal giving 2,800 koal/kg. In the winter about 5 to 10 kg, and in the rainy season about 30 to 40 kg, of lignite fuel will be required per ton of feed ore.

During the six-month period from the end of December to the beginning of June, the drier will have to work only in the first shift, with a very small quantity of fuel coal, up to approximately 10 kg of coal per ton giving a heat value of 2,800 koal/kg. This is only for maintaining the dry oondition of the ore. From June onwards, the drier must be operated in two shifts and from the start of the monsoon in three shifts. Only one belt in the hand-sorting hall will deliver the ore of less than 100 mm and greater than 40 mm via the bypass (transfer point), escaping the second crusher and oontinuing by the main dry ore oonveyor on its way to the storage silos. Ore which is oooled in the previous day's second shift will be fed in the hand-sorting shift in the morning. The system of feeding ore for hand-sorting must be flexible enough to acoommodate day-to-day olimatio ohanges. The main principle to be adopted is to ensure that a full quantity of dried ore is always available between two heavy showers. During the monsoon period, however, the measurement of the temperature of the exhaust gas from the drier and the moisture of the dry ore must be oontinously done every two hours. This will be one of the important duties of the processing engineer in charge of the plant.

The dust aspiration system of the drier, the main conveyor line from the drier to the storage silos and the high aspiration in the storage silos as a result of cooling have no connection with the central aspiration system of the plant. The separate aspiration system of drying the cyclone and mill section needs to be worked out in the final project.

Working conditions and worker protection

Nearly 90% of all the workers in the plant are engaged in the hand-sorting department. This makes it imperative to locate the hand-sorting department in the most protected zone of the plant.

The hand-sorting hall is 28 m long and 16 m wide. The first 5 m of hall space is for the feed ore arrangement line. Two transport belts coming up from the first screening carry big and small-size feed ore from the first screen to the Hand-sorting Department. These belts pass below the second screen also, where they collect material passing the second screen which they transport along with this material to the first screen for further distribution to the Hand-sorting Department. The maximum height of the two belts will be approximately 6 m to 7 m from the ground-level. The transport belts are 600 mm in width with the speed of 1 m/sec. The material coming from these belts is fed to horizontal belts in the 5 m section of the hall. These two horizontal belts have a width of 1,000 mm with a speed of 0.25 m/sec. The horizontal belts are located at a height of 2 m from the sorting conveyor belt. The sorting conveyor belt has a width of 1,000 to 1,200 mm, with a speed of 0.5 to 0.1 m/sec. This arrangement for the distribution of material to the hand-sorting conveyor is used in the 5 m section of the main hand sorting hall. The 5 m section has to be kept as isolated as possible from the main hall to avoid dust arising and polluting air in the main hall. The out-flow of the material coming in for distribution in the Hand-sorting Department is provided through small openings through which the horizontal sorting belts pass. This 5 m section should be well connected to the central aspiration system. In the main sorting hall, about 14 m of its width is occupied by four hand-sorting belts. The remaining 2 m to 3 m space is provided as a working place for the separation of long fibre belonging to crude grading Nos. 1 and 2. Each work-table provided for the long-fibre workers must be connected by an aspiration-hood with the central aspiration system of the plant. At each work-table the tools necessary for obtaining long fibre are provided.

The hand-sorting operations are conceived on two levels: at the upper level, the operation of hand-sorting is carried out, whereas on the ground level, belts are provided for carrying the hand-sorted ore and the barren rejects. The dressing room has one long corridor 2 m wide as a passage to the hall steps. The wall of the hall on the side of the main transport system, conveyor, drier etc. must be completely closed with no openings. A line of windows may be provided, but it has to be so designed that direct sunlight does not enter the hall through the windows.

The finger tips of all the workers have to be protected with special leather semi-gloves which would also ensure protection at the time of handling the dry ore which may have a temperature as high as 40° C. The shafts through which the sorted material passes may be protected against noise by covering them with rubber lining. Each working place has its two channels for piling up the ore for individual sorting purposes.

Production, maintenance and process control

The production of asbestos fibre in the new plant requires the following distinct operations: receiving ore from the mines; testing and classifying the ore and directing the cargo to the proper depot, which should be suitably numbered; supply of proper feed ore to the first silo of the jaw-crusher line; and control of moisture in dried ore. All these operations are connected with the daily operation programme, including the choice of the particular flow-sheet that has to be followed in the processing line. This daily programme, which forms part of the weekly operation programme, has to be charted out by the processing engineer, who will be responsible for the department.

It is most desirable to ensure that the depots storing the prepared ore maintain at all times a reserve stock equivalent to at least one week's requirements. During the last two days of each week, the processing engineer has to visit all the mines from which the supply is being drawn and also the depots where the material received from the mines is kept, to check on the quality of the ore by taking some random sample and carrying out laboratory tests where neoessary. This will make it possible to chart out production plans for the next week before the weekly day of rest.

It is very important to keep track of the quantities being brought in each day to the storage depots. The material delivered by each truck should be weighed on a truck weighbridge. Pending installation of the weighbridge, measurement and determination of the weight volume ratio must be done at frequent intervals to avoid disastrous mistakes regarding the estimation of quantity. The final quality control is done through a belt balance at the ore entrance stage in the milling department (see annex III, section D). It is necessary to ensure that each truck is given clear instruction by the processing engineer or his foreman regarding the place at which the material has to be unloaded.

The basic classification of ore in the processing line is given with three different flow-sheets (see annex III, section A). The laboratory ore testing is dealt with in the expert's technical report of April 1976.

Indian engineers took part with the expert in laboratory examinations that were carried out at the mine site and at the regional research laboratory. This has given adequate practice to the Indian engineers in ore-testing methods.

Instead of providing a large run of mine ore silo, the new Pulivendla asbestos plant provides silos for dry ore storage and silos in the milling department. A provision has been made for storage of 10,000 tons of plant feed ore (an area of 100 m x 200 m or 20,000 m^2). A quantity of 10,000 tons will be more than adequate for a month's requirement of the plant. A tractor shovel of 1.9 m^3 will be supplying the feed ore to the plant.

Testing the effectiveness of drying will be done by the control instruments at frequent periodic intervals during the running of the drier. A periodical control every two hours for a period of a week is also envisaged. Daily control testing is to be done on ore samples of dried ore of less than 5 mm from the storage depot where the ore was kept drying the day before.

The work-force required in the first department is described below:

(a) On the grizzly of the first silo there are three workers in the first shift for hand-crushing oversized lumps. The necessary equipment, such as two hand-hammers of 10 kg each and two hand-shovels, are provided;

(b) The jaw-crusher line is supervised by one semi-skilled worker, who will use electrical switches for the control of the equipment. The supervisor oversees the work of the feeder from silos to the belt. This place is connected by telephone to the control room transfer point;

(c) The drier line at the furnace place needs one skilled stoker with one unskilled worker for carrying coal, supplying coal to the furnace, and removing and carrying the slag to its dumping place. The stoker is connected by telephone to the control room at the main transfer point;

(d) The hand-sorting hall engages 80 female workers on hand-sorting and 20 for long-fibre sorting;

(e) The semi-skilled worker supervises the ground-floor operations, including those involving the two granulators and the dried ore belt. This is also connected by telephone to the control room of the main transfer point;

(f) The dispatcher at the control room in the main transfer point is the chief of the first department and he will be provided with an assistant for running the feeder and control of the storage. All bypasses for this department are directly under the dispatcher whose jurisdiction extends from ore depots to belt-scale in the milling department.

With regard to maintenance, proper cleaning facilities are to be provided in the main sorting hall. The floor of the hall has to be in cement-concrete with adequate drainage. Cleaning is to be done every day after work. During the washing of the floor, all belts and motors etc. must be covered properly. The water remaining in the belt has to be wiped out after cleaning.

The workshop foreman will ensure daily supervision of the work of the machines and equipment and plan weekly maintenance, to be carried out on plant off-days. Two working days each month have to be reserved for maintenance of the machines.

The hand-sorting arrangements line, the storage feeders, the silos arrangement line in the second department and the main electrical control table need a good telephone connection.

D. Asbestos Milling Department

Flow-sheet for asbestos milling

The main principle of asbestos ore dressing is to separate all free fibre which is partly fiberized and which has to be aspirated from the barren rock. Examinations of Pulivendla ore, especially the fine ores, reveal that 30% to 50% of the asbestos content is free fibre. After the preparation of the ore in the first part of the plant, the main technological task is the extraction of the free fibre before any milling is commenced. The semi-industrial tests are based on the same principle.

Every effort has been made to adopt the same principle in the evolution of the proposed flow-sheet (annex III, section B). Half of the equipment of the Milling Department is employed for the purpose of extraction of free fibre before any milling.

Schedule 2 of the semi-industrial test includes five stages of fiberization in the rock circuit (annex I). The investment required for all equipment used in the five stages of milling with fibre extraction is not justified for the small-capacity Pulivendla asbestos plant.

The solution proposed in the flow-sheet involved two vertical mill fiberizers, the first with a two-stage hammer and the second with a four-stage hammer. But both the mills will work in two turns each for two stages of crushing, and thus achieve the results obtained during the semi-industrial plant milling. The basic conditions for this system are as follows:

(a) The mills should have a capacity of 15 ton/h each, and the silos must be adequate to accomodate stock for at least half a day's plant capacity;

(b) Each mill must be equipped with elevators for screening;

(c) The connections for the middlings must be provided with adequate bypass;

(d) The level above the silos of the mills and screens also has to be equipped for arranging feed to all screen silos (after milling, the daily milling for processing new ore could be arranged for the next step of screenings).

The flow-sheet is planned for only two fibre lines, one for long fibre and the other for short fibre. Starting with four de-dusters to ensure reduction of dust in the end product, the line is separated in two ways, going to two air-separators and then to the grader. For long fibre belonging to groups three and four, two standard graders have to ensure the Canadian level of grading. There are two fibre circuits for middlings. They are two closed circuits of grading in the first-stage turbo-fiberizer circuit and for the short grinder. The mixing is done with only one blender which has to operate for different groups. It is provided with asbestos fibre containers. Although there are no special machines envisaged for packing, the possibility of installing machines for packing is being taken into aocount.

Capacity and quantitative schedule

The daily quantity of prepared ore is 150 to 180 tons. The milling is carried out in three shifts for a total of 18 hours. The normal capacity is 10 tons/h.

The four screens have a minimum capacity of three tons per hour and maximum of five tons per hour, depending on the asbestos concentration. The screens should have to be worked with material from mills working in rotation.

The secondary ore deck screens could each have a capacity of two to three tons per hour. The deck screen cloth (annex III, section C, items 2.1, 2.3, and 2.5) is 19 mesh for the upper screen and 36 for the lower screen. For a single deck screen (items 2.2, 2.4, 2.6) it is 36 mesh. For the output of different size, the double deck screen is connected with the rotary aspirator with a capacity corresponding to the screen capacity of approximately 10 ton/h each.

All collectors/cyclones are of the same size, having 5 ft diameter and a capacity of 6,000 ft^3/min or three tons per hour. Each collector is connected to two points of fibre aspiration as shown at level 4. The vertical fiberizer of the mill has a diameter of 48" and a capacity of 15 tons/h. The single de-duster trommel has a diameter of 36" with a capacity of one to two tons per hour. The screens for fibre cleaning (item 7) are two deck screens having a cloth of appropriate mesh suited to the length of the fibre (12-mesh for long fibre, 30 mesh for middle and short fibre). The air-separator screener has a diameter of 42" and a capacity of one to three tons per hour. The standard grinder has a diameter of 26" with a capacity of one to two tons per hour. The turbo-fiberizer and the grinders each have a capacity of two tons per hour. The blender has a diameter of 9' and is 12' long, with a capacity of two to three tons per hour. The estimated general quantitative schedule is given in annex III, section B.

Working conditions

The Milling Department engages only three skilled workers and one operator. The foreman of the shift is in charge of the main electrical control panel. There are two assistants. One of the assistants is in charge of the ground-floor level and the filling of silos. The second assistant is in charge of all other floors and the central air stations. At the asbestos containers on on the second floor, there are two semi-skilled workers in each shift. In the first shift they supervise mixing and production by engaging four workers. These workers will be directly under the control of the foreman in charge of the end product.

The milling crew will consist of 10 workers in the first shift and five workers each in the second and third shift, totalling 20 workers. The following steps are suggested for protection of Milling Department workers from dust:

(a) The machines should be of special design, completely closed and connected with the dust aspiration system;

(b) All conveyors have to be totally covered and aspirated at both the ends;

(c) Regular maintenance must be carried out to keep the equipment in sound working condition in the central air-separator system which is collecting dust from the ore at every point where dust arises;

(d) The workers on level two who are working on the packing, mixing and other aspects of handling fibre in storage must be provided with special aspirators for protecting them from fine fibre dust.

Production and maintenance of processing control

The head of the plant is a processing engineer who works with two assistants, one an electrical engineer or technician, the other a mechanical engineer. The staff of the plant includes foremen of the following departments and activities: Hand-sorting Department; fibre-mixing, packing and storage of asbestos fibre; the three shifts of the milling department; the maintenance workshop.

Workshop organization and maintenance will be dealt with in the final project. A part of this project will concern the method of cleaning the Milling Department, which has to be done every week before the weekly day of rest.

Schematic layout of Milling Department

The second department schematic layout is based on the following main concepts.

Rock circuit mill fiberizers, all screens with fibre aspiration, and silos have to be arranged in two stages, in a steel compartment of 5 m x 6 m and 7 m x 6 m with a three-floor layout. On the ground-floor is the transport line arrangement with secondary screens and aspirators. On the first floor are the mills with main screens, while the second floor is for filling the silos.

The next part of milling involves a four-floor construction to include all the fibre line equipment in steel compartments of 7 m x 6 m. The fibre line part is designed to store a one-week's supply of the end product. The fibre is packed on the first floor of the fibre line, so that the packed asbestos fibre could be sent down through a slider to storage.

The sketch of the Milling Department is given in annex III, section C. However, owing to the lack of time, it is not based on adequate study of all the various possibilities of arrangement.

Guidelines regarding future development of the processing plant

The main conditions of the future development of the asbestos processing plant are the following:

(a) Special education in countries offering suitable technical training, such as Canada and the Union of Soviet Socialist Republics, for two processing engineers during the next 10 years as a long term programme;

(b) Specialization of engineers at existing asbestos plants with a capacity of 10,000 to 50,000 tons of asbestos fibre per year. Such plants are located, for example, in Austrialia, Canada, Cyprus, Spain and Yugoslavia;

(c) Maintaining a well-equipped asbestos processing control laboratory at the mine site with a special library having a good cross-section of professional asbestos books and journals.

The development of the new plant should in the first years aim at improving the effectiveness of the aspiration of fibre by equipment alterations, by the study of the milling effect and by correcting the mill revolutions. It is possible to develop the de-duster by experimenting with different revolutions of screened drum and also by combination of various screen cloths. Even if these experiments give satisfactory results in the main line of production, efforts to develop the secondary line should also be made. In all these experiments, primary consideration should be given to the recovery of long fibre followed by middle and short fibre.

E. Tentative flow-sheet

Plant capacities and asbestos fibre production

The capacities of the two departments are given en table 17.

Table 17. Plant capacity

Production period	First department run of mine ore (t)	Second department prepared ore (t)
Hour	50	10
Shift	300	60
Day	300	180
Month	6,900	4,140
Year	82,800	48,800

The asbestos fibre production is as follows:

Production period	Output
Hour	604 kg
Shift	3,620 kg
Day	10,870 kg
Month	250 tons
Year	3,000 tons

The distribution of asbestos fibre is given in table 18.

Table 18. Distribution of asbestos fibre

Group	Tons of asbestos fibre Annual	Daily	Hourly
3	450	1.63	0.09
4	1,650	5.98	0.33
5	450	1.63	0.09
6	150	0.54	0.03
7	300	1.09	0.06
Total	3,000	10.87	0.60

General layout design of the processing plant

The layout of the processing plant and the flowsheets are given in annex III. The underlying principles of the design are given in section B above.

Two important aspects of asbestos plants namely, the waste dumping yard and the central air system, are considered below.

Waste dumping yard. The place for dumping the waste will be behind the plant. When siting the plant care has to be taken to ensure that the dumping yard is capable of accommodating 20 years' waste rejects. Data on the quantity of waste is given in table 19.

Table 19. Asbestos waste

Distribution of material	Quantity (tons per day)	Volume (m^3)
Sorted barren rock (25 mm to 100 mm)	120	85
Stream water (from drier)	7	
Coarse tailings	70	48
Fine tailings	95	67
Dust	5	8
Total	297	208

Thus, there will be 200 m^3 of waste rejects per day. Annually, therefore, the waste rejects would amount to 55,200 m^3. For a period of 20 years, the total waste would be 1.1 million m^3. If the height of the dumps can be kept at 20 m, the surface area required for a twenty-year reject volume will be 552,000 m^2. If the height is 40 m, the surface area required for 20 years of waste rejects will be 276,000 m^2. It is therefore obvious that the location of the plant must be near a dumping yard of at least 30 ha for waste disposal.

Central air system. The main quantity of air circulated in the system is collection cyclone air amounting to 10 cyclones x 6,000 ft^3/min = 60,000 ft^3. Taking into dust aspiration, which produces 92 places x 4 ft^3/min x 35 = 12,800 ft^3, the total figure is 60,000 ft^3 + 12,800 ft^3 = 72,800 ft^3.

The plant air system has to be worked out in detail during the final project. In the layout design the central air station is shown as a separate item. The aspiration of the drier and the dried ore storage are a separate system with no connection to the central air connection.

Run of mine ore long fibre

The hand-sorting department includes the hand-cobbing of the long fibre cakes on each working belt and also a table production line. All necessary precautions are taken for achieving a high recovery ratio of the long fibre during the collection of the large sample. The recovery ratio of long fibre had worked out at only 51.5%. In the new sorting hall, the recovery ratio of the long fibre is expected to be 85%. The comparative findings were as follows: the recovery ratio of the special long fibre AS was 69%; that of the long fibre A group was 43%; and that of the long fibre B group was 53%. AS fibre is more than 1 1/4" longer than crude No. 1 of Canadian standard; A-grade fibre is 3/4" to 1 1/4" longer than crude No. 1 of Canadian standard; B-grade fibre is 1/4" to 3/4" longer than crude No. 2 Canadian standard.

The current and projected results of the recovery operations are given in table 20.

Table 20. Current and projected recovery ratios

Fibre type	Quantity (kg)	Recovery ratio (%)	Value ($)
		A. Current	
AS	135	69	3.6 x 135 = 486
A	189	43	3.0 x 189 = 567
B	679	52	2.0 x 679 = 1,358
			Total 2,411
		B. Projected at new plant	
AS	166	85	3.6 x 166 = 597
A	374	85	3.0 x 374 = 1,122
B	1,100	85	2.0 x 1,100 = 2,200
			Total 3,919

The quantities of long fibre referred to in the table above were produced from a sample of 55.34 tons mentioned in the expert's technical report of April 1976. The value of long fibre in one ton of run of mine ore was $43.6/ton. The value of long fibre expected in the new plant is $70.8/ton. This represents an increase in value of 62%. It may cause, however, a reduction in the quantity of group 3 fibre.

Milled fibre. A comparative account is prepared for the following three different flow-sheets: the processing of the above-mentioned sample (technical report of 1976); present processing methods (1978); new plant processing. The following calculations assume 5% asbestos in the run of mine ore.

(a) Processing of the sample

The box test results were 0 - 0.6 - 10.0 - 5.4, which is very close to the Canadian standard 5D, or 0 - 0.5 - 10.5 - 5.0. The price of 5D per ton is $391. A quantity of 100 tons of run of mine ore with 5% asbestos and a recovery ratio of 90% would yield a value of $1,759 (4.5 tons of asbestos fibre x $391). Therefore, the value of the run of mine ore for the milled fibre is $17.59/ton.

(b) Current processing methods

The present processing method is quite different compared with what it was two years ago. There are two main products, namely C1B (60% of the total) and D2B (40% of the total). The C1B is equivalent to the P4 USSR standard. The results of the box test are 0 - 7 - 5 - 4. The D2B is equivalent to the P5 USSR standard. The results of the box test are 0 - 0 - 12 - 4. The P4 USSR standard corresponds nearly to the 4D Canadian standard, which has the following box test results: 0 - 7 - 6 - 3. The P5 is exactly equivalent to the 5K Canadian standard, with the following box test results: 0 - 0 - 12 - 4. The price of C1B is $572/ton, and that of D2B is $391/ton. A quantity of 100 tons of run of mine ore with 5% asbestos and a recovery ratio of 90% would give a value of $2,248. The value of one ton of run of mine ore for the milled fibre is therefore $22.48, representing a 28% increase in value compared with the above-mentioned figure of $17.59/ton. The processing method is therefore 28% better than what it was two years ago.

(c) New plant processing

The new plant process yields from 100 tons of run of mine ore (with an asbestos content of 5% and a recovery ratio of 85%) 4.25 tons of asbestos fibre. The distribution in different groups, the price/ton and the value are given in table 21.

Table 21. Fibre production by new processing method

Group	Percentage	Quantity (kg)	Price per ton ($)	Value ($)
3	15	637	1,080	687
4	55	2,338	558	1,300
5	15	637	390	248
6	5	213	242	51
7	10	425	111	47
		4,250		2,333

The value of asbestos in one ton of run of mine ore will be $23.33. The increases in value compared with the above figures of $17.59 and $22.48 are, respectively, 33% and 4%. The total values for long fibre and milled fibre together obtained by the three different processes are given in table 22.

Table 22. Summary of fibre values

Long fibre ($/ton)	Milled fibre ($/ton)	Total
43.60	17.59	61.19
	22.48	75 to 80
70.80	23.33	94.13

Two years ago the value of production of one ton of run of mine ore was only $61.15. At present (1978), the value of one ton of run of mine ore is approximately $75 to $80. In the new plant, the value is expected to reach $94. The new processing plant is expected to increase the value by 20% compared with present values.

Final observations and recommendations

The time available to the expert was insufficient and the preliminary project had to be cut short. The expert's main task was to summarize all available data, which was presented in chapter IV, section A.

The semi-industrial test was carried out, but some very important technological data essential for accounting and flow-sheet design were not furnished by the contractor. All reject material from the semi-industrial test, weighing approximately 11 tons, was carefully examined with the assistance of APMC engineers and staff. Representative samples were processed in the regional research laboratory at Hyderabad. Analysis of the material has yielded sufficient data for the technological assessment of asbestos values required for making projections.

The following recommendations should be noted:

1. The APMC should collect all relevant data on machinery and equipment mentioned in annex IV. Information should be collected from Indian producers of the same type of machines and equipment or their nearest equivalent. At the same time, information from reputable foreign producers of such machinery and equipment could also be collected.

2. It should be borne in mind that the cost of construction work and of the installation of electrical apparatus and machinery has to be estimated by Indian engineers in accordance with Indian standards in the various fields.

3. The APMC should arrange for the critical examination of the preliminary project by experts in ore dressing, so as to elaborate and crystallise the conceptual basis of the final plant project.

Annex I

DATA ON THE RESULTS OF SEMI-INDUSTRIAL ASBESTOS ORE PROCESSING TESTS

Table 23. Detailed review of grain-size analysis of coarse tailings

Mesh: Tyler number	Mesh: Minimum diameter (µm)	1.S1 Bigger	1.S2 Smaller	18	16	29	24	15	13	12	14	19	26	38	9	42	45	30	44
		Weight percentage																	
		0.3	0	2.8	2.0	0.4	0	0.4	0	0	0	0	0	0.4	0	0	0	0	0
4	5150																		
		6.6	0.5	20.4	17.6	7.2	4.8	4.0	3.6	4.0	2.8	2.4	1.2	2.0	1.6	2.0	1.0	0.8	0.4
6	3180																		
		35.0	17.5	43.6	48.0	48.0	38.8	32.8	31.6	30.4	29.6	29.6	32.8	26.0	25.6	22.0	20.0	19.6	17.2
10	1680																		
		3.6	(Mesh No. 12 not used)																
12	1379																		
		26.5	30.0	22.4	22.8	27.6	30.8	32.8	32.4	32.0	33.0	34.0	31.6	33.6	28.0	32.8	32.7	30.8	32.0
14	1168																		
		18.9	27.0	7.2	6.8	12.0	15.2	22.0	18.8	18.0	21.6	23.2	19.2	23.2	22.0	27.0	25.4	30.4	28.0
20	833																		
		5.4	14.0	0	0.4	2.8	4.4	4.0	7.2	6.0	7.6	5.6	7.6	5.2	12.0	10.0	11.6	8.4	12.8
28	590																		
		2.7	7.5	0	0	0.8	3.2	1.6	2.8	4.0	2.0	2.4	3.2	2.4	6.0	4.8	6.7	7.6	6.8
35	417																		
			1.5	0	0	0	0.4	0	0	0.4	0.4	0	0	0.1	0.8	0.4	0.8	0.8	0.4
Losses		1.0	2.0	3.6	2.4	1.2	2.4	2.4	3.6	5.2	2.0	2.8	4.4	7.4	4.0	1.0	1.8	1.6	2.4
		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Drum weight (kg)				260	267	270	270	222	261	290	243	265	267	262	248	209	272	306	274
Weight-volume ratio (t/m^3)		1.50	1.59	1.57	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
Biggest sample grain observed (mm)				9.5	10.7	8.0	8.6	8.3	8.3	9.4	...	7.4	8.0	7.4	...	...	...	7.9	5.6
Process sieving effect coefficient (%)				94	97	95	90	92	86	84	88	89	85	85	77	83	78	82	77

Table 23 (continued)

Asbestos fibre observations during the sieving of coarse tailings

Tyler mesh	The biggest type from drum Nos. 18, 16, 29, 24 and 15	The middle type from drum Nos. 13, 12, 14, 19, 26 and 38	The finest type from drum Nos. 9, 42, 45, 30 and 44
6	Barren grains; no fibre; in drum No. 15, two pieces of asbestos	All samples - clean reject	Clean reject, no fibre
10	Two samples - clean reject; two samples with small asbestos needles; one sample with four asbestos pieces; no open fibre	Four samples - clean reject; two samples with traces of asbestos staples	Five samples of barren rock; one sample with two asbestos staples
14	Small asbestos staples in drum No. 29 (less than 0.5% asbestos staples)	Two staples of barren rock; four samples with asbestos in traces	Two samples only barren sand; two samples with traces of asbestos staples; one sample of less than 1% staple
20	Less than 1% needles and staples of short asbestos fibre	One sample only sand; two samples with asbestos traces; three samples with 0.5% to 1% short fibre	Four samples with asbestos needles; one sample with traces of needles
28	Three samples with asbestos needles	One sample without fibre; five samples with traces of fibre	All samples contain approximately 0.5% of asbestos needles
35	Two samples with less than 1% short fibre with staples	All samples with 0.5% to 1% short fibre and needles	All samples with short asbestos needles of 1% to 2%

Conclusions

1. The opening of asbestos fibre is completed in the milled ore of size less than 4 mesh. In the size bracket of 6 mm to 2 mm, 50% of the milled ore is in the first stage of fibre extraction, 20% in the middle stage and 10% in the last stage;
2. The coarse tailings belong to the rock circuit and it is 20-mesh screened and aspirated reject product;
3. In the coarse tailings there are no long or medium fibres. They contain only short fibre of less than 14 to 35 mesh.

Table 24. Systematization of middlings and sand tailings based on grain size analysis

Tyler number	Minimum diameter (μm)	Coarse tailing (yellow) 22
4	5150	0.8
6	3180	6.4
10	1680	17.2
14	1168	13.6
20	833	19.6
28	590	24.8
35	417	14.4
65	208	0
Losses		3.2
		100
Weight (kg)		270
Weight volume ratio t/m^3		1.48

Tyler number	Minimum diameter (μm)	7	31	37	43	17	6	4+8	25+ 34	20+ 28	3+5	40+ 41	21+ 35	33+ 39	10+ 11	1+2	32
		Weight percentage															
		Middlings I (yellow shade)					Middlings II			Sand tailings I				Sand tailings II			
		2.0	0.5	0.5	0.8	1.2	10.0	5.0	4.0	4.0	4.0	2.0	1.0	1.0	1.0	1.0	1.0
14	1168	5.0	12.0	6.0	6.4	7.6	12.0	6.00	6.0	8.0	7.00	1.0	5.0	2.0	1.0	2.0	1.0
20	833	37.5	47.6	52.2	32.8	9.6	8.0	8.0	7.0	7.0	5.0	5.0	5.0	3.0	2.0	4.0	4.0
28	590	34.0	27.0	26.0	34.4	26.0	27.0	29.0	29.0	14.0	13.0	26.0	19.0	24.0	24.0	21.0	20.0
35	417	12.00	5.0	8.4	12.0	27.6	14.0	15.0	14.0	28.0	32.0	28.0	28.0	35.0	35.0	33.0	35.0
65	208	9.5	3.4	5.6	10.4	22.8	26.0	35.0	37.0	36.0	38.0	36.0	38.0	34.0	35.0	35.0	36.0
Losses		0	3.9	1.3	3.2	5.2	3.0	2.0	3.0	3.0	1.0	2.0	4.0	1.0	2.0	4.0	3.0
		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Weight (kg)		136	255	218	251	235	240	497	473	563	505	473	467	424	531	509	280
Weight volume ratio t/m^3		1.24	1.26	1.25	1.29	1.28	1.05	1.15	1.12	1.41	1.37	1.30	1.32	1.30	1.30	1.30	1.40

Conclusions

1. Drum No. 22 (yellow coarse tailings) contained an oversized material of screened and aspirated product belonging to the rock circle;
2. Material from all the other drums were undersized products. The yellow-shaded sand belongs to the first tailings of the processing. The screen cloth was a combination of two different sizes. The first quarter of the screen was with 1.25 mm openings, while the remaining part was with about 30-mesh screen.

Table 25. Asbestos values and details of important parameters

Number	Name of drum sample	Weight (kg)	Long fibre Group (%)	Long fibre 4,high (kg)	Medium fibre Group (%)	Medium fibre 4,low (kg)	Medium fibre Group (%)	Medium fibre 5,high (kg)	Short fibre Group (%)	Short fibre 5,low (kg)	Short fibre Group (%)	Short fibre 6 (kg)	Short fibre Group (%)	Short fibre 7 (kg)	Totals (kg)
1	Coarse tailings	4,184	-	-	-	-	0.28	11.72	0.16	7.53	0.37	15.47	-	-	34.72
2	Coarse tailings (yellow shade)	270	-	-	-	-	0.03	0.07	0.01	0.03	0.03	0.08	-	-	0.18
3	Sand tailings I	1,541	-	-	-	-	-	-	0.15	2.31	1.15	17.71	0.82	12.64	32.66
4	Sand tailings II	2,211	-	-	-	-	0.15	3.31	0.30	6.63	0.78	17.24	0.63	13.83	41.01
5	Middlings I	1,095	0.015	0.164	-	-	0.28	3.04	1.79	19.16	1.01	11.04	1.38	16.11	49.51
6	Middlings II	1,210	0.58	7.018	-	-	0.21	2.55	5.64	68.24	0.03	0.36	5.26	63.65	141.82
7	Middlings III	88	0.74	0.650	0.168	0.150	1.31	1.21	0.18	0.16	0.02	0.02	0.03	0.03	2.22
8	Fine dust	204	-	-	-	-	-	-	-	-	5.00	10.20	3.00	6.22	16.42
	Totals	10,803	0.072	7.832	0.0014	0.150	0.20	21.90	0.96	104.06	0.67	72.12	1.04	112.48	318.54

Conclusions

1. The reject product from the semi-industrial test of Pulivendla prepared ore amounts to 2.94%. Asbestos fibre mostly includes 2.67% of short fibre, with medium fibre accounting for only 0.20% and long fibre only 0.072%.
   The asbestos values refer to the schedules I, II, and II (bulk)

2. Processed ore asbestos percentage account

	Amount of processed ore (kg)	Asbestos fibre produced (percentage)
Schedule I	3,000	5.356
Schedule II	2,915	6.22
Schedule II (bulk)	6,541	6.258
	12,456	

Table 25 (continued)

Medium asbestos recovery percentage referring to the schedule sample quantities.

(3,000 x 5.356%)+(2,915 x 6.222%)+(6,541 x 6.258%) : 12,456	6.01	
Asbestos percentage in reject products	2.94	
Asbestos content in processed ore (%)	8.95	

3. <u>Processing recovery ratio</u>

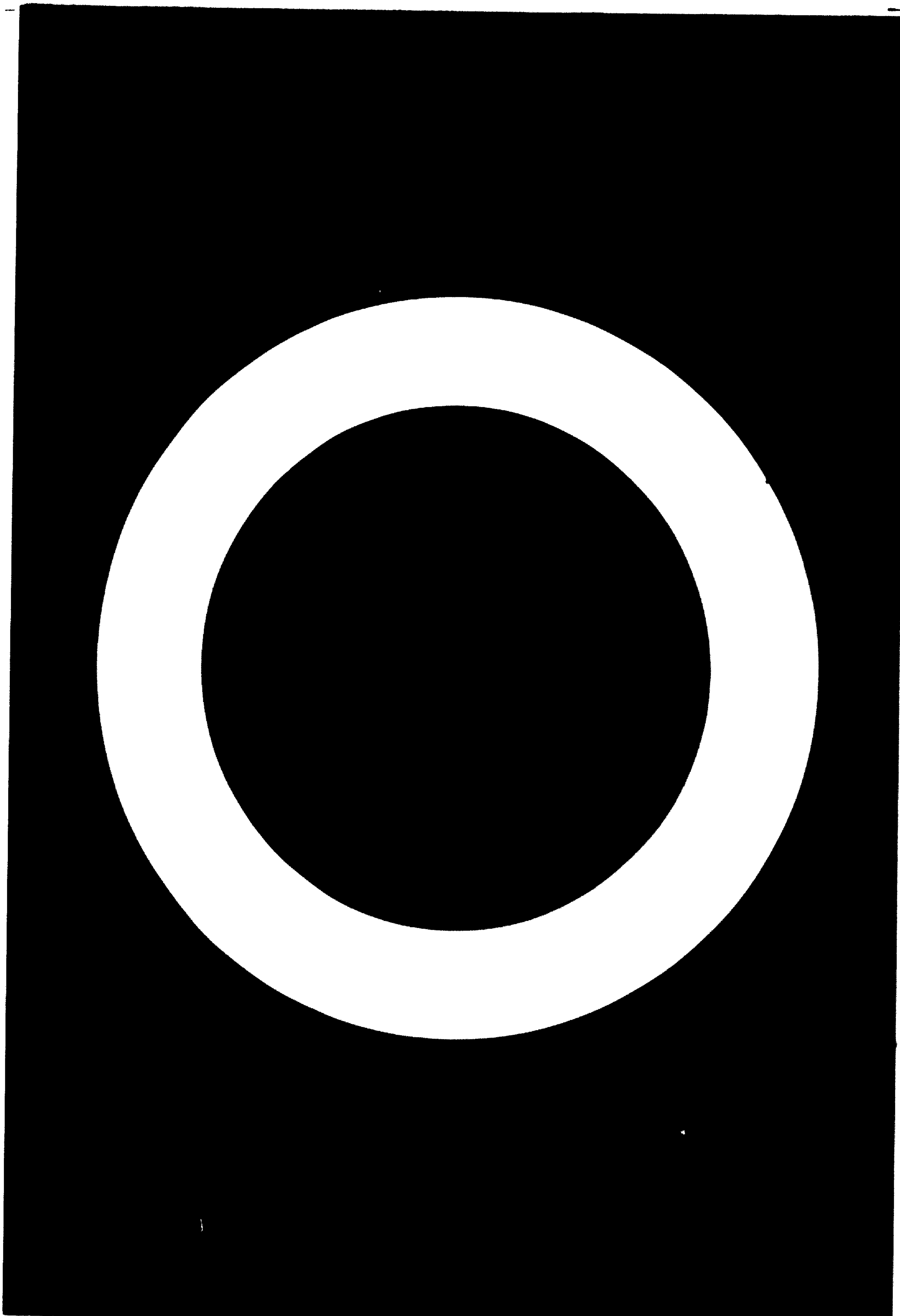
For long and medium asbestos fibre (6.01 :(6.01 + 0.27))	94.8%
For total asbestos fibre content (6.01 : 8.95)	67.5%

4. <u>Asbestos fibre assortment account (in processed ore)</u>

		Results	(%)
Group 3: (1.813 x 3,000)+(1.338 x 9,456) :	12,456	1.452	16.2
Group 4: (3.543 x 3,000)+(4.884 x 9,456) :	12,456 + 0.073	4.626	51.8
Group 5: 0.20 + 0.96		1.16	12.9
Group 6:		0.67	7.5
Group 7:		1.04	11.6
	Total	8.948	100.0

5. <u>Ore of mine asbestos content account</u>

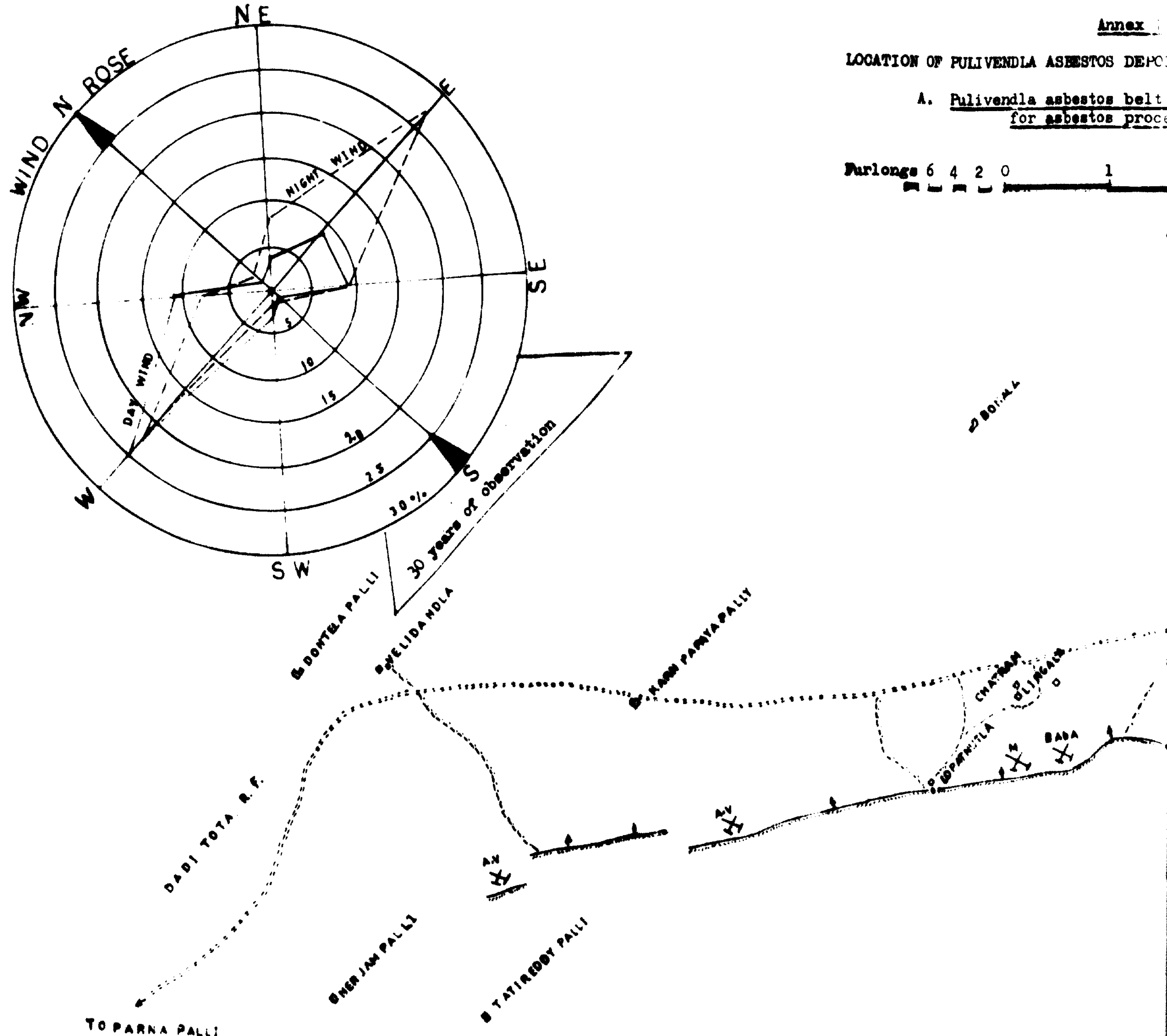
The ore of mine quantity divided for large test sample (table 3, annex II, terminal report of 26 March 1976)	27,728 kg	
The processed ore quantity for semi-industrial test (2.25 industrial crushing of the lumpy ore, 1976 technical report)	14,237 kg	
Correction coefficient 12,456 : 14,237 = 0.875		
The run of mine ore quantity referring to tested ore: 27,728 x 0.875	=	24,000 kg
Asbestos quantity in the processed ore: 12,456 x 8.95%	=	1,115 kg
Asbestos percentage in ore of mine: 1,115 : 24,400 = <u>4.53%</u>		



Annex

LOCATION OF PULIVENDLA ASBESTOS DEPO

A. Pulivendla asbestos belt
for asbestos proc

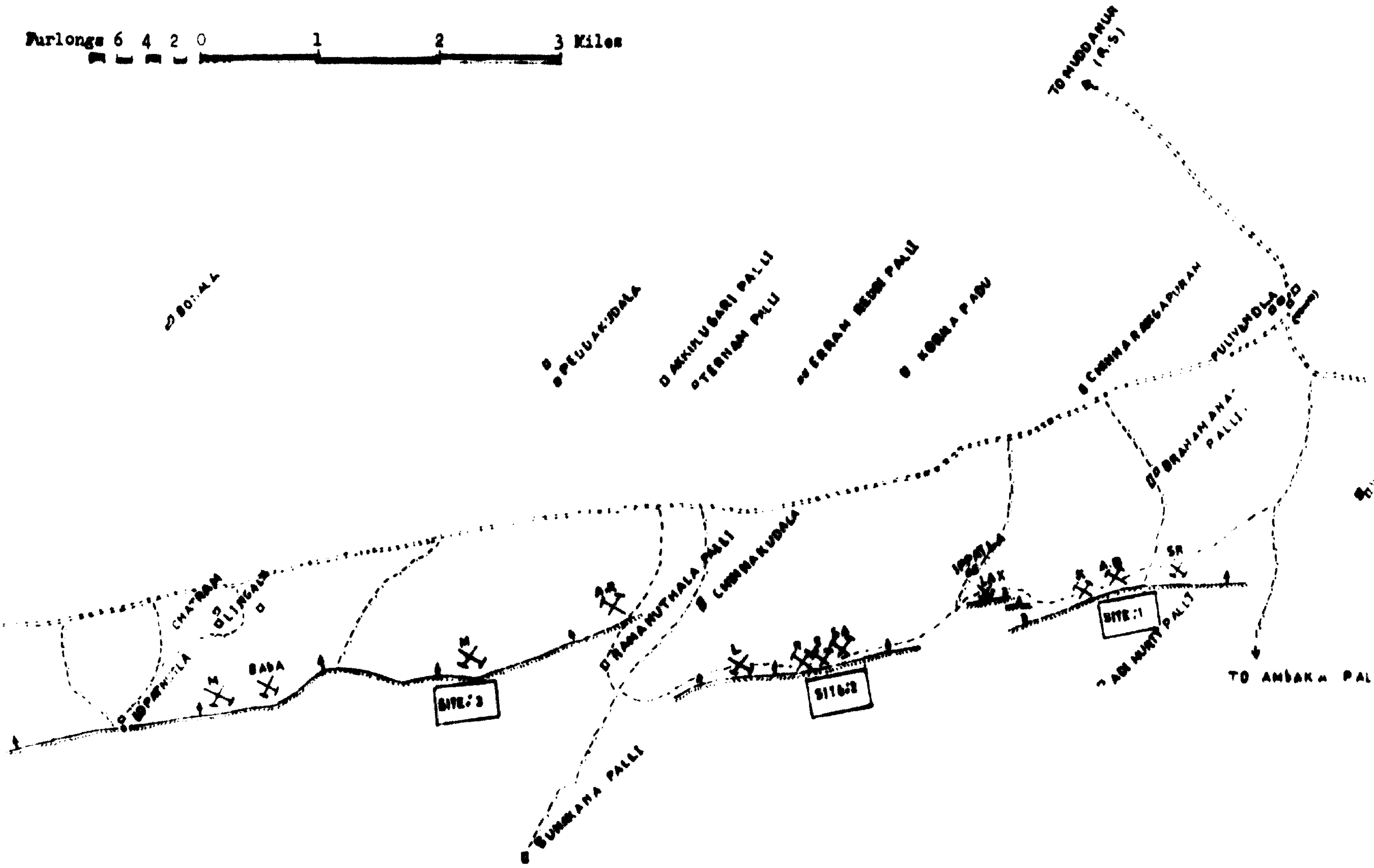


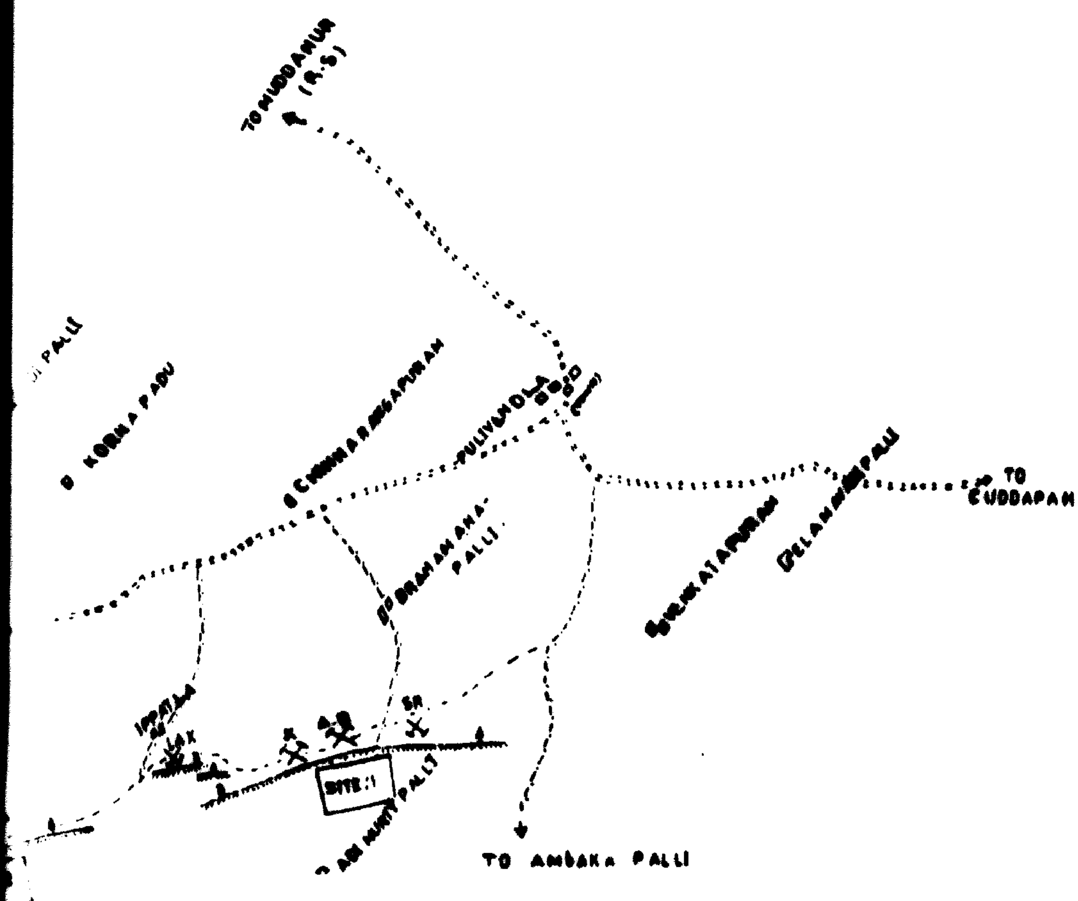
[redacted]

Annex II

LOCATION .F PULIVENDLA ASBESTOS DEPOSITS AND CLIMATOLOGICAL DATA

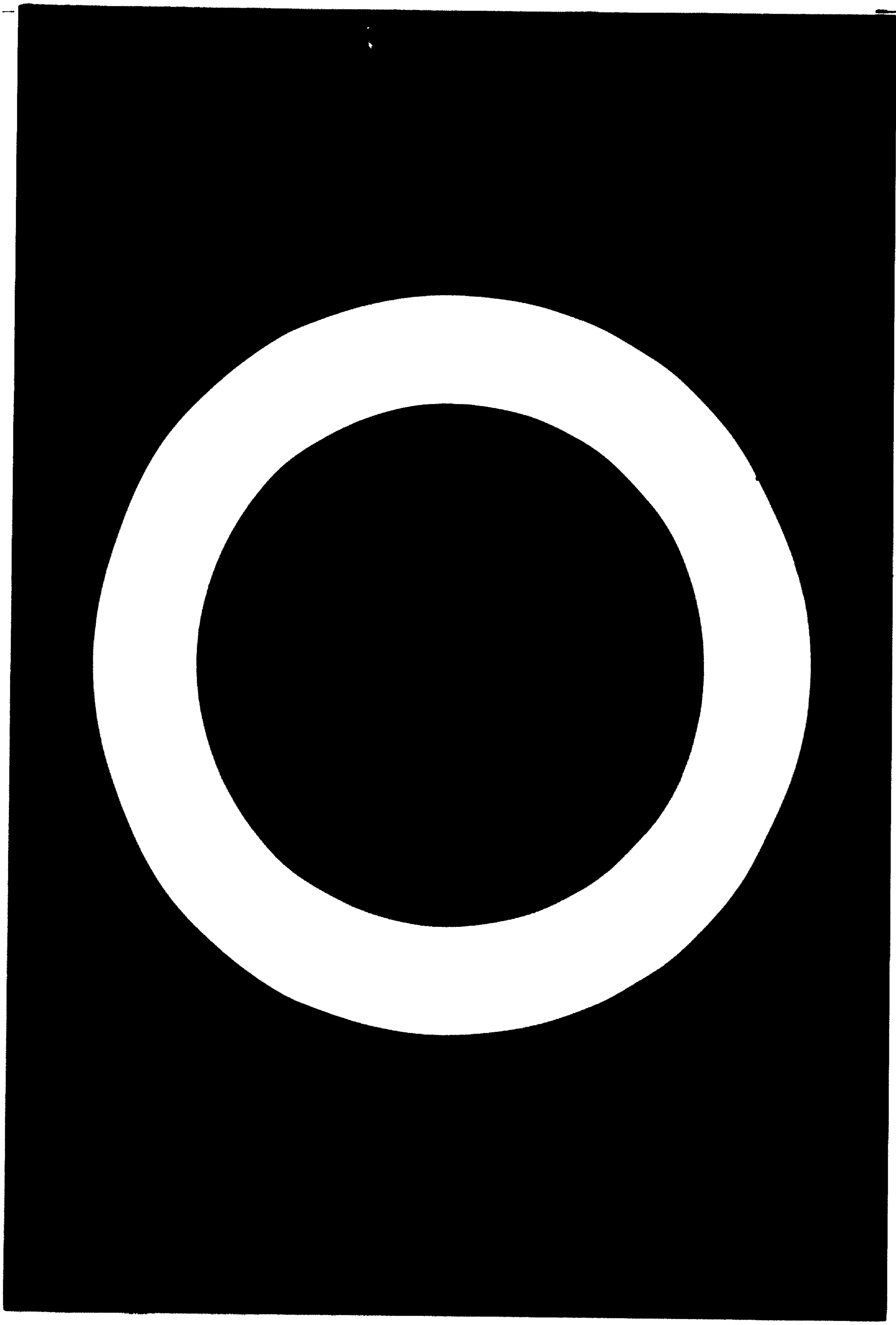
A. Pulivendla asbestos belt showing probable sites for asbestos processing plant





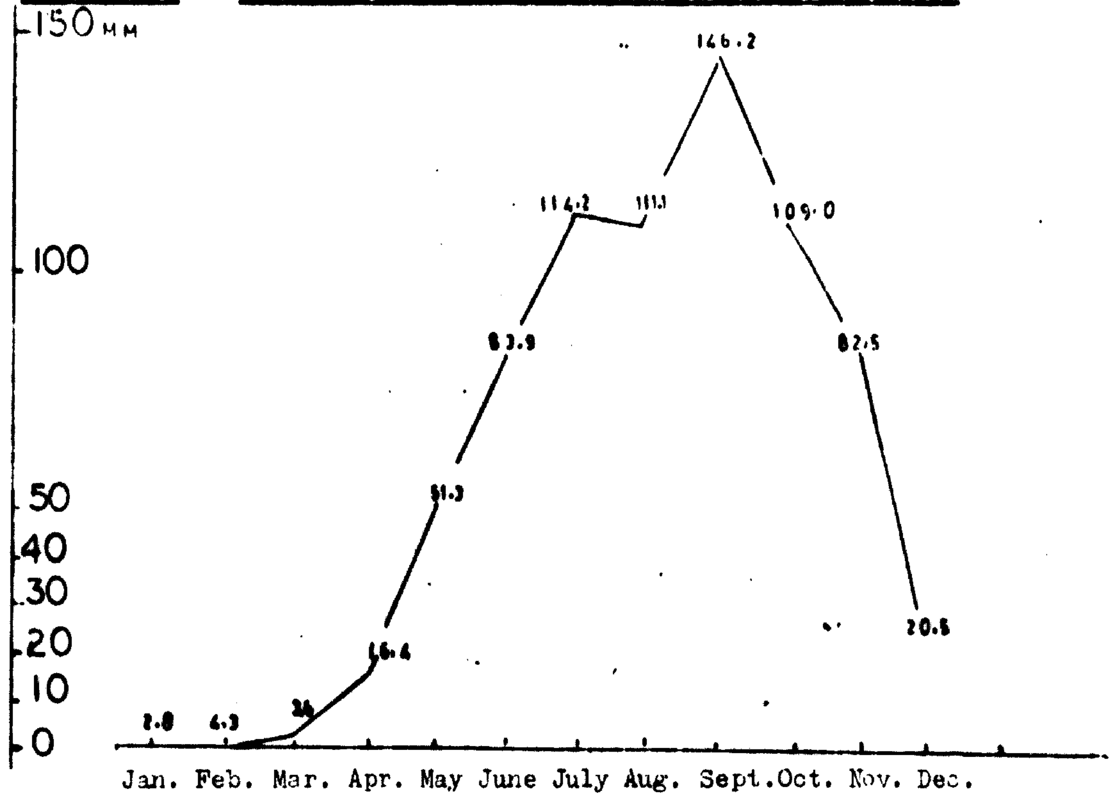
Key:

	Cart road
	Mine road
	Mineralised contact with dip direction
	Main road (tar)
	Village
SITE:1	Proposed sites for asbestos processing plant
A.R	APMC Rammuthala Palli mine
M	Merchant Syndicate Mine
BABA	Baba Mine
A.V	APMC Velidandla Mine
SR	Sarasvati Mine
AB	APMC Brahamana Palli Mine
K	Kalimani Gutta Mine
LAX	Laxmi Narayan Mine
SA	Saibaba Mine
S	Sita Dorasani Mine
R	Reddy Mine
L	Laxman Mine
	Working Mine
	Non-working Mine

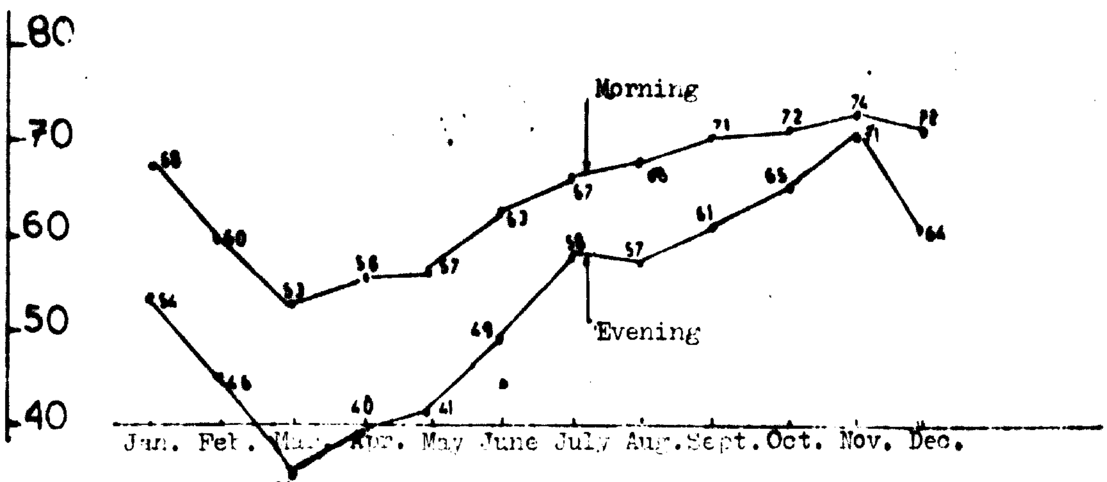


B. Climatological data

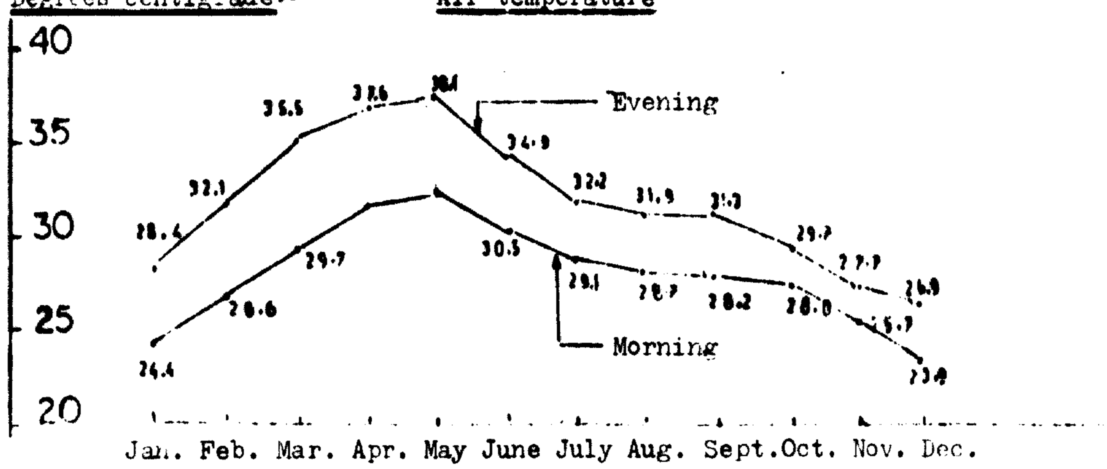
Millimetres — Monthly rainfall based on 30 years of observation



Percentage — Relative humidity



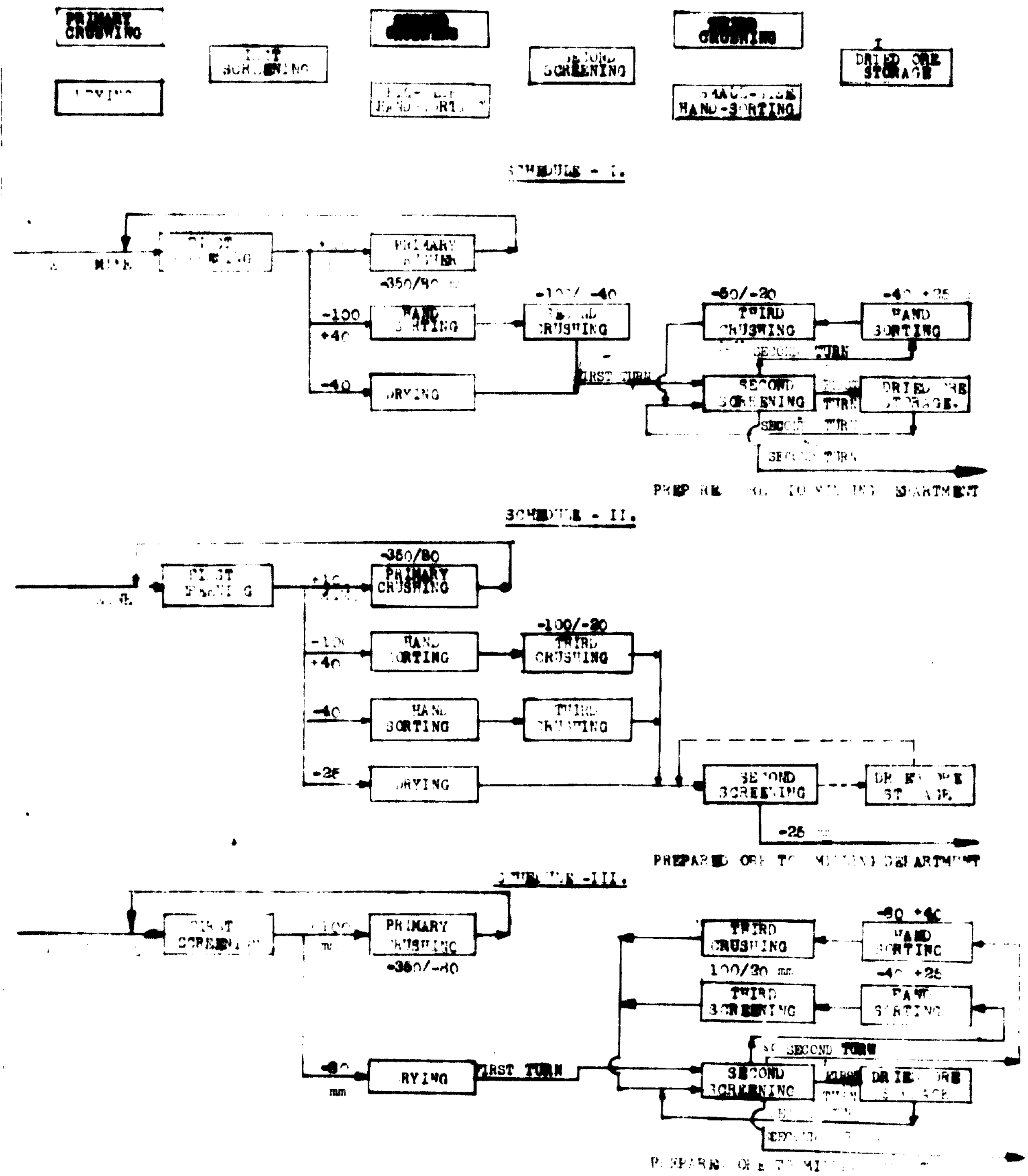
Degrees centigrade — Air temperature



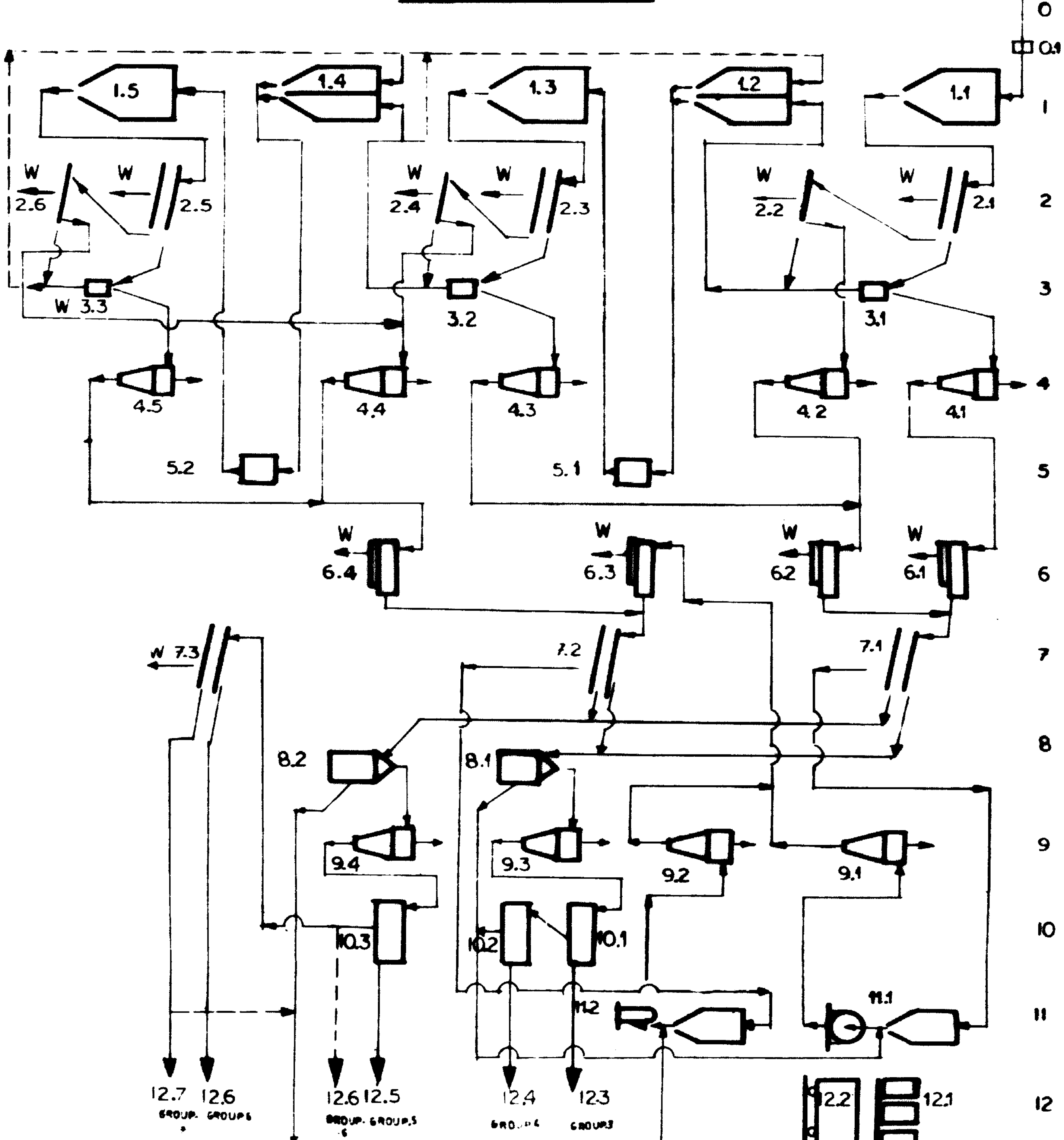
Annex III

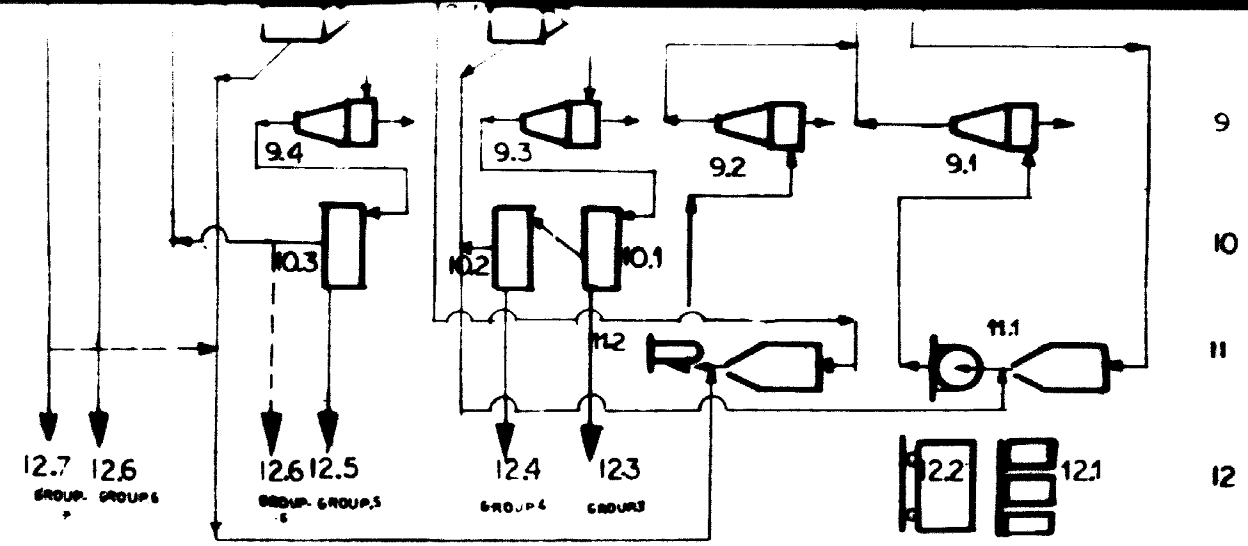
PULIVENDLA ASBESTOS PROCESSING PLANT DESIGN AND FLOW SHEETS

A. Fl[illegible] technological phases of first department



B. Flow-chart of milling department





Key:

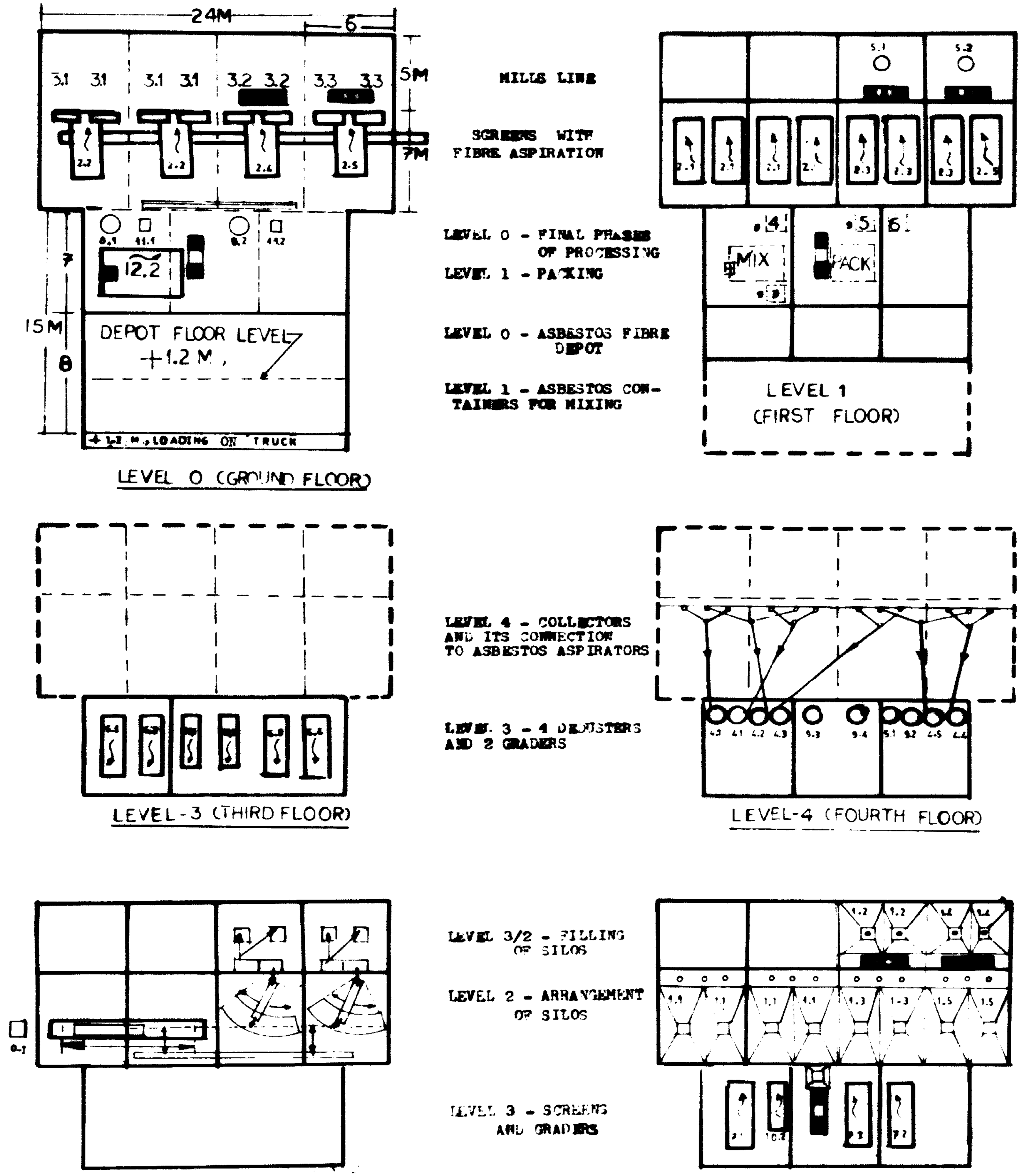
0. Feed ore from first department - Quantity: 150 to 180 tons/shift; size of ore: up to 25 mm; asbestos content: 6% to 9%

		Number of pieces
0.1	Belt scale for continuous weighing of total mill feed	1
1.	**Silos**	
	1.1, 1.3, 1.4 Ore silos for screen feed - Capacity: 40 m^3 each	8
	1.2, 1.4, Twin compartment ore silos for fiberizer feed - capacity: 120 m^3 each	2
2.	**Screens**	
	2.1, 2.3, 2.4 Two-deck gyratory screens - Screening surface: 4 m^2 each Two-deck rotex screens - Screening surface: 5 m^2 each	8
	2.2, 2.4, 2.6 One-deck rotex screens with aspirator hoods - Screening surface: 5 m^2 each	4
3.	**Rotary aspirators** - Diameter : 18 inches	8
4.	**Cyclone collectors** - Diameter : 5 feet	6
5.	**Mills**	
	5.1 Two-stage vertical fiberiser - Diameter : 48 inches	1
	5.2 Four-stage verticle fiberiser - Diameter : 48 inches	1
6.	**Dedusters** Single trommel deduster - Diameter : 36 inches	4
7.	**Two-deck rotex screens** - Screening surface : 5 m^2 each	3
8.	**Air gravity separator** - Diameter : 42 inches	2
9.	**Cyclone collectors** - Diameter : 4 feet	4
10.	**Standard graders** - Diameter : 26 inches	3
11.1.	**Turbo fiberiser**	1
11.2.	**Short grinder**	7
12.1	**Asbestos container** - Capacity : 4 m^3 each	25
12.2	**Blender - mixer** - Length : 12 feet : diameter : 9 feet	1

General quantitative data

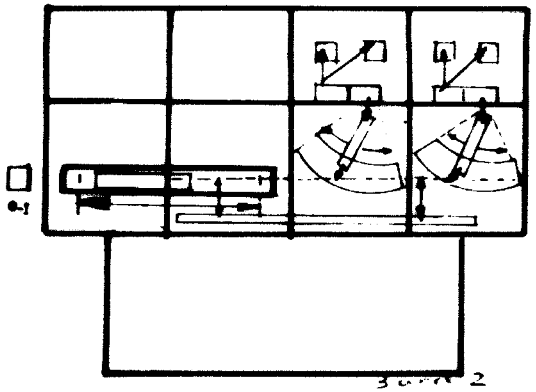
	Tons/day
Feed ore: 150 to 180 tons/shift	
Total quantity of: W (tailings) at (2.1 to 2.6 and 3.3)	110 to 140
Aspirated concentrates at (4.1 to 4.5)	40 to 50
W (tailings) at (6.1 to 6.4 and 7.3)	25 to 34
Dust at (central air system and bag filters)	4 to 6
Finished fibre at (12.3 to 12.7)	9 to 12

c. Layout of milling department



LEVEL-3 (THIRD FLOOR)

LEVEL-4 (FOURTH FLOOR)

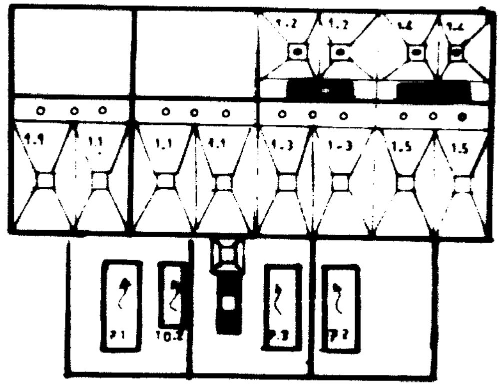


LEVEL BETWEEN 3 AND 2
IS LEVEL 3/2

LEVEL 3/2 - FILLING OF SILOS

LEVEL 2 - ARRANGEMENT OF SILOS

LEVEL 3 - SCREENS AND GRADERS

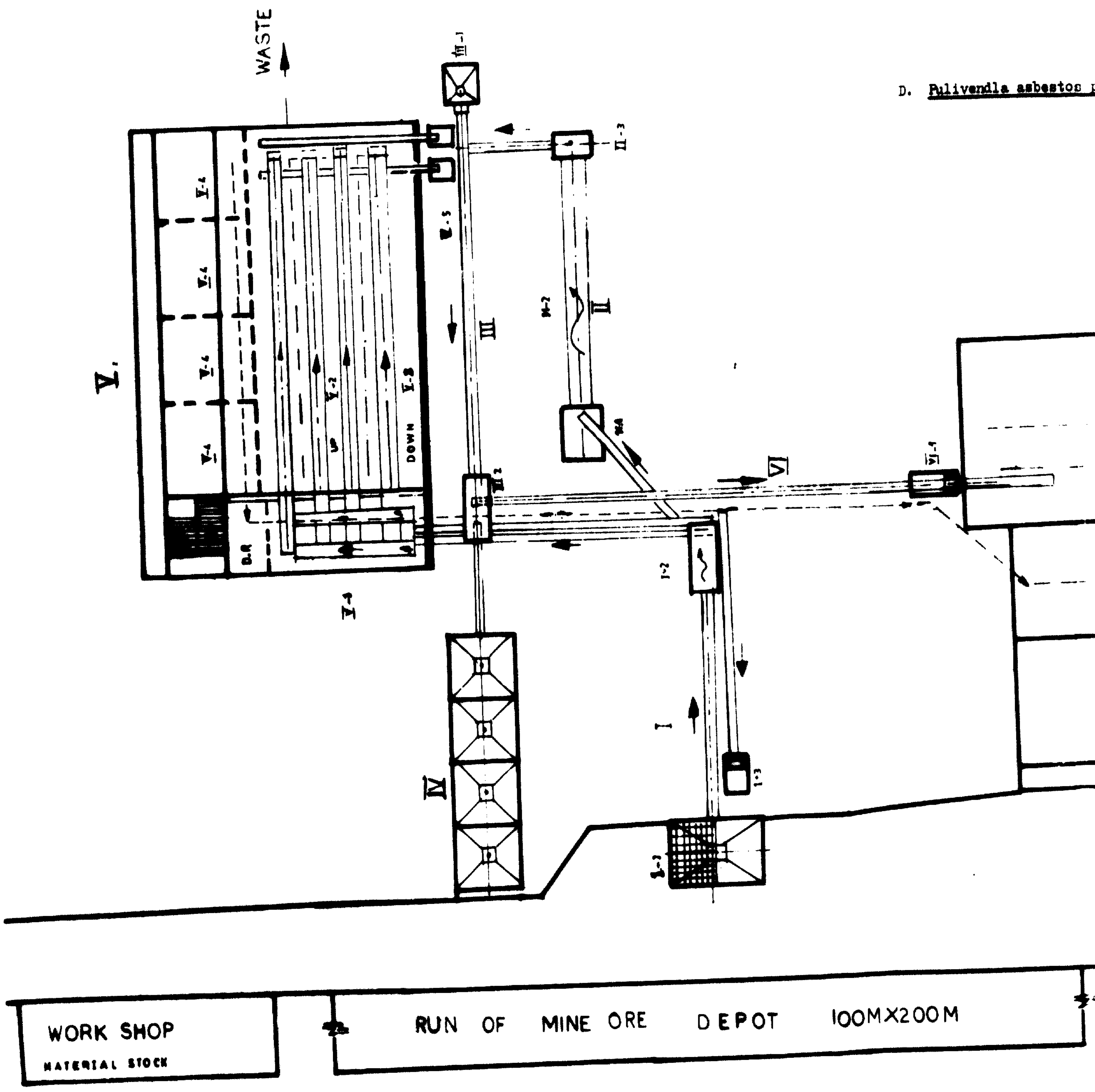


LEVEL-2
(SECOND FLOOR)

Key:

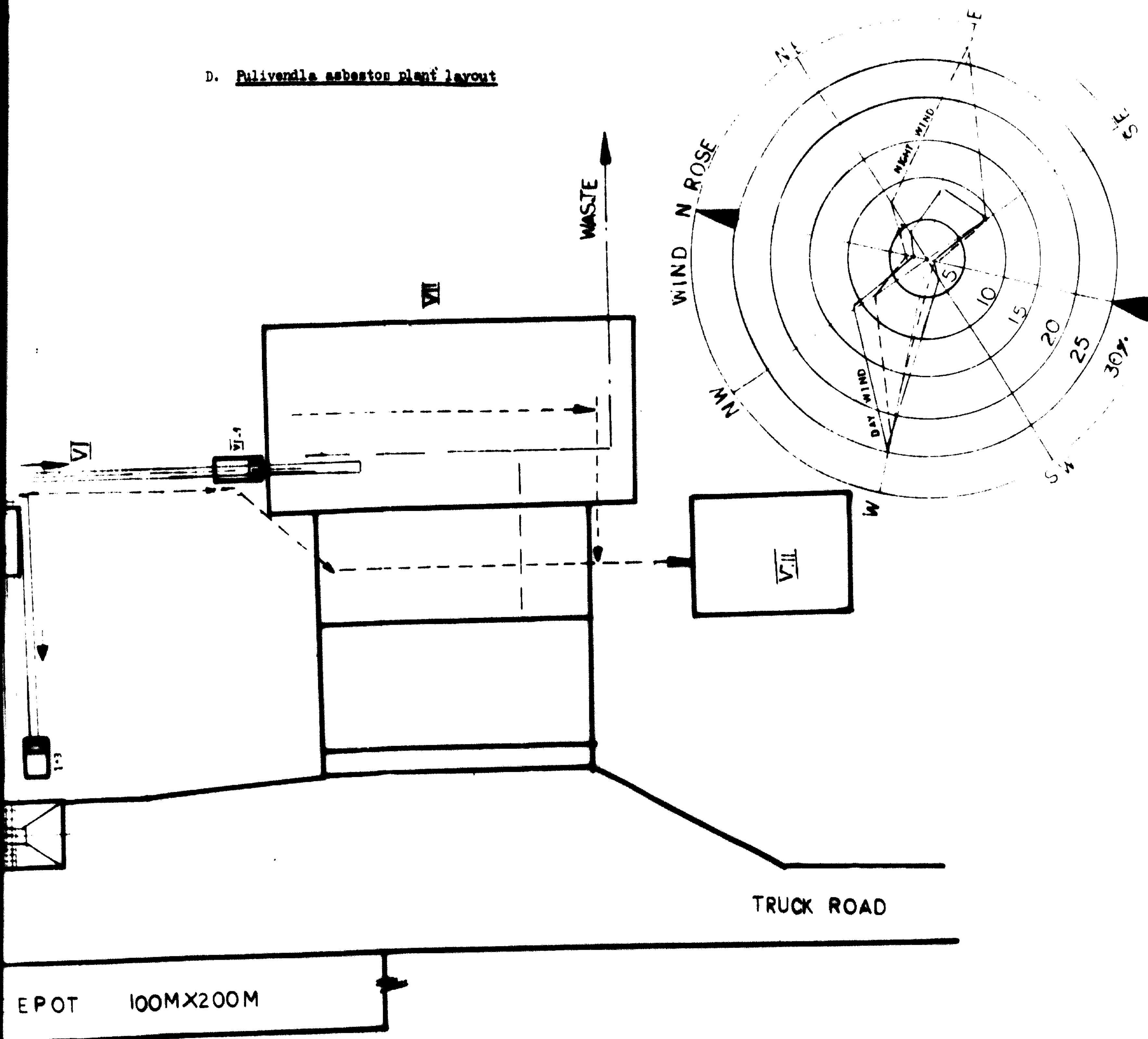
			Number of pieces
0.	Feed ore from first department - Quantity: 150 to 180 tons/shift; size of ore: up to 25 mm; asbestos content : 6% to 9%		
0.1	Belt scale for continuous weighing of total mill feed		1
1.	Silos		
	1.1, 1.3, 1.4	Ore silos for screen feed - Capacity : 40 m^3 each	8
	1.2, 1.4	Twin compartment ore silos for fiberiser feed - Capacity : 120 m^3 each	2
2.	Screens		
	2.1, 2.3, 2.5	Two-deck gyratory screens - Screening surface : 4 m^2 each or two-deck rotex screens - Screening surface : 5 m^2 each	8
	2.2, 2.4, 2.6	One-deck rotex screens with aspirator hoods - Screening surface: 5 m^2 each	4
3.	Rotary aspirators	- Diameter : 18 inches	8
4.	Cyclone collectors	- Diameter : 5 feet	6
5.	Mills		
	5.1	Two-stage vertical fiberiser - Diameter : 48 inches	1
	5.2	Four-stage vertical fiberiser - Diameter : 48 inches	1
6.	Dedusters	Single trommel deduster - Diameter : 36 inches	4
7.	Two-deck rotex screens	Screening surface : 5 m^2 each	3
8.	Air gravity separator:	Diameter : 42 inches	2
9.	Cyclone collectors	Diameter : 4 feet	4
10.	Standard graders	Diameter : 26 inches	3
11.1	Turbo fiberiser		1
11.2	Short grinder		1
12.1	Asbestos containers -	Capacity : 4 m^3 each	25
12.2	Blender - mixer	Length: 12 feet; diameter : 9 feet	1

D. Pulivendla asbestos p

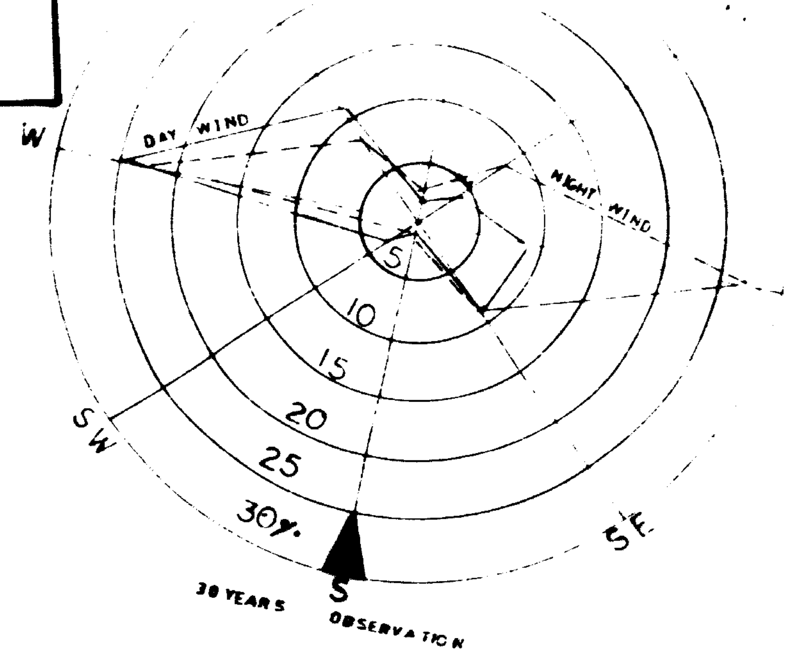


[redacted]

D. Pulivendla asbestos plant layout

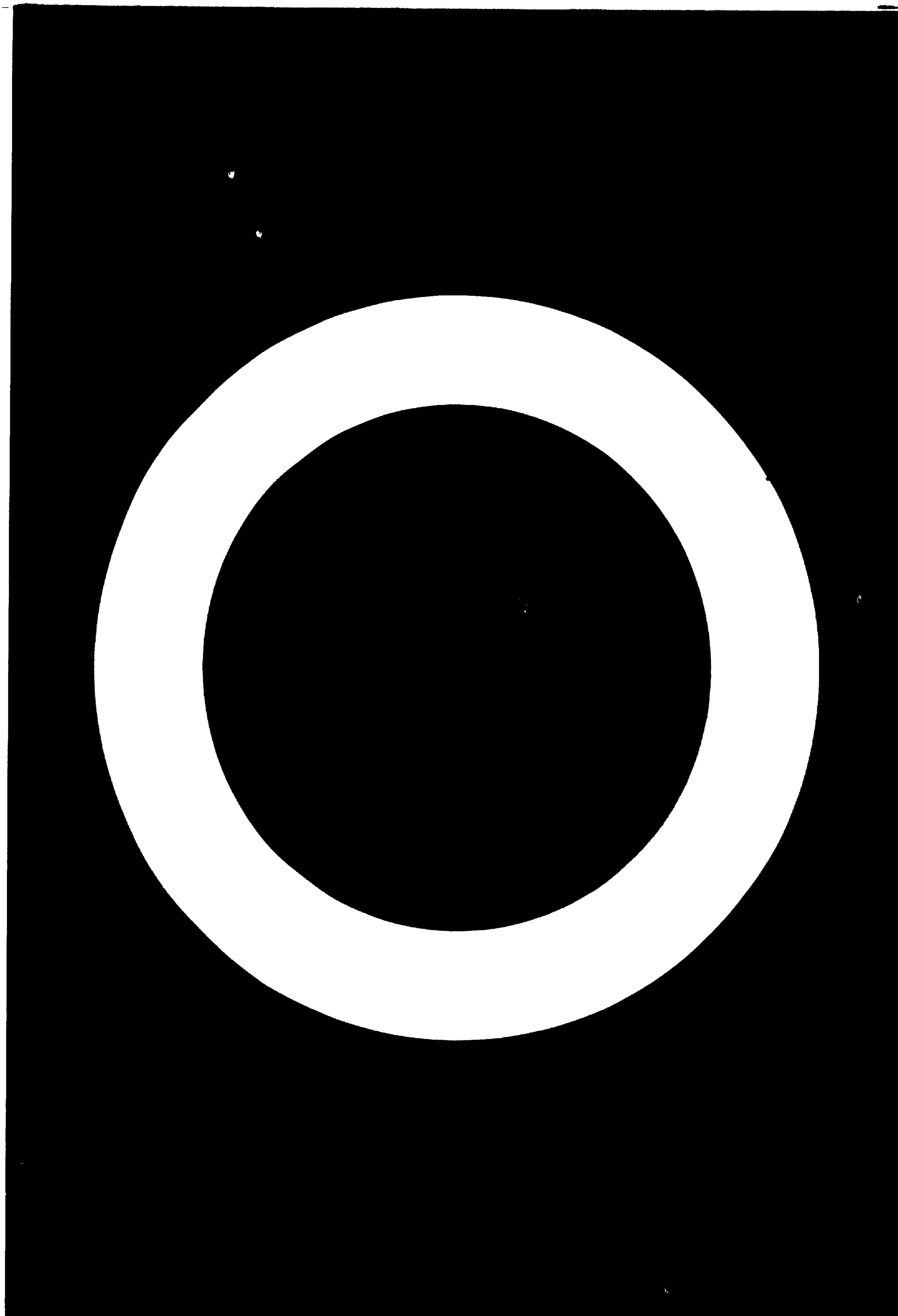


·UCK ROAD



Key:

I.	**Jaw crusher line**	I-1	Silo for run of mine ore – Capacity : 10 m^3
		I-2	Three-deck scalping screen (100/40/25 mm)
		I-3	Jaw crusher (350/80 mm)
II.	**Drier line**	II-1	Furnace with feed entry enclosure
		II-2	Rotary drier
		II-3	Dried ore exit enclosure
III.	**Dried ore main line**	III-1	Silo of 3 m^3 capacity with vibratory feeder and unloading point for fully prepared ore at the mine site
		III-2	Main transfer point with two-deck screen (40/25 mm) for : (a) Cooling and storage of dried ore (b) Feeding hand-sorting department (c) Feeding, milling department (d) Correcting mistakes in ore-dressing system, drying and other operations
IV.	**Dried ore storage line**		
V.	**Hand-sorting department**	V-1	Ore feeding arrangement line with feed control room
		V-2	Hand-sorting hall (first floor)
		V-3	Collector belts for hand-sorted products (ground floor)
		V-4	Dressing room for female workers (ground floor)
		V-5	Granulators (100/20 mm) for second and third crushing
VI.	**Main feed line to milling department:**	VI-1	Belt scale
VII.	**Milling department:**	See annex III, section C	
	Main aspiration line		



Annex IV

LIST OF ESSENTIAL EQUIPMENT

Table 26. Equipment description

Type of equipment	Quantity	Function and capacity	Power required (kW)
Crushers and mills[a]			
A. First crushing			
Jaw crusher, 750 mm x 375 mm; recommended feed size, 300 mm; 350 rev/min; 20 to 30 hp; weight, 7,500 kg	1	Primary crushing of feed ore of size 350 mm x 260 mm; capacity, 15 tons/h	16.0
Alternatives			
Impact jaw crusher, 500 mm x 300 mm; input feed size, 400 mm x 250 mm; 40 kW; weight, 6,420 kg		Primary crushing of feed ore of size 400 mm x 260 mm; capacity, 15 tons/h	20.0
Impact jaw crusher, 500 mm x 280 mm; input feed size, 400 mm x 250 mm; 40 hp; weight, 7,100 kg		Primary crushing of feed ore of size 400 mm x 260 mm; capacity, 15 tons/h	20.0
B. Second crushing			
Granulator-type jaw crusher with dodge-type fine teeth; input size, 100 mm; output feed size, 20 mm; weight, approximately 5,000 kg	1	Second and third crushing of feed ore, size 100 mm	35.0
Alternative			
Granulator-type crusher with dodge-type fine teeth; input feed size, 100 mm; output size, 40 mm; weight, approximately 4,000 kg	1	Only for secondary crushing of ore, size 100 mm	35.0

Type of equipment	Quantity	Function and capacity	Power required (kW)
C. Third crushing[a]			
Cone crusher; input feed size, 50 mm; output size, 10 mm; minimum gap width, 5 mm; crusher shell diameter, 700 mm; outside diameter, 1,290 mm; power, 60 hp; motor, 1,500 rev/min; weight, approximately 7,000 kg	1	Only for third crushing of feed ore, size 50 mm; capacity, 30 tons/h, or 15 m^3 to 18 m^3 per hour in open circuit	40.0
Cone crusher; maximum feed size, 50 mm x 50 mm x 55 mm; output size, 10 mm; minimum gap width, 3 mm; crusher shell diameter, 900 mm; outside diameter, 1,700 mm; power, 58 kW; motor, 980 rev/min; weight, 9,600 kg	1	Only for third crushing of ore, size 50 mm; capacity, 30 tons/h or 12 m^3 to 20 m^3/h	40.0
D. Milling			
(a) For item 5.1 of annex III, section C Two-stage vertical fiberizer with two heavy hammers; diameter, 48"; input feed size, 20 mm (with small percentage up to 25 mm), or 10 mm of cone crusher; output in first stage milling, 12 mm; output in second stage milling, 6 mm	1	For first and second stages of milling working in rotation; capacity, 15 tons/h	65.00
(b) For item 5.2 of annex III, section C Four-stage vertical fiberizer; diameter, 48"; output size in third stage, 6mm; output size in fourth stage, 4 mm	1	For third and fourth stages of milling working in rotation; capacity, 15 tons/h	75.00
(c) For item 11.1 of annex III, section C Turbo-fiberizer, horizontal fan-type impact mill; power, 40 hp; motor, 2,960 rev/min; weight, 1,200 kg	1	For fiberization of middlings in fibre circuit; capacity, 1 to 2 tons/h	30.0

Type of equipment	Quantity	Function and capacity	Power required (kW)
Alternative			
Ultraplex mill (without screen); motor 3,000 to 3,550 rev/min; weight 1,200 kg	1	For fiberization of middlings in fibre circuit; capacity, 1 to 2 tons/h	30.0
(d) For item 11.2 of annex III, section C	1	For opening of short fibre in the second stage of middlings treatment in the fibre circuit	30.0
Grinder for short fibres; power, 40 hp; weight, 800 kg			
Alternative[b/]			
Desintegrator; diameter, 600 mm; two rotors; feed size, 1 mm; output size, up to 0.5 mm; power, two 5 kW electric motors; weight, 700 kg	1	For opening of short fibre in the second stage of middlings in the fibre circuit; capacity, 2 to 5 tons/h	10.0
Screening machines	1	For first screening in rock circuit; capacity, 70 tons/h	10.0
(a) Three-deck screen; first deck with 100 mm scalping grizzly; second deck with 40 mm x 40 mm iron perforated sheet; third deck with 25 mm x 25 mm iron perforated sheet; weight, approximately 3,500 kg			
(b) Two-deck screen; first deck, perforated iron sheet with 40 mm holes; second deck, perforated iron sheet with 25 mm holes; weight, approximately 2,500 kg	1	For second screening in rock circuit	10.0
(c) Double deck screens for items 2.1, 2.3 and 2.4 of annex III, section C High speed two-deck gyratory screen, 5 ft x 10 ft, with screen cloth fitted on special wood frame to accomodate rubber balls for tapping the screens; first deck with screen cloth of 18 mesh; second deck with screen cloth of 36 mesh	8	For first screening phase with fibre aspiration; capacity, 2.1 tons to 4 tons/h, 2.3 tons to 6 tons/h and 2.5 tons to 7 tons/h	6.00 each

Type of equipment	Quantity	Function and capacity	Power required (kW)
(d) One-deck screens for items 2.2, 2.4 and 2.6 of annex III, section C Screen cloth, 36 mesh; screen equipped with aspiration hood	4	For second screening phase with fibre aspiration; capacity, 3 tons/h	4.00 each
(e) De-dusters for items 6.1 to 6.4 of annex III, section C Single-paddle trommel, or de-dusters; diameter 36"; screen cloth, combination of 15 and 36 mesh	4	For the de-dusting phases of the aspirated fibre concentrate; capacity, 2 tons/h	5.00 each
(f) Screens for items 7.1 to 7.3 of annex III, section C Two-deck screens similar to those specified in (d) above, but without aspirator hood	3	For the cleaning phases of the aspirated fibre concentrate; capacity, 2 to 3 tons/h	4.00 each
(g) Graders for items 10.1 to 10.3 of annex III, section C Standard grader; diameter, 26"	3	For the grading phases of the asbestos fibre; capacity, 1 ton/h	4.00 each
Air separators and cyclones			
(a) Air separator for items 3.1 to 3.3 of annex III, section C Rotary aspirator; diameter, 18"	8	For fibre aspiration during the screening stage involving items 2.1 to 2.6 of annex III, section C; capacity, 3 to 10 tons/h	0.30 each
(b) Air separator for items 8.1 to 8.2 of annex III, section C Gravity air separator; diameter 42"; 900 rev/min	2	Capacity, 1 to 3 tons/h	2.00 each
(c) Cyclone collectors for items 4.1 to 4.6 of annex III, section C Cyclone collector with rotary valves; diameter, 5' 0"	10	For collecting aspirated material; capacity, 6,000 ft^3/min, or 3 tons/h	0.30 each

Type of equipment	Quantity	Function and capacity	Power required (kW)
Other essential machinery			
Mixer - blender for item 12.2 of annex III, section C Mixer - blender; diameter, 9' 0" length, 12' 0"; main drive, 20 hp; feeder, 5 hp	1	For final mixing of fibre	22.0 each

a/ The following points should be noted:

(i) The cone crusher demands some alterations in arrangements for the third crushing. The best location is below the second screen, which would thus become part of a three-deck screen;

(ii) Before the cone crusher is incorporated in the flow-sheet, an industrial test of cone crushing of Pulivendla asbestos ore (less than 40 mm and greater than 10 mm in size) with screen studies of opening asbestos fibre must be completed.

b/ A disintegrator of 30" diameter could also be tried.

Table 27. Installed electrical capacity for the essential machines of the entire plant

Machinery	Power (kW)
Crushers and mills	286
Sieving machines	136
Air separator (without central air station)	10
Mixer	22
Central air system	75
Drier and dried ore storage aspirator	26
Conveyor and elevators	110
Lighting and other equipment	50
Total	715

C-10

79.11.14