IMPERIAL ETHIOPIAN GOVERNMENT
TECHNICAL AGENCY

DEVELOPMENT OF FRUIT PROCESSING INDUSTRIES IN ETHIOPIA

INDUSTRIAL PLANNING

VOLUME I

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I N D E X

Foreward

This volume considers the banana, a species of fruit which could be industrialised immediately.

We first make certain observations of a general nature about the types of product which can be obtained from the banana. These observations are similar to those made by L. Haendler of the Institut Français de Recherches Fruitières Outre-Mer (Produits de transformation de la banane) in the document presented by him to the 1st International Congress of agricultural and primary industries of the sub-tropical and tropical areas.

In the second and third parts respectively we propose the construction of a factory for the production of green banana flour and one to produce dehydrated fodder.

PART I - BANANA BY-PRODUCTS.

In the last fifty years, banana production has become one of the most important forms of world fruit production. With an annual production of 4,000,000 tons, it takes first place, in front of apples and citrus fruit.

In marketing such a large quantity of fruit, a considerable percentage necessarily remains unsold. This percentage is particularly high in the producing countries, both on the farms and at the port of loading.

The fruit which is imported has to be of a certain standard, as regards weight, quality and presentation, and must be healthy. The bananas which do not come up to these standards are discarded, forming the so-called "wastage". For other reasons, some fruit, even if it is of the required standard, cannot be exported (too large a harvest for the banana-boats, delay or non-arrival of the means of transport, or simply over-production). All these reasons, together with the fact that very often the quality of the fruit is defective at certain times of the year, force the producer countries to consider the problem of how to utilise the non-exported fruit.

The possibilities of processing the fruit or foliage of the banana are indicated below.

1) Products which have acquired or which are likely to acquire a certain economic importance.

- dried bananas or fig bananas (°), obtained by drying the fruit, generally whole, when it is ripe;

- creams, pastes, pulps, purées, compotes and jams produced by mashing the flesh of ripe bananas and conserving it under various conditions;

- banana flour (°), obtained by drying and then grinding the flesh of green bananas;

- flakes obtained by drying ripe bananas using the "séchoir tambour" process;

(°) The products marked with this sign are already marketed.

- powder obtained by atomizing the flesh of ripe bananas;
- ice-creams (°);
- baby-food (°).

2) Products of little economic importance or which have not been given great consideration from the point of view of exploitation.

- whole or sliced fruit conserved in various kinds of syrup (°);
- candied fruit (°) and frozen fruit, obtained by the same methods as those used to candy or freeze other types of fruit;
- fodder for animals: fresh or dried products obtained by using the whole fruit, green or ripe, the skins of ripe fruit and the sheaths of the pseudo-trunk;
- fertilizers, using the green parts of the plant;
- fibres and papers, made from the fibrous pseudo-trunk;
- starch extracted from the flesh of the rhyzome;
- syrup and juice extracted from the flesh of the fruit;
- chips (°) obtained by frying slices of banana when still fairly greenm
- alcohol, brandy, wine, beer, liqueurs, vinegar, obtained by fermenting the flesh of fairly ripe fruit.

3) Hypothetical products.

- anti-biotics, extracted from the fruit;
- essences obtained by distillation or extraction from the flesh or skin of the fruit;
- chlorophyll, extracted from the leaves.

Let us first consider the group of products which have already acquired or are likely to acquire a certain economic importance.

a) Dried bananas or fig bananas.

This product is not new; dry bananas have been marketed for a long time. But the products are usually blackish in colour, with a not very inviting appearance and often an unpleasant consistency.

A survey carried out among consumers of various countries confirmed that 75% like the taste of dried bananas, but are discouraged by their unpleasant appearance. A study of the possibility of producing dried fruit of a pleasing flavour, colour and consistency has been carried out by the I.F.A.C.

The composition and the quality of the vegetal material used were examined, in order to establish whether these factors could have any effect on the finished product.

Continuing this first series of studies, a second test was made in Paris and in Guinea, by agreement with the manufacturers of the necessary machinery, and this carried out a detailed study of the following:

- processing of the fruit before drying;

- drying process;

- presentation and packing of the fruit;

- equipment.

As a result of this study it was possible:

i) to define the methods of processing, packing and conservation by which it is possible to obtain a product of pleasing appearance and satisfactory consistency and flavour;

ii) to determine the type of equipment necessary for processing.

On the basis of the data collected during the various studies, precise, detailed projects for the creation of a new dried banana industry could be drawn up.

The results of the analyses shown in Table 1 give an idea of the chemical composition of the product and its food value.

Dried bananas have a very high sugar content, and may be classed as one of the products with a high nutritive value, easily absorbed and with good energy-giving properties, about the same as for dates (316 calories per 100 gr.) or figs (300 calories per 100 gr.); 125 gr. of dried banana per day is sufficient to cover one quarter of the food requirement of a child of 10 years in energy value, glucides, manganese and PP vitamins, vegetable protein, potassium, iron and magnesium. It also covers about one eighth of the phosphorus, chlorine, zinc and vitamin C requirements.

125 gr. of dried banana represents 7-8 dried fruit.

Table 1 - Composition of dried bananas according to various sources.

Substance	L. Randoin analysis: Table showing the composition of various foods 1961	P. Wranckx analysis: Leopoldville chemistry laboratory	G. Brooks analysis: chemistry service of the Ministry of French colonies	Kervegant analysis: The banana and its exploitation.
In grams per 100 gr. of edible matter.				
Calorific value	292	316.85	345	-
Water	-	13	23.20	23.20
Proteins	2.2	3	4.97	3.33
Fats	1.2	1.25	0.56	-
Glucides	66	73.40	67.04	65.17
Pectin	-	-	0.30	-
Cellulose	-	3.55	1.30	-
In mg. per 100 gr. of edible matter.				
Sulphur	36		-	
Phosphorus	90		80.04	
Chlorine	300		-	
Sodium	9		50.12	
Potassium	1140	ash 2.37gr.	854.50	ash 3.02gr.
Magnesium	105		23.34	
Calcium	21		35.30	
Iron	1.80		-	
Zinc	0.69		0.43	
Copper	0.66		0.39	
Manganese	2.10		1.09	
Iodine	-		-	
Ascorbic acid	3.50		2.67	-
Nicotinic acid (PP)....	2.90	-	-	-
Ca/P ratio	0.23	-	0.43	-

b) Creams, pastes and purées.

The various producers of bananas have for a long time been interested in manufacturing these products, which are similar to those made from other types of fruit. Some have tried to manufacture strictly natural products, with a flavour as near as possible to that of the fresh fruit. Others have added fats to the paste, to produce a substance which can be eaten as butter. Let us consider very briefly the techniques of manufacture, which are almost the same.

i) Natural cream.

This must be prepared carefully and extremely rapidly, as otherwise the flesh may take on a violet or blackish colour which is greatly harmful to the preparation.

The ripe fruit are peeled by hand. There are small machines which extract the flesh by squeezing it out of the skin, the ends of the fruit having first been cut off, but the paste obtained by this process has a higher tannin content, and it is not to be recommended if a perfect product is to be obtained. This method also makes it more difficult to blanch the fruit (blanched fruit is much less likely to go black).

After blanching, which is done by steam, and correction of the acidity level, to bring the pH to 4.5, the fruit are mashed and the paste refined according to the type of cream required. At this point other ingredients, such as sugar or acid, may be added, depending on the quality of the finished product which it is desired to obtain. At this stage of the process the paste may also be treated by désaération to be pulverized under vacuum. This avoids the risk of oxydisation, but the paste loses a certain amount of its aroma as a result, and this may harm the quality of the product: the technique must therefore be used with caution.

Sterilization would be advantageous if it is carried out at a high temperature (maximum 130°C) and as rapidly as possible. Flash-pasteurisateurs à plaque may be used to effect this treatment.

The paste is canned under heat, and the cans are turned over as soon as they are filled to ensure that the lid is sterilized. Cooling must be very thorough and takes a long time.

Cans of untreated sheet-steel may be used, but in the case of small cans destined to reach the consumer immediately, it is advisable to use treated tins.

ii) Cream with additional fats.

The selected fats are mixed with the banana pulp; the mixture is pounded hard and the product rendered stable by pasteurisation, as described above. The fat usually used is hydrogenated coconut fat, which has a melting point of about 32°C. During manufacture, every precaution must be taken to reduce as far as possible the oxydisation factor, to avoid the fat going rancid. In certain preparations sugar is also added, the proportions of the various ingredients varying according to the taste of the consumer: 42% banana, 16% sugar and 42% coconut fat is generally considered a good mixture.

Products of this kind are most easily marketed in Scandinavia; sale tests carried out in France have given rather disappointing results.

As regards the "natural" pastes, recent manufacturing tests produced a series of samples which enabled extensive market research to be carried out among the possible clients: the producers of pre-packed breakfasts, ices, cakes, confectionery etc. The product is generally considered to have satisfactory organolectic qualities and an attractive appearance.

Studies on the utilisation of this type of product are at present being carried out; in various sectors it is too early to tell the prospects for sale. However, it would seem from the initial favourable reaction that this product should find sufficient outlets onto the market to ensure the future of an industry specialising in this process.

The composition of the products varies greatly according to the emphasis given to the various factories. The natural creams are fairly similar to fresh banana pulp.

c) <u>Banana flour or slices of green banana.</u>

For this kind of processing green bananas are used, and although in this case the glucides in the product are mainly composed of starch, the treatment is important because it is one of the few which utilise fruit which, for one reason or another, are unable to reach full maturity.

In addition, there is a traditional market for banana flour, and certain well-known producers of pre-packed breakfasts have for some time based their advertising on the fact that they use banana flour in manufacturing their products.

From a technical point of view, the production of sliced bananas, the last stage before the manufacture of flour, has a great deal in common with the process used in drying bananas; however, the methods used are less complicated, and more simple equipment is necessary.

Studies for the production of good quality flour were carried out parallel to those for "fig" bananas, and as a result it was possible to define the systems for obtaining the product and the characteristics of the material to be used according to the working conditions.

The information obtained was used to draw up projects showing the total investments necessary, the volume of credit necessary for operation, and the price estimates of factories of varying capacities.

The results of the analyses of different types of flour, depending on the maturity of the fruit used, are given in Table 2.

As can be seen from the analyses, banana flour largely consists of starch, which gives it its energy value. It is very easily digested and absorbed, and is therefore used in the preparation of special foods for babies, old people and those on a special diet, as it possesses curative properties for gastro-enteritic infections which have been known for a long time.

d) Flakes.

This product, like banana flour, is obtained from the dried flesh of the banana, but in this case the fruit used are ripe, and are dried with the "séchoir-tambour" process.

Table 2 - Composition of green banana flour expressed in grams per 100 gr.

Maturity	Water	Protein	Total Sugars	Reducing Sugars	Saccharose	Starch	Cellulose	Fat	Ash
Green	8.18	3.78	87.25	5.68	5.76	67.51	4.22	1.15	3.23
Semi-green	5.58	3.84	87.62	31.80	7.26	43.35	4.25	1.11	3.28
Semi-ripe	7.73	3.81	83.85	41.50	3.23	35.00	3.58	1.02	3.17
Fully ripe	6.81	3.66	85.00	41.25	13.25	25.98	3.61	1.13	3.19

These analyses should be compared with those made by the Laboratoire de Chimie de Léopoldville and the Institut d'Hygiène alimentaire de Paris.

Green banana flour made from Gross Mitchel variety.
(M.P. Wranckx, Laboratoire de Chimie, Léopoldville)

Water	8.50%
Carbo-hydrates	82.20%
Fats	1.05%
Ash	2.00%
Cellulose	1.69%
Total protein and waste	4.26%
Probable protein	2.00%
Calorific protein per 100 gr.	346.25 Calories

Green banana flour.
Laboratoire de l'Institut d'Hygiène alimentaire Paris
(Hodgman, Atwater et Bryant)

Water	5.00%
Carbo-hydrates	79.90%
Fats	2.3%
Ash	3.06%
Cellulose	3.80%
Protein	4.98%
Calorific value per 100 gr.	283 Calories

This technique, which has been used in the production of dried milk for several decades, consists in spreading a thin layer of the product on the surface of a hot, rotating cylinder; when it is dried it is removed. The principle has been known for many years, but it is not possible to use the same machinery for bananas as for milk, and the first step to be taken is therefore to develop a machine for the treatment of banana pulp.

A prototype has been constructed in collaboration with a French designer, and this has permitted the definition of the manufacturing technique which must be used and the features of the machinery, which could serve as a basis for the construction of machines large enough to be used industrially.

The samples produced in the course of the tests provided the quantities necessary to carry out market research among the main users of this type of product.

The data obtained during the studies made it possible to collect all the information necessary to draw up a project and to create an industry for the production of banana "flakes".

The results of the analyses of the product are given below, together with those of banana powder.

e) Powder.

As for flakes, the processing consists of dehydrating the pulp of ripe bananas, but in this case the treatment used is atomisation, which consists of spraying the banana pulp, in a fine or rather less fine mist into a current of hot air. This method, which has been used for several years for various products, has usually given interesting results. To use this method for the treatment of banana pulp, however, it was necessary to adapt the machinery and to develop the manufacturing techniques.

Studies were made to adapt the material and to establish the process in collaboration with various French and foreign firms specialised in the manufacture of atomisers. These studies made it possible to produce a fine powder, with a good colour and appearance and a taste similar to that of fresh bananas. This product, which may be of interest to many different sectors of the food industry, has in general encountered a favourable reception, its only drawback being its hygroscopicity, which is harmful for certain products, such as food meals for babies and dietetic foods. So far it has not been possible to solve this problem by adapting the manufacturing technique. It seems that the only way of reducing hygroscopicity would be to use the powder mixed with products such as milk, cocoa, lactose, etc., instead of in a pure form, producing certain composite foods. A processing industry would have to be able to produce not only pure powder but also a whole range of mixtures destined to serve as the basis of various food industries.

The analyses of the powder are given in Table 3, together with those of the flakes. The data concerning the products obtained by quick-drying the pulp of ripe bananas indicates the food value of these products, which are mainly a source of energy, being composed of easily absorbed sugars.

The second and third analyses in Table 3, which are fairly similar, correspond to natural powder obtained from ripe bananas. Analysis n° 1 shows the percentage of starch in the product when the fruit is not sufficiently ripe. In analysis 4, the percentage of sugars and the pectin level seem to show that the product is not pure and that other ingredients have been added with the aim of reducing the hygroscopicity.

In the case of the flakes, the percentage of starch and the relative proportion of reducing sugars and saccharose indicates that powder n°5 was formed from less mature fruit than those used for powder n°6.

Calculating the averages of powders 3 and 4 and powders 5 and 6, it can be seen that the ingredients are very similar, and that from this point of view there is little difference between banana powder and flakes.

Table 3 - Composition of powder and "flakes" from ripe bananas (gr.per 100).

	Ripe Banana Powder				Flakes	
	Von Loeseke Analysis 1	IFAC Analysis 2	S.Africa control Laboratory Analysis 3	IFAC American Powder Analysis 4	Elesca Maille Analysis. 5	IFAC Analysis. 6
Total dry extract at 70°C	=	=	=	89.6	=	=
Insoluble extract	=	=	=	18.4	=	=
Wastage at 100/110°	=	=	=	=	4.10	=
Humidity in sulphur vacuum	2.59	2.65	4.00	10.4	0.66	1.00
Mineral substances	=	=	=	=	2.47	=
Ash	3.05	3.08	3.0	=	=	2.3
Reducing sugars..	15.62	25.92	27.6	15.25	19.90	39.5
Saccharose	33.25	44.90	46.2	8.45	50.10	40.5
Starch	29.87	3.71	=	8.1	14.95	5.0
Total sugars	48.87	70.82	73.8	23.7	70.00	80.0
Cellulose	=	1.01	=	1.00	1.52	1.0
Pectic substances	=	2.14	=	11.6	1.0	1.0
Nitrogen	=	=	=	=	0.98	=
Proteic substances (N x 6.25)	4.09	6.62	5.06	=	6.12	4.69
Carbohydrates ...	=	=	=	=	88.15	=
Fat Content	1.91	=	=	=	traces	=
Ascorbic acid (mg. per 100 g)	=	=	33.0	=	=	=
Calcium (mg. per 100 g)	=	=	=	=	67.00	=
Phosphorus (mg. per 100 g).....	=	=	=	=	12.00	=
Ca/P ratio	=	=	=	=	5.58	=
Calories per 100 g.	=	=	=	=	388.00	342.0

Conclusions.

The general trend of the banana market and the development of the various processing techniques lead one to think that the quantities of fruit which remain unsold in the producing countries will be of increasing importance, and that the necessity of exploiting this production will likewise become more pressing.

It can be seen from this study that considerable research has been made into the most important methods of processing, the techniques used being studied and developed, leading to the conclusion that the banana can be conserved in various forms and in good conditions.

The products obtained, which have a pleasing taste, are mostly of high food value, and should find a ready market. Many efforts must be made in commercialising the products. Market research and the search for new outlets must become the main concern of those interested.

PART II - GREEN BANANA FLOUR FACTORY

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INTRODUCTION

Green banana flour is a product used especially in the preparation of baby foods. In many producing countries this product is obtained by natural drying in the sun, which gives a flour with a higher water and sugar content, containing less starch and with unsatisfactory flavour and colour.

If artificial methods of drying are used, the process can be controlled and these characteristics considerably improved.

The productive capacity of the proposed factory is 900 tons/year of green banana flour, which corresponds to 5,000 tons/year of raw material, working one shift of eight hours per day and 250 days per year.

The actual drying operation will be carried out 24 hours per day, for obvious reasons of economy.

This project is based on the assumption that, at least in the first few years of production, the flour will be destined for the home market and will be packed in cloth bags containing 50 Kg., lined with plastic material.

The bananas used to make the flour should be three-quarters ripe, and should have been harvested no more than 24 hours previously. Under these conditions the fruit contains a sufficient percentage of starch and sugar to obtain a smooth and highly nutritive flour.

The factory will provide employment for 67 persons, of which 59 will be manual workers and 8 administrative and sales staff.

The total investment necessary, excluding the cost of the land, is estimated at 1,033,000 Eth. doll., of which 800,000 Eth. doll. corresponds to the fixed capital and 233,000 Eth. doll. to the working capital.

The profit after one year of operation will be 421,000 Eth. doll., which represents a yield on the total investment of 41.5%.

The break-even point will be reached with a production of 327.600 tons of green banana flour per year, i.e. when 36.4% of the proposed annual production capacity is used.

The enterprise can make use of the benefits provided under the law on industrial development, i.e. exemption from taxes on the importation of materials and equipment, and perhaps also from taxes on sale and income for a period of time to be established by the appointed authorities.

I - MARKET

1. Characteristics of the product
2. Demand
3. Prices

1. Characteristics of the product

The term "banana flour" refers to the product obtained by drying and then grinding green bananas.

Since the flour is extremely digestible and easily absorbed, it is particularly widely used as an ingredient in the preparation of special diets, such as special foods for babies and old people.

Green banana flour, and also plantain flour, which is very similar and is generally consumed in the country, is produced on a domestic scale in fairly small quantities. Production on an industrial scale would give a product of a better quality which could be marketed abroad.

According to the surveys carried out by the team of experts, green bananas can be bought in the producing areas for a price of 110 Eth. doll. per ton, transported to the factory.

2. Demand

Plantain flour has been the product normally, if not very widely, consumed in the country; only in the last few years has green banana flour been produced, and then on a small, family scale, to supplement the diet of that section of the population who get their food directly from the plots of land they cultivate, the value of which it is not possible to estimate owing to the distributive capillarity.

It can be calculated, however, that about 10,000 tons of these two products is absorbed, or rather consumed, per year, and of this green banana flour represents about 85%.

The production of the proposed factory will at first interest only the home market, but will later be exported, especially to Saudi Arabia and the European markets such as Italy, West Germany and the Scandinavian countries.

3. Sale prices

The sale price of the product, first on the home market and later abroad, may be 350-450 Lire per Kg. from the factory, corresponding to 1.40-1.60 Eth. doll. per Kg.

The same price can be maintained for sale on foreign markets, increasing it by the transport cost to the port of loading to give an F.O.B. price.

The present project assumes that the production of the factory will be sold to wholesalers in this sector, in order to avoid some of the tasks connected with the distribution and sale of the product.

II - Engineering of the project

1. Raw material
2. Physical, chemical and organolectic characteristics of the product
3. Production lines
4. Flow diagram
5. Production capacity
6. Location

1. Raw material

Green bananas which are 75% mature are used to make the flour. If the degree of maturity is any less, the flour produced has a slightly bitter and astringent flavour, and if the fruit is too ripe, the flour is yellowish, with a pleasant taste and appearance, and a characteristic smell, but dehydration is very difficult.

Fruit at an ideal stage of maturity can be obtained from the plantations or the grading centres for the production of green banana flour.

In order to achieve the production of flour proposed in this project, about 225,000 branches of bananas weighing approximately 23 Kg. each will be necessary.

The average characteristics of the type of green banana used for this project are shown in Table I.

Table I - Average yield of green bananas

	%
Percentage of stem per weight of branch	11.40
Percentage of pulp per weight of bananas in bunches	67.00
Humidity level of pulp	75.00
Percentage of flour with 8% humidity obtainable from peeled green bananas	27.00
Percentage of flour with 8% humidity obtainable from green bananas on the branch	16.20

To produce one ton of green banana flour with 8% humidity 6170 Kg. of green bananas on the branch are necessary, corresponding to about 250 branches.

2. Physical, chemical and organolectic characteristics of green banana flour

The problem of the production of green banana flour has been studied in detail, especially in the producing countries where there is a great need for the industrial processing of the banana.

During 1969 our team of experts visited several of these countries to collect all possible information concerning banana processing which might be of any interest for our study.

In particular, we followed very closely the studies carried out to analyse samples of green banana flour and to compare analyses of green banana flour obtained by artificial means, i.e. using a drying plant, and green banana flour produced by natural means, i.e. by sun drying.

The above-mentioned analyses took into account different qualities of banana, including several with characteristics similar to those of the type of banana at present produced in Ethiopia. In Tables 2 and 3, the comparative data resulting from these analyses is shown.

2.1 Chemical characteristics

The chemical analyses, of which the results are given in Table 2, demonstrated that this product has a high energy value, due to its large starch content.

Analyses were then carried out to determine its composition as regards humidity, proteins, reducing sugars, starch, raw fibre and solids insoluble in alcohol; the results of these analyses are shown in

Table 2 - Chemical analyses of green banana flour obtained from the "Gros Mitchel" type of banana

Substance	Amount
Water	8.50%
Carbo-hydrates	82.20%
Fats	1.05%
Ash	2.00%
Cellulose	1.69%
Total protein and waste	4.26%
Probable protein	-
Calorific value (per 100 gr.)	346 cal.

Note: The data given in the above table was taken from a study by the Institut Français Investigations Fruitières de Outre Mer.

Table 3.

The following conclusions can be drawn from the results of these analyses:

a) the humidity level of the flour produced by a drying plant is lower than that of flour dried naturally in the sun; this fact enables artificially produced flour to be kept longer than that produced naturally;

b) the quantity of reducing and non-reducing sugars in artificially produced flour is less than that in naturally produced flour, but the level of starch is higher;

c) as regards the content of solids soluble in alcohol, raw fibre and protein, there is no appreciable difference in the two cases.

2.2 Physical characteristics

As can be seen from Table 3, there is practically no difference between the density of artificially produced flour and that of naturally produced flour.

2.3 Organolectic characteristics

The samples to be studied were placed separately in small containers; they were then exposed to natural light in order to establish the difference in colour. The samples produced artificially were preferred, as they had a better appearance after the test.

Table 3 - Comparative chemical analysis of banana flour obtained by artificial means and that obtained by natural means

Content	SAMPLES				
	Artificial methods			Natural methods	
	1	2	3	4	5
Humidity	9.10	8.95	9.53	10.20	11.40
Reducing sugars	1.01	1.09	1.00	3.07	3.11
Non-reducing sugars	3.62	3.78	3.76	4.91	4.73
Starch	65.78	66.04	66.13	60.24	61.05
Solids insoluble in alcohol	85.07	84.92	85.04	86.66	87.40
Raw fibre	0.98	0.90	0.91	1.10	1.21
Protein	3.45	3.59	3.75	3.69	3.66
Density	0.66	0.66	0.67	0.79	0.75

Source: Laboratory of the Faculty of Chemical Engineering, University of Guayaquil

3. Description of the production lines

The production of green banana flour is divided into the following phases:

3.1 Selection of raw material

For the production of green banana flour it is best to use bananas which are 75% ripe, cut not more than 24 hours previously. In this condition the banana contains a sufficient percentage of starch and sugars, and dehydration is more economic.

3.2 Separating the bunches

The bunches of bananas are separated from the stem by hand, using a stainless steel knife, and the bananas are then separated in the same way.

3.3 Washing

During this operation the foreign substances and micro-organisms adhering to the skin of the banana are removed, in order to guarantee that the pulp will be uncontaminated for the next phase of the process.

After the preliminary wash in cold water, and another in hot water (40-45°C), the bananas are washed for a third time in water heated to 70-75°C. This operation makes it easier to remove the skin adhering to the outside of the mesocarp.

These three operations may be carried out in 5-6 minutes, using ordinary drinking water with no chemical substance added.

3.4 Peeling

The bananas are peeled by hand, using a stainless steel knife.

3.5 Chopping

In order to make drying easier, the flesh of the bananas is cut across and lengthwise into sections 2-3 cm. thick.

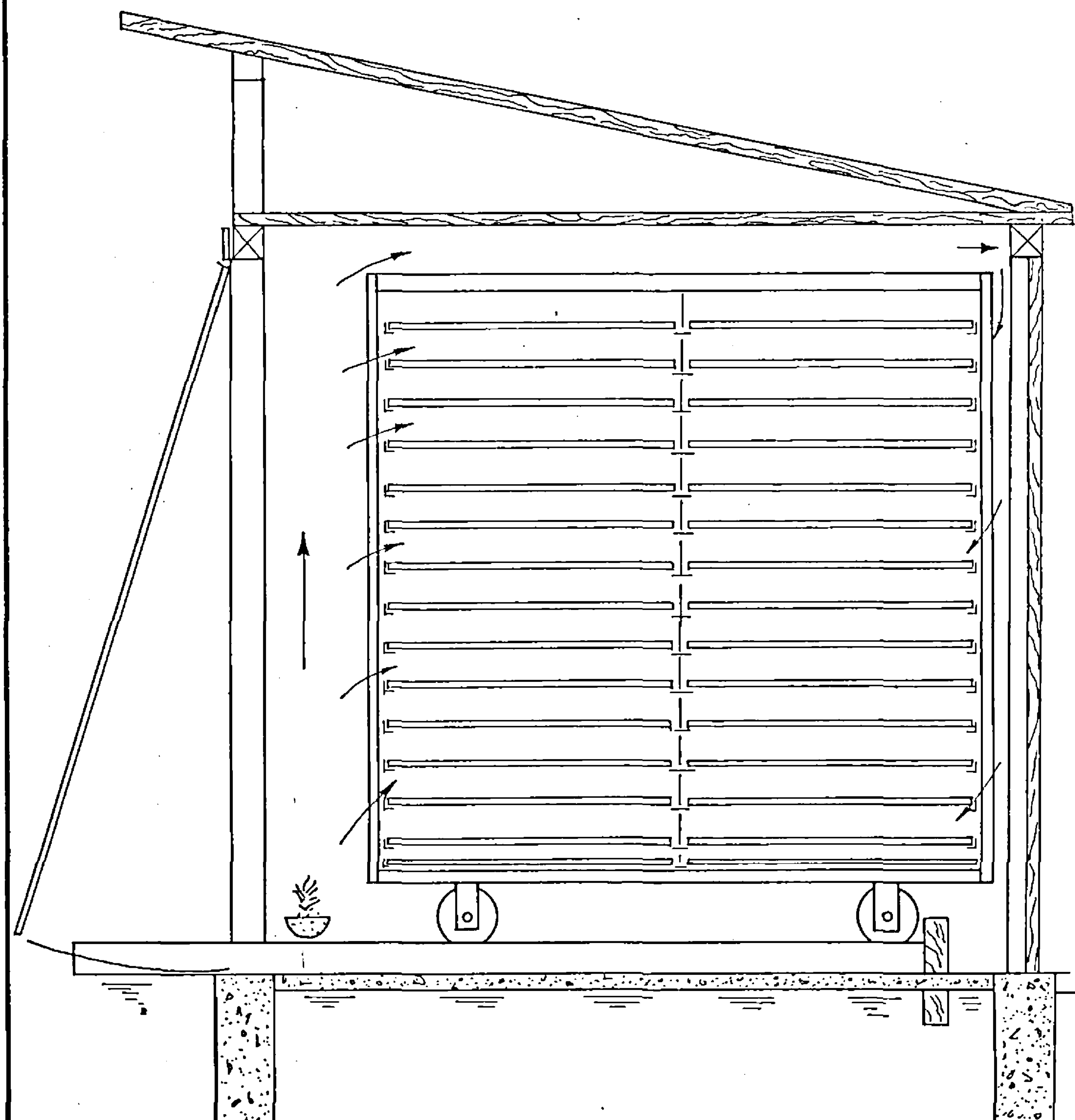
3.6 Sulphatization

The object of this process is neutralize the action of the enzymes, when the pulp comes into contact with the oxygen of the air, to avoid changes in colour, flavour and vitamin content.

The process consists of exposing the chopped pulp of green bananas to an atmosphere of sulphur dioxide for a period of 20-25 minutes.

This operation is carried out in a specially constructed room of very simple design, as can be seen from drawing n° 1.

Drawing - 1 SULPHATIZATION ROOM



CROSS SECTION

SCALE 1:20

3.7 Drying

To obtain the best results, the chopped pulp should be dried in tunnel driers. The method proposed for this project is described below.

The chopped flesh of the green bananas is put into containers with a surface area of one square metre, in the form of wire mesh supported by a wooden frame, each one with a capacity of about 10 Kg. These trays are then piled onto metal trolleys, which are in their turn put into the drying tunnel; here hot air circulates in the opposite direction to the movement of the trolleys, parallel to the surface of the trays.

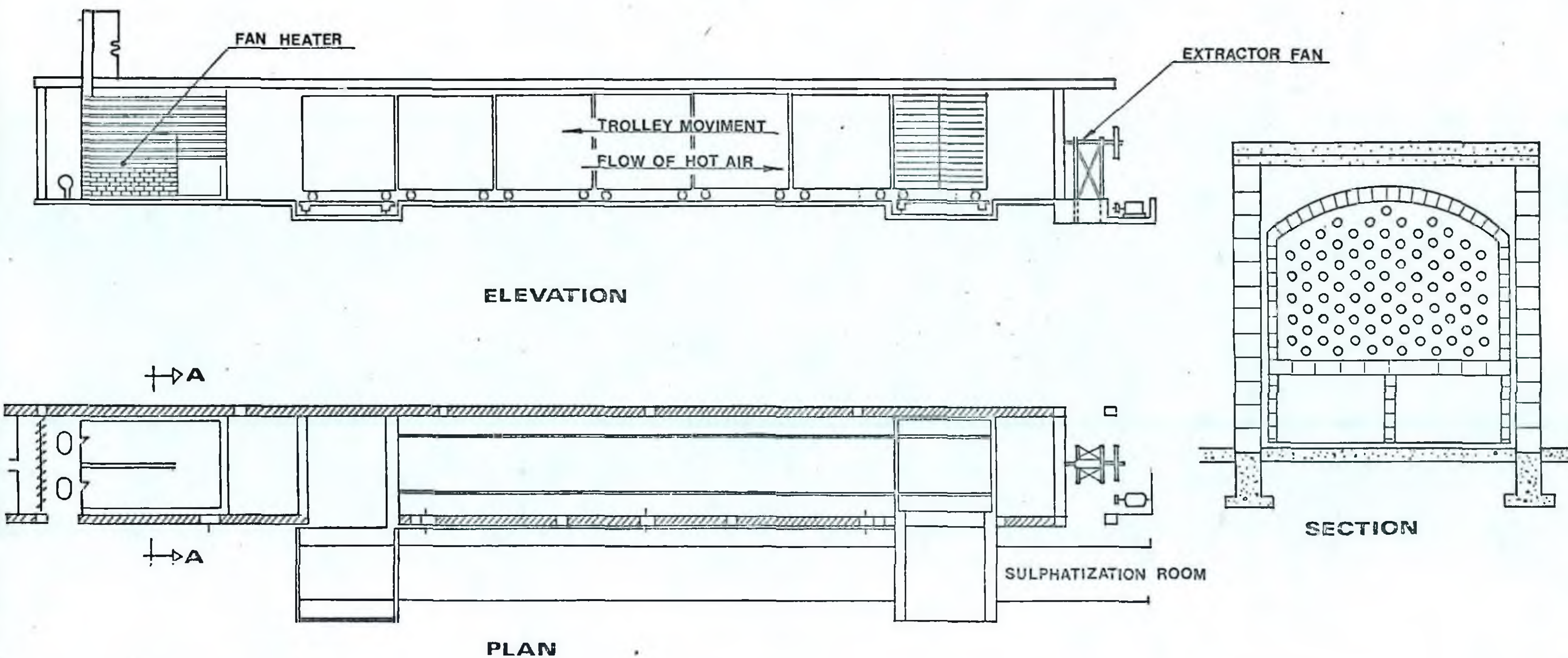
The hot air provides the warmth necessary to evaporate the water contained in the vegetable fibres of the banana pulp, and transports the water vapour formed to the outside of the tunnel.

The drying tunnel for the factory proposed in this study will dry the product in a period of 7-8 hours, according to the working conditions.

The chopped flesh of the green bananas is dried until a humidity level of 8% is reached; with this water level the product can easily be ground and stored.

The general type of drying tunnel proposed is illustrated in drawing n° 2.

Drawing 2 - DRYER LAY-OUT



3.8 Grinding

When the chopped, dried pulp comes out of the tunnel, it is left to cool at room temperature and then sent to be ground in the mill.

3.9 Sifting

The product obtained by grinding the dried pulp then passes to rotating or vibrating sieves. The fineness of the flour produced depends on the size of the mesh of the sieve.

3.10 Packing

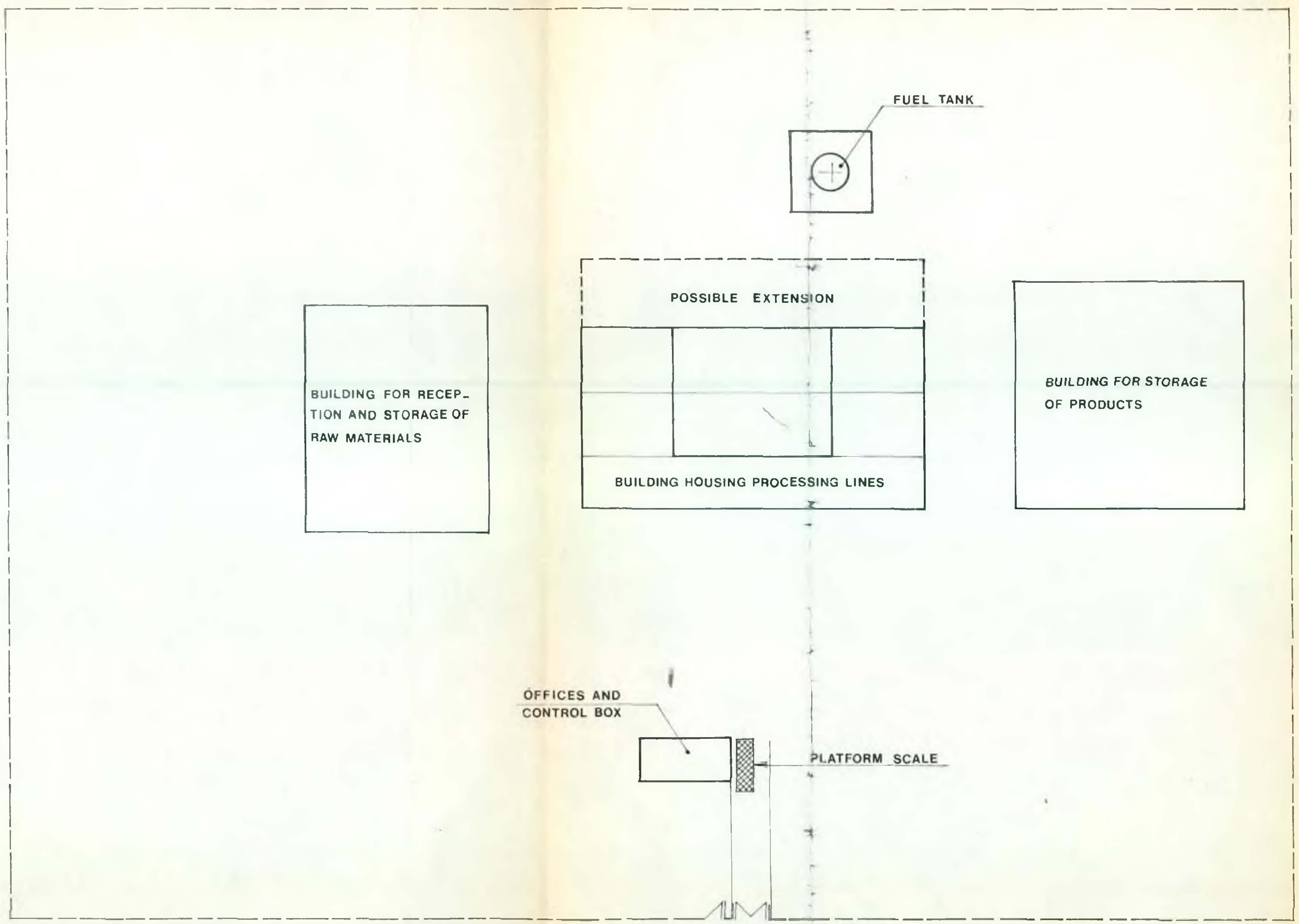
Green banana flour is a highly hygroscopic product, for which reason it must be packed in containers of plastic material, which must then be perfectly sealed.

The packing proposed in this project for sale is in linen bags lined with polythene, with a capacity of 50 Kg.

3.11 Storage

The green banana flour produced must be stored in very dry warehouses until it is sold.

On the basis of the above brief description, the lay-out of the factory has been planned, as shown in drawing n° 3 - General lay-out of the factory, and the Flow diagram.



Drawing. No 3 - GENE

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FLOW DIAGRAM

Arrival and storage of raw material	20 ton/day = 800 branches/day
Selection of raw material	20 ton/day = 800 branches/day
Separation of the bunches	
Washing	
Peeling	
Chopping	13,4 ton/day
Sulphatization	
Drying	
Grinding	3.62 ton/day
Sifting	
Packing	
Storage	

5. Production Capacity

The working capacity of the factory proposed in this project is 20 ton/day of green bananas on the stem, corresponding to approximately 800 branches per day.

With this capacity, working 250 days/year with one eight-hour shift per day (except for the drying section), the factory could process 5,000 tons of green bananas per year. The conditions necessary for making full use of this capacity are listed below.

5.1 13.4 tons of chopped green bananas must be produced per eight-hour working day.

5.2 The above-mentioned 13.4 tons of chopped bananas will be dried in a period of 24 hours, working continuously throughout the day.

The drying tunnel must be planned in such a way that as a trolley of dried pulp comes out, a trolley of fresh pulp goes in; this operation will take place about every 70 minutes.

The drier has a capacity of 7 trolleys, each bearing 60 containers (trays), which each hold 10 Kg. The total load of each trolley is therefore about 600 Kg. of fresh chopped bananas.

The fresh chopped bananas are dried until the water content is reduced to 8%, and the yield of the drying process, i.e. of fresh pulp to dry pulp, is 27%. In all, therefore, the drying tunnel produces 3.62 tons of dry pulp in a 24-hour working day.

5.3 The 3.62 tons of dried pulp produced per day is ground, sifted and packed. This operation can be done in one shift of eight hours per day.

It must be remembered, however, that the dried pulp must not be left exposed to the atmosphere for too long, and therefore, because of the difference in the working hours between the drier and the mill, storage must be provided which will maintain a low water content of the pulp until it is ground.

Thus, working 250 days/year, the factory will have a production capacity of about 900 tons/year of green banana flour.

6. Location

The complex under consideration could be sited in Eritrea, at Elaberet or Agordat for example, or alternatively in the second banana-producing region, i.e. the Awash Valley.

The factory should preferably be sited in a central position in relation to an area of production, or integrated with a fruit and vegetable centre.

In these zones it would be easy to find the necessary labour force, there would be good transport facilities and connections for water and electricity.

III - ECONOMIC ANALYSIS

- NOTE

1. Investments

2. Profit and loss

3. Break-even point

NOTE

The cost of the site for the factory has not been included in the economic estimate of the project. This has been necessary to give an indication of the feasibility of the factory, independently of its location, as it might be constructed in two completely different areas of the vast territory of Ethiopia.

In addition, we have noted that the large property owners in Ethiopia are often disposed to cede part of their land to industrialists wishing to build factories in the country, themselves taking part in the operation in the form of share-holders.

Finally, since the development of fruit-growing in Ethiopia is under the direct patronage of the authorities, they could put at the disposal of the industrialists certain lands near or forming part of the banana plantations, thus giving an incentive to Ethiopians and foreigners who might be interested in this form of investment.

1. Investments

1.1 Fixed investments

	Eth. doll.
- Civil works	184,000
- Equipment and machinery	400,000
- Auxiliary supplies	18,000
- Various costs	140,000
- Incidental expenses (~8% of 742,000 Eth. doll.)	58,000
TOTAL FIXED INVESTMENTS	800,000

1.2 Working capital

1.2 Working capital	233,000
1. TOTAL INVESTMENT	1,033,000

2. Profit and loss

	Eth. doll.	%
- Net return on sales	1,350,000	100.00
- Production cost	762,010	56.50
Net profit on production	587,990	43.50
- Sale cost	108,000	8.00
Net profit on sale	479,990	35.50
- Technical and administrative personnel	59.100	4.37
Net profit of the operation before counting any taxes or other legal deductions	420,890	31.13

Profit on total investments

$$\frac{420,890}{1,033,000} \times 100 = 41.5\ \%$$

3. Break-even point

The break-even point of the project is at approximately 36% of the nominal production capacity.

I_p = Estimated takings 1,350,000 Eth. doll.

C_f = Fixed costs 241,110 " "

C_v = Variable costs 688,000 " "

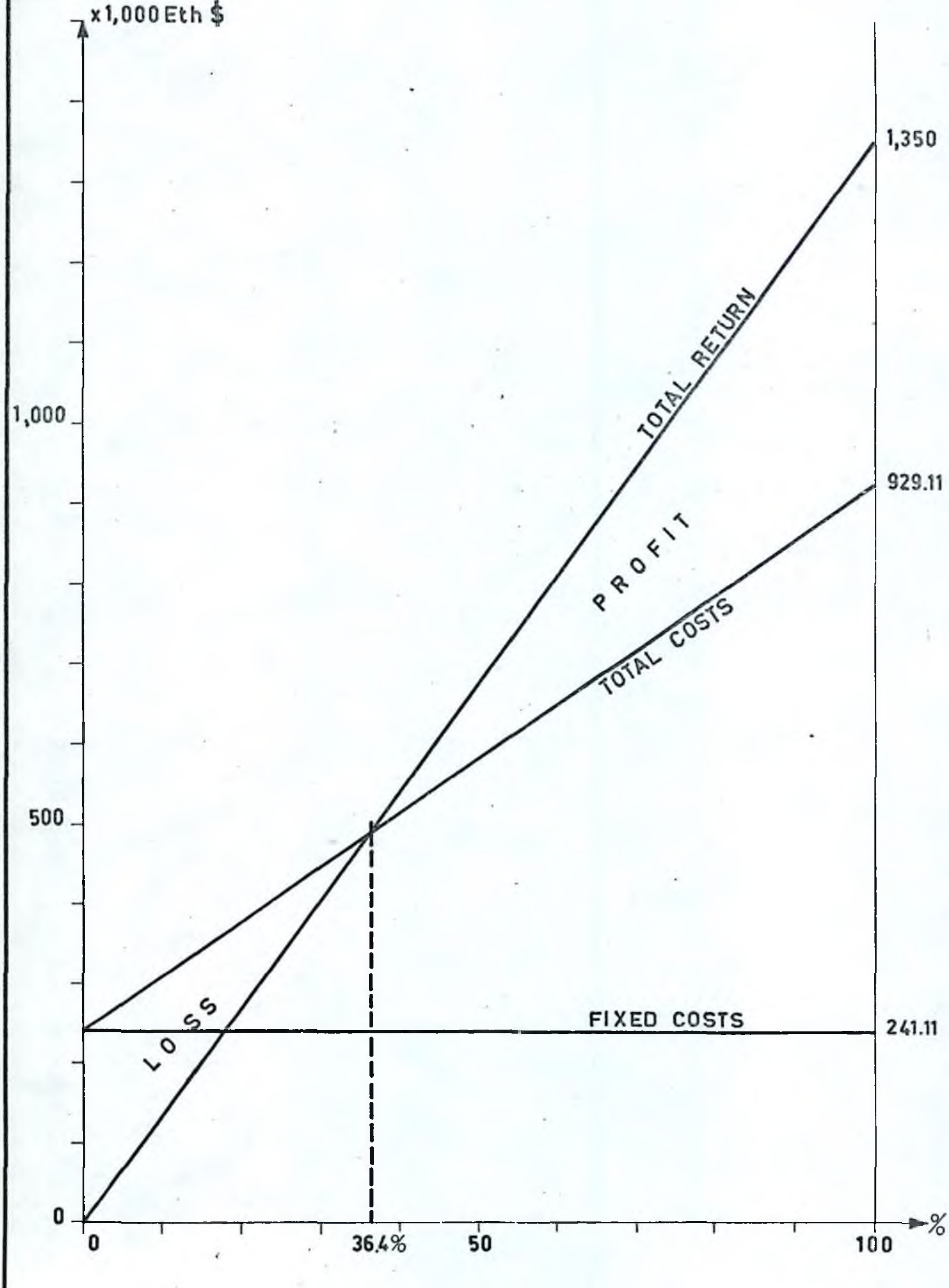
x = Break-even point, i.e. the level of production at which the takings are equal to the expenses (in percentage of the nominal capacity).

$$I_p.x = C_f + C_v.x$$

$$x = \frac{C_f}{I_p - C_v} = \frac{241,110}{1,350,000 - 688,000} = \frac{241,110}{662,000} = 0.364$$

In Graph n° 1 the costs and takings are shown with relation to production, and from the intersection of the graph of total takings and that of total costs the break-even point can immediately be seen.

Graph. 1 - EXPENDITURE AND RETURN WITH REGARD TO PRODUCTION



IV - ADDENDA

1. Civil works
2. Equipment and machinery
3. Auxiliary supplies
4. Various costs
5. Sales
6. Raw material
7. Indirect costs
8. Direct manual workers
9. Various expenses
10. Insurance
11. Analysis of annual costs
12. Production cost
13. Total running costs
14. Working capital

1. Civil works

ITEMS	Area in m^2	Unit cost in Eth. doll.	Total cost in Eth. doll.
- Building housing processing lines	300	200.0	60,000.0
- Building for reception and storage of raw material	200	140.0	28,000.0
- Building for storage of finished product	250	160.0	40,000.0
- Lay-out of site and earth-works (1)	5,000	-	50,000.0
- Fencing (2)	300	20.0	6,000.0
TOTAL COST OF CIVIL WORKS			184,000.0

(1) - This estimate has been made on the assumption that the site is ideal, with no large trees to be removed, flat and with no rocks in the subsoil.

(2) - The fencing is shown in linear metres.

2. Equipment and machinery.

ITEMS	n°	Unit cost in Eth. doll.	Total cost in Eth. doll.
- Tunnel drier	1	160,000	160,000
- Sulphatization room	1	16,000	16,000
- Conveyor belts	6	4,000	24,000
- Chopping machine	1	20,000	20,000
- Container for chopped fruit	2	2,000	4,000
- Metal trolleys for trays	15	1,000	15,000
- Wooden trays	1,000	10	10,000
- Platforms for trolleys	2	1,000	2,000
- Container for dried fruit	1	10,000	10,000
- Bucket elevator	1	6,000	6,000
- Mill	1	20,000	20,000
- Rotating sieve	1	10,000	10,000
- Bag-sewing machine	2	2,000	4,000
- Platform scale	1	20,000	20,000
- Scale	2	1,000	2,000
- Water and heating installations	-	-	12,000
- Electrical installations	-	-	40,000
- Internal means of transport	-	-	10,000
- Various expenses and contingencies	-	-	15,000
TOTAL COST OF EQUIPMENT AND MACHINERY			400,000

(1) - The costs are calculated on the work site, i.e. to the building yard.

3. Auxiliary supplies

ITEMS	Total cost in Eth. doll.
- Office equipment	8,000.0
- Laboratory	4,000.0
- Various accessories for the factory	6,000.0
TOTAL COST OF AUXILIARY SUPPLIES	18,000.0

4. Various costs

ITEMS	Total cost in Eth. doll.
- Installation and erection of processing lines	60,000.0
- Engineering services	50,000.0
- Cost of organization and establishment of firm	10,000.0
- Interest during construction	20,000.0
TOTAL VARIOUS COSTS	140,000.0

5. Sales

- Product	: Green banana flour
- Ex-factory sale price	: 1.5 Eth. doll./Kg.
- Quantity produced	: 900 ton/yr.
- Total return	: 1,350,000.0 Eth. doll./yr.

6. Raw Material

- Raw material	: Green bananas, about 75% ripe, bought in branches with an average weight of 25 Kg. each
- Unit price at factory	: 110.0 Eth. doll./ton
- Annual consumption	: 5,000 tons
- Total value	: 550,000.0 Eth. doll./yr.

7. Indirect costs

Administrative and technical personnal

	n°	Monthly salary in Eth. doll.	Total in Eth.doll.
- Technical manager	1	1,600	19,200
- Factory foreman	1	800	9,600
- Accountant	1	600	7,200
- Secretary/typist	2	200	4,800
- Gatekeeper	1	100	1,200
- Chauffeur	1	150	1,800
- Storekeeper	1	150	1,800
TOTAL	8		45,600
- Incidence of social benefits (13%)			5,900
- Bonus			3,800
- Reserve fund			3,800
INDIRECT COSTS - ANNUAL TOTAL			59,100

8. Direct manual workers

	n°	Monthly wages in Eth.doll.	Annual total in Eth. doll.
- Workers receiving incoming raw material	4	150.0	7,200.0
- Peeling	45	80.0	43,200.0
- Separating bunches	4	80.0	3,840.0
- Chopping	2	80.0	1,920.0
- Drying	2	200.0	4,800.0
- Packing	2	150.0	3,600.0
Total	59		64,560:0
- Incidence of social benefits 13 %			8,390.0
- Bonus			5,380.0
- Reserve fund			5,380.0
Total annual cost			83,710.0 ========

9. Various expenses

	Quantity	Unit price in Eth. doll.	Total cost in Eth. doll.
A. Auxiliary materials			
- Sacks of material lined with polythene	18,000	1.0	18,000.0
- Sulphur (Kg.)	2,000	0.8	1,600.0
- Thread	-	-	800.0
A. TOTAL ANNUAL COST			20,400.0
B. Materials consumed			
- Fuel (lit.)	10,000	0.2	2,000.0
- Water (cu.m.)	5,000	0.1	500.0
- Lubricants	-	-	100.0
B. TOTAL ANNUAL COST			2,600.0
C. Maintenance and repair			7,000.0
D. Stationary etc.			900.0
VARIOUS EXPENSES - TOTAL (A + B + C + D)			30,900.0

10. Insurance

	Eth. doll.
- Civil works (1% of 184,000 Eth. doll.)	1,840.0
- Equipment and machinery (1% of 510,000 Eth. doll. (1))	5,160.0
TOTAL INSURANCE	7,000.0

(1) - Estimated value of equipment and machinery installed, including engineering services.

11. Analysis of annual costs

	Eth. doll.
11.1 General expenses	
11.1.1 Personnel	
- Administrative and technical personnel	59,100
- Manual workers	83,710
TOTAL PERSONNEL	142,810
11.1.2 Materials consumed	
- Additional materials	20,400
- Fuels	2,600
- Maintenance and repair (spare parts)	7,000
- Stationary etc.	900
TOTAL MATERIALS CONSUMED	30,900
11.1.3 Insurance	7,000
11.1.4 Raw Material	550,000
11.1 TOTAL GENERAL EXPENSES	730,710

11.2 Depreciation and amortization	Eth. doll.
11.2.1 Buildings and constructions	
Amortization in 20 years (5% of 184,000 Eth. doll.)	9,200.0
11.2.2 Equipment and machinery	
Amortization in 10 years (10% of 400,000 Eth. doll.)	40,000.0
11.2.3 Office equipment	
Amortization in 10 years (10% of 8,000 Eth. doll.)	800.0
11.2.4 Laboratory	
Amortization in 10 years (10% of 4,000 Eth. doll.)	400.0
11.2.5 Various accessories for the factory	
Amortization in 5 years (20% of 6,000 Eth. doll.)	1,200.0
11.2.6 Contingencies	
Amortization in 10 years (10% of 58,000 Eth. doll.)	5,800.0
11.2.7 Installation and erection of processing lines	
Amortization in 10 years (10% of 60,000 Eth. doll.)	6,000.0

11.2 continued.	Eth. doll.
11.2.8 Amortization of non-depreciating goods:	
- Engineering services	
Amortization in 15 years (6.67% of 50,000 Eth. doll.)	3,335.0
- Organization and establishment of firm	
Amortization in 10 years (10% of 10,000 Eth. doll.)	1,000.0
- Interest during construction	
Amortization in 5 years (20% of 20,000 Eth. doll.)	4,000.0
- Amortization of working capital (8% of 233.000)	18,665.0
Total 11.2.8	27,000.0
11.2 - TOTAL AMORTIZATION AND DEPRECIATION	90,400.0

11A.3 Sale costs (1)	Eth. doll.
- bank dues, customs duties and dispatch costs (8% of 1,350,000 Eth. doll.)	108,000.0

(1) - Sale is considered as from the factory, and includes only the expenses mentioned above, excluding transport costs to the port and the possible rent of a warehouse in the port.
The economic analysis is therefore valid for the construction of a complex in either Eritrea or the Awash Valley.

			Eth. doll.
11.4	Recap of annual costs		
	11.4.1	General expenses	730,710
	11.4.2	Depreciation and amortization	90,400
	11.4.3	Sale costs	108,000
		11.4 TOTAL ANNUAL COSTS	929,110

11.5	Division of costs: fixed and variable	Eth. doll.
11.5.1	Fixed costs	
	a) Administrative and technical personnel	59,100
	b) Insurance	7,000
	c) Depreciation and amortization	90,400
	d) Direct manual labour	83,710
	e) Stationary etc.	900
	11.5.1 TOTAL FIXED COSTS	241,110
11.5.2	Variable costs	
	f) Raw material	550,000
	g) Other material consumed	30,000
	h) Sale costs	108,000
	11.5.2 TOTAL VARIABLE COSTS	688,000
	11.5. TOTAL ANNUAL COSTS	929,110

12. Production cost

	Eth. doll.	%
1. Raw material	550,000	70.00
2. Workers	83,710	10.65
3. Materials consumed	30,900	3.94
4. Insurance	7,000	1.21
5. Amortization and depreciation	90,400	14.20
	762,010	100.00

Average cost per ton of flour produced = 846.47 Eth. doll.

13. Total running costs

	Eth. doll.
- Production cost	762,010
- Sale cost	108,000
- Administrative and technical personnel	59,100
	929,110

Total average cost per ton of flour produced = 1,032.34 Eth. doll.

14. Working capital — Eth. doll.

14.1 Necessary stocks

14.1.1 Raw material

Stock of raw material in the factory for 2 months' operation:

$550{,}000 \times \frac{2}{12} =$	9,190

14.1.2 Materials consumed

Auxiliary materials, fuels, maintenance and repaire, calculated for 3 months' operation:

- Auxiliary materials:	20,400
- Materials consumed :	2,600
- Maintenance and repair :	7,000
- Stationary etc. :	900
	30,900

$30{,}900 \times \frac{3}{12} =$	7,725

14.1.3 Finished product

A store of two months' production is presumed, the costs being estimated as follows:

- general expenses :	730,710
- sale costs :	108,000
Annual total :	838,710

$838{,}710 \times \frac{2}{12} =$	139,785
14.1 TOTAL NECESSARY STOCKS	156,700

14.2	Suspended cash credit	Eth. doll.
	It is presumed that payment will be made every 30 days:	69,900
14.3	Minimum cash balance	
	4% of 14.1 (156,700)	6,400
14.	TOTAL WORKING CAPITAL	233,000

PART III - DEHYDRATED BANANA-LEAF FODDER FACTORY

I N D E X

1. Introduction

The country offers good natural conditions for raising livestock, both dairy cattle and animals for meat. The prospects for the export market of these products are very good, and it would be worth while developing this important sector.

This fact, which is generally recognized, naturally means that the demand for fodder will increase, and from our point of view we would advise the construction of a plant for the production of banana-leaf fodder; the study reported below demonstrates the feasibility of such a project.

If fodder of the type proposed by us were available, the farmers, both on the plateau and in the other regions would be able to face the droughts which occur periodically in Ethiopia and which hinder the development of animal farming.

Besides the direct advantage which would be obtained in the field of animal rearing, there would also be the indirect advantage of improving the agricultural possibilities by making use of a product which has until now been largely ignored.

If such a plant were constructed, it would provide the farmer with a product very rich in protein, for the preparation of a suitable diet. This type of fodder could be sold at an extremely reasonable price, mainly due to the low cost of the raw material: in fact, the only real cost would be the collection of the banana leaves and their transportation to the factory.

There should be no problems as regards obtaining sufficient quantities of banana leaves, as any area selected in the study has large areas of banana plantations.

2. Summary of the project

2.1 Description of the product

2.2 Market

2.3 Industrial protection

2.4 Production

2.5 Location

2.6 Investments

2.7 Profit, return and break-even point

2.8 Sale prices

2.9 Employment of personnel

2. Summary of the project

2.1 Description of the product

Dehydrated fodder made from banana leaves could form part of the diet of cattle.

The fodder is obtained by dehydrating and grinding the banana leaves and forming pellets.

2.2 Market

The project is based on the assumption that all the fodder produced will go to the local market, which, as will be shown in the relevant chapter, could easily absorb the 8,064 tons it is proposed to produce.

2.3 Industrial protection

The enterprise will have the benefit of the law providing exemption from taxes on the importation of machinery during construction and from various taxes and duties (tax on return etc.) during operation.

2.4 Production

By working four shifts per day, 280 days per year, the plant could produce 8,064 tons of fodder per year, corresponding to 35,482 tons/year of banana leaves.

2.5 Location

The zones which would be best for the construction of this plant, as for the banana flour factory, are: Elaberet, Agordat, Keren in Eritrea.

2.6 Investments

The total investment required for the erection of this plant is 1,819,690 Eth. doll., of which 1,541,000 Eth.doll. represents the fixed capital and 278,690 Eth. doll. the working capital.

2.7 Profit, return and break-even point

The profits of the enterprise, in a normal year of production, are estimated at 484,309 Eth. doll., which corresponds to a return on the invested capital of 26.61% per year. The break-even point corresponds to 34.45% of the nominal productive capacity of the plant.

2.8 Sale prices

An average sale price of 0.25 Eth. doll. per Kg. has been fixed for the fodder, and this price would permit competition with other similar products on the market.

In the present project it is assumed that the product will be sold to the wholesalers in this field, taking off the expenses connected with distribution and sale.

2.9 Employment of Personnel

The project will provide work for 67 persons, of which 54 correspond to the direct labour force (workers), and 13 to the technical and administration personnel.

3. Market

3. Market

3.1 Characteristics of the product

The product studied in this project is a type of fodder obtained by drying, grinding and shaping banana leaves; it is most useful for feeding cattle. Its chemical composition is similar to that obtained from maize, millet and alfalfa.

3.2 Uses

Dehydrated fodder made from banana leaves can be used in the same way as similar fodders made from maize, millet and alfalfa, i.e. in a direct form, as part of the diet of cattle and horses, or for the preparation of foods for chickens and balanced foods in general.

The Ethiopian market for this product is so vast that there should be no difficulties for the enterprise in disposing of its production. There will also be the possibility of exporting this product to neighbouring markets; however, we have not considered this possibility in our study, as the transport costs are very high compared with the sale price of the product, which would remain low.

3.3 Supply

It appears that fodder made from banana leaves is not produced on an industrial scale in the country.

The present market offers the following: natural and artificial foods, balanced foods (in very small quantity) and imported products.

3.3.1 Pasture

Unfortunately, Ethiopia does not possess very much natural grassland, with species of graminaceous plants of low nutritive value. Another disadvantage is the absence of any weed control, which leads to frequent seasonal crises.

These factors mean that the cattle are not well nourished, and that the production of meat and dairy products in Ethiopia is low.

3.3.2 Production of balanced foods

At present, balanced foods are manufactured in Ethiopia in a semi-industrial form, only on a few farms which possess small mixers.

It would seem natural, therefore, that the quantities thus produced do not go very far towards satisfying the potential demand which would exist if production were abundant, and to nourish the cattle in a suitable way.

3.4 Demand

3.4.1 Home demand

The cattle in Ethiopia should be fed prepared products, owing to the lack of hay, which is due to the small area of grassland and its low yield, and also to inefficient exploitation. A considerable proportion of the demand therefore remains unsatisfied, and this is reflected in the low production of meat, milk and dairy products in general.

According to our preliminary studies, banana leaf fodder may form up to 20% of a balanced food product. If fodder made from dehydrated banana leaves is fed directly and solely to cattle in production, the demand in 1971 could be as much as 360,000 tons.

3.4.2 Foreign demand

Although this product is of great value as a cattle food, it is nevertheless a very cheap product, and in considering the possibility of exporting it, the incidence of the transport costs must be taken into account; in the case of distant countries, these render the product uncompetitive. Nearby countries, such as Kenya, Uganda and the Sudan, could be of interest for export.

As a general estimate, we give below figures for the demand and consumption of fodder in some of the main countries raising livestock, in order to calculate the importance of fodder in the international field.

In 1965, Mexico imported 183,500 tons of fodder, with a total value of 17.8 million U.S. dollars; in 1966 135,000 tons were imported, with a total value of 16.1 million U.S. dollars. The average C.I.F. value for these two years was 97.0 and 119.5 U.S. dollars/ton respectively. The products imported originated almost entirely from the U.S.A.

Between 1963 and 1966 Venezuela imported fodder from the U.S.A., with an average of 11,000 tons of alfalfa per year, and the F.O.B. value in this period averaged 67.4 U.S. dollars/ton, with a minimum of 60.6 in 1964 and a maximum of 78.2 in 1963 (in 1966 the value was 69.4).

Colombia, Argentina and Brazil have asked the ALALC for licences to import fodder from the countries belonging to the organization.

3.5 Prices

Bearing in mind the current prices on the international market, and remembering that the proposed product is a novelty for Ethiopia, never having been tried before, we think it prudent to establish an ex-factory sale price of 250 Eth. doll. per ton.

3.6 Prediction of demand

Table 1 shows data obtained from the Central Statistical Office of Addis Ababa.

Let us suppose (although this does not correspond to the actual situation) that in 1970 there are about 25 million head of cattle in Ethiopia, of which about 5 million may be considered in production (i.e. they are either producing milk or being fattened for slaughter).

Let us also suppose that the average consumption of prepared products, for these cattle in production, is 1.0 Kg./day, and that the banana leaf fodder constitutes 20% of the mixture of these complex foods.

We can therefore calculate the annual pro capite consumption of balanced foods at about 360 Kg., with a total annual consumption of 1,800,000 tons. A quantity of 360 tons of banana leaf fodder per year is necessary to supply this demand.

Finally, we must note that in 1962 an area of about 1,350 hectares of millet was cultivated in Ethiopia, corresponding to an annual production of approximately 1,000,000 tons.

Table 1 - Estimates of livestock

Major species	1957	1961	1962	1963
	in thousands			
1. Cattle				
Cows	7,091.7	7,632.0	7,670.9	7,705.8
Calves under 1 year	2,471.7	2,657.0	2,671.2	2,684.4
Cattle 1-2 years ..	2,286.9	2,464.0	2,524.1	2,537.6
Cattle 2-3 years ..	2,171.4	2,332.0	2,840.8	2,397.9
Heifers 3-4 years .	1,039.5	1,130.0	1,131.0	1,135.3
Males 3-4 years ...	1,039.5	1,130.0	1.131.0	1,135.3
Bulls or Oxen	6,999.3	7,555.0	7,582.1	7,591.2
Total	23,100.0	24,900.0	25,051.1	25,187.5
2. Sheep				
Ewes	7,651.8	8,360.4	8,492.8	8,625.2
Lambs	8,000.6	8,639.5	8,779.5	8,917.5
Female 1-2 years ..	3,052.0	3,268.6	3,317.6	3,371.3
Male 1-2 years	2,005.6	2,062.6	2,095.1	2,129.1
Rams	1,090.0	1,168.9	1,187.7	1,206.4
Total	21,800.0	23,500.0	23,872.7	24,249.5
3. Goats				
Kids	6,528.6	7,054.2	7,155.8	7,258.7
Females 1-2 years..	2,333.8	2,530.0	2,565.9	2,602.9
Males 1-2 years ...	1,409.4	1,518.0	1,539.6	1,561.8
Goats over 2 years	5,167.8	5,590.5	5,670.9	5,695.6
Bucks	761.4	807.3	818.1	814.0
Total	16,201.0	17,500.0	17,750.3	17,930.0
4. Horses	1,200.0	1,300.0	1,310.0	1,320.5
5. Mules	1,200.0	1,300.0	1,310.0	1,320.5
6. Donkeys	3,400.0	3,700.0	3,715.0	3,730.0
7. Camels	860.0	930.0	935.0	940.6
8. Poultry	34,400.0	40,000.0	41,000.0	42,000.0

3.7 Conclusions

The manufacture of fodder from dehydrated banana leaves would make use of large quantities of raw material which are at present wasted. It would also supply the market with a quality product at low price, for which there would be a great demand from the farmers, thus ensuring the market.

The home demand for balanced foods for cattle in production, connected to a rational development of the field of animal farming, could reach 1,800,000 tons/year in the period 1971-72. If we assume that 20% of this quantity corresponds to banana leaf fodder, i.e. about 360 tons per year, it can be seen that the capacity proposed for the plant under consideration represents only 3 % of the potential demand.

The ex-factory sale price, established at 250 Eth. doll./ton, is well below the international price, should this product be imported.

4. Engineering of the project

4.1 The Product

4.2 Requirements of the livestock and comparison with similar fodders

4.3 Production capacity of the factory

4.4 Demand and supply of raw material

4.5 Location

4.6 Production process

Table 2 - ANALYSIS OF DEHYDRATED BANANA LEAF FODDER

Raw Material	Total Water Content (1) %	Residual Humidity (2) %	Ash %	Total Protein %	Raw Fibre %	Non-nitrogenous material %
- Whole leaf: L.C.	79.4	4.85	10.3	12.03	32.20	38.89
- Whole leaf: Quevedo G.M.	78.0	3.98	14.5	11.40	31.67	41.50
- Leaf without veins: Machala L.C.	77.3	4.39	11.8	13.87	33.32	37.24
- Veins of leaf: Machala L.C.	86.6	5.45	11.2	2.68	39.82	40.93
- Whole leaf: Santo Domingo G.M.	80.7	3.12	9.2	14.09	47.96	23.91
- Stem: Machala L.C.	95.2	7.20	22.4	2.34	30.76	47.46

(1) - The figure refers to the raw material, which is dehydrated and dried at 105°C.

(2) - The figure refers to the water content of the sample after dehydration at 70°C.

- Weight ratio of veins to whole leaf = 0.83
- L.C. = Large Cavendish.
- G.M. = Gross Mitchel.

4.1 The Product

Dehydrated fodder made from banana leaves is a product which is used mainly for the preparation of foods for cattle.

The product may be packed in the form of flour or pellets. Its chemical composition varies slightly according to the plantation from which the raw material is obtained. In Table 2. we give a general analysis of dehydrated banana leaf fodder, for the Large Cavendish and Gross Mitchel varieties of banana.

According to the analysis, the average protein content is about 13%; the product could therefore be considered as a source of protein. To increase the protein content in balanced foods, and to give a more complete formula for feeding livestock, the fodder is mixed with cottonseed flour, oat flour, soya beans etc., according to the requirements of each individual case.

The dehydrated banana-leaf fodder is extremely digestible, as is illustrated in Table 3.

Table 3 - Digestibility coefficient of dehydrated banana leaves

	Digestibility coefficient %
- Gross protein content	65
- Gross fats	58
- Non-nitrogenous material	71
- Gross fibre content	60

Source: Encyclopedia UTEHA, "Bromatologia, Zootecnia e Alimentazione Animale" by L. Revuelta Gonzales, 2nd edition.

4.2 Requirements of the livestock and comparison with similar fodders

The protein requirements for various types of livestock are as follows:

- meat cattle 12-14%
- dairy cattle 16%
- pigs 13-15%

In each case the content of fats, fibre and free extract of nitrogen varies.

These figures concerning the requirements of livestock, as regards the protein content, show that dehydrated banana-leaf fodder may be used for feeding meat cattle, dairy cattle and pigs.

Similar types of fodder, such as maize or millet, have a protein content of only 7.3 and 8.5% respectively; this is considerably lower than the product under consideration, which may contain as much as 13%.

4.3 Productive capacity of the factory

The final water content of the dehydrated product is 12%.

The driers, which set the pace of the production process, have to work 24 hours a day.

The production capacity of the entire plant is 1.2 tons/hr., corresponding to 28.8 tons/day, in three shifts of eight hours per day.

The factory must work at least 6 days per week, in order that the driers may give a high calorific yield; it is therefore calculated that the factory will work 280 days per year. In all, the factory will produce 8,064 tons/ year of dehydrated banana-leaf fodder.

4.4 Demand and supply of raw material

The raw material has an average water content of 80%. The content of dry matter in the product, remembering that it has a water content of 12%, is equal to 1,056 tons per hourly production.

It follows that the raw material corresponds to 5.28 tons/ hour, which equals 126.72 tons/day, working 24 hours per day, and 35,482 tons/year, working 280 days per year. The minimum capacity of the drier must be 3.6 tons/hour of evaporated water.

The raw material necessary for the factory is to be found wherever there are banana plantations.

According to the observations made and the information obtained by the team of experts during the mission to Ethiopia, each banana plant, under the most unfavourable conditions, produces an average of 15-20 Kg. of banana leaves. The density of the plantations is about 1,100 plants per hectare. The proposed factory would therefore use the foliage from about 1-2,000 hectares of banana plantation.

At present, bearing in mind that the area producing bananas for sale abroad, in Eritrea, is approximately 1,000 hectares, and there are another 1,000 hectares of land in Eritrea which are used for growing bananas to be sold locally, we can calculate that most of the requirement of raw material will be covered by the present plantations.

In the light of the prospects for future development, and remembering that it will be possible to make use of about 4,000 ha. in the Sabarguma Plain for growing bananas, we may conclude that there will be no difficulty in obtaining the raw material.

Finally, it must be remembered that one of the first operations to be carried out in the present banana plantations is that of increasing the yield of the land by increasing the density of the plants to 1,600 per hectare, which will give a production of banana leaves of 24 - 32 tons per hectare as against the present 16.5-22 tons. With this new unit production, the amount of raw material required by the factory could be supplied by an area of about 1,000 - 1,500 ha.

We must also point out that the factory under consideration could begin operating at 50% capacity, later increasing production, depending on the supply of raw material, to reach full nominal productive capacity, in accordance with the expansion of the market.

4.5. Location.

From the last paragraph it is evident that the only area in which such an industry could be established is Eritrea, or more precisely, on the western plain (Agordat, Elaberet), apart from the possible agricultural development of the Sabarguma plain, or the eastern plain, if it is wished to take these factors into consideration.

Siting the factory in Eritrea would make it easier to obtain raw material, and would also allow exportation to nearby markets, as the port of Massawa would be fairly near.

The transport cost for a full load, lorry plus trailer, from Agordant to Massawa, is about 500 Eth. doll., which is the equivalent of about 0.04 Eth. doll./Kg. of product transported. This must be particularly emphasised in choosing the site, for obvious reasons of economy: transport costs add to the sale price, not only for the export market, but above all for the home market.

4.6 Production process

4.6.1 Chopping

The banana leaves collected from the plantation must be chopped to a smaller size before being dried. This operation makes the subsequent treatment in the drier easier, and gives a product with extremely good characteristics and uniform dehydration.

4.6.2 Drying

The leaves, once chopped, are carried to the hopper of the drier by a conveyor belt; care must be taken that the drier is fed evenly.

In order to prevent air from the outside from entering the drier, the conveyor will be constructed with a cover.

The drying drum consists of three concentric cylinders through which the product passes. Inside these cylinders, the leaves are first carried across the inside cylinder by the current of air, and then across the middle cylinder in the opposite direction; finally they pass across the third cylinder in the same direction as that in which they crossed the first.

In order to obtain uniform drying, the lighter fractions are passed over the cylinders more quickly than the heavier pieces.

The heat necessary for dehydration is provided by a boiler fed by a burner. This boiler is coupled to a safety device which prevents impurities in the fuel and the odours they produce, which contaminate the product.

The temperature is controlled by a thermostat, which ensures that the dehydrated fodder will be dried evenly and will retain a good colour.

4.6.3 Cooling and grinding

When the product comes out of the drier, it is carried along a pipe linked to a ventilator to the primary collector, where the dry product is separated from the humid air. It is then carried to the cooling hammer mill, where the particles are reduced to the ideal size for transformation into flour.

4.6.4 Pelletization

When the product comes out of the mill, it is transported by means of a cyclone to the pelleting machine. This machine forms pellets, using a binding agent such as water vapour or atomized water.

The pelleting machine is electrically operated and has its own boiler for the production of steam.

The pellets may be of various shapes and sizes. The most usual form is an oval shape, with an average size of 0.5 - 3 cm.

Small quantities of molasses may be used as a binding agent to improve the quality of the dehydrated product.

4.6.5 Cooling

The pellets produced by the pelleting machine are conveyed to the cooling room; after this, they are ready for packing.

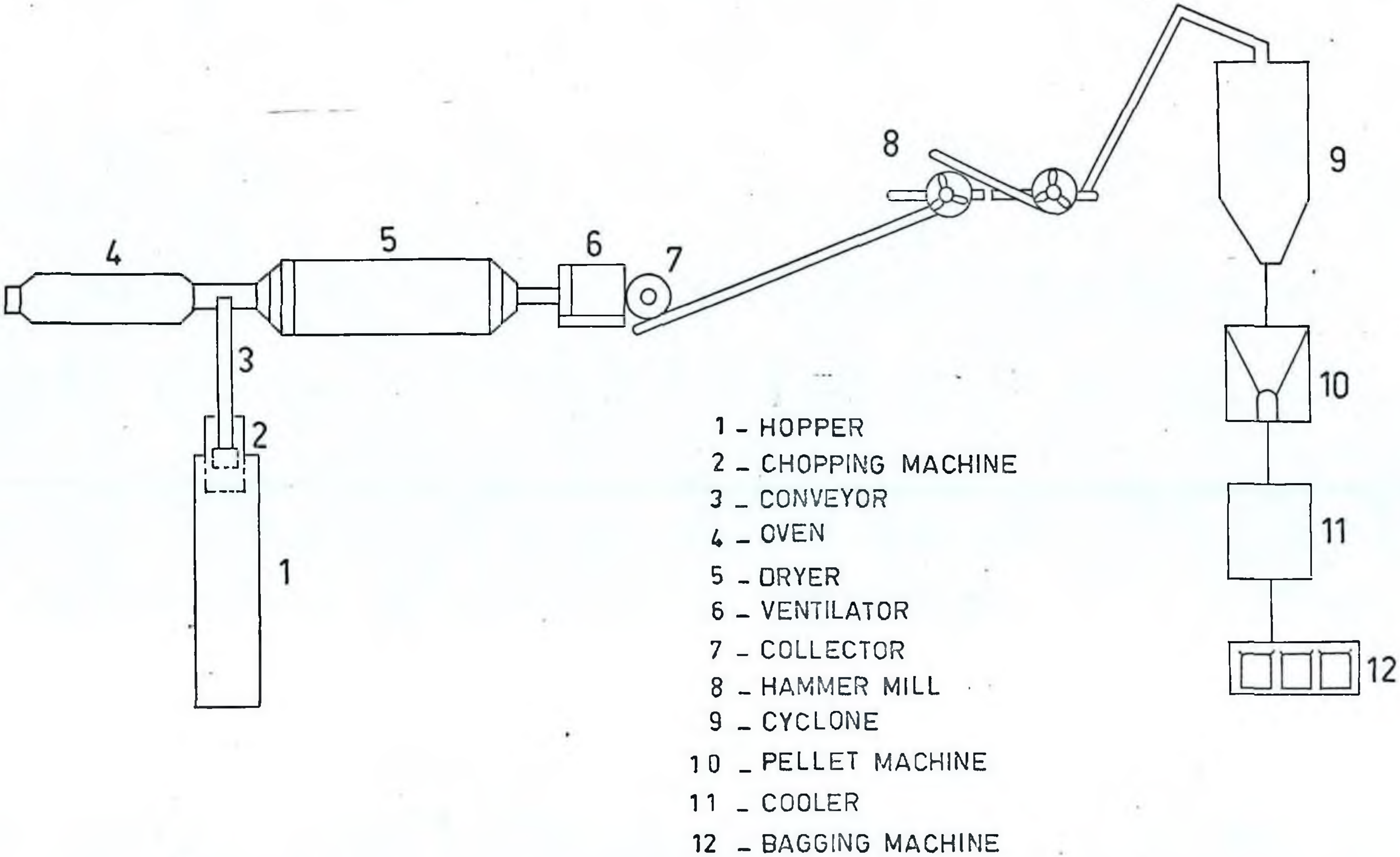
4.6.6 Packing

The product is packed in polypropylene bags, each with a capacity of 50 Kg.

The factory could also sell loose fodder, if the demand were sufficiently large, and this would reduce the production cost by 20 Eth.doll. per ton.

In drawing n° 1 the processing line of the factory is illustrated.

Drawing 1 – FLUX DIAGRAM



5. Economic analysis

5.1 Investments

	Eth. doll.
5.1.1 Fixed investments	
- Civil works	280,500
- Equipment and machinery	960,000
- Auxiliary supplies	50,000
- Various costs	140,000
- Contingencies (8% of 1,850,500)	110,000
5.1.1 Total fixed investments	1,541,000
5.1.2 Working capital	278,690
5.1 TOTAL INVESTMENTS	1,819,690

5.2 Gain and loss

	Eth. doll.	%
- Net return on sales	2,016,000	100.00
- Production cost	1,291,945	64.08
Net profit on production	724,055	35.92
- Sale cost	161,280	8.00
Net profit on sales	562,775	27.92
- Cost of technical and administrative personnel, stationery etc.	78,466	3.89
Net profit of the operation before deduction of taxes on the return and other legal duties	484,309	24.03

Profit on total investments

$$\frac{484,309}{1,819,690} \times 100 = 26.61 \ \%$$

5.3 Break-even point

The break-even point of the enterprise approximately corresponds to 34% of the production capacity.

I_p = Predicted takings 2,016,000 Eth.doll.

C_f = Fixed costs 254,541 " "

C_v = Variable costs 1,277,150 " "

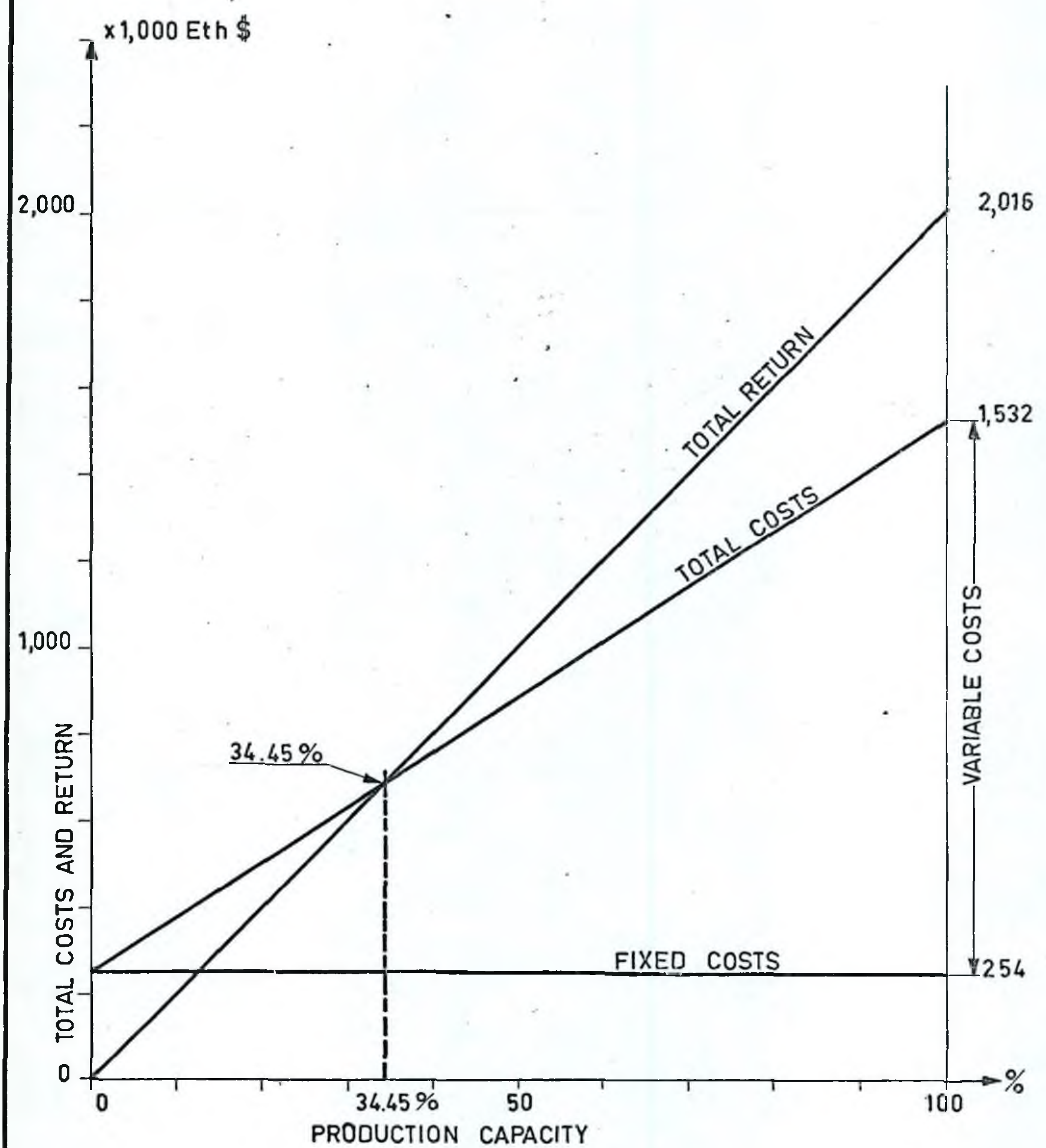
x = Break-even point, i.e. the level of production at which the takings are equal to the expenses (in percentage of the nominal capacity).

$$I_p . x = C_f + C_v . x$$

$$x = \frac{C_f}{I_p - C_v} = \frac{254,541}{2,016,000 - 1,277,150} = \frac{254,541}{738,850} = 0.3445$$

In Graph n° 1 the costs and takings are shown with relation to production, and from the intersection of the graph of total takings and that of total costs the break-even point can immediately be seen.

BREAK-EVEN POINT



6. Addenda

1. Explicative note
2. Civil works
3. Equipment and machinery
4. Auxiliary supplies
5. Various costs
6. Sales
7. Raw material
8. Indirect costs
9. Direct labour
10. Various materials
11. Insurance
12. Analysis of annual costs
13. Production cost
14. Total cost of operation
15. Working capital

1. Note explaining the estimates

1.1 Land and civil works

The cost of the land on which the factory is to be constructed has not been included in the economic estimate of the project, in order to give an idea of the economic feasibility of the undertaking, whether the plant is constructed on the western plain or on the eastern plain of the Governatorate General of Eritrea.

It must also be remembered that the large land-holders are often prepared to put part of their land at the disposal of industrialists who wish to construct factories in Ethiopia. The land-holders may also take part in the project in the form of shareholders.

We should point out that fruit-farming in Ethiopia is under the patronage of the authorities, and the main banana plantations are on land belonging to the State and leased out to be farmed. The authorities might therefore consider the possibility of putting a small area of these lands at the disposal of the industrialists on which they might construct a factory.

The cost of the civil works has been estimated on the basis of the present market prices, and take into account the incidence of imported metalwork for the construction of the buildings.

1.2. Equipment and machinery

Bearing in mind that there are laws in existence in Ethiopia to help the construction of factories, the customs duties on importation and other taxes connected with importation have not been included in the estimate of the costs.

1.3. Working capital

The estimate has been made with reference to one month's storage of all the materials, with the exception of:

- raw material, for which 10 days' storage is necessary;
- fuel, for which a reserve of 15 days is necessary, as it is relatively easy to obtain.

1.4. Raw material

A price of 10 Eth. doll. per ton has been fixed for banana leaves brought to the factory. This practically corresponds to the cost of harvesting and transport to the factory alone.

Bearing in mind that the average transport cost is 0.10 Eth.doll./ton/Km., and that the raw material is supplied by plantations within a radius of not more than 50 Km. from the factory, transportation will not cost more than 5 Eth. doll. per ton.

1.5. Spare parts and maintenance

Since the factory will operate for 24 hours/day and 280 days/year, there must be a good reserve of spare parts, corresponding to 5% of the value of the Equipment and machinery.

2. Civil Works

Items	Area in m^2	Unit cost in Eth.doll.	Total cost in Eth. doll.
- Buildings housing processing lines	500	200.0	100,000.0
- Warehouses	800	140.0	112,000.0
- Offices	50	250.0	12,500.0
- Lay-out of area, earthworks, drain, wells (1)	5,000	-	50,000.0
- Fencing (2)	300	20.0	6,000.0
TOTAL COST OF CIVIL WORKS			280,500.0

(1) - The estimate is made on the assumption that the land is ideal, needing no great works for its lay-out, flat and without rocks.

(2) - The length of the fencing is expressed in linear metres.

3. Equipment and machinery

Items	n°	Unit cost in Eth. doll.	Total cost in Eth. doll.
- Dryer	1	200,000.0	200,000.0
- Hopper	1	50,000.0	50,000.0
- Hammer mill	1	80,000.0	80,000.0
- Pellet machine with boiler	1	100,000.0	100,000.0
- Cutting machine	2	60,000.0	120,000.0
- Fuel tank and pre heating equipment	1	30,000.0	30,000.0
- Bagging machine	1	20,000.0	20,000.0
- Electrical installations ...	1	150,000.0	150,000.0
- Spare parts and accessories......	-	-	40,000.0
- Cost of erection	-	-	120,000.0
- Platform scale	1	20,000.0	20,000.0
- Mechanical means of internal transportation ..	-	-	10,000.0
- Miscellaneous and contingencies	-	-	20,000.0
TOTAL COST OF EQUIPMENT AND MACHINERY:			960,000.0

(1) The costs are understood "on the work site" i.e. in the building yard.

4. Auxiliary supplies

Items	Total cost in Eth. doll.
- Office equipment	8,000.0
- Laboratory	6,000.0
- Mechanical workshop	10,000.0
- Various accessories for the factory	6,000.0
- Vehicles	20,000.0
TOTAL COST OF AUXILIARY SUPPLIES	50,000.0

5. Various costs

Items	Cost in Eth. doll.
- Engineering services	100,000
- Cost of organization and establishment of the firm	10,000
- Interest during construction	30,000
TOTAL VARIOUS COSTS	140,000

6. Sales

- Product	: dehydrated banana leaf fodder
- Ex-factory sale price	: 250.0 Eth. doll. per ton
- Quantity produced	: 8,064 ton/year
- Total return	: 2,016,000 Eth. doll.

7. Raw Material

- Raw material	: green banana leaves
- Buying price, brought to the factory	: 10 Eth. doll. per ton
- Annual consumption	: 35,482 tons/year
- Value	: 354,820 Eth. doll./year

8. Indirect costs

Technical and administrative personnel

Employees	No.	Monthly salary in Eth.doll.	Annual cost in Eth.doll.
- Technical manager	1	1,600.0	19,200.0
- Factory foreman	1	800.0	9,600.0
- Accountant	1	600.0	7,200.0
- Secretarial staff	1	300.0	3,600.0
- Typist	2	200.0	4,800.0
- Mechanical electrician	1	400.0	4,800.0
- Gate-keeper	3	100.0	3,600.0
- Store-keeper	1	150.0	1,800.0
- Chauffeur	2	150.0	3,600.0
TOTAL	13		58,200.0
- Incidence of social benefits			7,566.0
- Bonus			4,850.0
- Reserve fund			4,850.0
TOTAL INDIRECT COSTS			75,466.0

9. Direct labour (manual workers)

Employees	No.	Monthly wage in Eth.doll.	Annual total in Eth.doll.
- Reception of raw material	4	150.0	7,200.0
- Chopping	3	150.0	5,400.0
- Drying	1	200.0	2,400.0
- Mill	1	150.0	1,800.0
- Packing	5	150.0	9,000.0
- Boiler	1	150.0	1,800.0
- Assistants	2	80.0	1,920.0
- Pellet machine	1	150.0	1,800.0
TOTAL	18		31,320.0
- Incidence of social benefits (13%)			4,072.0
- Bonus			2,610.0
- Reserve fund			2,610.0
Total direct labour: 1st shift			40,612.0
" " " : 2nd " (1)			44,673.0
" " " : 3rd " (2)			50,765.0
TOTAL DIRECT LABOUR			136,050.0

(1) - An additional 10% must be added to the 1st shift
(2) - " " 25% " " " " " " "

10. Various materials

Items	Quantity	Unit cost in Eth. doll.	Total cost in Eth. doll.
10.1 Auxiliary materials			
- polypropylene bags, capacity 50 Kg. each	165,000	1.0	165,000
- thread etc.	-	-	4,000
10.1 Total cost of auxiliary materials			169,000
10.2 Fuel			
- fuel for dryer (tons)	2,000	180.0	360,000
- fuel for electrical installations	300	220.0	66,000
- lubricants	-	-	1,000
10.2 Total cost of fuel			427,000
10.3 Repair and maintenance (5% of 3)			29,000
10.4 Stationery etc.			3,000
10. ANNUAL TOTAL OF VARIOUS COSTS			628,000

11.	Insurance	Eth. doll.
	- Civil works (1% of 280,500)	2,800.0
	- Equipment and machinery (1% of 960,000)	9,600.0
	11. Annual total insurance	12,400.0

(1) - Sum calculated on equipment and machinery, including engineering services.

12. Analysis of annual costs

	Eth. doll.
12.1 General expenses	
12.1.1 Personnel	
- technical and administrative personnel	75,466.0
- labourers	136,050.0
12.1.1 Total personnel	211,516.0
12.1.2 Materials used	
- auxiliary materials	169,000.0
- fuels	427,000.0
- repair and maintenance (spare parts)	29,000.0
- stationery etc.	3,000.0
12.1.2 Total materials used	628,000.0
12.1.3 Insurance	12,400.0
12.1.4 Raw material	354,820.0
12.1 TOTAL GENERAL EXPENSES	1,206,736.0
12.2 Depreciation and amortization	
12.2.1 Buildings and constructions Amortization in 20 years (5% of 280,500)	14,025.0
12.2.2 Equipment and machinery Amortization in 10 years (10% of 960,000)	96,000.0

		Eth. doll.
12.2.3	Office equipment Amortization in 10 years (10% of 8,000)	800.0
12.2.4	Laboratory Amortization in 10 years (10% of 6,000)	600.0
12.2.5	Mechanical workshop Amortization in 10 years (10% of 10,000)	1,000.0
12.2.6	Various accessories for the factory Amortization in 5 years (20% of 6,000)	1,200.0
12.2.7	Vehicles Amortization in 5 years (20% of 20,000)	4,000.0
12.2.8	Contingencies Amortization in 10 years (10% of 110,500)	11,050.0
		127,675.0

12.2.9 Amortization of non-depreciating goods

- engineering services amortization in 15 years (6.67% of 100,000 = 6,670)
- organization and establishment of the firm amortization in 10 years (10% of 10,000 = 1,000)

Eth. doll.

- interest during construction amortization in 5 years (20% of 30,000 = 6,000)
- amortization of working capital (8% of 278,690 =22,330)

12.2.9 Total amortization of non-depreciating goods	36,000.0
12.2 TOTAL AMORTIZATION AND DEPRECIATION	163,675.0

12.3 Sale costs (1)

- bank, customs and dispatch expenses (8% of 2,016,000 Eth. doll.)	161,280.0

12.4 Summary of annual costs

12.4.1 General expenses	1,206,736.0
12.4.2 Amortization and depreciation	163,675.0
12.4.3 Sale costs	161,280.0
12.4 TOTAL ANNUAL COSTS	1,531,691.0

(1) - Sale is considered ex-factory, and includes only bank, customs and dispatch, omitting transport costs to the port and the possible rent of a warehouse in the port.

	Eth. doll.
12.5 Division of costs: fixed and variable	
12.5.1 Fixed costs	
a) Technical and administrative personnel	75,466.0
b) Insurance	12,400.0
c) Amortization and depreciation	163,675.0
d) Stationery etc.	3,000.0
12.5.1 Total fixed costs	254,541.0
12.5.2 Variable costs	
e) Direct labour	136,050.0
f) Raw material	354,820.0
g) Other materials	625,000.0
h) Sale costs	161,280.0
12.5.2 Total variable costs	1,277,150.0
12.5 TOTAL ANNUAL COSTS	1,531,691.0

13. Production cost

	Eth. doll.	%
13.1 Raw material	354,820	27.46
13.2 Labour	136,050	10.53
13.3 Materials used	625,000	48.38
13.4 Insurance	12,400	0.96
13.5 Amortization and depreciation	163,675	12.67
13 TOTAL	1,291,945	100.00

Average cost per ton of fodder produced = 160.21 Eth. doll.

14. <u>Total cost of the operation</u>

		Eth. doll.
14.1	Production cost	1,291,945
14.2	Technical and administrative personnel	75,466
14.3	Stationery etc.	3,000
14.4	Sale costs	161,280
14	TOTAL COST OF OPERATION	1,531,691

Average cost per ton of fodder produced = 189.94 Eth. doll.

15. Working capital

Eth. doll.

15.1 Necessary stocks

15.1.1 Raw material

Stock of raw material in the factory for 10 days' operation

$354,820 \times \frac{1}{36} =$ 9,856

15.1.2 Materials used

Auxiliary materials, fuels, repair and maintenance, stationery, lubricants, calculated for 1 month of operation:

- auxiliary materials	169,000	
- lubricants	1,000	
- repair and maintenance	29,000	
- stationery etc.	3,000	
	201,000	
$201,000 \times \frac{1}{12} =$		16,750

Fuels calculated for 15 days' operation:

$426 \times \frac{1}{24} =$	17,750
15.1.2 Total materials used	34,500

		Eth. doll.
15.1.3 Finished product		
A store of one month's production is presumed, the costs being estimated as follows:		
- general expenses	1,206,736	
- sale costs	161,280	
Annual total	1,368,016	
$1,368,016 \times \frac{1}{12} =$		114,000
15.1 Total necessary stocks		158,356
15.2 Suspended cash credit		
It is presumed that payment will be made every 30 days:		114,000
15.3 Minimum cash balance		
4% of 15.1 (158,356)		6,334
15. TOTAL WORKING CAPITAL		278,690

PART - IV

TYPICAL COLD-STORAGE WAREHOUSE

FOR STORING CITRUS FRUIT UNDER REFRIGERATION

INDEX

1. General observations

The feasibility study for this cold-storage warehouse has been drawn up on the basis of the following:

- adoption of the most suitable refrigerator cycle for the goods which it is proposed to store, namely citrus fruit for the most part, and also other fresh fruit and vegetables where necessary;
- adoption of a highly-centralised complex, so that only short distances separate its various parts and control is as easy as possible;
- detailed study of traffic, so that internal movement is rapid and without crossings;
- division of the total storage capacity into many smaller cold-storage rooms, in order that the complex may operate with great elasticity;
- strictly modular structure of the complex, so as to use materials with common characteristics and to make expansion as easy as possible.

The essential features of the project are described below and are illustrated in the drawings and specifications.

In the one complex are included: cold-storage rooms, pre-refrigeration tunnels, refrigeration system, water system, services for the workers, a small administrative and commercial centre, watchman's lodgings, control box, and sales office.

The maximum storage capacity of the complex is 2,500 tons of fruit.

2. Refrigeration and conservation process

The process of conservation and refrigeration has been planned in such a way as to obtain cold-storage of citrus fruit in particular, and fresh fruit and vegetables in general, under ideal conditions.

In order to conserve these goods for long periods, the results of experiments carried out with various species of fruit and vegetables must be put into application.

According to the suggestions of the "Institut International du Froid" (Institut International du Froid, Commission IV, Conditions recommandées pour l'entreposage frigorifique des denrées périssables, Annexe au Bulletin de l'I.I.F. n° 6, 1959), for normal storage the temperature should be between -1.5°C and +10.0°C, according to the quality of the product to be stored, with a relative humidity of 80-90%; for gas storage, of which more will be said below, the temperature should be between +3.5°C and +5.0°C, with a relative humidity of 90-95%.

All products suitable for storage which are subject to physiological deterioration are "live" products, and therefor show considerable biological activity when collected and delivered to the warehouse. The higher the temperature, the greater is this activity, and the period of time for which the products remain in good condition is inversely proportional to the biological activity and, in the final analysis, to the temperature at which they are kept.

The lower limit of the above-mentioned biological activity is constituted by the freezing point, which should never be reached, as this destroys the live cells; the upper limit, on the other hand, determines the length of time for which the product may be kept. The longer it is wished to preserve the goods, the lower must be the temperature at which they are stored, approaching, but never reaching, the freezing point.

Among other things, carbon dioxide is given off by all types of fruit and vegetables during the biological processes, which are accompanied by a considerable increase in temperature, as can be seen from Drawing n° 1 (page 4); this rise in temperature must be counteracted by refrigeration, and must not be forgotten in designing the complex.

As a result of the investigations, the following conclusions were reached:

- the products stored produce a certain quantity of carbon dioxide (CO_2) which varies according to the type of product and increases in proportion as the temperature rises;
- during the storage process, the products produce a certain quantity of heat, which varies according to the product and increases in proportion to the temperature of the surroundings.

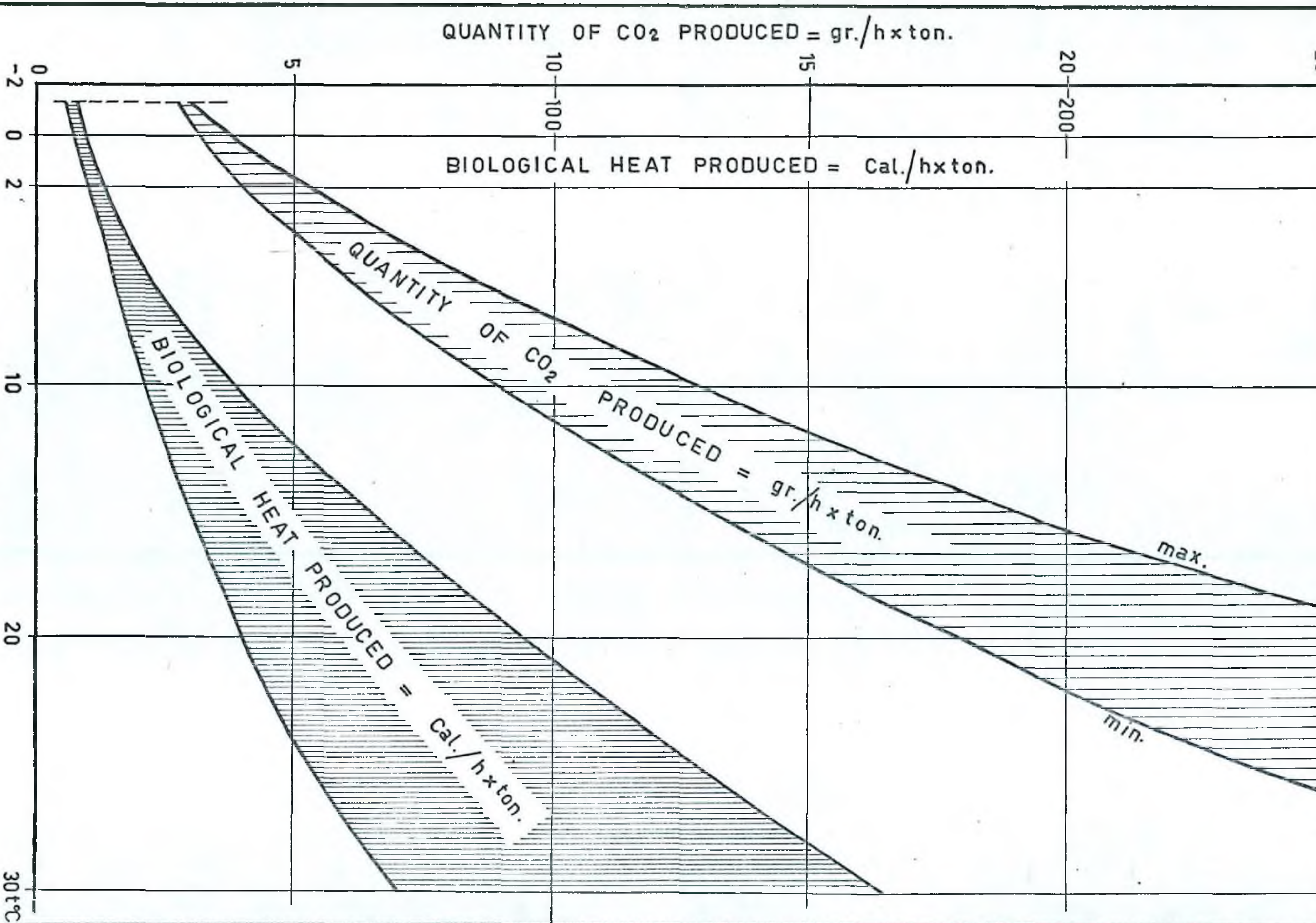
By way of example, Drawing n° 1 shows the graphs illustrating these phenomena, for pomaceous fruit in general.

To summarise, a temperature of 0°C in the storage rooms corrisponds to an average of 200 calories/hr. produced by every ton of fruit, and a production of carbon dioxide equal to 4 gr./ton/hr.

Incidentally, the carbon dioxide which is given off helps to preserve the products which are packed in plastic bags: within these bags, the atmosphere is poor in oxygen and rich in water vapour and carbon dioxide, thus considerably reducing the biological activity of the product harvested from the plant.

The products may be stored by two different methods:

- by cold-storage, in isothermic surroundings, where the relative humidity may be controlled and maintained at the


QUANTITY OF CO_2 PRODUCED = gr./h×ton.
BIOLOGICAL HEAT PRODUCED = Cal./h×ton.
0
5
10
15
20
25
100
200
-2
0
2
10
20
30t°C
QUANTITY OF CO_2 PRODUCED = gr./h×ton.
BIOLOGICAL HEAT PRODUCED = Cal./h×ton.
max.
min.

Drawing No 1

desired level;

- in refrigerated surroundings, isothermic and with insulated walls, in which the chemical composition of the atmosphere is pre-established and maintained during the entire storage period (the method known as gas storage).

The second method is obviously the most costly, as regards both the installation costs and the running costs, and needs special equipment and highly-qualified staff. This method is therefore more suitable for plants where these costs can be amortized more easily.

There is also another possibility, half-way between the two solutions mentioned above, which has given good results. This intermediate solution consists in putting the products in suitable sacks of ordinary plastic, which are then placed in wooden boxes and put into the refrigerator. No other provisions are necessary.

The catabolism of the products creates an atmosphere rich in carbon dioxide inside the bags; this reduces biological activity and helps to preserve the goods longer. This method may be used in any storage centre, providing that the temperature and relative humidity of the surroundings are kept at a constant level.

These preliminary observations induce us to propose the adoption of the simpler method of refrigerated storage, i.e. storage in surroundings with a constant temperature and relative humidity. Nevertheless, the plants can be planned in such a way that it will later be possible to change to the gas storage system with no complicated alterations, by merely adding the necessary equipment.

Bearing in mind these considerations, it should be possible to maintain the temperature and relative humidity of the cold-storage rooms at a constant, pre-established level, so that the plants may be used to store fruit and various products, and to preserve them satisfactorily.

It has already been established that the temperature of the cold-storage rooms should be between -1.5°C and +10.0°C, and the relative humidity between 80% and 90%. Under these conditions, it will be possible to store, besides citrus fruit, most types of fruit and vegetables in their natural state; fuller use can therefore be made of the plant.

Furthermore, it is proposed to surface the inside walls of the cold-storage rooms to make them impermeable, so that if it is ever wished to adopt a gas storage system, the plant may be easily adapted by installing the necessary equipment. This equipment will be connected to the canalization already planned for the introduction of fresh air and the extraction of used air, which will be installed between the ceiling of the cold-storage rooms and the roof of the building.

In describing the refrigerator plant, we should like to point out the extreme simplicity of the system by which these conditions are obtained. Our experience leads us to state that a plant used for agricultural products must be simple, very easy to run and extremely reliable, able to be operated by ordinary personnel, not highly-qualified technicians. The chances of a breakdown must be reduced to the minimum, and the continuous operation of the plant should be totally guaranteed, except under exceptional circumstances. Repair and maintenance should be as easy as possible.

3. Size and composition of the warehouse

As has already been said, the criteria adopted in drawing up the project of the refrigerated warehouse have been thoroughly studied, with the aim of achieving the greatest possible flexibility of operation and complete standardization of the cold-storage rooms and the machinery.

For example, it has been considered necessary to construct rooms of varying sizes which nevertheless conform to standard measurements. In this way, a single type of equipment may be employed for the small rooms, and a single type for the large rooms, thus unifying the machinery of the refrigerator complex.

The plant is constructed on the basis of a group of cooling elements (aerorefrigeranti) in each room, which ensure refrigeration of the surroundings; in addition, each room is fed by fresh air, which keeps the atmosphere at a pressure slightly above that of the outside air, thus guaranteeing that the desired conditions are maintained. The air is changed by means of two suitable air-conditioners, one for each of the wings of the warehouse. These conditioners, and the relevant canalization to convey the fresh air, are installed between the ceiling of the rooms and the roof of the building. Two ducts, one for each wing of the warehouse, are also installed in this space for the extraction of the used air from the rooms. Each room therefore has a small opening letting fresh air in and another by which the used air is extracted; these are controllable.

(For further clarification of the above, see the drawings of the general plan).

At a later stage, the above-mentioned ducts may be connected to the machinery controlling the atmosphere of the rooms, to form a gas storage system; this machinery may also be mounted in the same space, between the ceiling of the rooms and the roof of the building.

The storage capacity has been determined on the basis of a floor load of 1.25 tons/sq.m., for goods packed in cases piled to a height of 3.5m., giving a density of 380 Kg./cu.m., in such a way as to provide excellent ventilation and to leave enough space for movement within each room.

The warehouse includes the cold-storage rooms, distribution corridors, ante-rooms and pre-cooling tunnels. The latter are designed for pre-cooling with rapid circulation, which is particularly economic, as under this system it is not necessary to open the doors of the rooms frequently, and the cooling elements need only be large enough to counteract loss and generation of heat within the room itself.

There are two tunnels, each of which is loaded every 48 hours and therefore unloading and loading of goods in each tunnel takes place every 24 hours. If it should be necessary, the two pre-cooling tunnels may also be used to store products, thus considerably increasing the capacity of the warehouse.

Allowing for rooms of two different sizes, the plant will comprise 20 rooms in all: four large and sixteen small. This allows great flexibility of operation.

The size and minimum temperature of each room is shown in the plan.

The goods may leave the rooms by means of a service corridor wide enough to allow manually-operated and/or fork-lift trucks to pass, and a wide, air-conditioned ante-room connected to the exit from the pre-cooling tunnels.

In front of the tunnels is an ante-room communicating with the entrance hall; this has been designed with particular attention, so that the trucks do not need to cross each others paths.

The service corridors are kept at a temperature half-way between that of the cold-storage rooms and that of the outside air, with the aim of protecting the health of the workers and also of preventing hot, humid air from entering the rooms when the doors are opened.

4. Materials and structures.

In tables 1 and 2, given below, are shown the coefficients of thermal conductivity of the materials it is proposed to use, and the film coefficients of heat transfer in the upper strata of the refrigerator.

Drawing N° 2 shows the minimum internal and the maximum external temperatures used in calculating the dimensions of the refrigerator and the thickness of isolation.

In tables 3, 4, 5, 6, 7, 8 and 9, are shown the constructional and dimensional characteristics of the limiting elements of the refrigerator, calculated on the basis of the data given in tables 1 and 2 and in drawing N° 2.

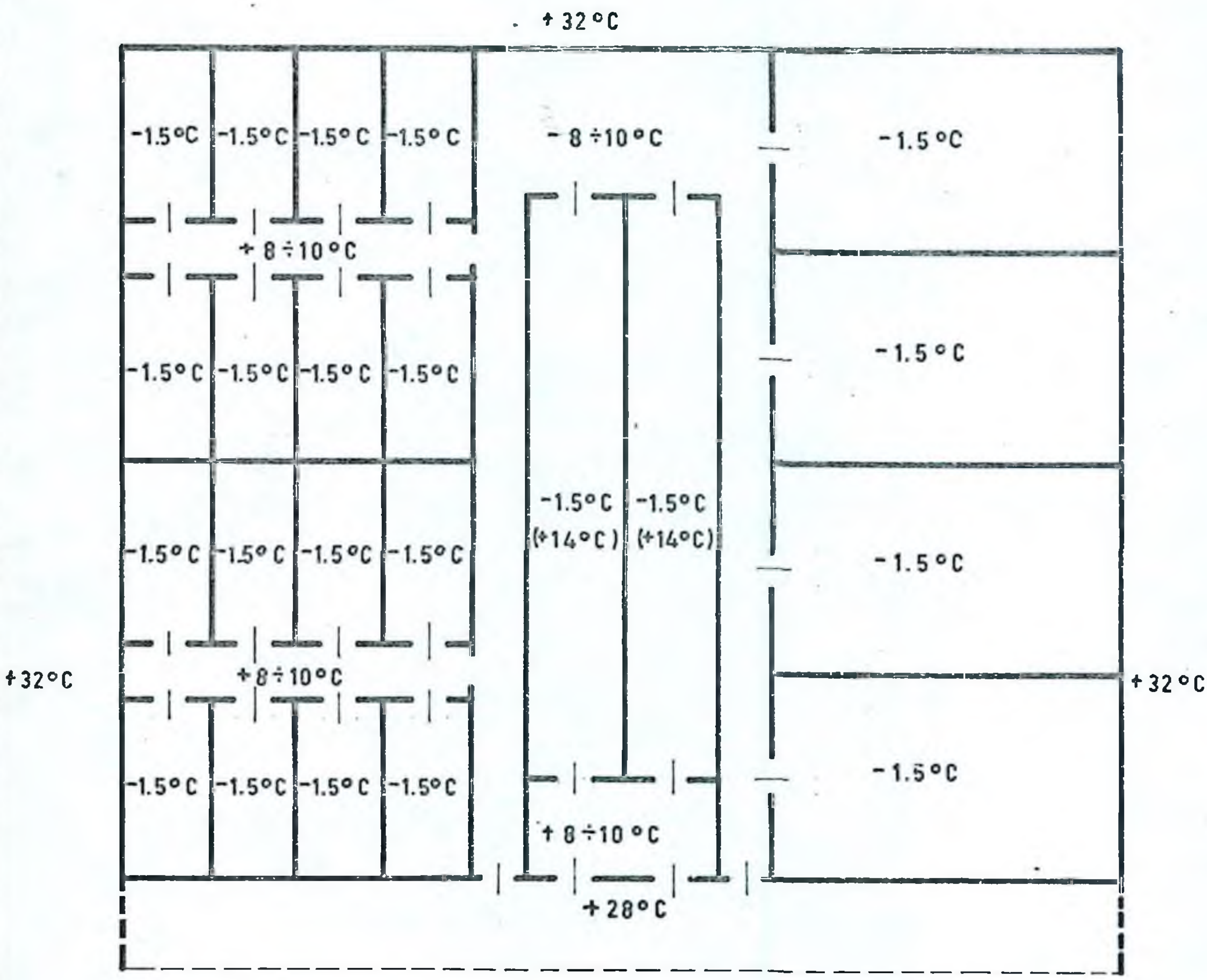
Table 1 – Thermal conductivity of the materials

– Frigolit, 20 Kg./cu.m.	tc = 0.03 cal/m.°C.hr.
– Solid-brick masonry	tc = 0.80 " "
– Concrete	tc = 1.20 " "
– Plaster of mortar of cement (except in certain cases, such as for the rooves, it is assumed that the plaster increases the thickness of the walls by 2 cm.)	tc = 0.80 " "
– Concrete and tile floor	tc = 0.85 " "

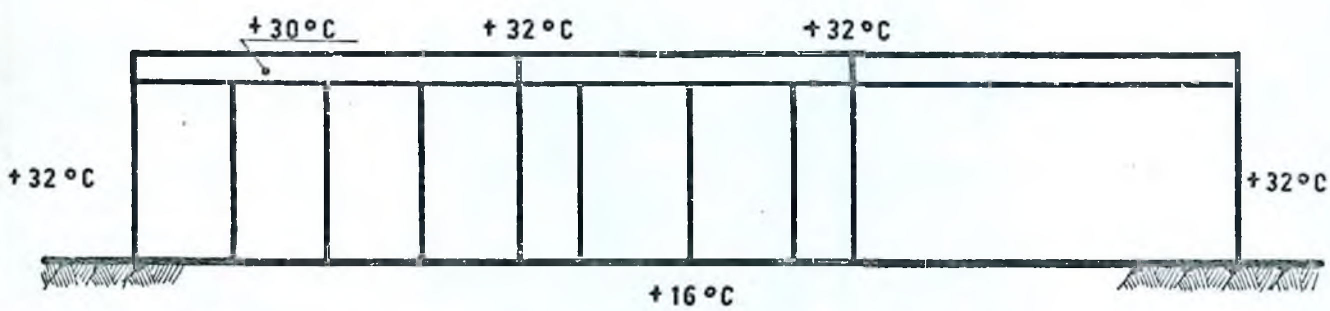
Table 2 – Coefficients of heat transfer of the impermeable strata

– Outside walls, services and offices	a = 12 cal/sq.m.°C.hr.
– Walls of the rooms	a = 16 " "
– Tunnels	a = 25 " "
– Corridors	a = 14 " "

Drawing No 2 MINIMUM INTERNAL AND MAXIMUM EXTERNAL TEMPERATURES



PLAN



SECTION

Table 3 - Outside walls

A. Composition:

- solid-brick masonry	thickness	0.21 m.
- impermeable stratum	"	-
- frigolit, 20 Kg./cu.m.:		
a) in the rooms	"	0.12 "
b) in the corridors	"	0.08 "
- solid-brick masonry	"	0.07 "
- finished plaster of mortar of cement, on white concrete base	"	0.02 "

B. Coefficients of heat transfer

a) rooms Q221 cal/sq.m.°C.hr.

b) corridors Q313 " " " "

Table 4 - <u>Dividing walls</u> (between rooms, tunnels and corridors, anterooms and corridors

A. Composition of the walls

- finished plaster of mortar of cement, on white concrete base	thickness	0.02 m.
- solid-brick masonry	"	0.07 "
- impermeable stratum	"	-
- frigolit, 20 Kg./cu.m.	"	0.08 "
- solid-brick masonry	"	0.14 "
- ordinary plaster	"	0.02 "

B. Coefficients of heat transfer

a) between rooms and corridors	0.398 cal/sq.m.°C.hr.
b) between tunnels and corridors	0.401 " " " "
c) between tunnels and anterooms	0.401 " " " "

Table 5 - Dividing walls (between cold-storage rooms, corridors, anterooms and areas at normal temperature)

A. Composition

- finished plaster of mortar of cement, on white concrete base	thickness	0.02 m.
- solid-brick masonry	"	0.07 m.
- impermeable stratum		-
- frigolit, 20 Kg./cu.m.		
a) rooms and tunnels	"	0.10 "
b) corridors	"	0.08 "
- solid-brick masonry	"	0.14 "
- ordinary plaster	"	0.02

B. Coefficients of heat transfer

a) cold rooms and internal areas at normal temperature	0.441 cal/sq.m.°C.hr.
b) corridors and anterooms and internal areas at normal temperature	0.319 " "

Table 6 - <u>Dividing walls</u> (between one room and the next, one tunnel and the next)

A. Composition

- reinforced concrete rendering	thickness	0.02 m.
- solid-brick masonry	"	0.07 "
- impermeable stratum	"	-
- frigolit, 20 Kg./cu.m.	"	0.06 "
- impermeable stratum	"	-
- solid-brick masonry	"	0.07 "
- cement rendering	"	0.02 "

B. Coefficients of heat transfer

a) between one room and the next	0.410	cal/sq.m.°C.hr.
b) between one tunnel and the next	0.418	" "

Table 7 - Floors (cold-storage rooms, corridors, anterooms and pre-cooling tunnels)

A. Composition

- layer of reinforced concrete, with mesh reinforcement and iron dust incorporated in the upper layers	thickness	0.14 m.
- impermeable stratum		-
- frigolit, 20 Kg./cu.m.		
a) corridors and anterooms	"	0.06 "
b) tunnels	"	0.10 "
c) rooms	"	0.10 "
- layer of concrete	"	0.12 "
- basic filling		-

B. Coefficients of heat transfer

a) corridors and anterooms	0.438	cal/sq.m.ºC.hr.	
b) tunnels	0.278	"	"
c) rooms	0.276	"	"

Table 9 - Roofs (pre-cooling tunnels)

A. Composition

- impermeable layer of tarred felt	thickness	-
- practicable layer of tiles and cement	"	0.16 m.
- impermeable stratum	"	-
- frigolit, 20 Kg./cu.m.	"	0.14 "
- impermeable stratum	"	-
- plaster of mortar of cement, reinforced and finished, based on white concrete	"	0.02 "

B. Coefficients of heat transfer

- pre-cooling tunnels 0.200 cal/sq.m.°C.hr.

5. Calculations

This section is subdivided into the following three parts :

- calculation of heat losses
- calculation of the temperature necessary for pre-cooling and cold storage
- various sources of heat.

5.1 Calculation of heat losses

The heat losses have been estimated on the basis of the data given in paragraph 4, in which are given the various coefficients which make up the total coefficients of heat transfer of the various structures, e.g. walls, floors and ceilings.

The same paragraph also describes the structural characteristics of the above-mentioned parts of the building, and the respective coefficients of heat transfer.

Drawing N° 2 shows a plan and cross-section of the plant, giving the proposed temperatures of the various sectiions.

As regards the relative humidity, we may give the following figures:

- maximum humidity of the air in the space between the roof and the ceiling of the rooms: 93%
- relative humidity of the cold-storage rooms: 90%.

On the basis of the above, we may calculate the following:

1) Small rooms (which have the least favourable thermal conditions)

- floor	292 cal/hr.
- ceiling	292 "
- large wall on outside	341 "
- wall on corridor side	138 "
- small wall on outside	224 "
1) total	1,376 cal/hr.

The rounded off total is 1,400 cal/hr.

2) Large rooms (which have the least favourable thermal conditions)

- floor	1,300 cal/hr.
- ceiling	1,700 "
- large wall on outside	900 "
- small wall on outside	391 "
- wall on corridor side	241 "
2) total	4,532 cal/hr.

The rounded off total is 4,550 cal/hr.

3) Large internal rooms (with more favourable thermal conditions)

From the above it can be seen that the quantity of heat lost through the large outside wall is 900 cal/hr.; this is deducted from the above total, giving a figure of 3,650 cal/hr.

4) Pre-cooling tunnels

- floor	719 cal/hr.
- ceiling	913 "
- walls on side of corridor and anteroom	894 "
4) total	2,544 cal/hr.

This figure may be rounded off to 2,600 cal/hr.

5) Anteroom

- floor	175 cal/hr.
- roof	299 "
- walls on side of large hall	147 "
5) total	621 cal/hr.

The figure may be rounded off to 700 cal/hr.

6) Corridors and distribution hall

- floor	1,724 cal/hr.
- roof	2,944 "
- wall on outside	613 "
- wall on side of large hall	196 "
6) total	5,477 cal/hr.

The figure may be rounded off to 5,500 cal/hr.

To recap, the totals are as follows:

1) Small rooms	: 16 x 1,400 =	22,400 cal/hr.
2) Large rooms with least favourable conditions	: 1 x 4,550 =	4,550 "
3) Large internal rooms	: 3 x 3,650 =	10,950 "
4) Pre-cooling tunnels	: 2 x 2,600 =	5,200 "
5) Anterooms	: 1 x 700 =	700 "
6) Corridors and distribution hall	: 1 x 5,500 =	5,500 "
TOTAL HEAT LOSSES		49,300 cal/hr.

5.2 Calculation of refrigeration units necessary for pre-cooling and cold storage

In order to calculate the quantity of heat which must be subtracted for pre-cooling, taking into account the weight of the packing, etc., a specific heat should be attributed to the products, equal to 1 cal/Kg.°C; on this assumption, to cool a product from the temperature at which it enters (taken to be 28°C) to its average final temperature (-1°C) in a period of 48 hours, it will be necessary to subtract 29,000 cal/ton. The refrigeration requirements would therefore total the rounded figure of 600 cal/ton.hr.

Furthermore, during storage at a temperature of 0°C, each ton of the product generates a quantity of heat equal to around 190 cal/day, i.e. approximately 8 cal/ton.hr.

On the basis of these figures, the quantity of heat which must be subtracted from the products may be immediately calculated, subdividing the process into its various stages.

5.2.1 Rapid pre-cooling

As regards rapid pre-cooling, it must be remembered, as mentioned in paragraph 3, that the actual pre-cooling takes place in two parallel tunnels, each of which is loaded with goods every other day.

The cooling process is carried out at a certain temperature for the first 24 hours and a lower one for the next 24 hours; each tunnel therefore operates with the same load for 48 hours at a time. After this the tunnels are unloaded and loaded with fresh products, the cooling elements operating once more at the higher temperature.

To conclude, the refrigeration units necessary may be calculated on the basis of the following:

- maximum quantity of goods introduced daily — 40 tons
- maximum quantity of heat to be subtracted hourly: 40 tons x 600 cal/ton.hr. — 24,000 cal/hr.

Taking into account the loading and unloading operations and relevant movement, it must be considered that the cooling process takes 40 hours every two days, and therefore the quantity of heat to be subtracted per hour is in effect equivalent to:

$(48 \div 40) \times 24{,}000 = 28{,}800$ cal/hr.

5.2.2 Storage

In this case, also, it is considered that the refrigeration plant will work 20 hours per day, with a floor load of 1.25 ton/sq.m.

Large rooms: 280 sq.m. x 1.25 ton/sq.m. = 350 ton
Small rooms: 60.48 " x 1.25 " " = 75 "

The heat generated biologically during storage will therefore be:

Large rooms:
$350 \text{ ton} \times 8 \text{ cal/ton.hr.} \times \frac{24}{20} = 3{,}360$ cal/hr.

Small rooms:
$75 \text{ ton} \times 8 \text{ cal/ton.hr.} \times \frac{24}{20} = 720$ " "

The total figures are therefore:

- large rooms: 4 x 3,360 cal/hr. = 13,440 cal/hr.
- small rooms: 16 x 720 " " = 11,520 cal/hr.

Total 24,960 cal/hr.

The figure may be rounded off to 25,000 cal/hr.

5.3 Various sources of heat

The main source of heat is the fresh air. It is proposed to change the air in each cold-storage room completely once every 24 hours; therefore, bearing in mind the external and internal temperature, approximately 19 cal/cu. m. of air which enters the room must be subtracted.

This gives the following figures:

- large rooms: 1,350 cu.m. x 19 cal/cu.m. x $\frac{1}{20}$ hr.
  = 1,280 cal/hr.
- small rooms: 290 cu.m. x 19 cal/cu.m. x $\frac{1}{20}$ hr.
  = 275 cal/hr.

The other sources of heat consist of the workers, the illumination and the opening of doors etc. The quantity of heat thus generated is difficult to calculate with any degree of accuracy, as is the time at which it will be produced. Our calculations must therefore be based on an empirical principle, giving all these accidental sources of heat a value of 100 cal/hr. for the small rooms and 300 cal/hr. for the large rooms.

5.4 Summary of the cold requrements

From the figures given in the preceding paragraphs, it is possible to summarize the various amounts of heat for which the refrigeration produced by each installation must compensate.

Nevertheless, we take into account the observation made previously, i.e. we shall suppose that the refrigeration complex will work for 20 hours/day instead of 24: the heat losses calculated must therefore be increased by 24/20. This gives the following figures:

Small rooms:

- losses: 1,400 cal/hr. x $\frac{24}{20}$	=	1,680 cal/hr.
- heat produced biologically	=	720 " "
- accidental sources of heat	=	100 " "
Total for small rooms		2,500 cal/hr.

Large rooms (these are considered the most exposed):

- losses: 4,550 cal/hr. x $\frac{24}{20}$	=	5,450 cal/hr.
- heat produced biologically	=	3,360 " "
- accidental sources of heat	=	300 " "
Total for large rooms		9,110 cal/hr.

(NOTE: The quantity of heat which must be subtracted to compensate for the fresh air entering the rooms is calculated separately, bearing in mind that the fresh air is treated, as has been mentioned, by suitable air-conditioners mounted in the space between the ceiling of the rooms and the roof of the building.)

Pre-cooling tunnels:

- losses: 2,600 cal/hr. x $\frac{24}{20}$	=	3,120 cal/hr.
- pre-cooling	=	28,800 " "
Total for pre-cooling tunnels		31,920 cal/hr.

Anterooms:

- losses: 700 cal/hr. x $\frac{24}{20}$	=	840 cal/hr.
- accidental sources of heat	=	200 " "
Total for anterooms		1,040 cal/hr.

Corridors etc.:

- losses: 5,500 cal/hr. x $\frac{24}{20}$	= 6,600 cal/hr.
- accidental sources of heat	= 900 " "
Total for anterooms	7,500 cal/hr.

From the partial totals given above, the following overall totals may be obtained:

- Small rooms: 16 x 2,500 cal/hr.	= 40,000 cal/hr.
- Large rooms: 4 x 9,110 " "	= 36,440 " "
- Tunnels : 2 x 31,920 " "	= 63,840 " "
- Anterooms : 1 x 1,040 " "	= 1,040 " "
- Corridors : 1 x 7,500 " "	= 7,500 " "
- Changing the air:	
- Small rooms: 16 x 275 cal/hr.	= 4,400 " "
- Large rooms: 4 x 1,280 " "	= 5,120 " "
TOTAL	158,340 cal/hr.

6. Capacity of the refrigerator plant and circuits

Below we give a brief description of the production and control mechanism of the refrigerator plant.

The installations are planned on the principle of distribution from above with hot gas thawing. Under this system it is possible to control the evaporation temperature of the freezing agent in each evaporator independently. Consequently, different temperatures can be obtained in the various rooms from the same refrigeration plant.

This system is especially useful for the cooling tunnels, if it is wished to effect cooling in two distinct phases with the same cooling elements and an automatic circuit-breaker. During the first phase, pre-cooling is at a higher evaporation temperature than during the second. This avoids excessive dehydration of the fruit during the cooling process. At the exit from the cooling elements, special valves are mounted in two distinct circuits, each of which is intercepted by an electro-magnetic valve controlled by the automatic circuit-breaker.

In this way, the cooling elements operate at an evaporation temperature of +18°C for the first phase; after this, the automatic circuit-breaker stops the element operating at low temperature (evaporation temperature -6°C), and the cooling process is completed by the second phase, of the same length as the first.

The operation, as described above, is completely automatic, but can also be carried out by manual control.

The evaporation temperatures proposed for the various parts of the plant are as follows:

- in the rooms: -6°C
- in the tunnels during the first pre-cooling phase: +18°C

- in the tunnels during the second pre-cooling phase: -6°C
- corridors and anterooms: +2°C

The total cold requirement, for which the calculations are given below, is equal to 158,340 Frigorie/hr.

Allowing a reasonable safety margin, and to meet unexpected difficulties and overloading, it would be as well to plan a refrigerator plant and cooling elements with a capacity higher than that which seems necessary from the calculations.

It will therefore be advisable to install three refrigerating compressors with a nominal capacity of 100,000 Frig/hr. each; one of these will act entirely as a reserve.

These compressors will operate under the following conditions: - 6°C and + 25°C; they will allow a maximum capacity more than 15% higher than the nominal capacity.

Finally, the following cooling elements should be installed:

ROOMS	n° of rooms	n° of elements per room	unit capacity: Frig/hr.	total n° of elements	total Frig/hr.
Small rooms	16	1	4,500	16	72,000
Large rooms	4	1	11,000	4	44,000
Anteroom	1	2	2,000	2	4,000
Corridors etc	1	10	1,500	10	15,000
Tunnels	2	5	1,500	10	15,000
Fresh air	1	2	5,000	2	10,000
Total				44	160,000

The plan of operation described above allows the number of machines and mechanisms of control and regulation to be reduced to a minimum, at the same time guaranteeing the maximum flexibility in the operation of the cold-storage warehouse, besides perfect safety and a high degree of automation.

Besides the above-mentioned compressors, the refrigerator unit will include evaporators, condensors, control mechanisms etc.

7. Civil works

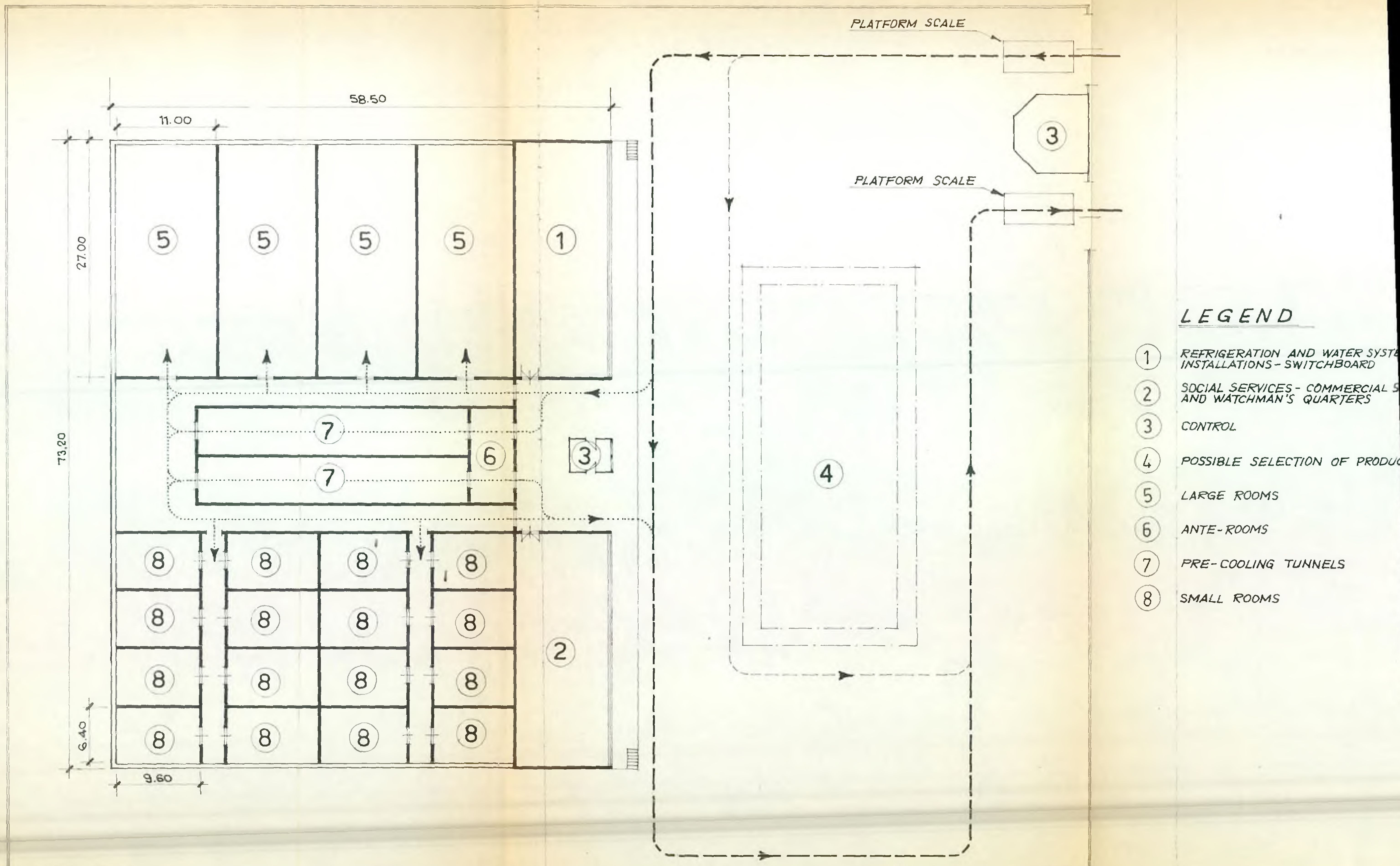
Our project includes the civil works indicated briefly in the general lay-out shown in drawing n° 1, which gives the basic dimensions of the cold-storage warehouse.

The building housing the warehouse will be constructed in concrete, with block walls, of a modular type with fairly large spaces left through which the machines may be installed inside the building.

The warehouse ought to be situated slightly higher than the surrounding land, to isolate it and to make loading and unloading easier.

8. Other installations

The project allows the space necessary for a department for selecting, washing and grading the fruit. This department, which is not included in our calculations, could be added to the project to form a true fruit centre, should the local conditions make this advisable.


PLATFORM SCALE
PLATFORM SCALE
58.50
11.00
27.00
73.20
6.40
9.60
LEGEND
1 REFRIGERATION AND WATER SYSTE
INSTALLATIONS - SWITCHBOARD
2 SOCIAL SERVICES - COMMERCIAL S
AND WATCHMAN'S QUARTERS
3 CONTROL
4 POSSIBLE SELECTION OF PRODUC
5 LARGE ROOMS
6 ANTE-ROOMS
7 PRE-COOLING TUNNELS
8 SMALL ROOMS

INDUSTRIA

9. - ECONOMIC ANALYSIS

9.1 Investments

9.2 Running costs

9.1 Investments

		Eth. doll.
9.1.1	Fixed investments	
	- civil works	1,969,000
	- equipment and machinery	1,100,000
	- auxiliary supplies	5,000
	- various costs	245,000
	- contingencies (4% of 3,329,000 Eth. doll.)	131,000
9.1.1	Total fixed investments	3,450,000
9.1.2	Working capital	40,400
	9.1 TOTAL INVESTMENTS	3,490,400

9.2 Running costs

Total annual costs	: 457,180 Eth. doll.
Maximum storage capacity	: 2,500 tons
Unit cost	: 162,620 Eth. doll./ton
Unit incidence of fixed investments:	$\frac{3,450,000 \text{ Eth.doll.}}{2,500 \text{ tons}}$
	= 1,380 Eth.doll./ton

10. ADDENDA

INDEX OF ADDENDA

10.1 Civil works

Item	area in m^2	unit cost in Eth.doll.	total cost in Eth.doll.
- building housing cold-storage warehouse	4,400	400	1,760,000
- lay-out of area, with civil works for bridge scale, transformers, earthworks etc.	12,500	-	200,000
- fencing (1)	450	20	9,000
10.1 Total for civil works			1,969,000

(1) - The fencing is measured in linear metres.

10.2 Equipment and machinery	Eth. doll.
- refrigerator plant	200,000
- machinery for cold rooms, tunnels and the other refrigerated areas; connecting system	525,000
- insulating doors	100,000
- transformer cabin	100,000
- electric switchboards, connection and distribution system	50,000
- spare electrical installations	100,000
- various installations	75,000
- hydraulic installations	80,000
- extras and contingencies	50,000
Total cost of machinery and equipment	1,100,000

The costs are taken to include the incidence of transport and assembly.

10.3 Auxiliary supplies	Eth. doll.
- office equipment	2,000
- various accessories	3,000
10.3 Total cost of supplies	5,000

10.4 Various costs	
- engineering services	220,000
- cost of organization and establishment of the firm	10,000
- interest during the course of construction works	15,000
10.4 Total various costs	245,000

10.5 Indirect costs

Technical and administrative personnel

	n°	Monthly salary in Eth. Doll.	Total in Eth.doll.
- technical manager	1	1,600	19,200
- controller	1	800	9,600
- accountant	1	600	7,200
- secretaries and typists	1	200	2,400
- watchman/gatekeeper	2	100	2,400
- driver	1	150	1,800
Total	7		42,600
Incidence of social benefits:13%			5,540
Bonus			3,550
Reserve fund			3,550
10.5 Total annual indirect costs			55,240

10.6 Direct labour

	n°	Monthly salary in Eth.doll.	Total in Eth.doll.
- for receiving raw materials	4	150	7,200
- for internal transportation	16	80	15,360
- for the refrigerator plant	2	150	3,600
- refrigerator mechanic	1	200	2,400
- electrician	1	200	2,400
Total	24		30,960
Incidence of social benefits : 13%			4,030
Bonus			2,580
Reserve fund			2,580
10.6 Annual total indirect labour			40,150

10.7 Fuel		Eth.doll.
- Electricity (1)		
Total annual consumption = 200,000 kWh. For the first 120,000 kWh the unit cost is 0.10 Eth.doll., giving a total cost of	12,000 Eth.doll.	
For the remaining 80,000 kWh the rate is 0.05 Eth.doll./unit, giving a total of........	4,000 " "	
10.7 Total for electricity		16,000
10.8 Insurance		
- civil works: 1% of 1,969,000 Eth.doll.		19,690
- equipment and machinery: 1% of 1,100,000 Eth.doll.		11,000
10.8 Total for insurance		30,690

(1) - The tariff rates are those charged by the E.E.L.P.A.

- commercial and industrial tariff:

first 1,000 kWh per month............ 0.10 Eth.doll./kWh

exceeding 1,000 kWh per month .... 0.05 " " "

10.9 Analysis of annual costs	Eth.doll.
10.9.1 General expenses	
10.9.1.1 Personnel	
- administrative personnel	55,240
- manual workers	40,150
10.9.1.1 Total	95,390
10.9.1.2 Consumed materials	
- fuels	16,000
- repair and spare parts	20,000
- stationery	1,000
10.9.1.2 Total	37,000
10.9.1.3 Insurance	30,690
10.9.1 TOTAL GENERAL EXPENSES	163,080
10.9.2 Depreciation and amortization	
10.9.2.1 Civil works Amortization in 20 years 5% of 1,969,000	98,500
10.9.2.2 Equipment and machinery Amortization in 10 years 10% of 1,100,000	110,000
10.9.2.3 Auxiliary supplies Amortization in 10 years 10% of 5,000	500

		Eth.doll.
10.9.2.4	Contingencies Amortization in 10 years 10% of 131,000	13,100
10.9.2.5	Amortization of non-deprecia-ting goods:	
	- engineering services amortization in 15 years 6.67% of 220,000	14,780
	- organization and establish-ment of the firm amortization in 10 years 10% of 10,000	1,000
	- interest during construction amortization in 5 years 20% of 15,000	3,000
	- amortization of working capital 8% of 32,400	2,590
10.9.2.5	Total amortization	21,370
10.9.2	TOTAL DEPRECIATION AND AMORTIZATION	243,470
10.9	TOTAL ANNUAL COSTS	406,550

10.10	Working capital	Eth.doll.
	10.10.1 Current items	
	10.10.1.1 Personnel	
	calculated for two months' operation $95{,}390 \times \frac{2}{12} =$	15,900
	10.10.1.2 Consumed materials	
	calculated for two months' operation $37{,}000 \times \frac{2}{12} =$	6,160
	10.10.1.3 Insurance	
	calculated for three months' operation $30{,}690 \times \frac{3}{12} =$	7,700
	10.10.1 Total current items	29,760
	10.10.2 Minimum cash balance	
	6% of 38,100 Eth.doll.	2,300
10.10	TOTAL WORKING CAPITAL	32,060