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TECHNO-ECONOMIC INVESTMENT PROJECT PROFILE ON

# SISAL ROPE AND TWINE

PREPARED FOR UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO), VIENNA

BY

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INVESTMENT PROJECT PROFILE

SISAL ROPE AND TWINE

## Introduction

1. While demand for rope and twine has continued to grow in industrialized and developing countries, there has been considerable substitution in industrialized economies of the basic materials from which these products are manufactured and presently rope is produced from fibres which can be either natural or man-made. The common natural fibres used in rope and twine production are sisal, manila, jute, hemp, abaca etc., which are available in a number of countries, mostly developing economies, and which constituted an important source of export earnings in earlier decades. In recent decades, however, rope production in industrialized countries has become principally based on man-made synthetic fibres, comprising various types of polymers, including nylon, polyester, polyethyelene and polypropylene. Various types and varieties of both natural and synthetic fibres can be utilized in different combinations of colour, strength, stretchability and other properties.

2. The extent to which natural or man-made fibres would be utilized as the basic material for rope and twine manufacture primarily depends on the availability and cost of alternative raw materials. In countries where sisal, manila or jute are abundantly available, these would constitute more economic sources of production. Synthetic fibres, while more expensive, would have to be used as the basic raw materials, particularly where availability of natural fibres are limited and transport costs of such materials are high.

3. Sisal is the leaf fibre obtained from the plant **agave sisalana** and is extensively used in the production of rope, cord and twine in a number of countries. The plant, which originated in the Yucatan peninsula in Mexico, has been extended to several semi-tropical regions and is presently cultivated in a number of countries, including Brazil and other parts of Central and South America, Haiti, Indonesia, Madagascar, and in several African countries, particularly in semi-arid areas with relatively loose soil. The fibre designation is generally identified with the region where it is produced, so that reference is made to East African sisal, Haitian sisal etc.

<u>Products and Specifications</u>

3. Rope is usually comprised of three to six strands of fibrous material, twisted in such manner that the twist of the rope offsets the twist in the strands, thus making it possible for the strands to fold together. Till the middle of the nineteenth century, most fibre rope was made from hemp (Cannabis sativa) or soft fibre cultivated since ancient times. Currently, well over 90 per cent of the cordage utilized is made up of hard fibres, such as abaca and sisal etc.

4. Twine is a a thinner variant of rope, usually composed of two or more threads or yarn. A strand is defined as two or more yarns or threads twisted together, with the twist in a direction opposite to that of the threads. In commercial twine, the twist is usually right-handed. Cord is defined as small commercial twine, comprising of two or more threads.

5. Rope and twine are generally classified by the kind of fibre (natural or man-made), diameter length or weight per coil, degree of twist and colour. The standard packaging of rope is 1,200 ft (equals 200 fathoms) and is termed a coil. Rope is also packaged in half and quarter coils.

6. Most synthetic fibres used for the manufacture of rope and twine face a cost disadvantage in relation to natural fibres, if these are locally available. At the same time, natural fibres such as manila and sisal, lose strength when exposed to dry air over long periods, though this can be regained considerably by reconditioning, provided the exposure temperature is not excessive. Exposure to air in excess of 250°F (121°C) can cause strength reduction of 10 to 20%. Among synthetic materials, nylon can withstand higher temperature but, apart from its cost, tends to stretch considerably when loaded. Saran fibres can be utilized up to about 170 °F (77°C) but loses strength at higher temperatures. Polyethylene is essentially unaffected by temperature changes below 220°F (104°C) but tends to be slippery and more difficult to use with capstans and winches.

7. The main characteristics required in all rope and twine products are high tensile strength, compactness with no looseness in the structure, high degree of pliability and ability to avoid distortion of form while in use. The tensile strength is determined by the type of fibre used, the accuracy with which the fibres are aligned along the axis of the cord and the amount of twist which is inserted to bind the fibres together and prevent them from sliding apart.

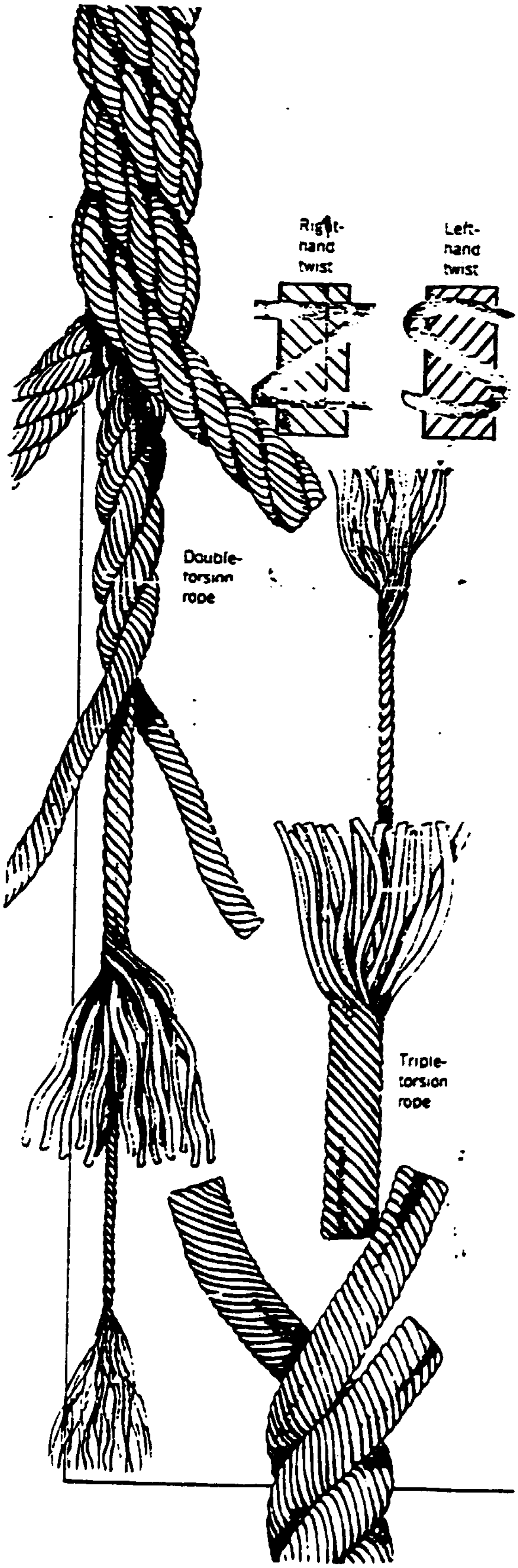



**Figure 1. Characteristics of rope**

8. Characteristics of Sisal: The major single use of sisal is for production of rope and twine for a variety of functions, ranging from tying bundles of agricultural products to holding various forms of packages, and various other uses. The chemical analysis of sisal fibre is: cellulose 77.2%, moisture 6.2%, ash 1%, lignine and pectines 14.5% and extractives 1.1%. The plant has a short thick stem from which grows a rosette of leaves. The stem is usually about 6 inches (152 mm) in diameter at just above ground level, and its diameter increases to around 9 inches (229 mm) at a height of 1 ft. (304 mm) above ground. The leaves grow from the summit of the stem, and are long, roughly triangular in cross-section, and dark green in colour. The leaves can grow to about 6 ft (1.8 m) in length and an average width of about 6 inches (152 mm). New leaves appear from the center of the rosette, so that the oldest leaves are on the outside. The leaves have virtually no marginal prickles, unlike henequen and other agave fibre plant leaves. Successive cuttings of leaves are made twice each year for a period of 4 to 6 years. A well-grown plant yields 140 to 200 leaves during its lifetime.

9. Sisal cells show no crossmarkings, have wide prominent lumens and blunt ends which are occasionally forked. Lumen is often wider than cell wall and is more rounded. Cell dimensions are 0.8 to 7.5 mm in length, 0.007 to 0.047 mm in diameter, and cross sections are sharply polygonal.

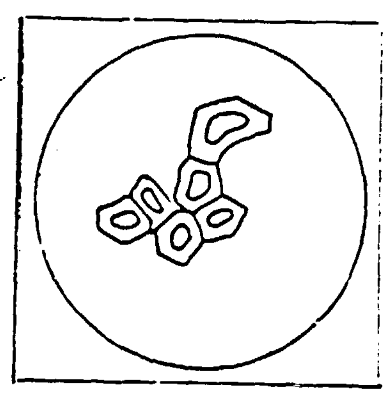


**Figure 2. Sisal cells**

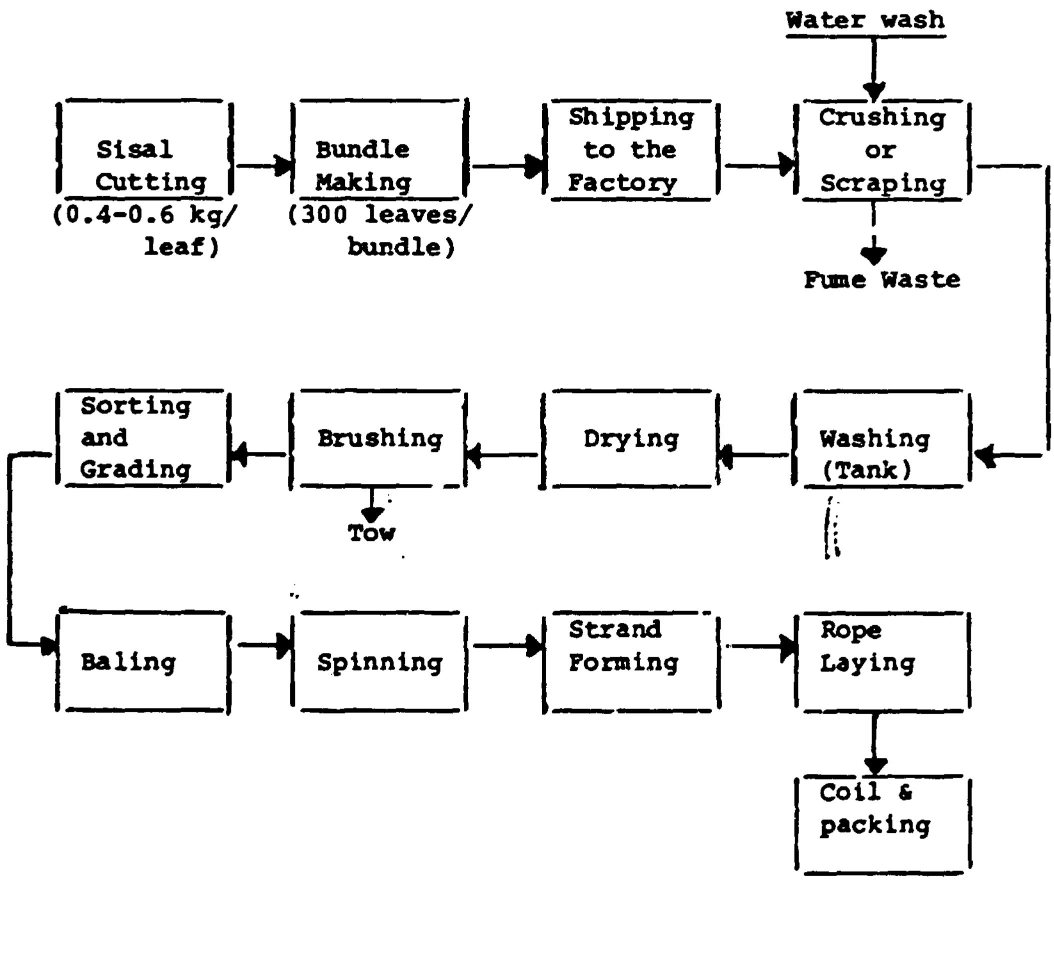
## Plan of Production

10. The production capacity has been defined at 3600 tons a year of sisal rope and twine (mainly rope), with product thickness 2.8 mm to 26 mm. This capacity is appropriate and reasonable for a single-shift (8 hours a day) operation, and with the plant operating for 25 days per month/300 days per year. If the demand for rope justifies additional production, a second shift can be introduced which would result in substantial increase in capacity. A third shift could also be added, if necessary.

11. The introduction of a second shift would wholly depend on the growth of demand and size of market to be served. Even single-shift operation would result in considerable production, though this can be rapidly absorbed if demand from the agricultural sector in particular, is high.

12. The process flow chart for manufacture of sisal rope is provided in Table 1 below and the process is described in detail thereafter.

Table 1. Sisal rope and twine manufacture process flow chart



Process Description

13. The sisal leaves, when they are ready for harvesting, are cut off at the point where they join the main stem using aspecially-curved sickle knife. Care has to be taken not to damage the younger leaves which are not sufficiently developed for harvesting. One leaf, as cut, weighs between 1 and 1 1/2 lb (0.4-0.6 kg). The spike at the top of each leaf is cut away, and the leaves are made up into bundles of about 30 leaves each. These bundles are transported to cleaning machine for extraction of the fibre. Sisal fibre is graded first according to the country of origin. Indonesian sisal is often considered superior to other sisal fibres on the basis of colour and reliability of grading. Other major country gradings comprise of East African sisal, Philippines sisal, Haitian sisal and Brazilian sisal. In grading, cleaning and brushing are important considerations, besides two sub-groups which are determined by colour.

Figure 3. Sisal, ready for harvesting

14. The fibre is usually cleaned within 24 hours of the cutting, as otherwise it becomes leathery and impossible to decorticate properly when allowed to dry. The fibres are extracted by crushing or scraping to remove surrounding green matter. This process is carried out using mechanical decorticators which scrape away the pulpy tissue at a rate of 200 to 300 leaves per minute. The leaves are first crushed between fluted metal rolls and the crushed leaf is then clamped at midpoint, and free ends delivered to sets of drums, the faces of which are fitted with dull brass blades. The fast moving blades beat and scrape away the pulpy tissue. The clamped portion of the leaf is then released and similarly decorticated. The cleaned fibre is dropped into a tank of water, where it is rinsed, and then either air or oven dried. When dry, the fibre is usually brushed on rotating brushing drums to remove adherent dust and weak fibres, and to impart some lustre to the fibre. The fibre bundles are baled after being sorted according to grade. The short fibres, together with waste from cleaning, brushing and occasional end-cutting, are graded and sold as tow and flume waste. A considerable amount of tow is spun and twisted into wrapping twines. Flume waste consists of the short fibres recovered from the waste carried away from the decorticater by a stream of water. Sisal tow is used as a padding material in upholstery.

15. The further stages of processing include automatic yarn spinning, strand forming and rope-laying. The automatic spinner or spinning jenny is a type of gill spinner which is mainly used in the manufacture of hard fibre (sisal) yarn. The machine is built in units of two flyers. The spinning process consists of drawing, spinning, and winding the yarn on to the bobbing. The yarn is fed into the strand-forming machine. As the yarn is twisted together to form the strand, compactness is ensured in the strand by dragging the component yarn through a compression die or tube, as these are being bound together by the twist. At the same time, this tube serves to guide the individual yarns into their correct relative positions in the strand structure. The yarns for the strands are taken from an assembly of bobbins supported in a creel and, in some creels, the pins supporting the bobbins are sufficiently long to allow two bobbins, one above the other, to be supported on each pin, with the yarn from the inside of one bobbin being tied to the outside of the yarn from the other, so that a longer continuous run of the yarns can be obtained. From the creel, each yarn is taken through its appropriate hole drilled in a "register plate" of curved cross-section and then into the strand tube. In practice, the strand tube is located as close as possible to the register plate, in order that the yarns will have to bend sharply and any protruding fibers standing out from the yarns will be sheared off thereby. Twist is inserted in the strands using a flyer principle and, since the tensions used are high, hauling capstans are also employed.

16. Various types of rope laying machine ranging from horizontal to vertical can be utilized. A typical horizontal rope-laying machine consists of four component units:

(a) the rotating flyers for the strand bobbins
(b) the compression and sleeking die
(c) the rotating hauling capstans
(d) the rotating flyer which winds the rope on a bobbin, with its associated traverse screw for even winding and tension control.

All rotating component units turn in the same direction. The strand bobbin flyers are equipped with friction blocks which, by pressing against the rims of the bobbins, can regulate the tension of the emerging strands. The operation consists of placing the strand bobbins in their respective flyers, and running the strands through a compression and sleeking die. During the twisting operation, tension in the twisted rope is regulated by weighting the friction pulley in the afterturn component. The strand tension is adjusted for each respective strand to ensure that strand cackles and overtwisting are avoided, and that the tensions of respective strands are comparable. When the rope receiving bobbin is filled, the entire bobbin may be removed from the machine, or the gear train set so that the rope may be pulled off the free-running bobbin. Figure 5 shows three strand flyers, but the machine is also available with two or four flyers.

For a typical 25 mm and larger rope size:
flyer speed: 20 rpm; driving power: 8 HP and approximate bobbin capacity up to 1300 lbs.

For a typical 12 mm and larger rope size:
flyer speed: 160 rpm; driving power 6 HP and approximate bobbin capacity up to 600 lbs.

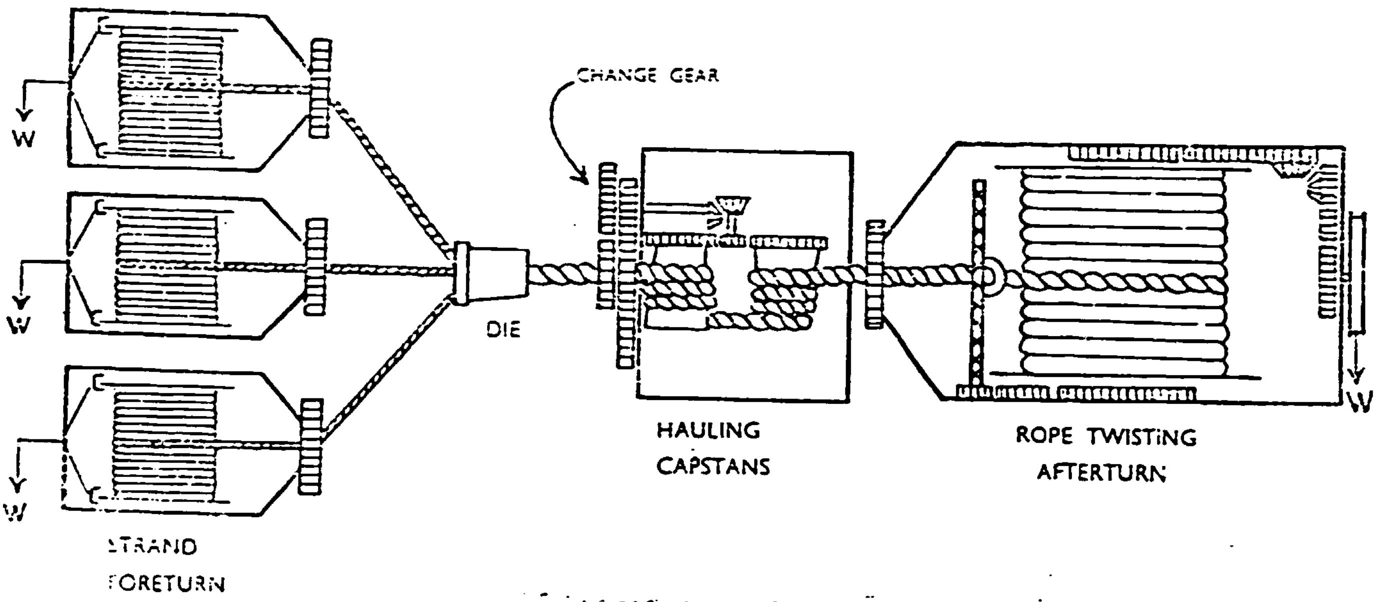



**Figure 4. Horizontal rope-laying machine**

17. The view of a modern rope-making plant may be seen from Fig. 5.

**Figure 5. A modern rope-making plant**

18. Twine production: There are three general types of twine: laid, twisted, and plaited or braided. The difference between laid and twisted cords and twines is in whether foreturn is provided or not. Twisting is simply twisting together of the component yarns, while laying is the provision of foreturn during the twisting operation, this producing a better balanced structure. Plaiting or braiding is the interlocking of crossed yarns. The protraction machines used to manufacture twine operate in much the same way as those employed in making strands and ropes but, since smaller diameters and weights are involved, much lighter and speedier mechanisms are used. Laid twine and cords usually have a hard, rounded cross-section and high strength, adequate abrasion resistance and a tendency to resist bending. Twisted twines are softer and less resistant to wear.

## Requirements of Machinery and Equipment

19. The following major items of machinery and equipment would be required for a sisal rope and twine manufacturing plant:

### Table 2

| | | |
|---|---|---|
| a) | Mechanical Decorticators | 1 unit |
| b) | Wash Tank | 1 unit |
| c) | Rotating Brushing Drum | 1 unit |
| d) | Automatic Spinning Machine | 3 units |
| e) | Strand-forming Machine | 3 unit |
| f) | Rope Laying Machine | 3 sets |
| g) | Braiding or Plaiting Machine | 1 unit |
| g) | Pumps and Auxiliary Equipment | 2 units |

The total installed cost of the above equipment supplied from Europe or the United States (at January 1989 prices) would be approximately US$ 1,160,000. The machinery items can be obtained from several alternative sources and selection and ordering of such equipment should not present any difficulty. Delivery of equipment would take 6-8 months. Equipment installation should also not present any problems and the total project implementation period should range from 10 to 12 months.

Contractual Arrangements

20. Production technology for sisal rope and twine is incorporated in the equipment to be purchased and no separate arrangement for technology transfer is required. If desired, consultancy services can be obtained for calling of bids for machinery, selection of machinery suppliers, negotiation of machinery supply agreements, including performance guarantees, trial runs and training of local personnel, and for front-end engineering or turnkey installation of the plant.

Locational Considerations

21. The plant for sisal rope and twine should be located in the region where sisal is available and can be easily transported to the plant. There are no major environmental aspects to be taken into account.

Plant Site, Buildings and Facilities

22. The plant site would require an area of 780 $m^2$ and would require to be suitably prepared for factory construction. The cost of the factory building is estimated at $345,000 at an approximate cost of $40/sq. ft. In addition, an ordinary storage warehouse would be required, which would cost about $130,000. Utilities and ancillary facilities for water, electricity, telephone etc. and for roads, electricity substation and the like would also need to be provided. Provision should also be made for training and pre-production costs and for miscellaneous expenses.

Table 3

| | | |
|---|---|---|
| (a) | Cost of factory building | $345,000 |
| (b) | Cost of storage warehouse | $130,000 |
| (c) | Utilities and ancillary facilities | $110,000 |
| (d) | Training and pre-production expenses | $100,000 |
| (e) | Miscellaneous expenses | $100,000 |
| | Total | $785,000 |

## Raw Material Requirements

23. The principal raw material required would be sisal leaves, besides pigments (if desired) and certain chemicals in small quantities. Adequate supplies of sisal leaves obviously constitute an essential prerequisite for successful operations of the plant.

Table 4. Raw Material Requirements

Sisal leaves - 1350 kg (per ton of product).
Pigment (if desired) - 6.25 kg (per ton of product).

## Manpower Requirements

24. Manpower requirements for the plant will not be very high and should comprise the following:

Table 5. Manpower Requirements (for 8 hour shift/day)

| | |
|---|---|
| Plant manager /chief engineer | 1 |
| Foreman | 1 |
| Operators | 5 |
| Factory workers | 8 |
| Maintenance mechanic | 1 |
| Quality control inspector | 1 |
| Administrative/clerical Staff | 3 |
| | 20 |

If a second shift is introduced, an additional 12 persons would be required.

## Manufacturing costs

25. The manufacturing cost of sisal rope (1/2 in. = 12.7 mm) should range from US 3.5 cents to US 6 cents per linear foot, which can be achieved at the production capacity of 3,600 t/y subject to local site conditions and sisal supply. Such cost would enable sisal rope to sell in major markets at whole sale prices of 7 to 9 cents/ft., which would be lower than rope from Manila (13 to 15 cents/ft.) and substantialy less than rfor made from nylon (18 to 21 cents/ft.).

26. The summary of initial capital costs for a proposed plant for production of sisal rope and twine would be approximately as follows:

Table 6. Summary of Initial Investment Costs

| | | |
|---|---|---|
| (a) | Land | To be determined. |
| (b) | Buildings | $475,000 |
| (c) | Utilities and ancillary facilities | $110,000 |
| (d) | Machinery and equipment, including installation | $1,160,000 |
| (e) | Training and pre-production costs | $100,000 |
| (f) | Miscellaneous expenses | $100,000 |
| | Total | $1,945,000 */ |

Say, US$ 1.95 million.

*/ Excluding cost of land and site development.