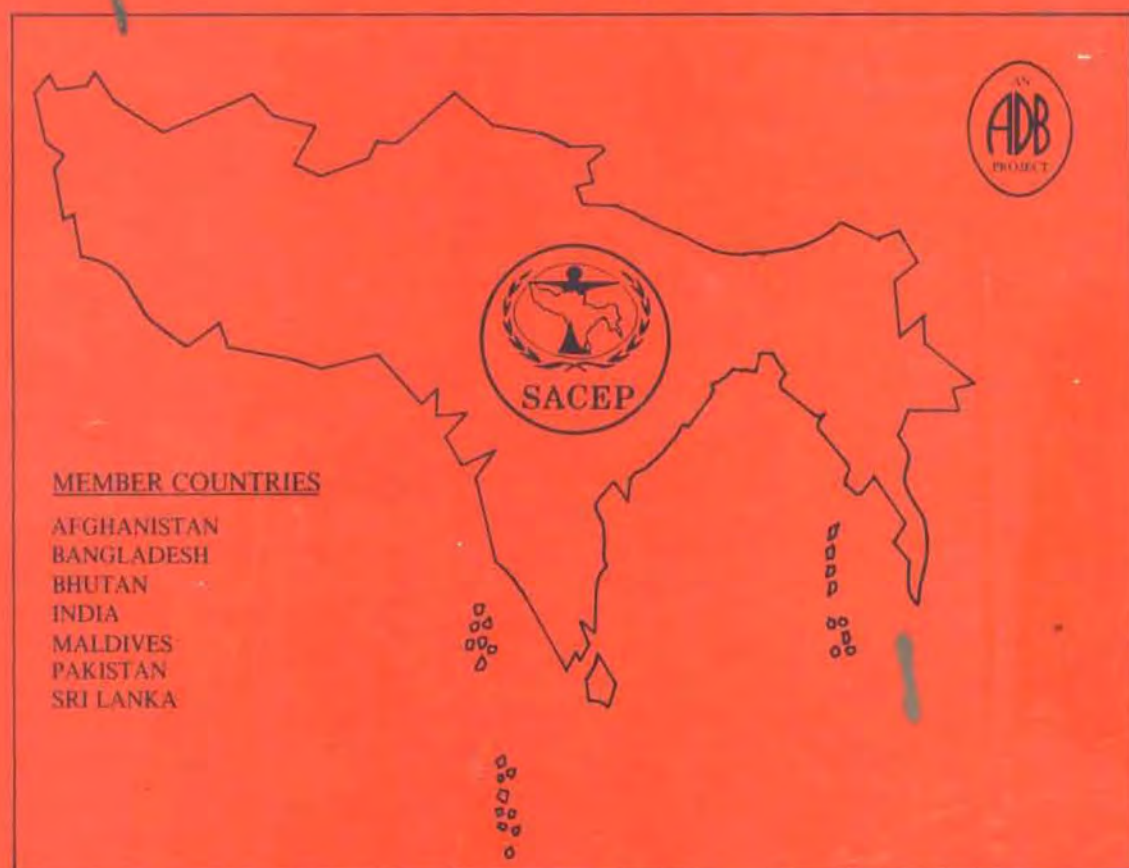


REGIONAL ENVIRONMENTAL AND NATURAL RESOURCES INFORMATION CENTER (RENRIC)

ASIAN DEVELOPMENT BANK
TECHNICAL ASSISTANCE PROJECT

A SOUTH ASIAN EXPERIENCE ON APPROPRIATE RESEARCH & DEVELOPMENT

NATIONAL ENGINEERING RESEARCH & DEVELOPMENT CENTRE
SRI LANKA



SOUTH ASIA CO-OPERATIVE ENVIRONMENT PROGRAMME (SACEP)

APRIL 1991

A SOUTH ASIAN EXPERIENCE ON APPROPRIATE RESEARCH & DEVELOPMENT

NATIONAL ENGINEERING RESEARCH &
DEVELOPMENT CENTRE
(NERD)
SRI LANKA

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At the Workshop Held By RENRIC
in Colombo from 21 - 23 February 1991

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FOREWORD

The Regional Environmental and Natural Resources Information Centre (RENRIC) funded by the Asian Development Bank was established in July 1990, at the South Asia Co-operative Environment Programme (SACEP) in Colombo.

The primary objectives of this RENRIC is to set up a clearing house mechanism so that the member states viz. Afghanistan, Bangladesh, Bhutan, India, Maldives, Pakistan and Sri Lanka will have ready access to relevant information in order to assist in their development efforts. The focal points in member countries will concentrate on collection of information dealing with area/topic assigned to it by the clearing house.

The broad objectives of the RENRIC project are:

- I. Establishment of an environmental and natural resources clearing-house unit within the SACEP Secretariat;
- II. Establishment of environmental and natural resources information network within the SACEP membership utilising the existing subject matter Focal Points to the extent possible;
- III. Provision of an information network system including appropriate hardware and software; and
- IV. Provision of advisory support and training for member country representatives by presenting a SACEP Workshop.

RENRIC held a Workshop at the Agrarian Research and Training Institute, Colombo, Sri Lanka from 21 - 23 February 1991. A request was made by the participants of the Workshop to publish the experience on Appropriate Research & Development on the utilisation of renewable energy resources presented by the National Engineering Research & Development Centre (NERD), Sri Lanka.

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THE NATIONAL ENGINEERING RESEARCH AND DEVELOPMENT (NERD) CENTRE SRI LANKA :

A SOUTH ASIAN TECHNOLOGY DEVELOPMENT SUCCESS STORY.

Abstract

This paper describes some of the engineering research done at the NERD Centre, Ja-Ela, Sri Lanka, for the development of environmentally sound and sustainable technologies, using locally available resources.

The underlying philosophy of the engineering R & D is self-reliance at the national level, in competition with free imports in an open economy, without any subsidies whatsoever. The NERD Centre story, something of a success story in the regional context of South Asia, is of interest especially because these technologies can be replicated in other South Asian countries with comparable factor endowments.

Historical background

Under British colonial rule a plantation sector was developed in Sri Lanka. At Independence in 1948, tea, rubber and coconut accounted for some 90% of all export earnings. Nevertheless, value added to primary agricultural products was minimal. All types of manufactured capital and intermediate goods were imported.

The flourishing plantation sector was served by agricultural research institutes, the Tea (TRI), Rubber (RRI) and Coconut (CRI) Research Institutes, but industries were altogether neglected. The traditional agriculture sector was served by the Central Agricultural Research Institute (CARI), but the staple rice, and other foodstuffs were imported. Engineering inputs into the plantation sector were provided by private sector companies with linkages to principals in Britain, the 'Mother Country'.

After Independence the Ceylon Institute of Scientific & Industrial Research (CISIR) was set up in 1955 followed by the Industrial Development Board (IDB) in 1957. It was only in the seventies that the need to have an engineering research and development centre to fill the gap between the CISIR and the IDB was recognized, and the NERD Centre project was mooted. However it was only after Dr. A N S Kulasinghe was appointed Chairman in 1977 that positive steps were taken to undertake the type of engineering research and development that is a prime necessity in any developing country. Under Dr. Kulasinghe, emphasis was given to projects which provide answers to identifiable problems, give direct and indirect benefits to a majority of people, and contribute thereby to socio-economic development in priority areas. Housing, Water and food supply, and Energy, were recognized as national priority areas. Engineering R & D projects were taken up in these areas which provided inputs into the agricultural and industrial sectors of the economy.

It was immediately apparent that this approach to engineering research and development resulted in the creation of environmentally sound and sustainable technologies. The proof of the pudding is in the eating - the technologies developed at the NERD Centre are seen to fulfil the theoretical criteria defined for such technologies. Moreover, these technologies can easily be replicated and reproduced in other South Asian countries with similar factor endowments that are faced with comparable problems of development, such as the ever increasing problems of the environment.

The problem of environmental degradation

Even in an agricultural country like Sri Lanka problems of environmental degradation do exist. Natural forest cover has been steadily depleted over the years, and it is estimated that less than 30% of the land is covered with forest today, a very low figure for a small island in the humid tropics.

Depletion continues because fuelwood accounts for over 70% of Gross Energy Supply (Fig. 1). Half this amount is consumed by the plantations, tea, rubber and coconut, with tobacco and sugar taking a further 10% and 2% respectively. Hotels, eating houses and bakeries account for a further 23%, and mineral based industries for most of the rest (Fig. 2). NERD Centre research was directed to finding fuel substitutes to help conserve fuelwood, and some success has been achieved.

Another important consequence of deforestation is the scarcity of building timber, and considerable amounts of timber are being imported at great cost. NERD Centre low cost building research addressed this problem, and came up with timber substitutes for roof, door and window frames and sashes.

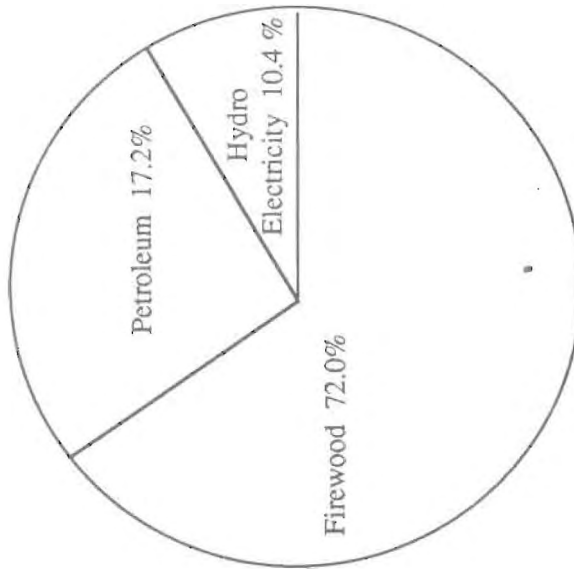
Certain agricultural by-products are conventionally described as agro-waste, and when these accumulate in increasing amounts, they become another aspect of the degradation of the environment. In Sri Lanka well-known examples are paddy husk, straw, coconut fibre dust called 'kohubath', and in some areas, saw dust and wood shavings.

Apart from these examples of agro-waste bio-mass, there are also a number of weeds and parasites that proliferate, like salvinia, a pest that spreads very fast in inland waterways, and water hyacinth, as well as other wild plants that grow away from water.

NERD Centre alternative energy research also looked into possibilities for converting these sources of environmental pollution into sources of energy. Producer gas and bio-gas applications were the result.

SRI LANKA ENERGY SUPPLY PATTERNS 1986

Figure 1

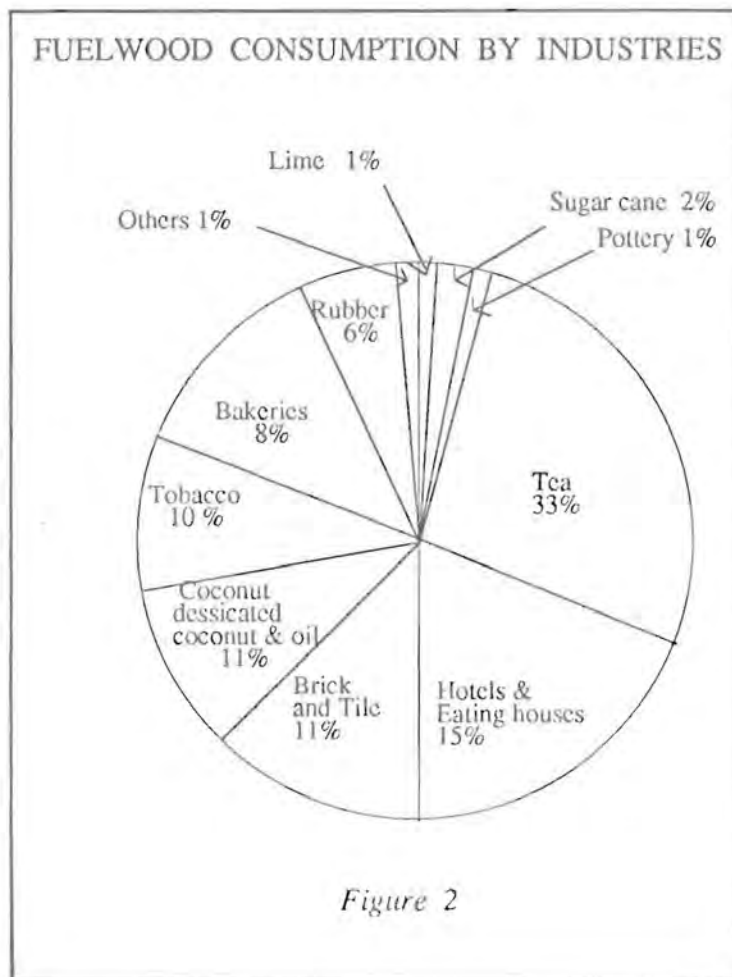


Gross Energy Supply



Useful or net energy supply

Source : Energy unit, Ceylon Electricity Board



Sources of power in nature

Utilisation of bio-mass is one example of the approach adopted at the NERD Centre to utilise the renewable sources of power and energy in nature. Other sources that have been successfully harnessed are solar thermal energy, wind energy, and hydro-power.

The approach adopted that has been very successful is to develop full-scale engineering prototypes using technologies based on these energy sources, which are tested, modified as necessary, and when successful, approved for commercial production under license.

These alternative energy technologies together with low cost but advanced construction technologies are the most important areas for engineering R & D at the NERD Centre.

The following is a partial list of projects based on these technologies that are now under commercial production and operation in various parts of the country:

1. Solar thermal energy technology
 - solar hot box cooker
 - solar dryer
 - solar water heater
 - solar still
2. Wind energy technology
 - Windmill generator and battery charger
 - Windmill powered air compressor
 - Windmill operated pneumatic water pump
3. Mini hydro-power technology
 - Banki cross-flow turbine
 - Pump operating as a turbine producing hydro-electricity
 - Barrel pump for lifting water for irrigated agriculture
4. Bio-mass technology
 - gassifiers for producer gas application in:
 - * low-cost high-efficiency heat exchanger
 - * tea drying
 - * tea manufacture
 - * bakery operation
 - * non-ferrous foundry operation
 - * shaft power applications/petroleum replacement including vehicle and boat operation, and electricity generation
 - bio - gas production for:
 - * domestic heating (cooking)
 - * domestic lighting
 - * shaft power applications/petroleum replacement including vehicle operation and electricity generation
5. Low-cost building technology
 - housing
 - shell-roof large span public buildings

(1) Solar Thermal Energy Technology



Solar hot box cookers with mirror



Improved mirrorless solar hot box cooker

(1) Solar Thermal Energy Technology



Direct gain Solar dryer



Solar water heaters with horizontal and vertical tanks

(1) Solar Thermal Energy Technology



Solar water heater with 30 gallon horizontal tank



Solar Still

(2) Wind Energy Technology



*Windmill generator and battery charger together
with windmill powered Air compressor*

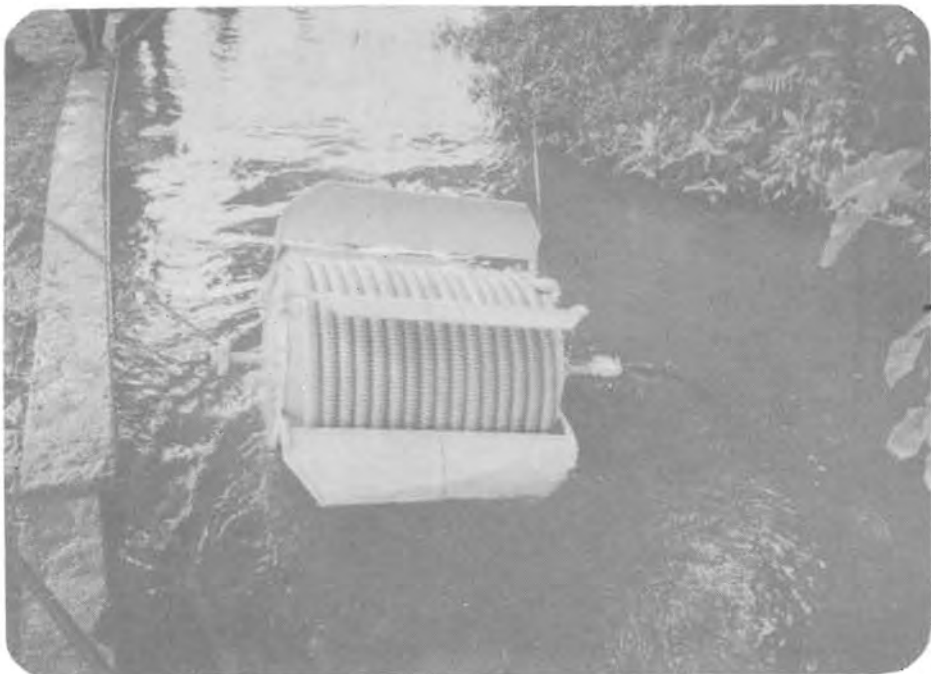


*Windmill operated pneumatic water pump
installed and in operation*

(3) Mini hydro - power technology



Components of Banki cross flow turbine



Rotating barrel pump in operation

(4) Bio - mass Technology



*Wood gasifier installed at Morawaka tea factory
for drying tea*



Rice husk bakery oven

(4) Bio - mass Technology



Gasifier operated non ferrous foundry furnace

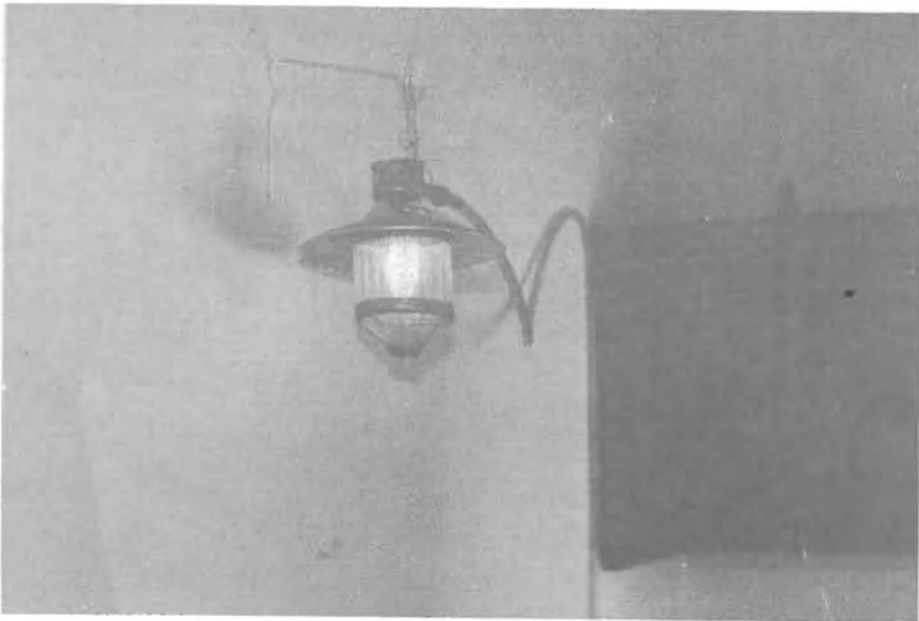


Vehicle propulsion with gasifiers

(4) Bio - mass Technology



Cooker used for Bio - gas generator



Lamp used for bio - gas generator

(5) Low - cost Building Technology



Low - cost model house



Low - cost house

(5) Low - cost Building Technology



Low - cost house on going construction



Shell - roof large span public buildings

Appropriate technology

The once widely used term 'Appropriate Technology' is not given too much prominence at the NERD centre, where the philosophy is problem-oriented engineering research, and development of research based local technologies. It has been shown elsewhere that in Sri Lanka, as in other developing countries, there are just four types of technology, namely:

- Traditional technology
- Empirical local technology
- Research-based local technology
- Transferred technology

Transferred (foreign) technology can easily suppress traditional and empirical local technology. Only research-based local technology can offer an alternative to transferred technology.

It is therefore evident that Sri Lanka will achieve a measure of economic independence, based on technological non-dependence, to the extent that research-based local technologies like those developed at the NERD Centre are competitive with transferred technologies.

This does not mean however, that an indigenous engineering R & D capability is to be judged only by inventions and innovations measured, for example, by the number of patents taken out. On the contrary what is most necessary initially is the ability to offer some local alternative to the uncontrolled inflow of transferred technology. This means the existence of a local capability to adapt imported technologies to better suit local factor proportions in the first instance. Innovation and invention will inevitably follow.

In this regard the pioneering endeavours and achievements of the NERD Centre have been recognized by the government. Several Cabinet Ministers have visited the Centre and several projects have been set up in their respective areas which are operated on a commercial basis very successfully. Recently His Excellency President Ranasinghe Premadasa himself has made a public statement that Sri Lanka should get out of the 'debt trap' of borrowing from international agencies. Undoubtedly the development of local research-based technologies is a vital element.

ANNEX 1

1. SOLAR THERMAL ENERGY TECHNOLOGIES

The use of solar thermal appliances in the domestic, industrial, commercial and institutional sectors of Sri Lanka could alleviate the strain on petroleum and fuel wood, whilst improving the environment.

Since most parts of the island receive at least 600 MJ/m^2 of global solar insolation (on a horizontal plane) per year, solar thermal technology holds much promise for the future. Utilizing this important source of energy with indigenously produced devices to suit the local conditions means a considerable saving in conventional energy and an improvement in the balance of payments due to the saving in foreign exchange.

The NERD Centre of Sri Lanka has developed several solar thermal appliances. Of these, the solar hot box cooker, solar water heater, solar still and solar dryer will be described in the following text.

Reducing cost and improving efficiency wherever possible, has been the concept behind all these developments. Apart from this, durability and ease of operation have also been given priority. The use of a solar hot box cooker along with an improved firewood stove in rural homes could drastically reduce the consumption of firewood.

Apart from the domestic, commercial and institutional sectors, hot water is used extensively in most process industries. Hot air is also utilized in these industries. Fuel wood is still the major source of energy for supplying this process heat in Sri Lanka. Solar water heating systems could supplement the required hot water in most cases. Where temperatures exceeding 80°C are required, solar energy could be utilized for pre-heating the feed water. Properly designed solar air collectors could supplement the hot air requirements.

The dehydration of fruit and vegetables is a lucrative export oriented business in Sri Lanka, which could earn much foreign exchange. The dependence on fuel wood and conventional energy for generating hot air could be avoided by the use of solar dryers.

A direct consequence of present day environmental pollution is the non-availability of clean drinking water. Solar stills, if used in areas where only brackish water is available, could reduce most of the health problems. Conventional energy used in the production of distilled water for lead-acid batteries could also be saved by the use of solar stills.

These systems need not be expensive, if manufactured locally with available materials.

1.1 Solar hot box cooker

Conventional solar hot box cookers which work on the green house effect, typically consist of an insulated metal tray, blackened to absorb the solar radiation, outer cover, double glass aperture and an adjustable mirror. Such box cookers made at the NERD Centre can be seen in Figure 1.1.

*Figure 1.1
solar hot box cookers with mirror*



These cookers, which were made with an aperture of 610 mm x 610 mm, were found to be very effective when tested at the NERD Centre. Maximum temperatures on the surface of the absorber tray were noted to reach between 130°C to 145°C.

The items of food to be cooked could be placed in blackened saucepans covered with their lids, and inserted in the cooker through a side opening. A complete Sri Lankan meal consisting of 250g rice, 500g meat or fish and 200g vegetables took usually about 2 1/2 hours to cook on a normal sunny day. The cooker was also capable of baking a 500g cake within 3 to 3 1/2 hours.

Some disadvantages were encountered with this type of box cooker during consumer trials. The main complaint by the consumers was the price. A box cooker with light gauge aluminium casing, double glass aperture and reflector mirror cost a little over Rs. 2000/-.

The periodical adjustment of the mirror was also reported to be inconvenient. Apart from this, problems encountered during operation were minimal.

To overcome these disadvantages, the conventional box cooker was modified. A new cooker which was intended mainly for the rural population, had to be designed. It had to be low cost as well as easy to operate.

A study on solar water heaters had revealed that for smaller collector areas, single glass covers were sufficient under the climatic conditions encountered in the semi-dry to dry zones of Sri Lanka (See 4 in the Reference List). A similar argument was used for the box cooker and it was made with a single 3 mm thick glass cover. To further improve the transmittance the glass cover was fixed inclined at the approximate latitude angle for Sri Lanka, which is 7° N.

The reflector mirror was seen as an added cost. Furthermore, the periodic tracking with the mirror did not find favour with the rural population. Methods of attaining higher temperatures in the cooker without the use of reflectors was next investigated.

The sun path diagram for the Sri Lankan latitude was used (Figure 1.2) to obtain the shadow angles during different seasons. From the sunpath diagram, the altitude angles (α) and azimuth angles (θ) could be selected for different times of the day as well as for different seasons. This is illustrated for June 22 in Figure 1.3. Using the extreme cases in June and December when the sun was in the northern-most and southern-most positions respectively, and making use of some solid geometry, the worst shadow angles for all four sides of the box cooker were evaluated.

When the box cooker was placed facing south, shadowing from the sides would be prevented throughout the year between 10.00 AM and 2.00 PM (and all four sides would be well illuminated) if the sides of the absorber tray could be inclined at the angles shown in Figure 1.4.

The thermal insulation on the back and the sides of the cooker was given due consideration (see 5 in the Reference List). Whilst it was essential to prevent losses through improved insulation, in order to reduce the cost and also to improve the balance of payments situation in a developing country, the use of indigenous insulating material was advantageous. Such material was also not harmful to health, unlike most imported fibrous insulants.

FIGURE 1.2

SUN PATH DIAGRAM

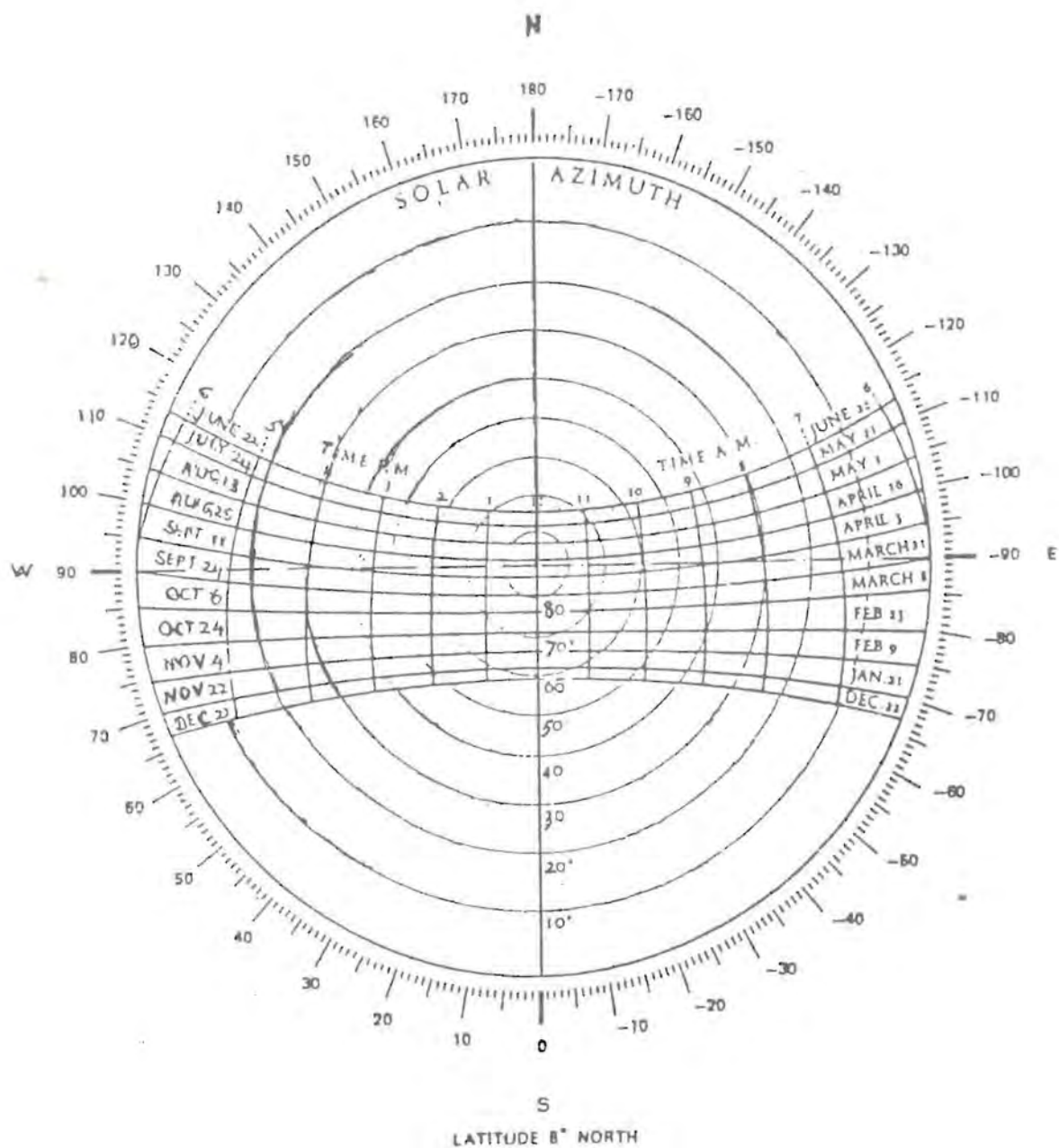
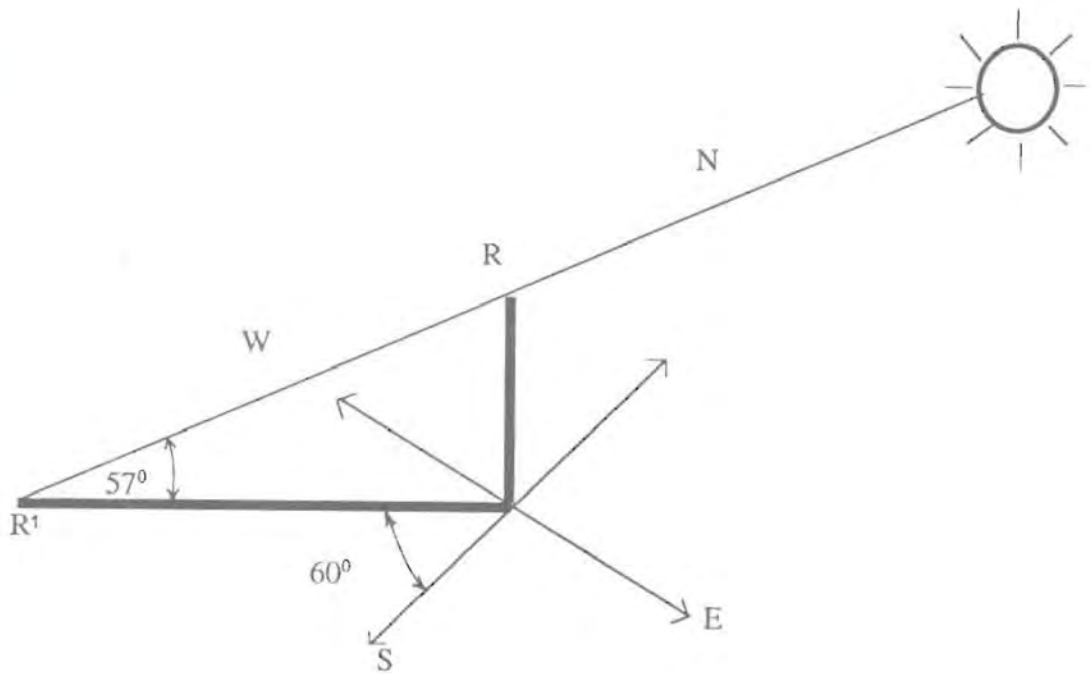


Figure 1.3
 Shadowing on June 22 at 10 a.m



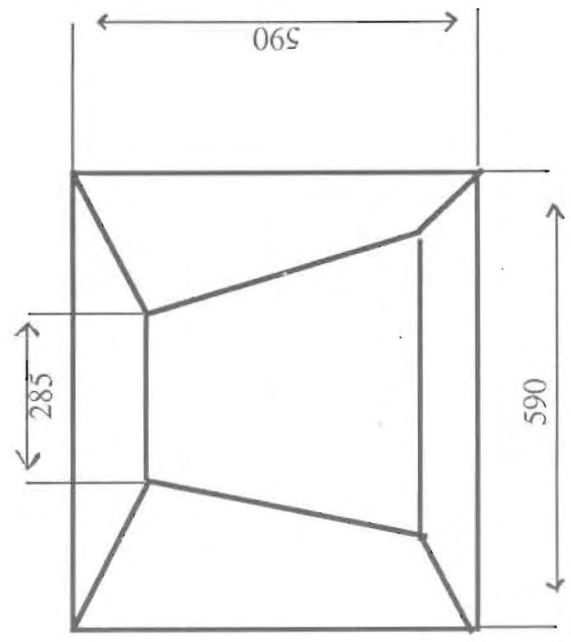
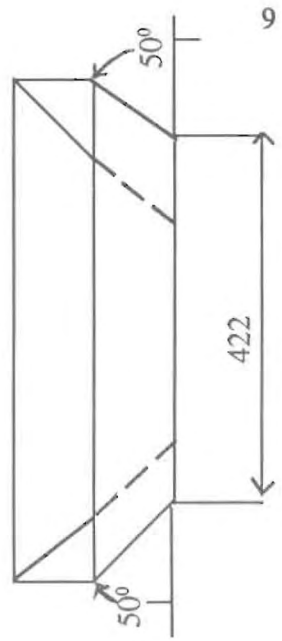
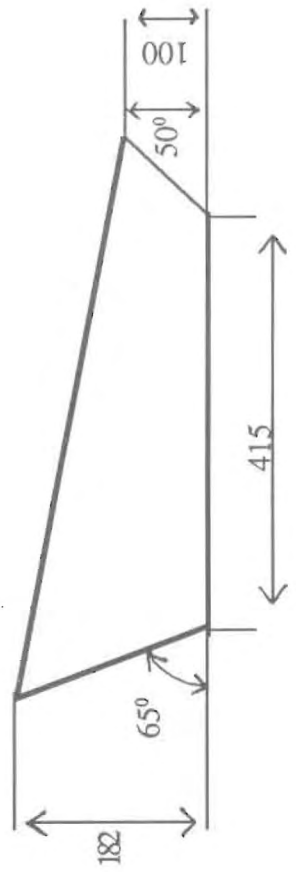
ALTITUDE AND AZIMUTH ANGLES FROM SUN PATH DIAGRAM

	10 A.M.	12 NOON	2 P.M.
JUNE 22			
α	57°	74°	57°
θ	60°	180°	120°
DEC. 22			
α	47°	58°	47°
θ	-45°	0°	45°

α = ALTITUDE ANGLE

θ = AZIMUTH ANGLE

Figure 1.4
Absorber tray of the Mirrorless Box cooker



DIMENSIONS IN mm
MATERIAL : 24 G M/S

Coir fibre (obtainable from the husks of coconuts) was readily available and was also very cheap. A composite insulation consisting of polystyrene, aluminium foil and coir fibre proved to be very effective. The outer box was lined on the inside with 10 mm thick polystyrene, locally made and available as 'rigifoam'. Aluminium foil was also readily available locally and inexpensive. Aluminium foil was pasted over the polystyrene. The gap between this and the absorber tray was finally filled with coir fibre.

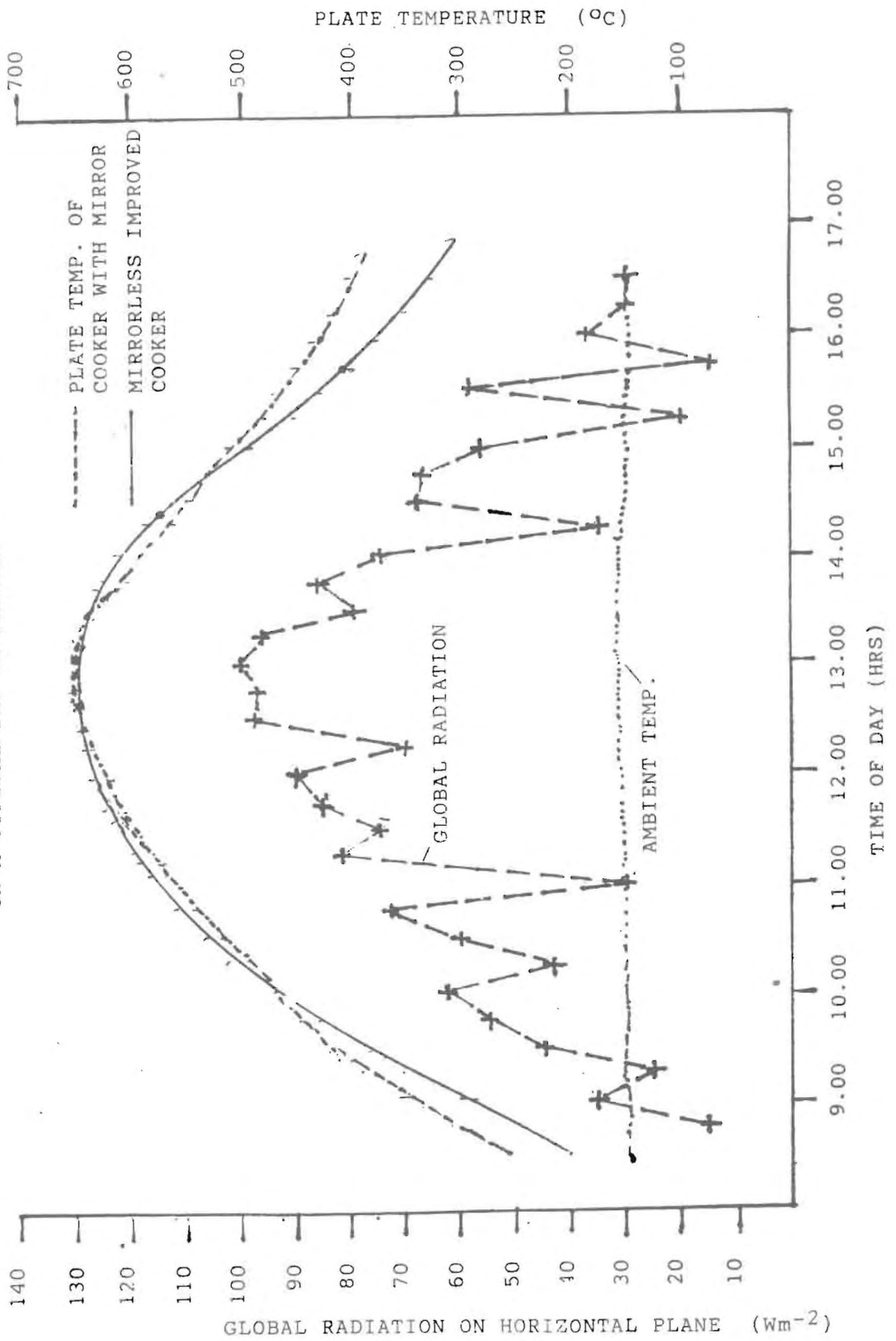
To reduce costs further, indigenous material options were studied for the outer cover of the cooker. Concrete was cheap and durable, however, the problem was to achieve a good finish. This problem was overcome by casting thin steel fibre reinforced concrete panels on glass sheets, using a release agent. A superior smooth finish was obtained with this technique. These panels could either be spray painted after casting or a colour pigment could be added to the surface layer of the concrete during casting. Figure 1.5 shows such a cooker made at the NERD Centre.

Figure 1.5
The improved mirrorless hot box cooker



Temperatures attained on the surface of the absorber of this cooker was compared with those of the cooker with mirror. The results are shown in Figure 1.6.

FIGURE 1.6
 DIURNAL VARIATION OF COOKER PLATE TEMPERATURES
 ON A TYPICAL DAY IN JANUARY



Before 10.00 AM and after 2.30 PM, the cooker with mirror registered higher temperatures, due to the advantage of the mirror tracking in more insolation from low sun angles. However, between 10.00 AM and 2.30 PM the improved transmittance of the single glass, better exposed surface to solar radiation of absorber and superior insulation of the mirrorless cooker was evident. Somewhat higher temperatures were recorded in the mirrorless cooker during these times, although highest temperature recorded in both at about 1.00 PM was about the same.

The optical efficiency of a solar box cooker may be expressed as :

$$\eta = \frac{U_{LS} (T_{PS} - T_a)}{I_{HS}}$$

Where, U_{LS} is the overall heat loss factor of the cooker in $Wm^{-2} ^\circ C^{-1}$ at stagnation temperature T_{PS} ($^\circ C$).

I_{HS} is the global solar insolation on a horizontal surface at the time of stagnation, expressed in Wm^{-2} , and T_a ($^\circ C$) is the ambient temperature.

As described by Garg (See 6 in the Reference List), the performance of a solar box cooker can be gauged from the above expression, which can be rearranged to obtain the Saxena, Kandpal, Mullick figure of merit F_1 .

$$F_1 = \frac{\eta}{U_{LS}} = \frac{T_{ps} - T_a}{I_{HS}}$$

For a solar cooker to function properly,

$$F_1 \geq 0.12$$

From Figure 1.6, for the mirrorless box cooker,

$$F_1 = \frac{130 - 31}{500} = 0.198$$

Therefore, it is very suitable as a solar cooker.

1.2 Solar water heater

The NERD Centre's efforts were concentrated on developing a solar water heater suitable for manufacture in a small workshop using only indigenous technology. Initially, several prototypes were developed and tested for durability and performance. Field tests were performed on systems installed at different locations in the island. In 1986, a relatively low cost model was developed, and the technology required for its manufacture was transferred to a small entrepreneur who possessed some previous experience installing imported solar water heaters.

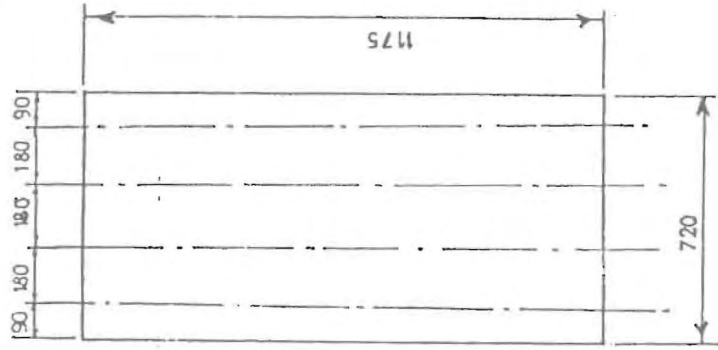
Two standard models, for supplying domestic hot water, are produced at present. The basic difference between the two models is the capacity. A model with a 67 litre (15 gallon) storage tank consists of a single collector of 610 mm width and 1220 mm length, and a model having a storage tank of 135 litre (30 gallon) capacity consists of two such collectors. Figure 1.7 shows the 15 litre model at left, together with an experimental model with vertical tank. Larger systems comprising of several collectors are designed and installed under the guidance of the NERD Centre.

Figure 1.7

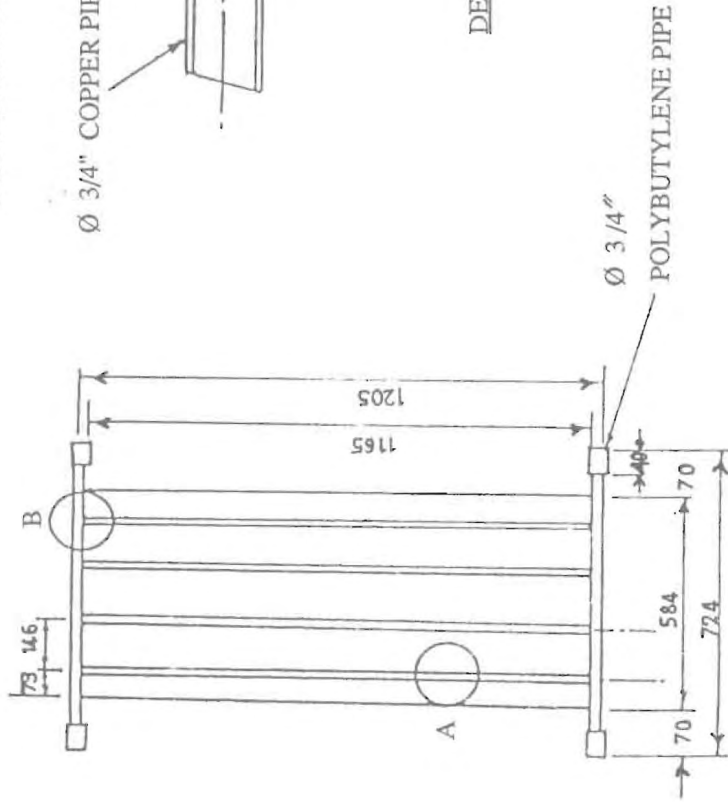


Figure 1.8

PLATE MARKING DETAIL



COMPLETE RECEIVER

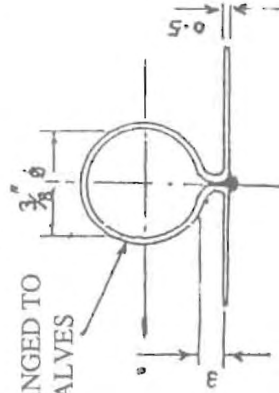


DIMENSIONS MM UNLESS OTHERWISE STATED

Ø 3/4" COPPER PIPE

DETAIL AT B

THIS WAS CHANGED TO TWO HALVES



DETAIL AT A
(SECTION)

MATL - 30 G COPPER

DESIGNED	NATIONAL ENGINEERING
DRAWN	RESEARCH & DEVELOPMENT
CHECKED	CENTRE OF SRI LANKA
DATE	TITLE
03/07/86	COPPER RECEIVER
SCALE	

Both models are fairly compact direct thermosyphon systems, having cylindrical glass wool insulated stainless steel tank mounted horizontally. The collector is made of copper absorber consisting of four riser tubes of 10 mm diameter each. The risers are formed on the copper plate by means of a steel die and the seams are subsequently gas welded as shown in Figure 1.8. This production technique has been found suitable for a small workshop. The header pipes are of 20 mm diameter copper. The absorber is insulated at the back with glass wool, and enclosed in a thin gauge aluminium casing with a 3mm thick glass aperture.

The external pipes are of 20 mm diameter polybutylene, which do not require additional insulation.

The selling price of the system is approximately half that of an imported system of the same capacity. Presently, these systems have been installed in several domestic, industrial, commercial and institutional establishments in Sri Lanka.

The manner in which performance data for solar collectors are presented is explained by Duffie and Beckman (See 7 in the Reference List). The efficiency of a flat plate collector is expressed by the equation :

$$\eta = F_R (T\alpha)_e - U_L F_R \frac{(T_{ci} - T_a)}{I_T}$$

Where, F_R is the collector heat removal factor, $(T\alpha)_e$ is the effective transmittance-absorptance product, U_L is the overall loss coefficient of the collector in Wm^{-2} , I_T is the global solar radiation on the plane of the collector, T_{ci} ($^{\circ}C$) is the collector fluid inlet temperature and T_a ($^{\circ}C$) is the ambient temperature.

Efficiency of the collector is also expressed as,

$$\eta = \frac{\text{Actual useful energy collected}}{\text{Solar energy incident on or intercepted by the collector}}$$

$$\eta = \frac{Q_u}{I_T A_c}$$

Where A_c is the area of collector.

For different fluid inlet temperatures, Q_u can be evaluated ($Q_u =$ Thermal capacity of fluid \times Temperature rise), and thus values of η can be obtained.

If the efficiency is plotted against $\frac{T_{ci} - T_a}{I_r}$ a straight line will result, with a slope of $F_R U_L$ and a Y-intercept of $F_R (T_a - T_{e})$.

Figure 1.9 shows the efficiency curve for the collector of the NERD centre solar water heater, plotted with varying water inlet temperatures.

Theoretical investigations based on a performance correlation technique developed by Hobson and Norton (See 8 in the Reference List) have shown that the system could be optimised further by (i) using a vertical tank placed at a point where it did not shadow the collector on a south facing slope of about 20° from the horizontal (ii) improving the insulation, and (iii) modifying the absorber of the collector to accommodate 6 riser tubes of 15 mm diameter each instead of the present 4 tubes of 10 mm diameter each.

To investigate the validity of point (i) above tests were performed with the existing collector, mounted to 67 litre tanks kept horizontally and vertically. The vertical tank was fabricated with 6 mm thick PVC pipe of 305 mm internal diameter. This was not insulated, to give some advantage to the horizontal tank, which was made of fibre glass lined steel and insulated with 25 mm of glass wool.

As seen by the results, Figure 1.10, during continuous withdrawal tests under the same conditions, the vertical tank gave water at increased temperatures throughout the day, due to improved stratification in the tank and increased circulation through the system.

PVC was found to be suitable for the tank since the stagnation temperatures did not exceed 75°C . The PVC tank cost 1/3 that of the stainless steel tank, thus inspiring a cost reduction of the system. A further advantage was that the PVC pipes were manufactured locally, enabling some saving in foreign exchange with the use of this item in the locally produced solar water heater.

FIGURE 1.9

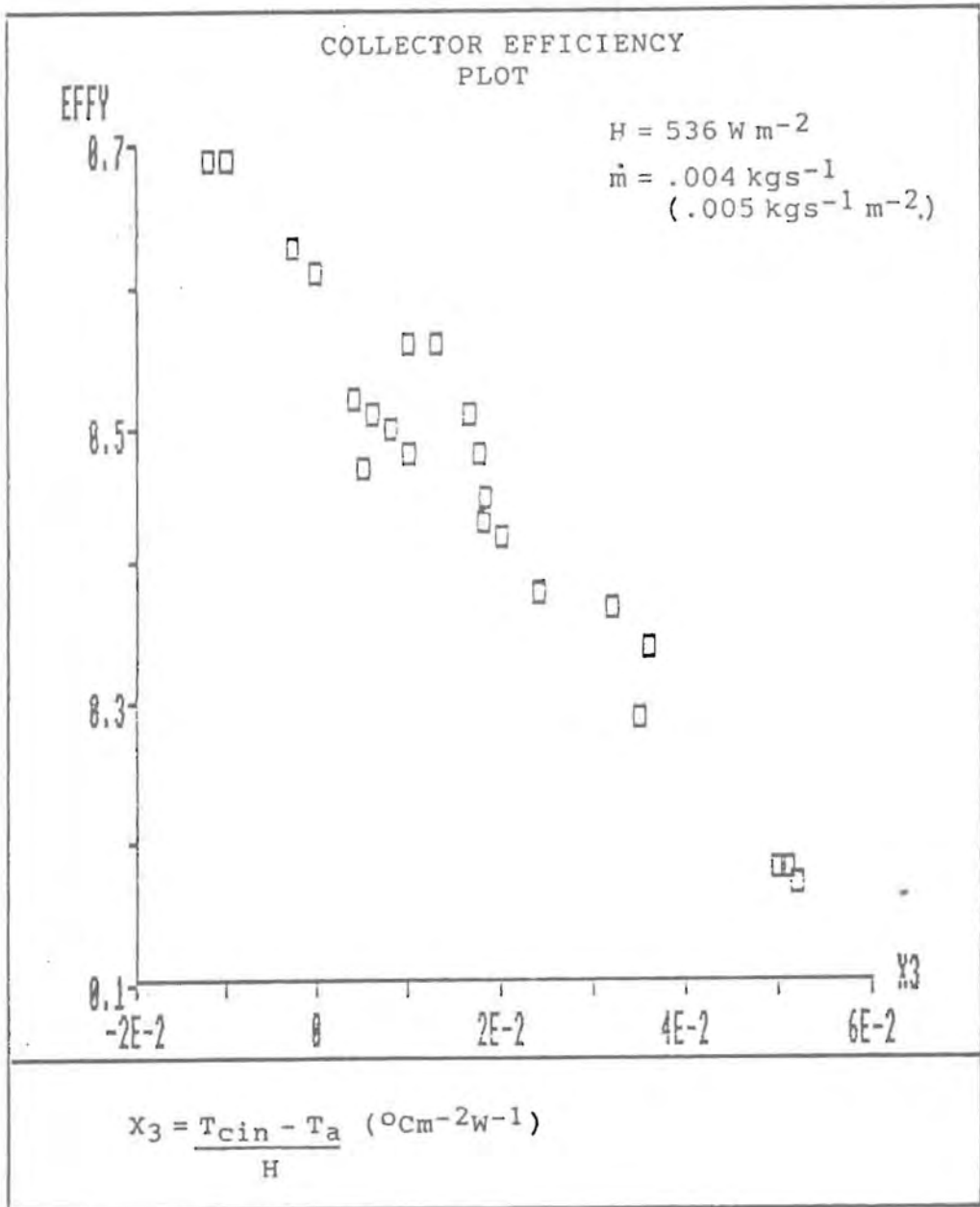
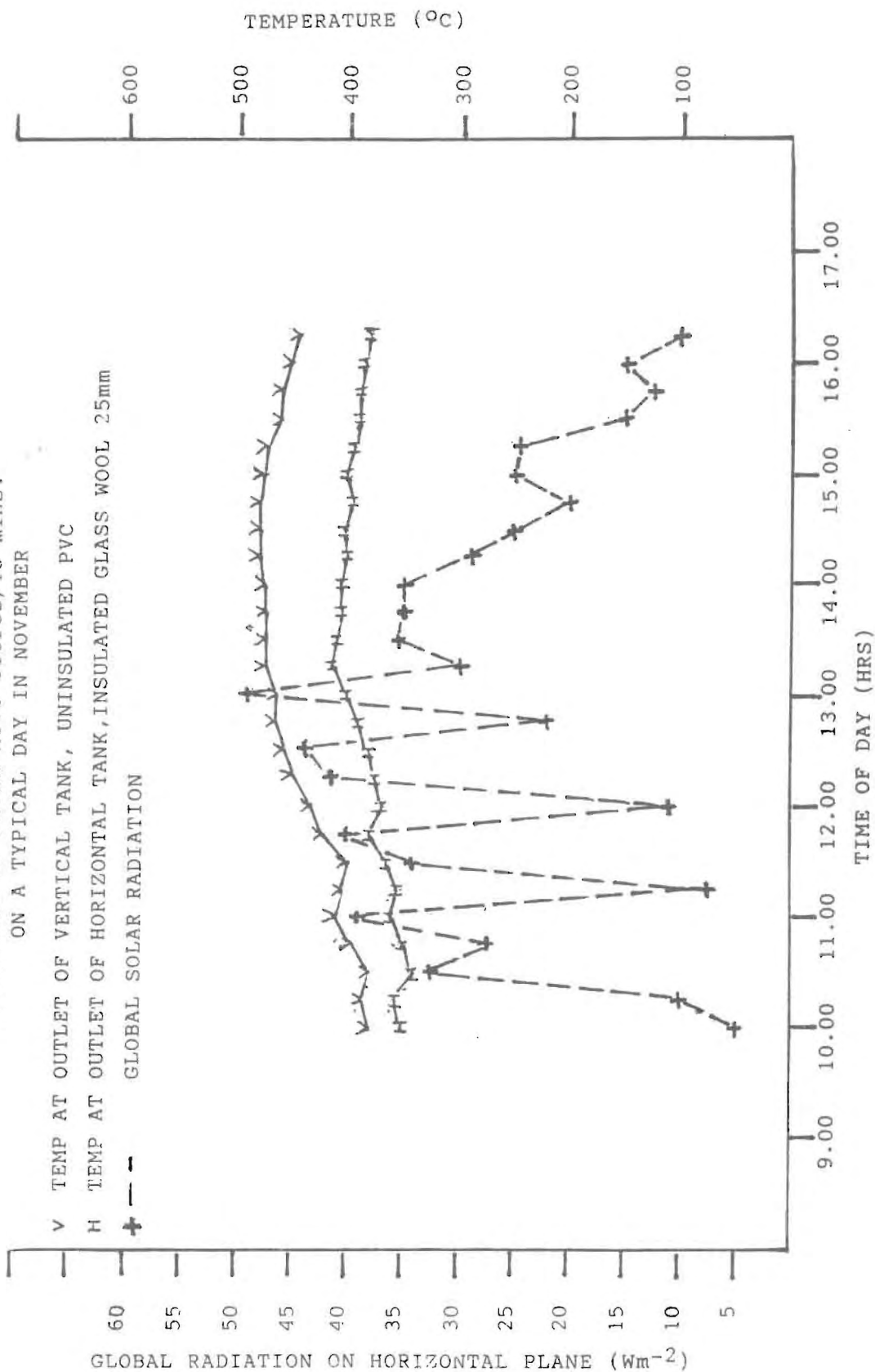


FIGURE 1.10

WITHDRAWAL OF WATER AT 5 litres/15 mins.
ON A TYPICAL DAY IN NOVEMBER



1.3 Solar dryer

Several versions of solar cabinet dryer were tried out at the NERD Centre. These consisted mainly of collector, drying chamber and chimney (Figure 1.11).

The initial trials were with non-glazed collector having a corrugated sheet receiver. The chimney was without the exhaust fan.

Trials were done subsequently with glazing and Savonius wind mill driven exhaust fan. The dryer with exhaust fan showed a marked improvement over the other cabinet dryers, due to the enhanced air flow which was beneficial at the initial stages of drying (See 9 in the Reference List).

Based on the cabinet dryers, a prototype solar Roof - top dryer was also made (Figure 1.12). This was non-glazed and had a collector area of 55.74 m². Although the efficiency was found to be somewhat lower than the glazed cabinet dryers, it was more advantageous for a small scale food processing industry, since a comfortable space was provided beneath the collector which could be utilised for the workshop.

Figure 1.11

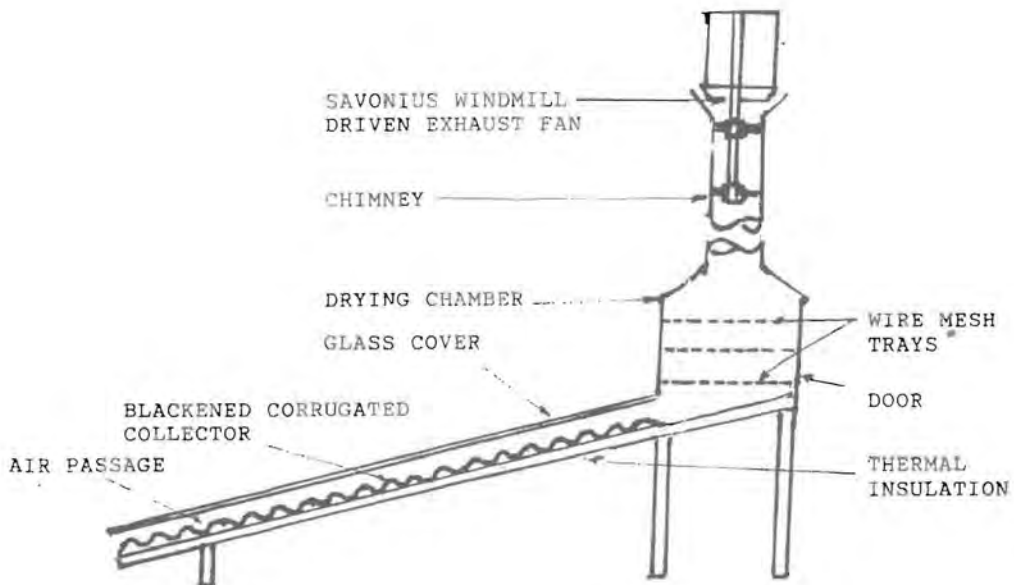


FIG 1.11 NERDC SOLAR CABINET DRYER

Figure 1.12

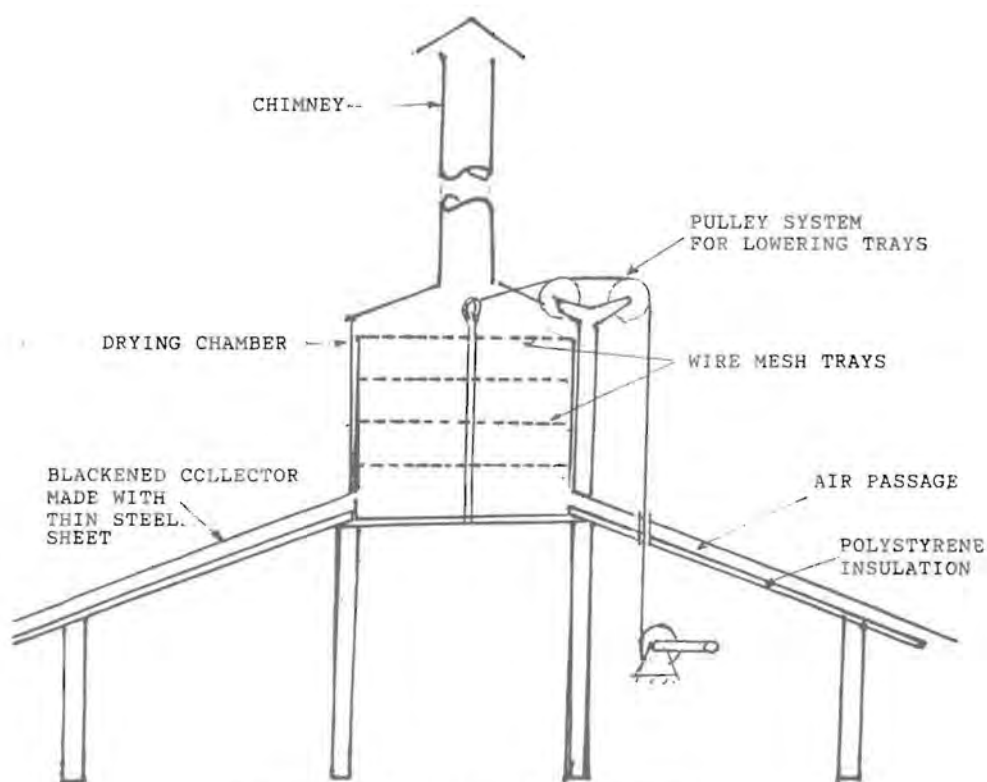


FIG. 1.12NERDC SOLAR ROOF TOP DRYER

Drying of fruits and vegetables were tried in these dryers according to standard methods (See 10 in the Reference List) and results similar to the trials in solar cabinet dryers in West Africa (See 11 in the Reference List) were obtained.

A constraint during efforts to market the cabinet dryers was the cost. The cabinet with the chimney and exhaust fan increased the price of the dryer considerably.

Direct gain dryers were studied to overcome these problems. A low cost, relatively simple to operate dryer which works on the direct gain principle, was designed.

A model of this dryer is shown in Figure 1.13, and with details of construction in Figure 1.14.

Figure 1.13
Direct gain solar dryer



The collector comprises a series of withdrawable trays with absorber made of blackened corrugated steel. The direct gain is enhanced by placing the material to be dried in the troughs of the corrugated collector trays, enabling heat transfer from the blackened absorbing crests to the troughs. Vents were provided at the lower and upper ends, and air flow was achieved by buoyancy driven convection. The low cost reinforced concrete beams enable the drier to be assembled as a roof, in which case a comfortable working environment will be provide beneath.

Scraped coconut, chillies, grains, fish and several types of vegetable were dried in this dryer. The drying times were much better than with the cabinet dryers. Figure 1.15 gives the results for dehydration of scraped coconut. The scraped coconut dried in this has been used in an oil expeller to produce high quality white coconut oil.

The drying of coir dust has also been carried out on requests from prospective entrepreneurs who were interested in exporting this item as a soil nutrient in horticulture.

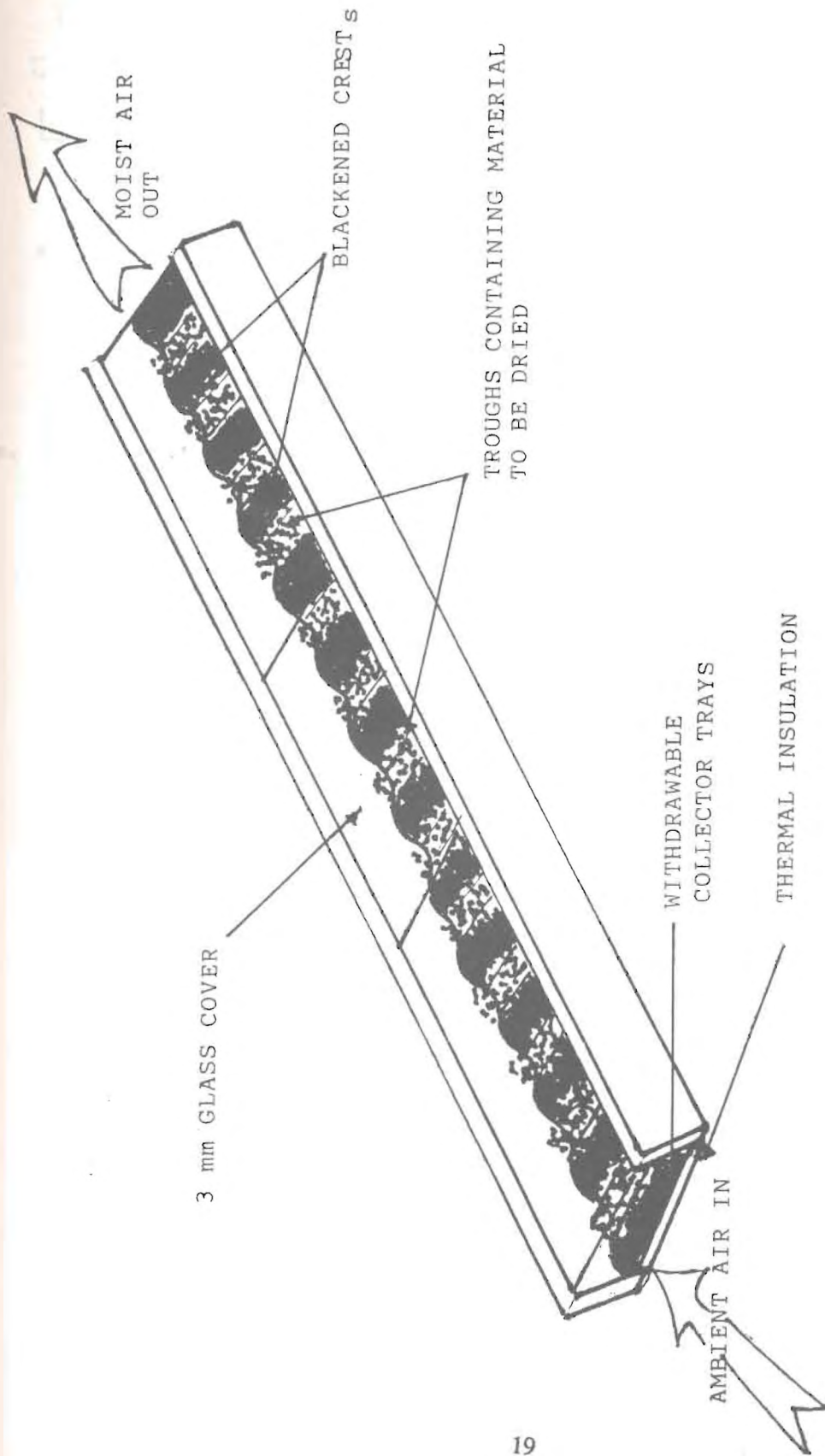
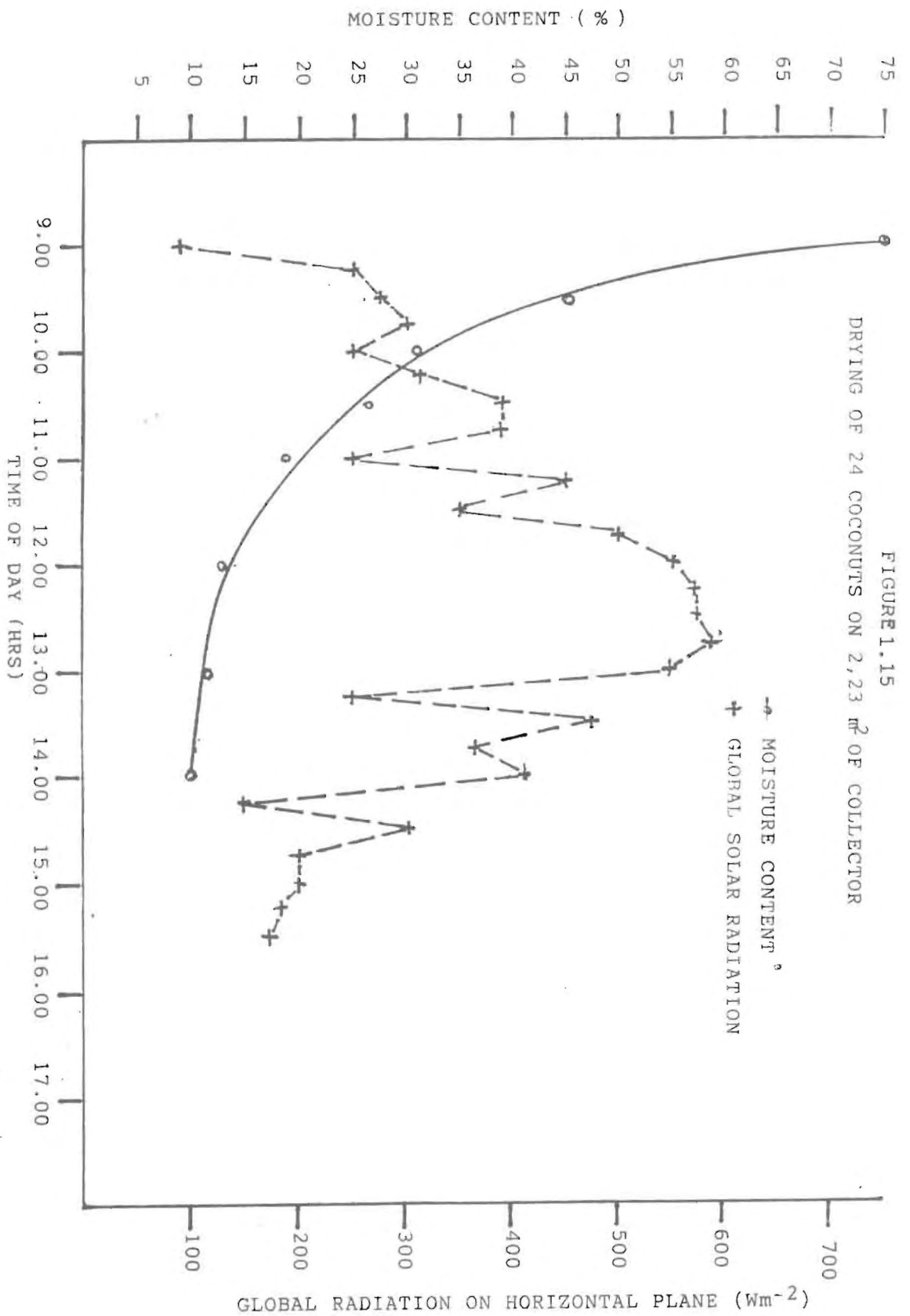


FIG 1.14 NERDC SOLAR DRIER - DIRECT GAIN TYPE

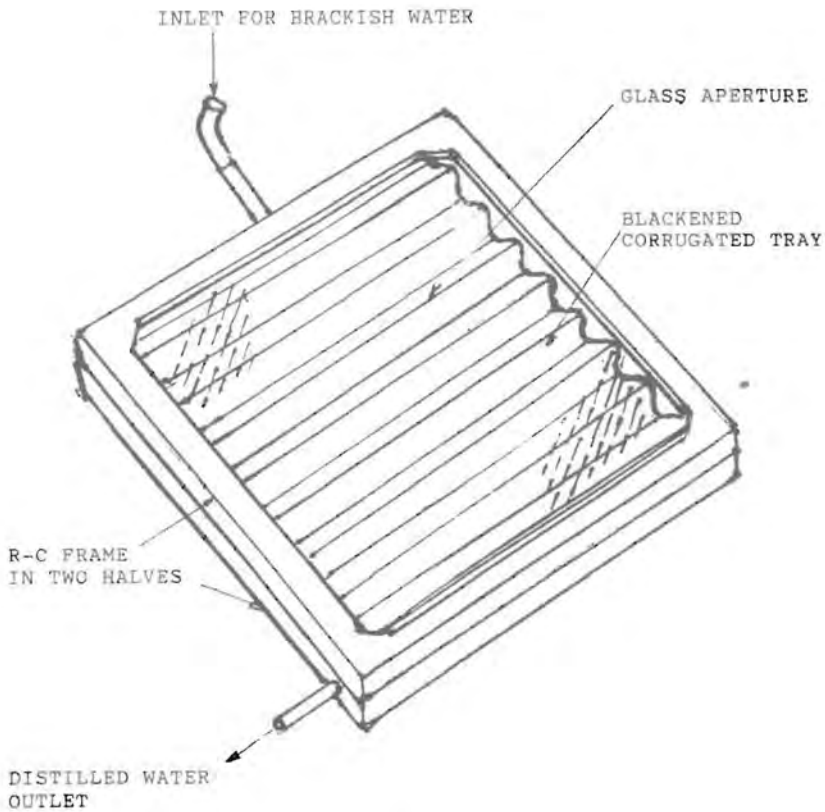


1.4 Solar still

The NERD Centre has developed a low cost solar still having a corrugated basin for retaining the brackish water to be distilled. This basin is kept inclined at 7° to 10° to a glass sheet. The entire framework is of reinforced concrete. This design, which is shown in Figure 1.16, has resulted in increasing the distilled water yield considerably over that of a conventional solar still. A material saving was obtained by bringing the glass aperture closer to the basin. Thereby, a cost reduction was also achieved.

Figure 1.16

Fig 1.16 SOLAR STILL WITH INCLINED CORRUGATED BASIN AND REINFORCED CONCRETE FRAME



The initial prototypes of solar stills made at the NERD Centre were mainly of the conventional type (Figure 1.17). In a conventional solar still the water to be distilled is kept in flat bottomed basin. This basin is blackened for the absorption of solar radiation, and is thermally insulated at the bottom. A glass sheet, which is the aperture, is fixed above this at an inclination of about 30° to the horizontal. Usually two glass sheets are fixed as shown.

Solar radiation, which is of short wavelength, penetrates the glass aperture. Some of this radiation is absorbed by the black surface at the bottom of the basin, which then heats up. This heat is transferred mainly by conduction and convection to the water to be distilled. The heated water evaporates and deposits on the inner surface of the glass as droplets of pure condensate. This condensed water trickles down the inclined glass and is collected in troughs fixed at the lower end of the glass. This water which flows along the troughs, is finally collected outside the still as distilled water.

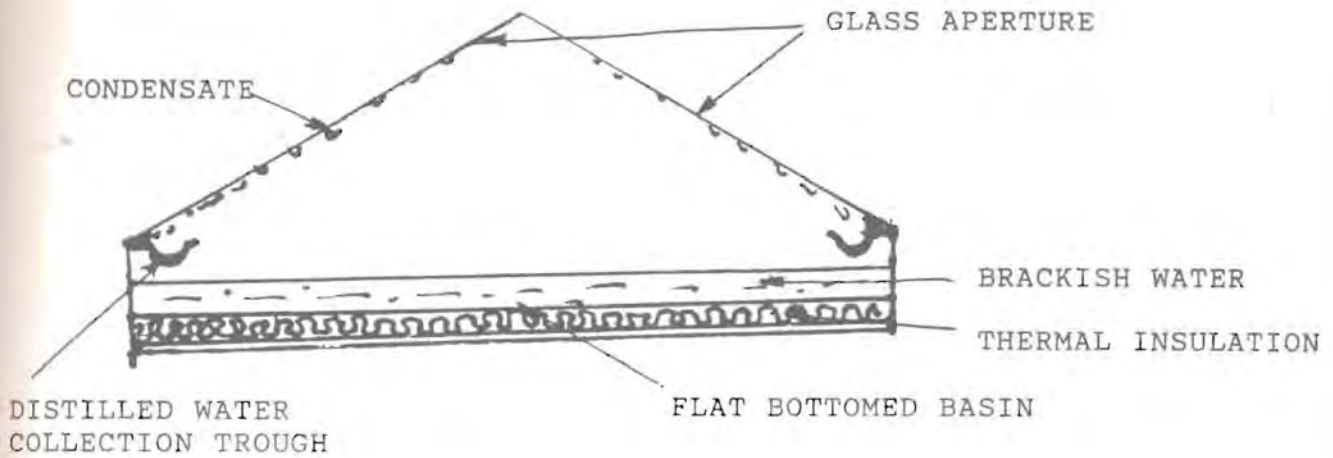
In the new solar still developed by the NERD Centre (NERDC Still-2) a series of dry surfaces of the corrugated basin act as extended surfaces of fins, and are exposed to incoming solar insolation, unlike in the stepped basin stills (See 12 in the Reference List).

The intensity of the insolation reaching the dry surfaces is higher than that reaching the surface beneath the water. These hotter dry crests of the corrugated basin transfer the heat to the water in the troughs. The water is heated by this method as well as by the method encountered in the conventional still. Furthermore, the water is divided into smaller volumes by the troughs, and is closer to the aperture. All these factors enable a higher heating rate and evaporation rate of the water to be achieved.

Several performance tests were carried out on the improved NERDC Still -2. During comparison tests, the yield from the inclined still was always considerably higher, usually more than double that of the conventional solar still. Figure 1.18 depicts a typical day's results of a comparison test between the inclined basin solar still and the conventional solar still.

The average annual output of the NERDC Still - 2 for the Ekala region was 375 ml (1/2 standard bottle) per square foot of the solar still.

FIG 1.17 CONVENTIONAL STILL



INCLINED STILL WITH CORRUGATED BASIN

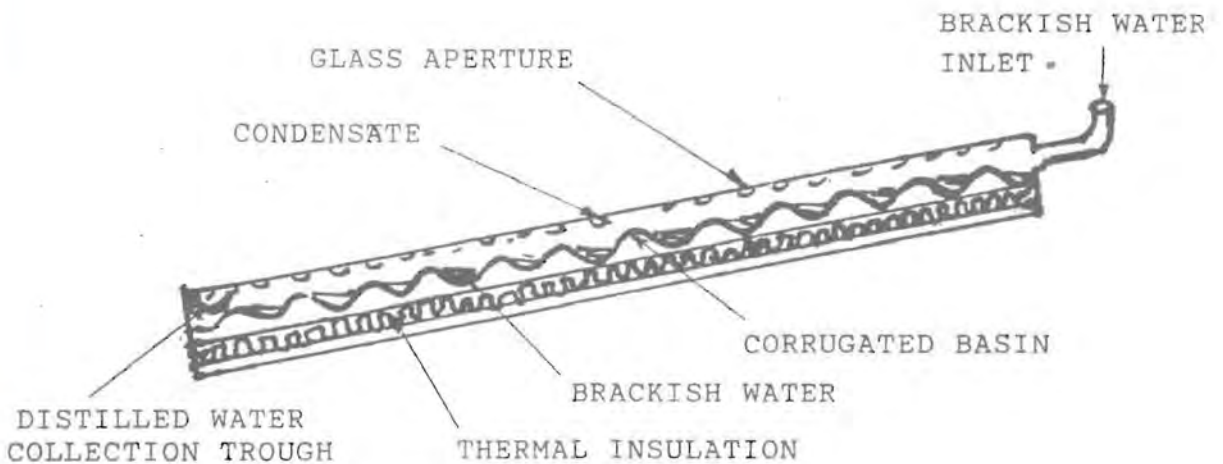
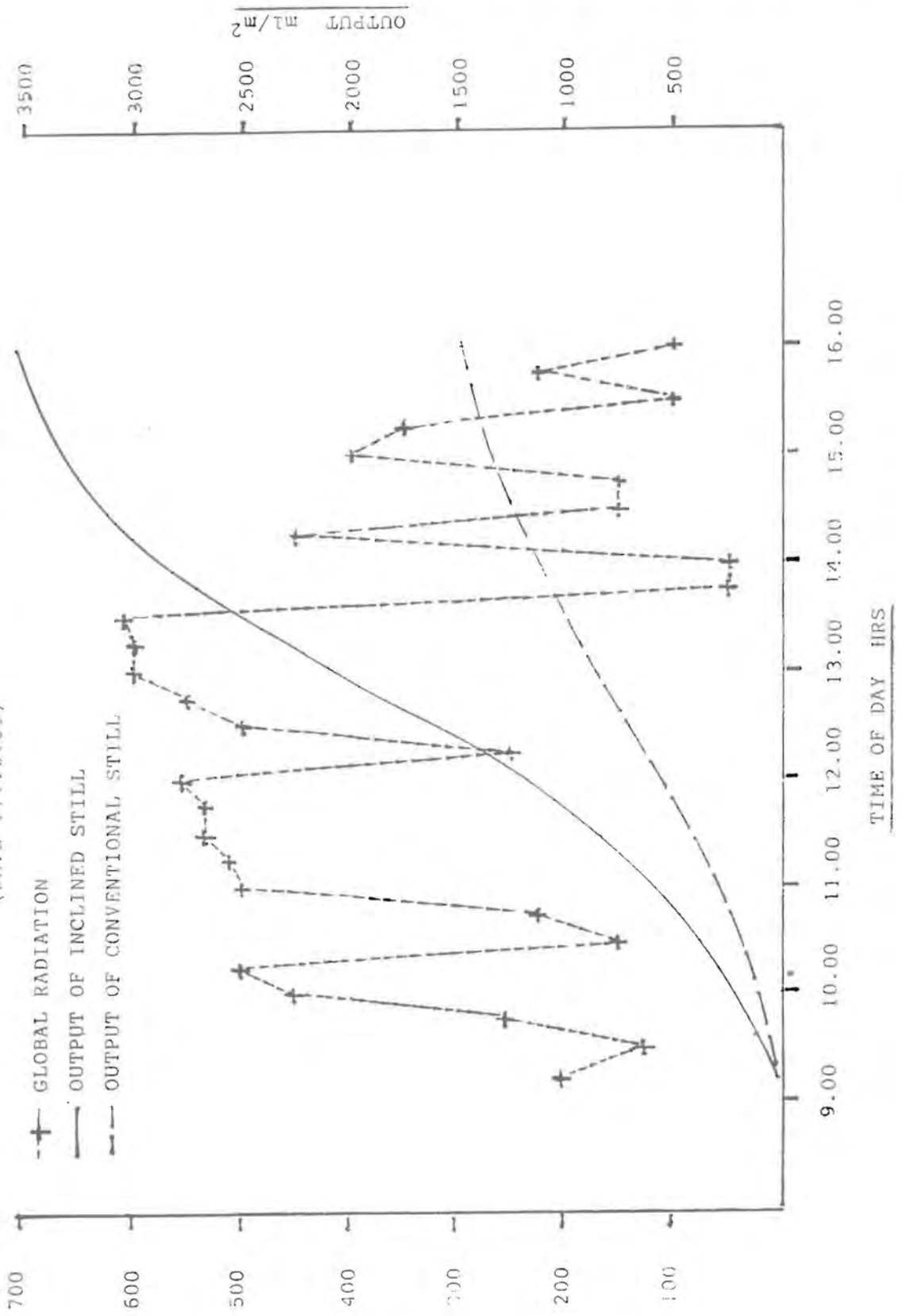


Fig 1.18 A DAY'S RESULTS FOR SOLAR STILL'S
(DATE 17.10.89)



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ANNEX 2

2. WIND ENERGY TECHNOLOGIES

NERD Centre has been engaged on the following projects in the exploitation of renewable wind energy:

- 1) Small scale wind power generation from 25 watts to 200 watts.
- 2) Windmill compressors for supplying air for aeration of water in inland fish ponds and tanks.
- 3) Windmill operated pneumatic water pumps for both shallow well and deep well applications.

The design and construction of Wind machines undertaken by the NERD Centre are as follows :

2.1 Windmill

- | | | |
|--------------------------------|---|---|
| a) Type | : | Horizontal axis twin bladed |
| b) Blade Design & Construction | : | Blade profile conforms to NACA standards and is carved from light weight solid timber. Blade is given a weather protective coating using Fibre Glass and Resin and then painted. |
| c) Regulating Device | : | <ol style="list-style-type: none">i) Rigid Tail vane and turning the windmill out of wind by rotation around a horizontal axis. The tilting movement is controlled and dampened by weights and springs.ii) Articulated Tail Vane and off centered windmill rotor. These are connected together by springs. At high winds the windmill turns against the spring load and comes to stall condition when the windmill axis becomes perpendicular to the wind direction. |

- d) Tower : Both self-supporting and stay-wired towers have been used. They usually consist of steel fabrications in 10 ft lengths, assembled at site. However, for small wind machines of capacities upto 100 Watts and for a height of towers up to about 30 ft. the 32 ft concrete V-poles which are readily available in the State Engineering Corporation have been successfully used.
- e) Generator : Permanent magnet alternating current generator.
- f) Air Compressor : Commercial Air Compressors, single cylinder and twin cylinders, and of capacities from 1/2 HP to 1 HP.
- g) Coupling Method : Windmill blade is directly coupled either to the generator or to the compressor. No gear box has been used.
- h) Orientation System : Attachments of a Tail Vane is the only method used in orienting the windmill towards the direction of the wind.

2.1.1 Wind generators

Wind generators of capacities 25, 40, 100 and 200 Watts have been studied. Each of them was designed for the primary purpose of providing electricity for household lighting in remote areas. This was achieved by charging batteries from the electricity generated by the wind generators and then using the stored electrical energy for house lighting. Different capacities of wind generators were considered for different applications.

a) 25 Watts Wind Generator

- Purpose : To provide electricity for lighting needs of individual families who do not have immediate access to grid electricity.
- Aim : Primarily, it is meant for inhabitants of coastal fishing villages as the chief beneficiaries of this project.

- Objective : To design and develop a low cost wind generator which is affordable to individual families and fulfills their minimum lighting needs. The low cost aspect of the project is mainly derived from the small size of the machine and the maximum use of local raw materials for construction of an inexpensive tower.
- The design : Rotor :
 1.22m (4 ft) diameter twin bladed conforming to NACA 4412 profile. Blades were carved as a single unit out of solid wood and surface treated for weather protection.
 Tip speed ratio taken for the design is 9.
 Rated Power :
 64 Watts at 6 m/sec wind speed and at 846 rpm.
 Generator :
 Permanent Magnet generator, designed and constructed by NERD Centre using locally available material.
 Output :
 3 Phase, 14 - 18 Volt, 24 Watts at 680 rpm.
 Charging system :
 Rectifier giving an output of 12 - 15 Volt DC.
 Inverter Optional.
 Test Results :
 The wind generator is still under-going field tests at NERD Centre's testing sites for the last two years. The results obtain show good promise for its intended purposes.

b) 250 and 100 Watts Generators

- Purpose : To provide electricity for domestic lighting requirements of small to medium size communities who do not have immediate access to grid electricity
- Aim : This project is aimed at small to medium size communities such as fishing villages, irrigation settlements etc. which are remotely located.

Objective : To design and develop a community type wind generator which can cater to a number of families. The maintenance of the system is to be carried out by one trained person and supported by the fee/rent levied on the consumers. It is intended to charge a number of batteries at a time so that the whole community can be served comfortably throughout.

The design : Rotor :
2.13 m (0.7 ft) diameter twin bladed conforming to NACA 4412 profile. Blades are made as a single unit carved out of solid wood and surface treated for weather protection. Tip-speed ratio taken for the design is 9.

Rated Power :

196 Watts at 6 m/s wind speed and at 485 rpm.

311 Watts at 7 m/s wind speed and at 565 rpm.

Generators :

(i) 100 Watts Generators Unit.

Permanent magnet generator, fully tropicalised.

Output :

3 phase, 8 pole, 100 Watts, 28 volts, at 400 rpm.

Charging system:

Rectifier unit giving a DC output of 24-28 V.

Inverter available for obtaining 230 AC.

(ii) 200 Watts Generators.

Permanent magnet generator, fabricated by NERD Centre.

Output :

3 phase, 8 pole, 200 Watts, 24-28 V at 600 rpm.

Charging system :

Rectifier unit giving a DC output of 24-28 V.

2.2 Windmill air compressors - 1/2 hp and 1 hp

Purpose : To produce compressed air which can be used for numerous applications such as water pumping, aeration of water in fish ponds and tanks etc.

Aim : The primary aim of this project is to supply compressed air to pump water using NERD's pneumatically operated water pumps.

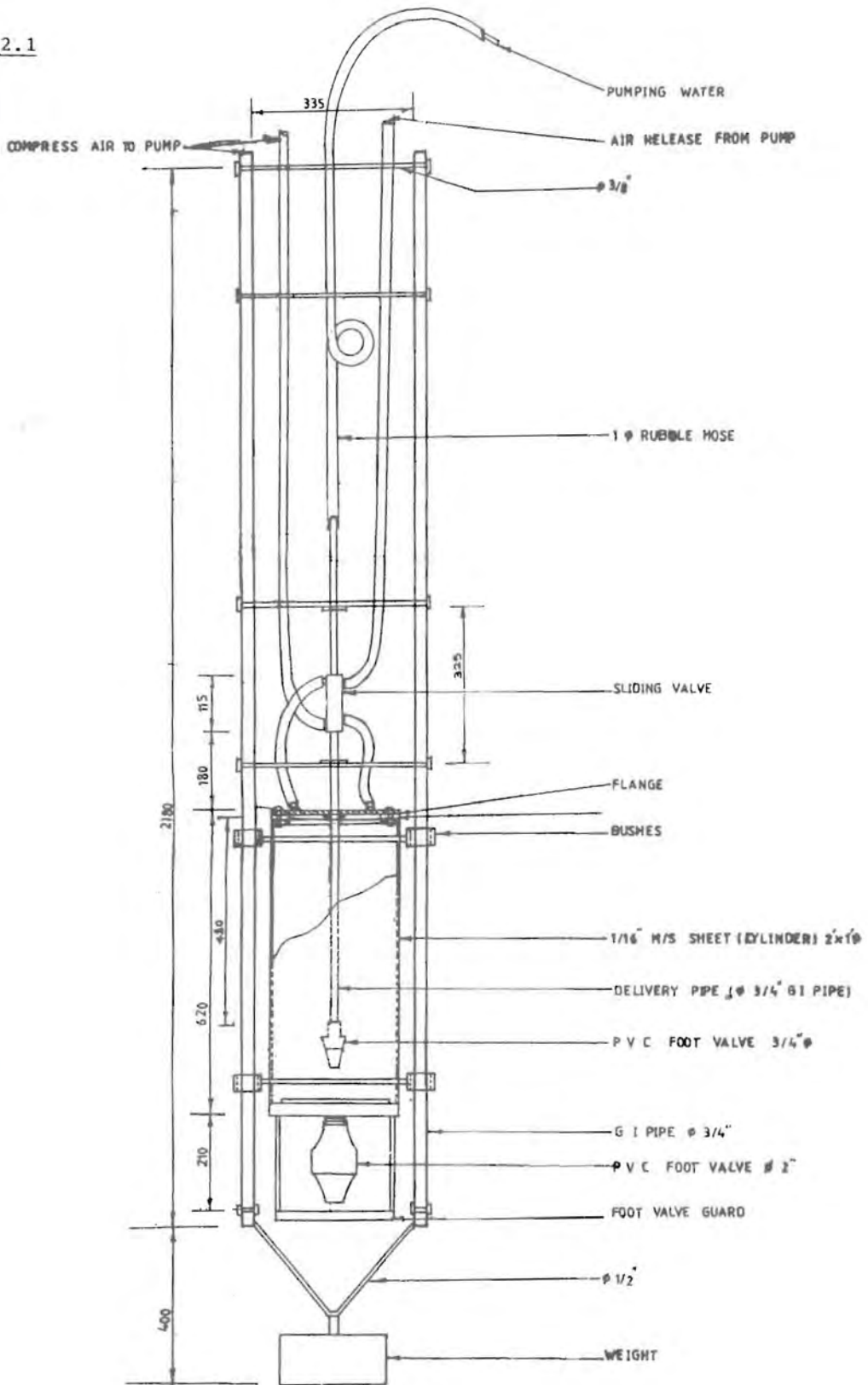
- Objective : To design and develop a consistent and reliable means of pumping water for human consumption, irrigation and other industrial applications using non conventional energy sources and appropriate technology. The projects can be either on individual basis or community basis.
- The design : Rotor :
 3.2 m (10 1/2 ft) diameter twin bladed conforming to NACA 4412 profile. Blades are made as a single unit carved out of solid wood and surface treated for weather protection.
 Tip speed ratio taken for the design is 9.
 Rated Power :
 440 W at 6 m/s wind speed and at 320 rpm and, 860 Watts at 7.5 m/s and at 400 rpm
- Air Compressor : Commercially available piston type reciprocating air compressor 1/2 hp Single Cylinder and 1 hp Twin Cylinder

2.3 Pneumatic water pump

This is a new concept of pneumatic water pumping designed, developed and tested by NERD Centre. The principle features of this self-standing, automatic water pump are,

- * It includes no moving parts except for an air valve which operates intermittently.
- * Since the pump is operated by compressed air the source of compressed air supply can be at a distance from the pump. This flexibility gives a number of definite advantages over the traditional pumps which require the prime mover either as a part of the pump or located very close to it. When using a windmill compressor (or even a hand operated air compressor for that matter) one has the freedom of choosing the best location for the windmill (or hand compressor) and for the water pump separately for a given site. Figure 2.1 shows a schematic view of this pump.

Figure: 2.1



Test Results : Table 2.1a and Table 2.1b give test results of two Windmill operated pneumatic water pumps at two different sites. Fig. 2.2 & 2.3 represent graphically the discharge of these pumps for the months of January and February, 1991.

It can be seen that the total discharge of the two installations are as follows.

1 hp Compressor	- 19,145 gal in 21 days for January
	- 16,090 gal in 31 days for February
1/2 hp Compressor	- 9,685 gal in 31 days for January
	- 5,520 gal in 31 days for February

Table 2.1 (a)

Pump Discharge Data

Windmill: 3m Rotor with
0.5 hp Compressor
Pump: 1" Dia., 2 ft long
Pneumatic Pump

Date	Output - Gal.	
	January	February
1	235	75
2	135	850
3	175	860
4	275	850
5	325	850
6	325	320
7	325	600
8	520	525
9	200	120
10	225	120
11	50	120
12	480	160
13	480	60
14	480	
15	480	
16	280	
17	55	
18	65	
19	100	
20	100	
21	100	
22	130	
23	120	
24	50	
25	50	
26	940	
27	935	
28	930	
29	260	
30	260	
31	350	

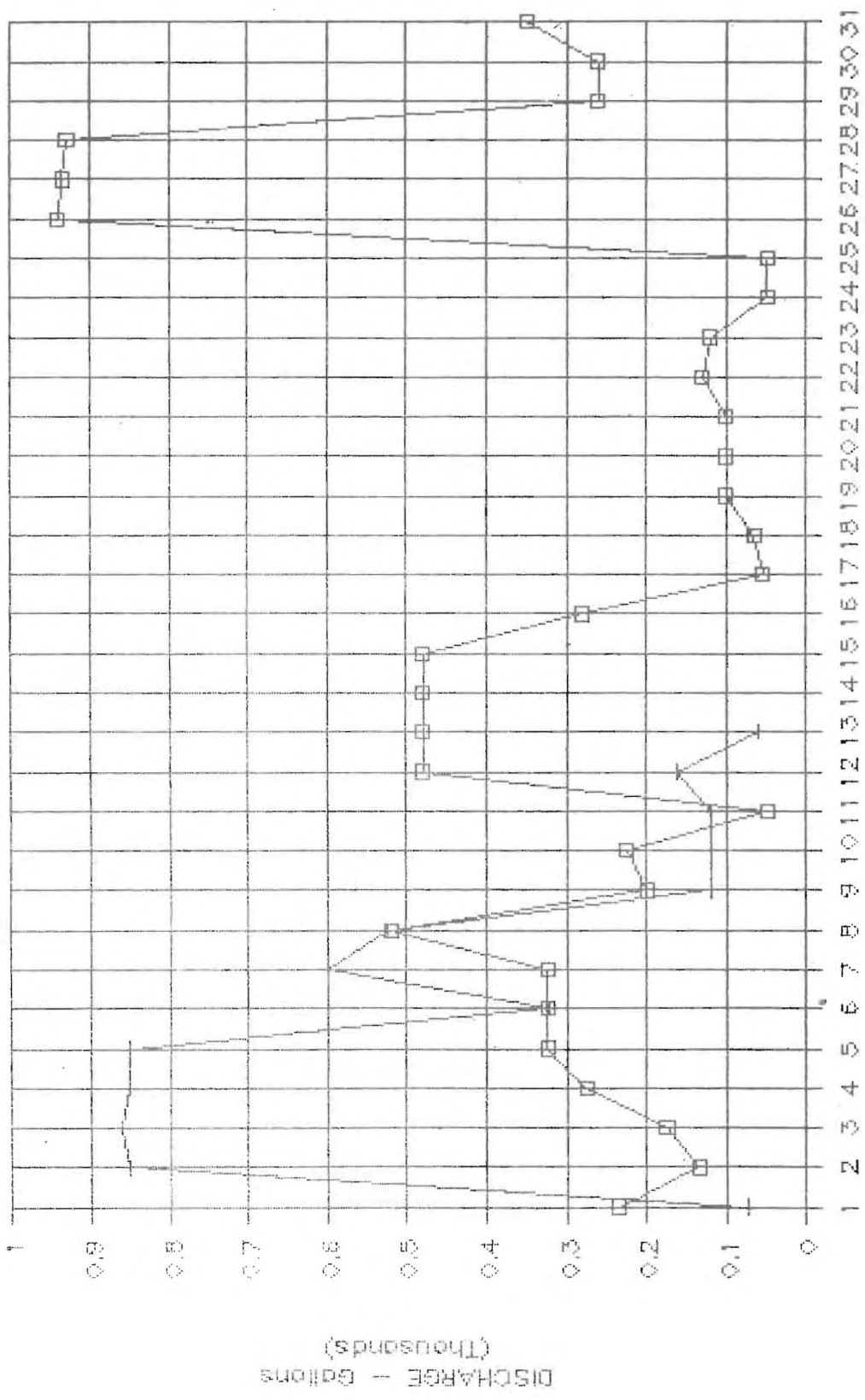
Table 2.1 (b)

Windmill: 3.2 m Dia Rotor with
1 hp Compressor
Pump: 1" Dia., 2 ft long
Pneumatic Pump

Date	Output - Gal.	
	January	February
1	-----	740
2	-----	850
3	-----	850
4	-----	850
5	-----	850
6	-----	150
7	-----	3550
8	-----	2950
9	-----	1340
10	980	1340
11	375	1340
12	450	480
13	450	800
14	450	
15	450	
16	850	
17	380	
18	240	
19	480	
20	480	
21	480	
22	760	
23	2400	
24	2780	
25	2800	
26	980	
27	980	
28	980	
29	720	
30	680	
31		

WINDMILL OPERATED PNEUMATIC WATER PUMP

DISCHARGE VS TIME - 0.5 HP COMPRESSOR



DISCHARGE VS TIME - 0.5 HP COMPRESSOR

Fig. 2.2

WINDMILL OPERATED PNEUMATIC WATER PUMP

PUMP DISCHARGE VS TIME -- 1 HP COMPRESSOR

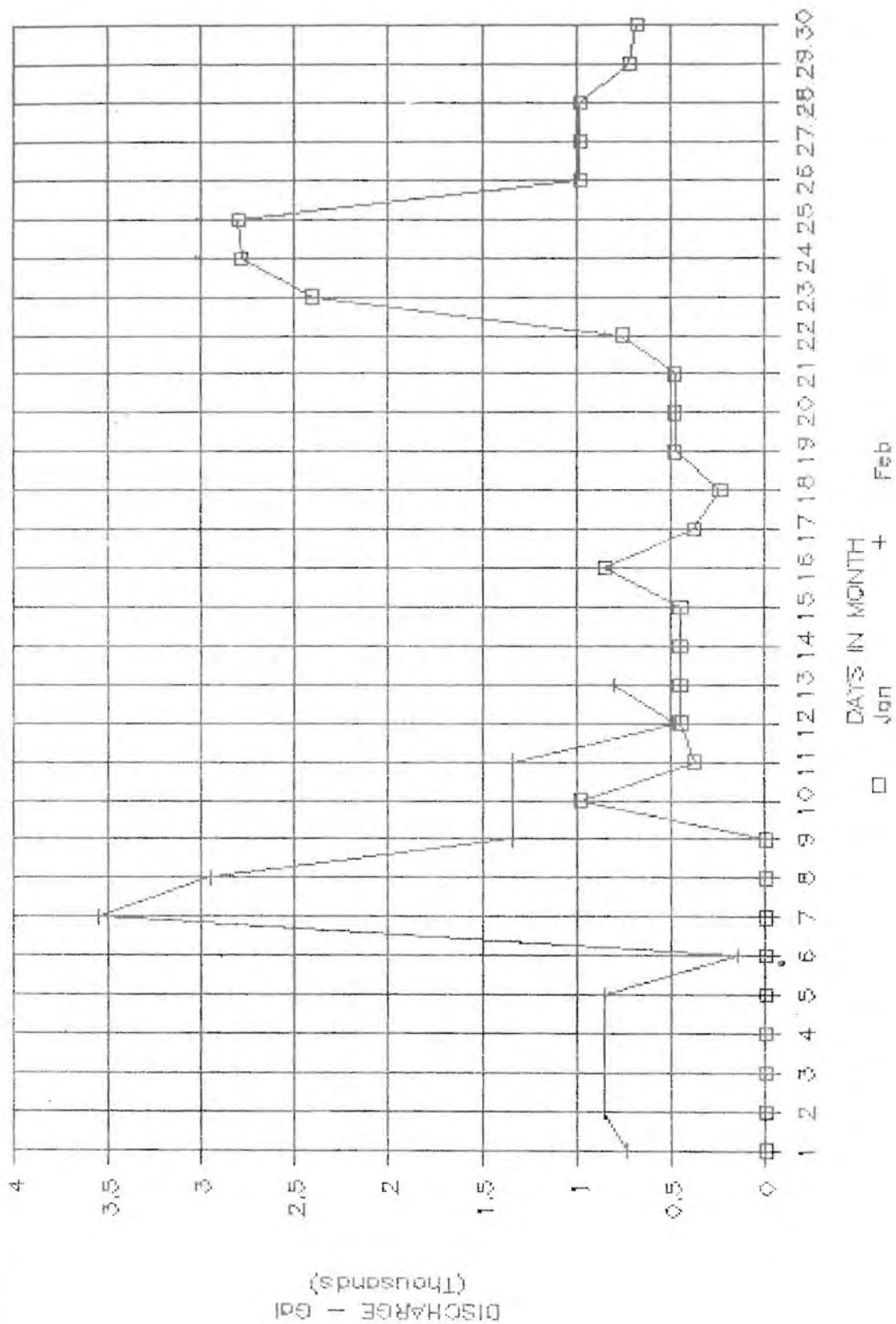


Fig. 2.3

ANNEX 3

3. MINI HYDRO POWER TECHNOLOGIES

3.1 Banki cross flow turbine

Studies on Mini hydro have been continued for a long time at the NERD Centre. NERD Centre's activities in developing mini hydro have been mainly on the design and development of a Banki Cross flow turbine.

First of its kind, fabricated at NERD Centre's Workshop, was installed for testing at Bowatenna reservoir somewhere in 1983. Although a few test runs were done a comprehensive study could not be made of the results mainly due to the non-availability of a suitable electrical load.

With the upward revision of electricity tariffs, interest in development of Mini hydro technologies has been increasing rapidly during the recent past.

NERD Centre has successfully designed, developed and fabricated a number of Banki Cross-flow Turbines ranging from 25 KW to 100 KW capacities in the Hydraulics Laboratories at the NERD Centre. These have yet to be installed, performance monitored and the results analysed.

3.2 Pump running as a turbine

High cost of turbine units has been one of the constraints in the development and popularisation of small hydro - electric power projects. NERD Centre, being concerned about this, decided to try out a commercial water pump to run as a turbine and then drive an induction generator from it.

Several tests were carried out at NERD Centre under simulated conditions to study the efficacy of such an alternative. The results thus obtained are promising and further R & D work would be undertaken to support its commercial applications. The details of the tests are given below in Table 3.1 and the performance curve shown in Figure 3.1. It shows that for the trial carried out the maximum energy conversion efficiency obtained is 54%.

Generator details:

3 ph Induction generator of 2.2 KW (3hp) and 1500 rpm

Maximum electrical power obtained:

1.8 KW at 0.864 cu. ft/sec flow and 20 psi pressure.

PUMP RUNNING AS A TURBINE

EFFICIENCY VS FLOW

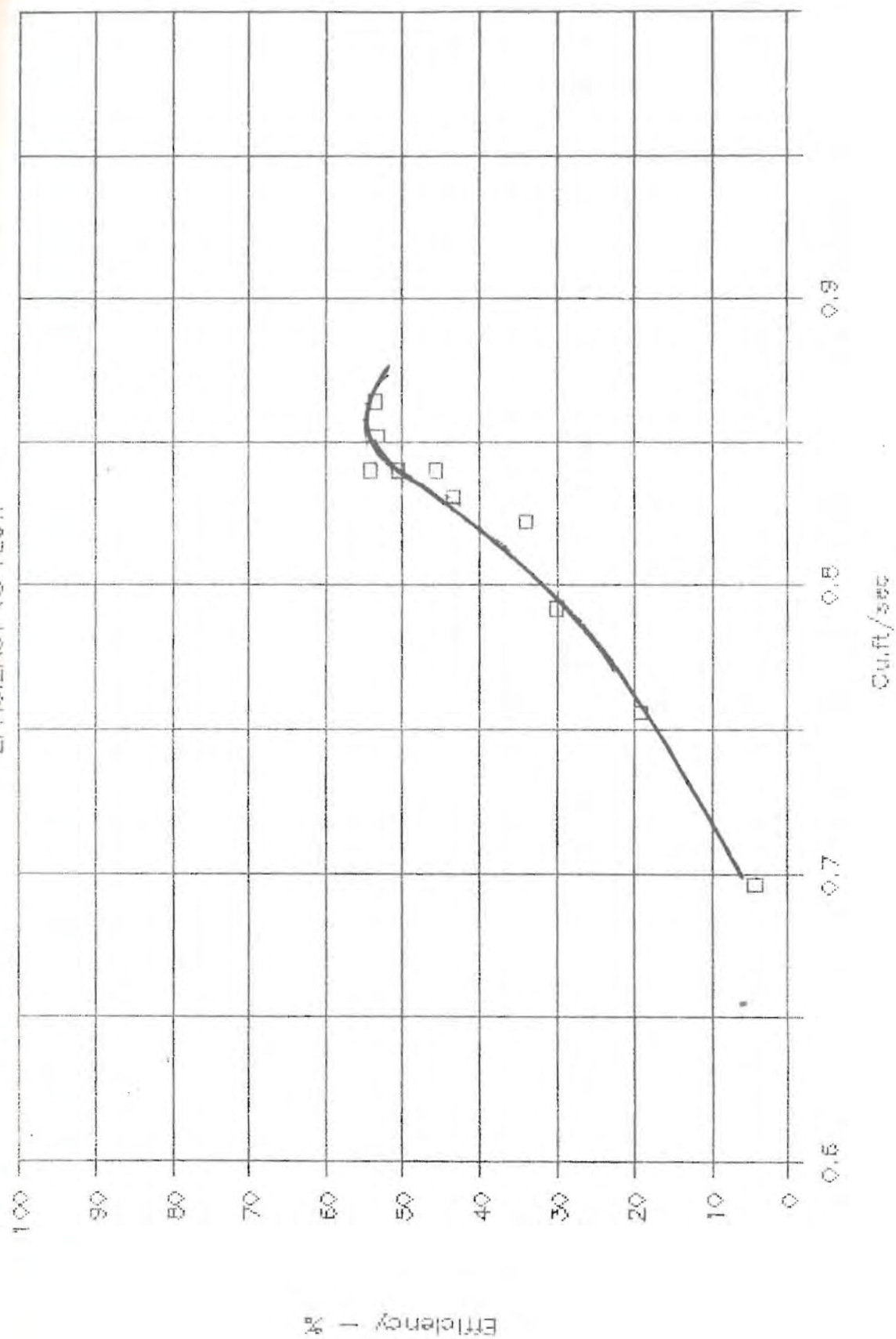
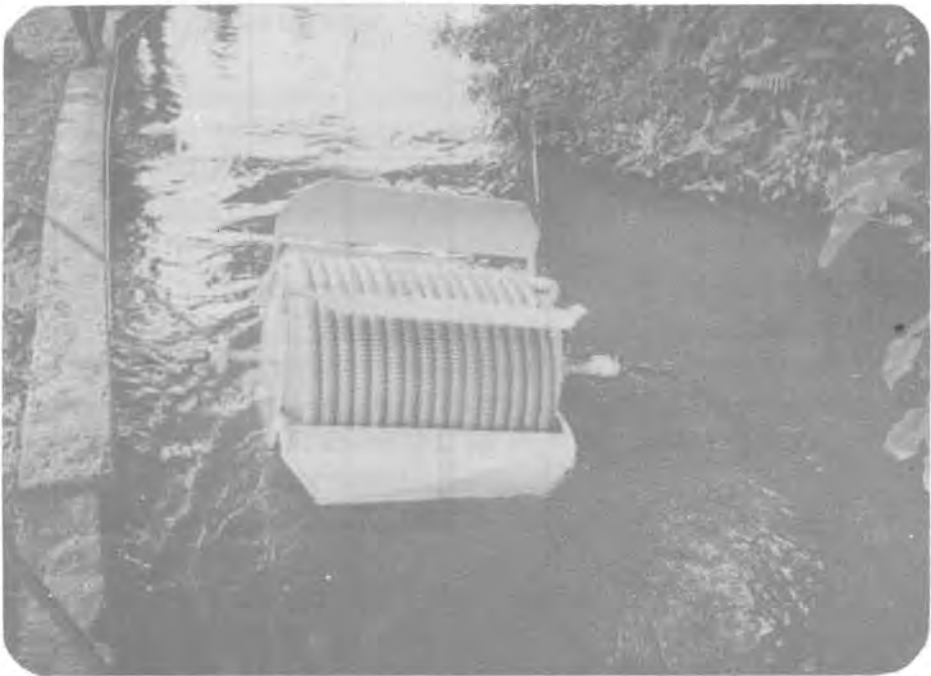


Fig. 3.1

Table 3.1
Results of Pump Running as a Turbine Coupled to an induction Motor.

Reading No	Flow Velocity m/sec	Flow Rate cu. ft/sec	Pressure psi	Power Input hp	Power Output hp	Efficiency %
1	2.32	0.696	10.0	1.82	0.08	4.4
2	2.52	0.756	12.5	2.47	0.48	19.4
3	2.64	0.792	13.0	2.70	0.81	30.0
4	2.74	0.822	15.0	3.23	1.09	34.0
5	2.77	0.831	15.0	3.26	1.41	43.3
6	2.80	0.840	16.0	3.52	1.61	45.7
7	2.80	0.840	17.0	3.74	1.89	50.5
8	2.80	0.840	19.0	4.18	2.26	54.1
9	2.84	0.852	20.0	4.46	2.38	53.4
10	2.88	0.864	20.0	4.52	2.42	53.5

Figure 3.2
Rotating coil pump



3.3 Barrel pump or rotating coil pump

This pump, very simple in design, is a classic demonstration of the use of non-conventional energy for lifting water for moderate heights. The pump works from the energy available in a flowing stream of water and does not require any regulation. It can be fabricated from locally available raw materials and requires no expensive workshop facilities. Since the pump operates by itself when lowered into a flowing stream, no training of personnel is required for its operation, and maintenance is minimal.

This is an ideal low cost, fuel free pump for lift irrigation work where a flowing stream is available. (See figure 3.2)

Design

A flexible hose of suitable diameter is wound on a closed drum, the diameter and length of which must be enough to exert sufficient up thrust on the pump so that the pump would float half immersed when lowered into water. One end of the hose is open and is in intermittent contact with water when the pump rotates and the other end is taken out along the axis of rotation of the drum and through a rotating joint and serves as the delivery. When in operation the pump is held against drifting down stream with the flow by fixing it to the banks of the stream using ropes.

Velocity of stream

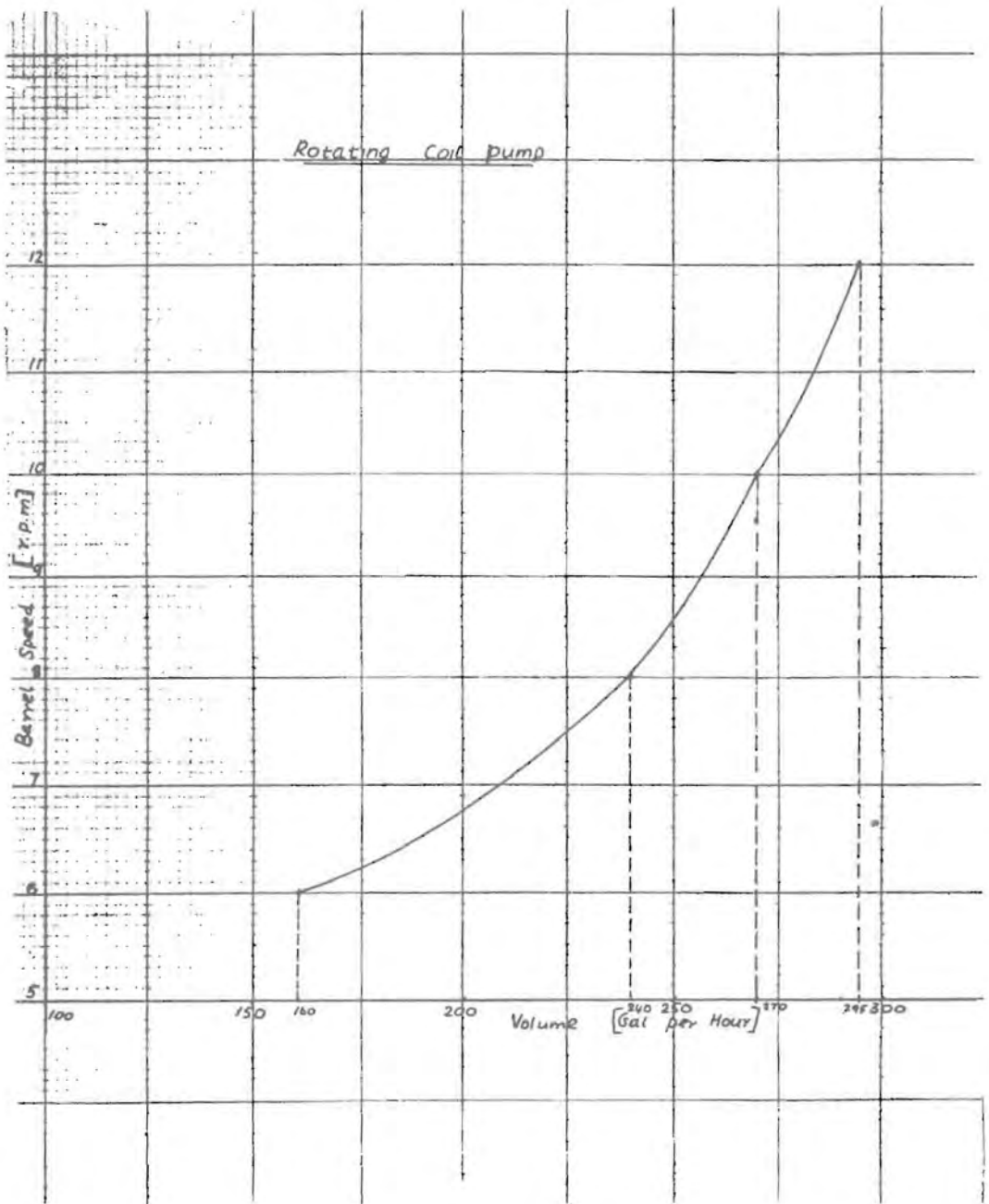
Stream velocity of 2 to 3 ft/sec would be sufficient to operate the pump and the discharge of pump can vary from 160 to 300 gal/hr for barrel speeds of 6 to 12 rpm. Some test results obtained are given in Table 3.2 and the performance is represented graphically in Fig 3.3.

Table 3.2
Rotating coil pump
(One inlet, 2 1/4" diameter - 12 coils, 25" dia).

Test Results

Barrel Speed (r.p.m)	Volume (Gal.)	Time	Head ft.	Volume (g.p.h)
6	12	4 min 30 sec	8	160
7	12	4 min	8	180
8	12	3 min	8	240
7	9	3 min 40 sec	6	148
8	9	2 min 30 sec	6	216
10	9	2 min	6	270
12	9	1 min 50 sec	6	294

Figure: 3.3



LIST OF POPULARISATION PROJECTS UNDERTAKEN

Wind generation

- (a) Muthupanthiyagama Fishing Village.

Size of Community : 75 - 90 Households.

Capacity : 100 Watts - One Unit
200 Watts - One Unit

Performance : Served the community for a period of nearly 1 1/2 years. Average charging rate was 4 batteries a day.

The project had to be discontinued due to the non-availability of a care taker from the project site. Maintenance work was being carried out by NERD during that period.

- (b) Ceylon Tobacco Co. Ltd., Kandy.

Demonstration model and to investigate supply of electricity to communities in the Tobacco Plantations.

Capacity : 100 Watts - One Unit
Status : To be installed shortly.

Windmill operated water pumps

- (a) Chief Minister - North Central Provincial Council.

Supply and installation of 11 Nos. water pumps for irrigation purposes.

Capacity : 1 hp compressor unit with 3.2m wind rotor.
Expected output : 4000 gal/day per unit.

Status : On going project.
The first unit is being installed.

- (b) Kirindiwela Wind pumping project for Mr.Sarathchandra Rajakaruna, State Minister for Energy Conservation.

Capacity : 1 hp compressor operating two pneumatic pumps alternatively.
Lift of water nearly 200 ft. for farm work
Capacity : 400 gal/day.

Mini hydro

No.	Project	Location	Status	Client
1	Aggrelbedda	---	Design completed Fabrication in Progress	CECB
2	Poysland	---	Design completed Fabrication in Progress	CECB
3	Indurana Ela	Kegalle	Report Submitted	Min. of Energy Cons.
4	Hunas Falls	Matale	Survey to be done	Min. of Energy Cons.
5	Peakfield State Murray Falls	Maskeliya	-----do-----	Pvt.
6	Opalgala State Plantation	Gammaduwa	-----do-----	SLSPC
7	Endana Ela	Kahawatta	Survey Completed	SLSPC
8	Hapugastenna	Ratnapura	Survey to be done	SLSPC
9	Walaboda State	Balangoda	-----do-----	SLSPC
10	Dankanda State	Rattota	-----do-----	SLSPC

4 Barrel pump

Mahaweli Economic Agency, Galnewa

ANNEX 4

4. BIO MASS TECHNOLOGIES

4.1 Development of producer gas energy systems

During the last nine years NERD Centre has successfully developed, utilized and commercialised gasifiers and allied energy systems. NERD Centre demonstrated its capabilities and shared the experience gained with representatives from the SAARC member countries at an International Conference on bio-mass gasification at the NERD Centre in June 1990.

4.1.1 Gasification and producer gas

Producer gas, is generated as the product of partial combustion of solid fuels such as firewood in a gasifier. This partial combustion process, called gasification is accomplished by restricting the supply of air in burning. Producer gas generated from fuelwood feed stock by air-blown gasifiers is a mixture of gases. Typical constituents are shown in Table 1.

Table 4.1 - Typical constituents of a producer gas mixture generated with fuel wood in an air blown gasifier

Constituents	Percentage	Remarks
Carbon Monoxide CO	20 - 22%	Combustible Components
Hydrogen H ₂	12 - 15%	
Hydrocarbon gases such as methane	2 - 3.5%	
Nitrogen N ₂	50 - 54%	Inerts
Carbon Dioxide CO ₂	9 - 10%	
Oxygen O ₂	0.5 - 1.5%	

The uncleaned gas may contain some tarry matter, water vapour, ash, dust and volatile substances. Tarry liquids and ashes carried with the producer gas have to be removed before the gas is used. The gas cleaning equipment depends on the application, whether it is for shaft power or for direct heat application. If the raw producer gas is not cleaned sufficiently, the equipment where the gas is finally used, for burning, will have clogging and malfunctioning problems, caused by accumulating tar, moisture and ashes.

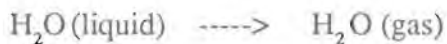
The heating value of the producer gas, fuel is 4-6 MJ/Nm³. The typical thermal efficiency of the gasification process ranges from 75% to 85% when using drywood as the feed stock.

The quality of the gas, depends mainly on the calorific value and tar content. These depends on the following factors :

- i) Quality of the feed stock, specially the moisture content, variety of wood and the dimensions of the pieces of fuelwood.
 - ii) Design of the gasifier.
 - iii) Operating temperature of the gasifier.
 - iv) Gasification media and flow rate.
- Several basic gasifier designs are available.

4.1.2 Characteristics of different zones

The drying or evaporation takes place at a temperature between 25^o to 150^oC.

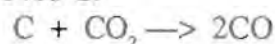


The product H₂O (gas) will be used as a reactant in gasification process.

Pyrolysis (distillation) process takes place between 150^oC-900^o C in the distillation zone where solid fuel decomposes to tar, oils, acids, lighter gases and char etc.

The combustion (oxydation) takes place in the hearth zone where combustible matter or solid fuel reacts with O₂ to give rise CO, CO₂ etc. The temperature of this zone is 900^o to 1400^o C.

In the reduction zone the following reaction takes place mainly at temperatures 600^o to 1400^oC.



This is an endothermic reaction which is very important in the gasification process.

4.1.3 Gasifier designs

Up draft gasifier:

In the up draft type of gasifier, the gas and the solid fuel move in counter current flow. Unless the fuel is of very high quality, it tends to produce a gas which is contaminated with tar, and therefore unsuitable for internal combustion engines. Its use is limited to heating application only.

Down draft gasifier:

In the down draft gasifier, the gas and the fuel move concurrently downwards.

This type is most common and it is the first choice in most of the shaft power applications. It is more difficult to design and fabricate than up draft gasifiers, but when working properly it breaks down tars evolved in the gasification process, thus producing clean gas.

Cross draft gasifier:

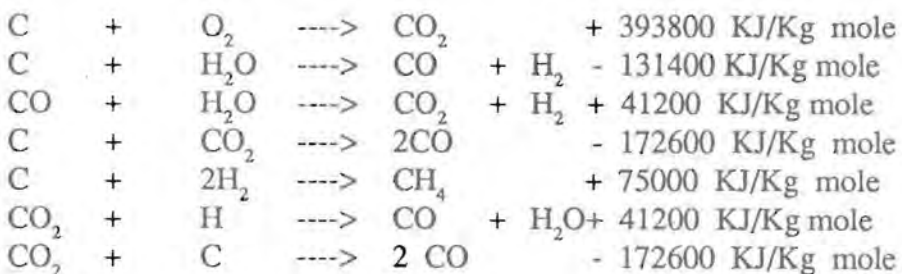
The cross draft type of gasifier is mainly designed to meet the needs of vehicle propulsion. It is light weight in construction and requires clean high quality fuel, mainly charcoal.

Fluidised bed gasifier:

In this type fuel particles are kept in suspension by the gas flow. The fluid beds are generally well mixed and the different combustion zones can hardly be distinguished. Comparatively large quantities of ash and char will be carried out of the bed by the gas flow. This type is very suitable for direct heat application such as hot air and steam generation.

4.1.4 Chemistry

Following chemical reactions take place within a gasifier of the hearth zone, where the temperature is above 800°C.



Energy content of the producer gas depends on the gasification agent. Oxygen, Hydrogen and air are generally used as the gasification agents, but O_2 and H_2 are expensive to use. Therefore in normal practice, air is used as the gasification agent.

4.1.5 Remarks

The application of gasifiers can be divided into two: shaft-power applications, where the gas is used to run engines, and direct heat applications where it is burnt directly in a boiler, furnace or kiln to provide heat.

Among the various basic designs which were discussed before, down draft gasifiers are preferable and suitable for most of the applications since they produce very good quality gas having low tar and volatile content.

4.2 Application of gasifiers in tea industry

4.2.1. Tea drying with gasifiers

The tea industry is one of the main pillars of the Sri Lanka economy and it is also the largest fuelwood consumer in the country (Figure 4.1). Sri Lanka produces 200 million kg. of made tea utilizing 400 million kg. of fuelwood per year on an average. Therefore reduction of firewood consumption in the tea industry remains an important issue from the national point of view. The possibility of utilizing gasifiers in the tea industry to minimize fuel consumption was investigated.

4.2.2 Thermal energy requirement in tea manufacturing

In the manufacture of tea thermal energy is required as an input in two stages. Firstly, withering requires approximately 2.8 MJ/kg of made tea, and drying needs approximately 11.4 MJ/kg of made tea. This heat is generally produced by combustion of firewood or fuel oil.

Due to the high cost of fuel oil, at present almost all the driers are being operated on fuelwood except in the hill country. The hot air required for tea processing is obtained from a heat exchanger, where the fuelwood is burnt inside the furnace containing flue tubes, through which air is drawn from the atmosphere, via a blower. In the drying chamber, the tea moves from the inlet at the top to the discharge at the bottom against the draft of hot air, and is dried in the process.

FUELWOOD CONSUMPTION BY INDUSTRIES

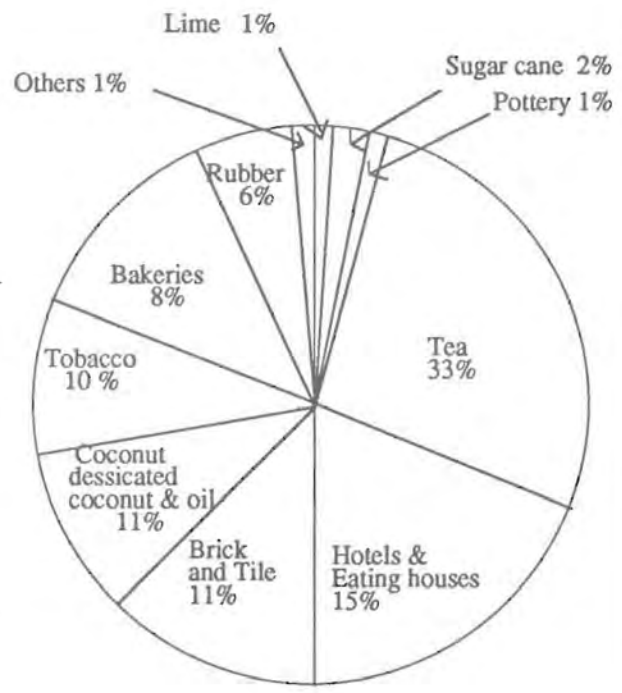


Figure 4.1

Figure 4.2 shows the common arrangements of a six level tray drier and the hot air generator. Figure 4.3 shows a schematic diagram, of the drier heat exchanger assembly. Table 4.2 shows different types of tea-driers and their capacities.

Table 4.2 - Capacities of different Tea - Driers

Type of the Drier	Capacity GJ/Hr	Output kg/Hr	Power Output KW
6 Foot drier	3.15 - 3.36	250	875 - 930
5 Foot drier	2.6 - 3.15	150	720 - 875
4 Foot drier	2.1 - 2.6	125	555 - 720
3 Foot drier	1.6 - 2.1	75	445 - 555

Presently, tubeless heat exchangers and fluidised bed driers are employed in some factories. But this paper does not deal with them.

4.2.3 Moisture removal in tea processing

Moisture content of tea, at different stages of the manufacturing process, have been investigated and reported in Table 4.3.

Table 4.3 - Moisture content of tea at different stages of production

Stages of Production	Average Moisture content	Preferable Moisture content
1. Green - leaf		
A. Dry day	70%	-
B. Wet day	83%	-
2. Withered leaf		
A. Dry day	40%	
3. Made tea	-	2.5-3%

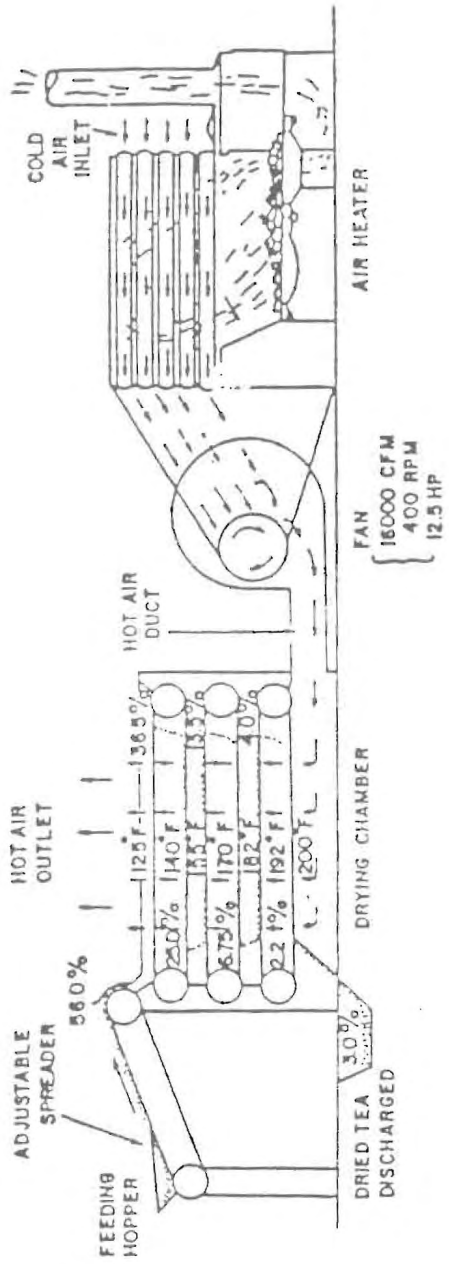


FIGURE 4.2 MODERN SIX TRAY DRYER

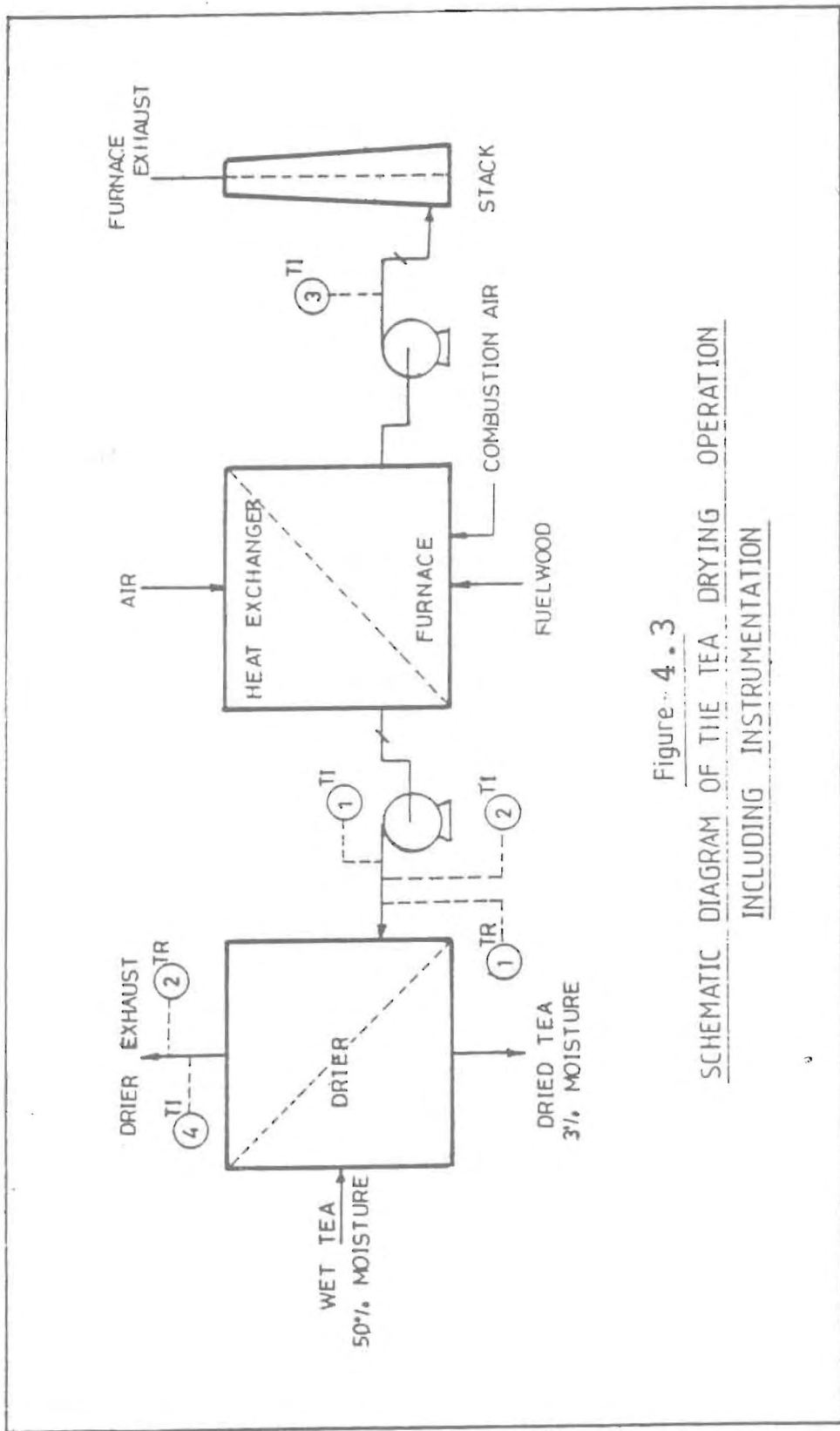


Figure 4.3

SCHEMATIC DIAGRAM OF THE TEA DRYING OPERATION
INCLUDING INSTRUMENTATION

The moisture content of green leaf is reduced to 55% from 80% in the withering process using conditioned air. The temperature of the air is about 25^o-40^oC, which is only to maintain a hydrometric difference of 4^oC.

The moisture content of made tea is reduced to 2.5% from 55% in the drying process, using hot air. The optimum drying temperature should be between 85^o-90^oC; therefore hot air just entering the drier should be about 93^o-96^oC. The optimum drier exhaust temperature is 50^o-55^oC. The residence time of tea in the drier varies according to the drying temperature. For a drying air temperature of 85^o - 95^oC, the residence time should be 18 - 24 minutes.

4.2.4 Fuel wood in tea processing

To wither 1 kg. of made tea it requires 0.7 kg. of firewood and to dry 1 kg. of made tea it requires 2 to 2.5 kg. of firewood. Therefore three kg. of firewood is required to produce 1 kg. of made tea. These values may be considered as average figures and the true value generally depends upon the efficiency of the furnace/ heat exchanger/drier combination.

In 1986 Sri Lanka had produced 211.3 million kg. of made tea with an estimated consumption of 377.4 million kg. of firewood. This is really a large amount of firewood and if this consumption pattern is allowed to continue, the effect on the environment will be disastrous. An improved combustion efficiency is achieved by converting the firewood to producer gas and then burning it to generate heat energy.

4.2.5 Sizing the gasifier

The sizing of the gasifier was done with the help of previous extensive experience on a variety of applications. 35% overall efficiency was assumed for the design calculations, covering the primary combustion in gasifier, secondary combustion of producer gas in the burner and heat transfer in the heat exchanger. Based on the available data and the above assumption, which was also based on previous experience, suitable gasifiers were designed, for 6 foot and 4 foot driers. The specifications of the gasifiers are shown in Table 4.4. Later the validity of the assumptions were confirmed from the test results.

Table 4.4 - Specifications of gasifiers

Drier type	Gasifier	Rated Fuelwood Consumption kg/Hr	KW (Thermal) power output	price Rs.1000
6 Foot	AF 250	170	850	200
4 Foot	AF 200	100	500	175

4.2.6 Salient features of the design

In order to cater for the tea manufacturing requirements, the gasifiers have to operate for 16 to 18 hours continuously. This is achieved by introducing a tapered hopper, with a capacity sufficient for 12 hours operation of the gasifier. Because of the tapered configuration fuel bridging problems are avoided.

A correctly sized cyclone separator is connected to the gasifier to remove ash and char particles which are carried along with the producer gas to the furnace.

A refractory layer is used to protect the internal walls and the components of the gasifier hearth zone against very high temperatures and oxidizing environment prevailing in the hearth zone

The producer gas burner is a simple one and specially suitable for low calorific value gases.

To achieve a high flame temperature, a certain amount of secondary combustion air is used. It is possible to obtain a flame temperature about 1100°C. The temperature of the drying hot air can be controlled, by manipulating the primary air flow into the gasifier for gasification reactions; and the secondary air supply for the combustion of producer gas.

The following safety devices and control equipment are installed.

1. Interlock device, which prevents the possibility of starting the air blower of the gasifier before starting the ID fan of the furnace.
2. Flame monitor, which indicates audibly and visually the unavailability of the flame.
3. Once the flame goes off, an electronic signal immediately switches off the air blower of the gasifier. This arrangement prevents the accumulation of fuel gases inside the furnace.
4. Temperature controlling device, which controls the temperature of the hot air and maintains the hot air temperature between 110°C and 90°C.

All the essential features of the gasifier are presented, in the Figure 4.4 and gasifier furnace drier assembly is shown in Figure 4.5.

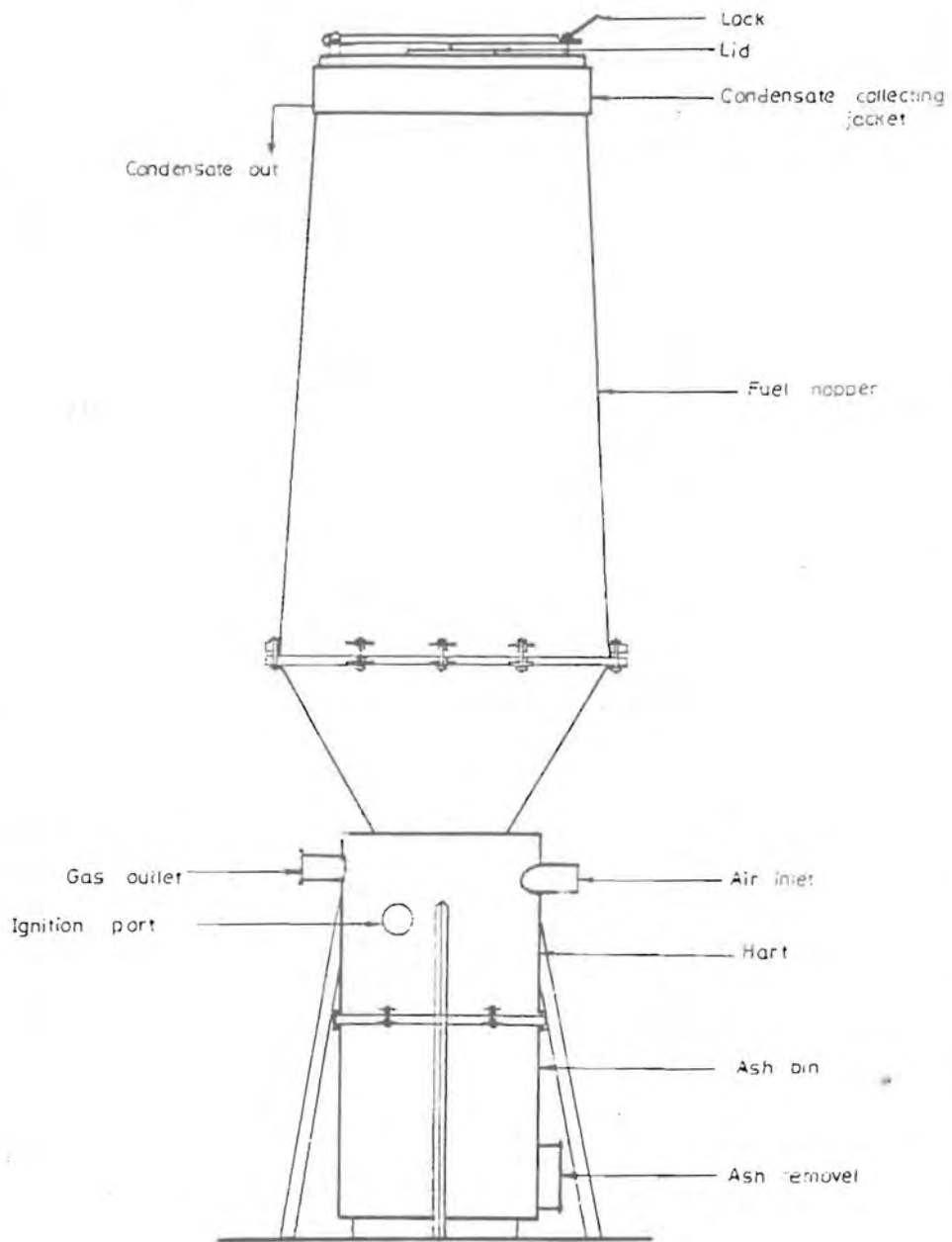


FIGURE 4.4
Main Details of a GASIFIER

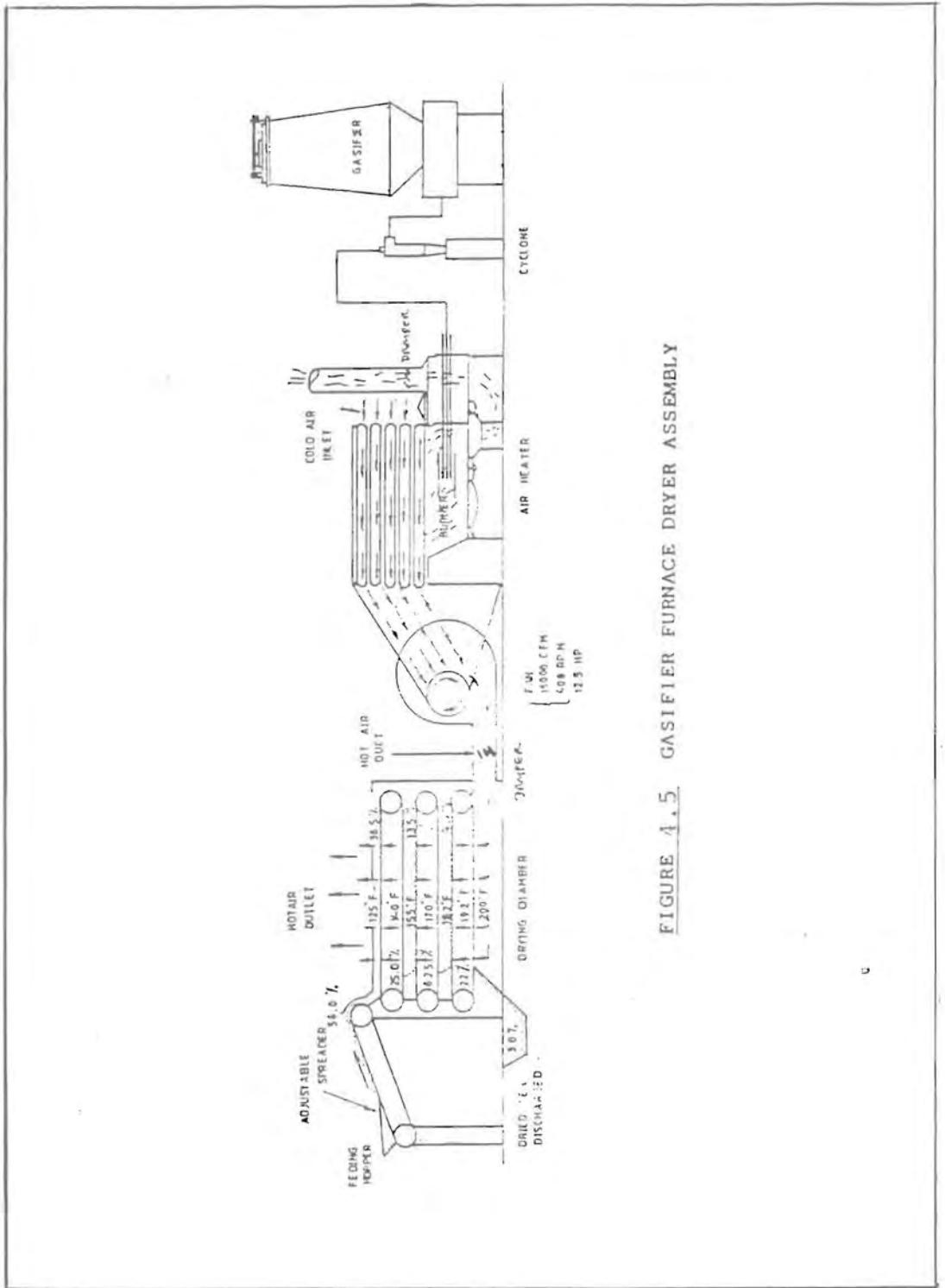


FIGURE 4.5 GASIFIER FURNACE DRYER ASSEMBLY

4.2.7 Tea drying with gasifiers

The gasifier system is installed to fuel the furnace, which generates hot air for tea drying. In this setup the location of the burner in the furnace is very important, since it has a bearing on the temperature of the outgoing air from the heat exchanger. The flame of the burner should not touch the heat exchanger tubes. The temperature of the hot air varies with the design of the heat exchanger and the distance from the burner tip to fire door.

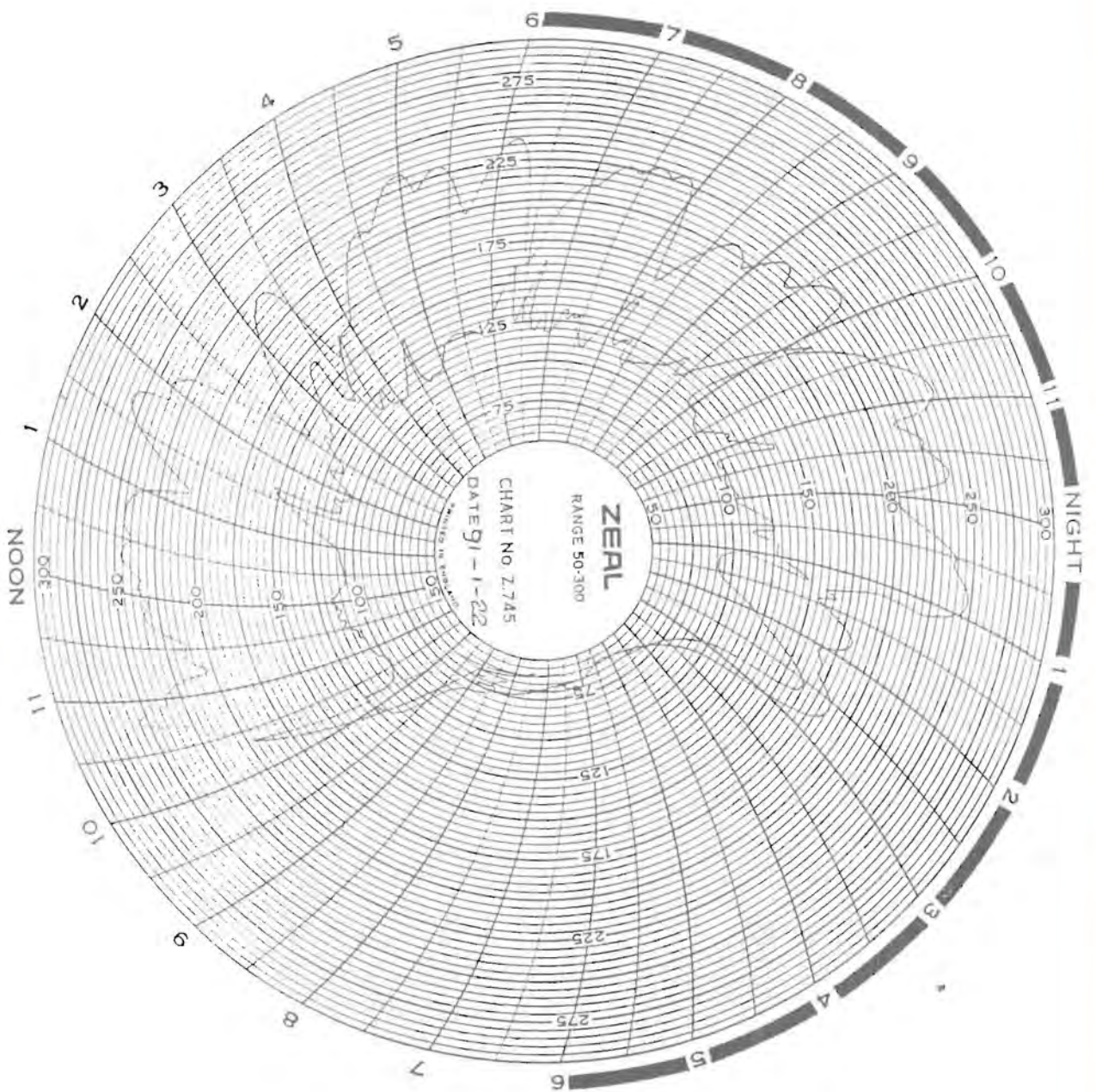
The flue gas damper is adjusted suitably to stabilise the flame. After determining the location of the burner and the flue gas damper position properly in order to get the correct drying temperature, drying of tea can be performed.

4.2.8 Drying experiments and results

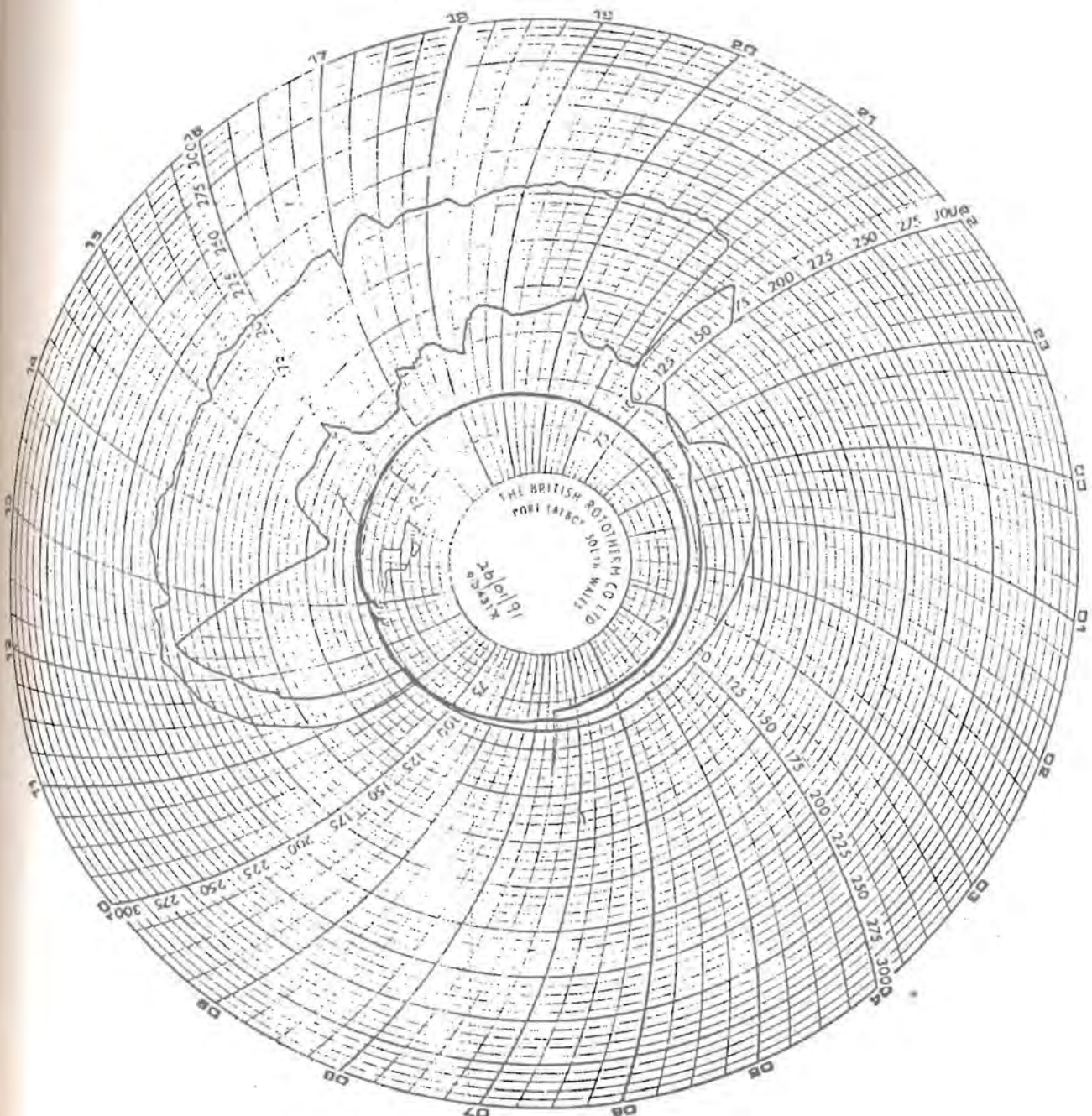
After starting the fire inside the gasifier, it generally takes 5 - 10 minutes to produce combustible gas which can be burnt, inside the furnace, to generate process heat. It usually takes 30-45 minutes to attain a process air temperature, which is suitable for drying of tea, depending on the efficiency of the furnace/heat exchanger. The continuous operation of the entire gasifier system revealed that the fuelwood consumption in tea drying can be reduced at least by 50% of the current fuelwood consumption, maintaining the same temperature of the hot air.

The temperature fluctuation of the drying air was between $\pm 5^{\circ}\text{C}$; whereas in the case of direct firewood combustion, the temperature fluctuation is in the order $\pm 25^{\circ}\text{C}$. As a result of the constant drying air temperature, the output of the drier could be increased, in some situations. An increase of throughput as high as 40% was achieved in some occasions.

Figures 4.6 and 4.7 illustrate the typical thermograph of the drier which was operated in traditional manner and with producer gas respectively.



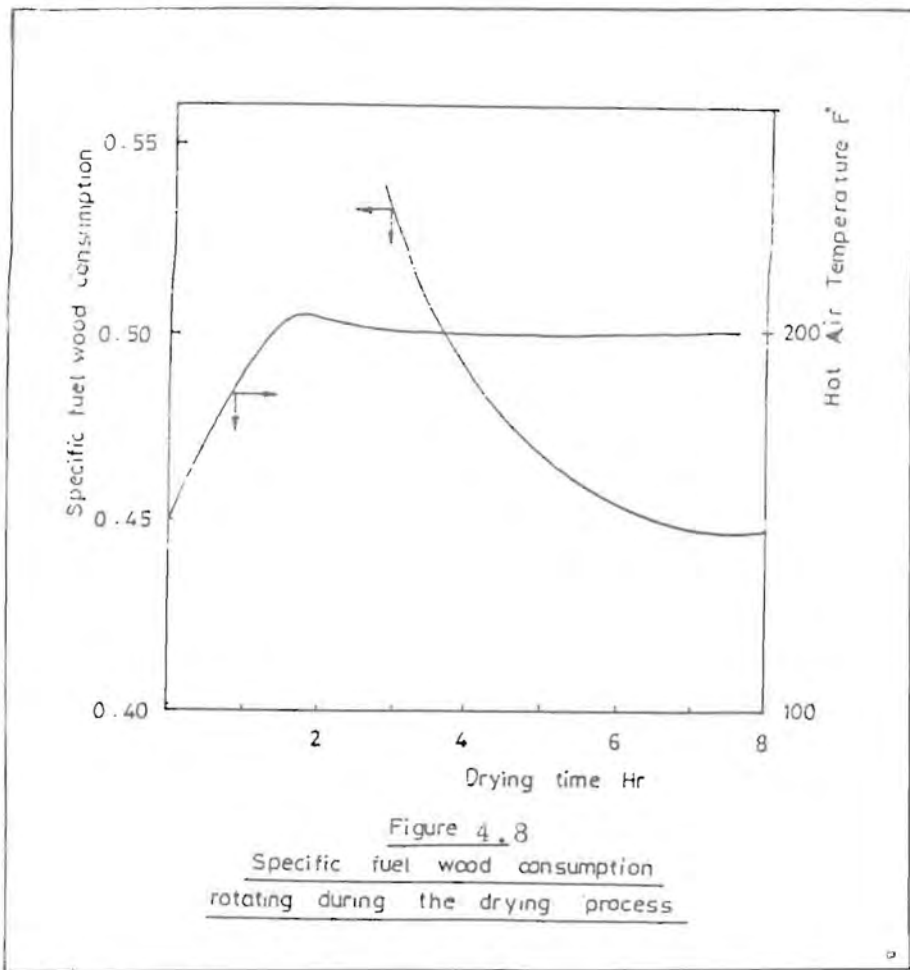
Thermo graph of the tea drier
hot air inlet temperature
when wood logs are being burnt.
Figure 4.6



Thermograph of the tea drier
 hot air inlet temperature
 when producer gas is being burnt

Figure 4.7

The specific fuelwood consumption was measured at increased capacity and the results are shown in Figure 4.8. Here the specific fuelwood consumption is defined as weight of firewood required to produce unit weight of made tea.



On this basis the capital cost of the gasifier equipment can be recovered within only six months.

4.2.9 Direct heat of producer gas for tea - drying

Experiments were carried out to realise the advantages of application of direct heat for tea drying. Cleaned producer gas was burnt in a separate chamber and fresh air was supplied to reduce the temperature to the required level, which is suitable for tea-drying. The experimental set up is illustrated in Figure 4.9. A small gasifier was used for this purpose, and fuelwood consumption was less than 25% of the conventional consumption. To promote this application much more experiments and modifications have to be done; especially the safety aspect of the process has to be improved by modifying the present equipment.

4.2.10 Future of the project

Since the economic viability and operational reliability, of this process has been proven, the technology has been commercialised through a private commercial agency which is responsible for the manufacture, marketing and promotional work in application of gasifiers in the plantation sector.

4.3 Low cost - high efficiency heat exchanger

Recently NERD Centre has introduced a low cost - high efficiency heat exchanger for the tea industry.

This heat exchanger is utilised to generate clean hot air to be used in tea drying. In comparison with the traditional heat exchanger, NERD heat exchanger is very low in capital cost and efficient in heat exchanging.

The NERD heat exchanger, has been fabricated out of thin M.S. sheet metal and no castings are involved, whereas the traditional heat exchangers are made of heavy castings. A typical heat exchanger consists of 16 heat exchanger modules, each module consisting of 10 heat exchanger elements (tubes). A heat exchanger module and a tube are illustrated in Figure 4.10.

The same temperature, same flow rate and same heat output can be achieved with the NERD low-cost high efficiency heat exchanger.

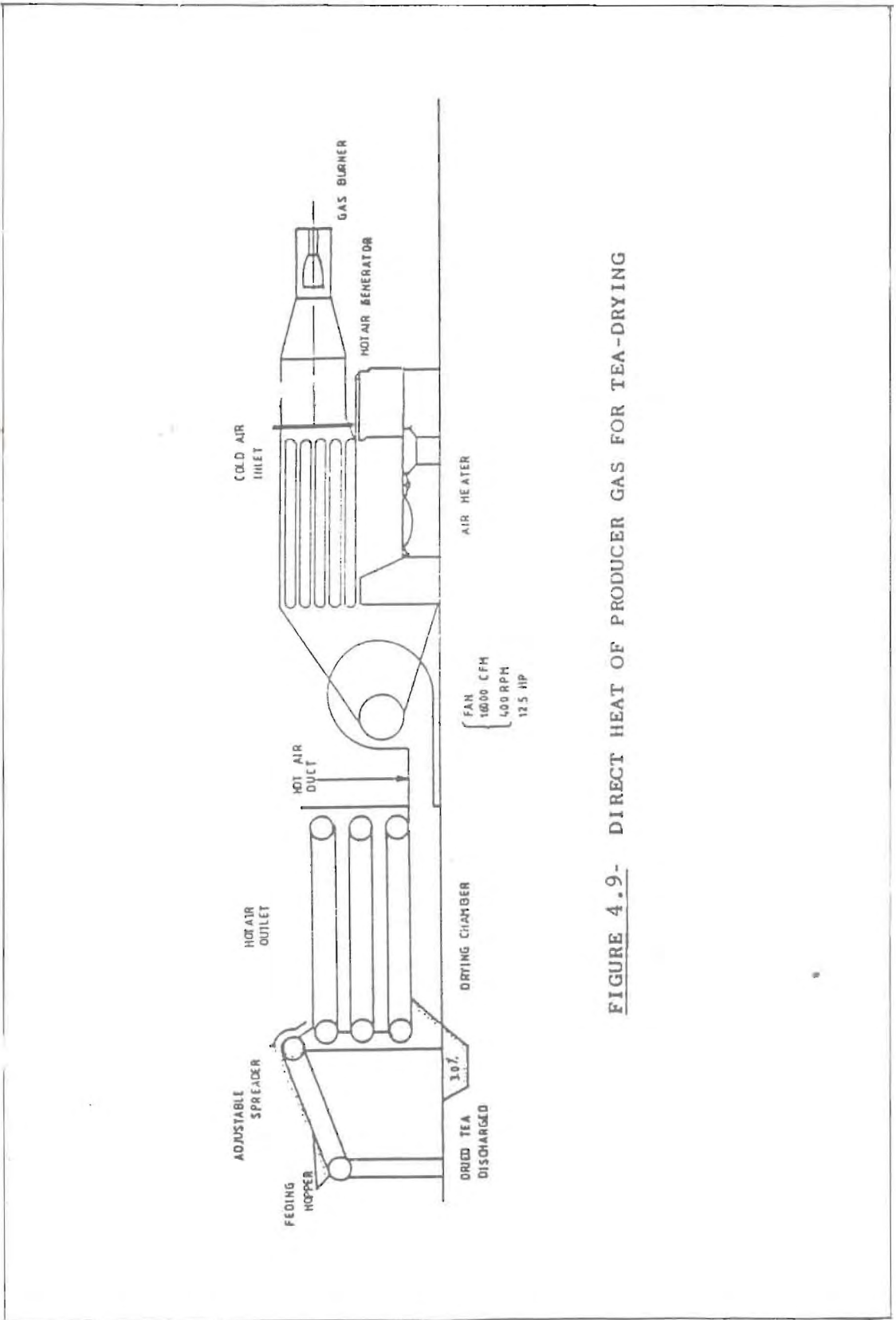
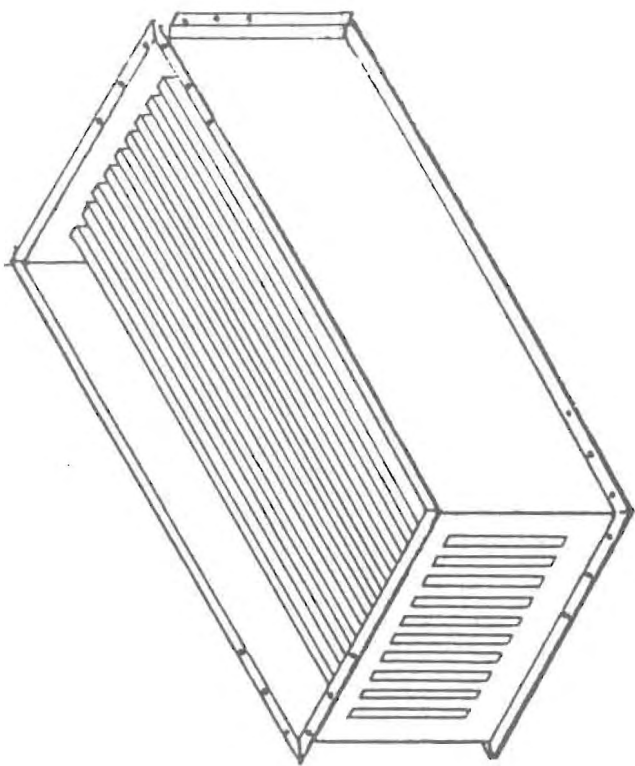
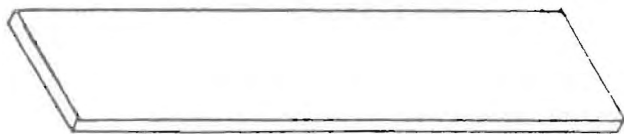


FIGURE 4.9- DIRECT HEAT OF PRODUCER GAS FOR TEA-DRYING



MODULE OF A HEAT EXCHANGER



HEAT EXCHANGER TUBE (ELEMENT)

Figure 4.10

NERD LOW COST HIGH EFFICIENCY
HEAT EXCHANGER MODULE & A TUBE.

4.4 A gasifier operated furnace for non ferrous foundries

Although the production of castings on a large scale is a sophisticated and capital intensive business, there is a need for small scale foundries which produce fittings for buildings, spare parts for machinery and equipment and ornamental handicraft items.

Sri Lanka has had a traditional technology for non ferrous foundry production for a long time. These foundries have been manufacturing brass and aluminium fittings such as hinges, tower bolts, door and window locks etc. for the building industry. During recent years this industry has been facing the problem of rising cost of liquid fuel which has been used practically by every small scale foundry. A certain amount of spent lubricating oil from the transport industry has been used to supplement the furnace oil. However, the cost of this spent oil has also been increasing and there is a shortage due to high demand.

This situation has created considerable difficulties for the small-scale non-ferrous foundry industry with the result that the cost of the products have increased considerably and some foundries have had to close down. An alternative fuel for this purpose, has been coconut shell charcoal but with the increased demand for coconut shell charcoal for the manufacture of activated carbon, for which high prices are available in the world market, the cost of this fuel also has increased to the level of the liquid fuels. In this scenario NERD Centre undertook research to solve the problem of reducing the fuel cost in non-ferrous foundries.

4.4.1 Development of the furnace

The knowledge and experience gained in producer gas R & D led to its use as the alternative fuel in the foundry. Since producer gas is a low calorific value gaseous fuel, a suitable burner was developed to achieve very high furnace temperature which is sufficient to melt aluminium and brass scrap.

The hot gas and air mixture is fed directly into the burner of the foundry for combustion. In this manner it is possible to obtain a high temperature of about 1100°C. By firing the crucible from the top it was possible to melt 1 kg. of brass using 1.6 kg. of firewood.

4.4.2 New method of firing the charge

The traditional practice of firing the crucible from the bottom results in rapid deterioration of the crucible due to very high temperature gradient that exists across the crucible wall. It has been found that while an imported crucible has a life time of 20-30 melts, the locally manufactured crucible which is available at a fraction of the cost of the imported one could only have a life time of 3-5 melts with traditional firing practices.

A new method of firing the charge was devised in order to increase the life time of the crucible and to achieve high fuel efficiency by avoiding the high temperature gradient across the crucible wall. This is accomplished by firing the crucible with the charge from the top of the crucible where the flame impinges directly on the charge. Essential features of this arrangement are shown in Figure 4.11.

In this manner a considerable amount of fuel could be saved with the reduction of melting time, in addition to extending the life of the locally manufactured crucibles from about 5 melts to about 25 melts.

Based on the experiments carried out at the NERD Centre a comparison of the performance of both the firing modes are illustrated in Table 4.5.

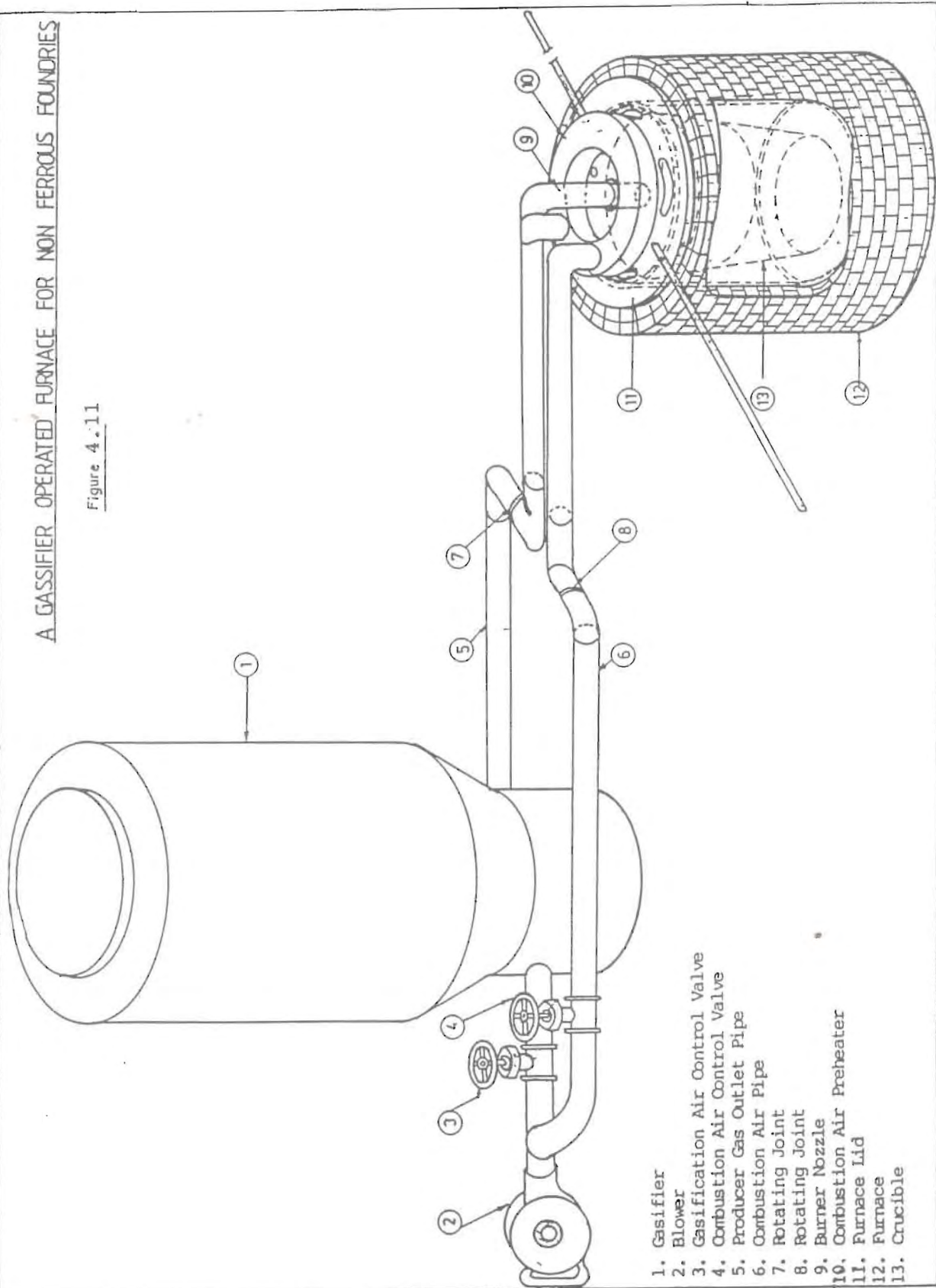
Table 4.5 - Comparison of the performance of two different firing modes for melting 20 k.g. of brass.

Firing mode	Fuel consumption kg.	Time taken min.	Life of the crucible in No. of melts
Crucible is fired from the bottom	33	70	3 - 5
Charge is fired from the top	20	35	25-30

The machinability, hardness and tensile strength of the castings which are cast using these methods are found to be within acceptable limits.

A GASSIFIER OPERATED FURNACE FOR NON FERROUS FOUNDRIES

Figure 4.11



- 1. Gasifier
- 2. Blower
- 3. Gasification Air Control Valve
- 4. Combustion Air Control Valve
- 5. Producer Gas Outlet Pipe
- 6. Combustion Air Pipe
- 7. Rotating Joint
- 8. Rotating Joint
- 9. Burner Nozzle
- 10. Combustion Air Preheater
- 11. Furnace Lid
- 12. Furnace
- 13. Crucible

4.4.3 Advantages

The distinct advantages of the utilization of this alternative fuel can be summarised as follows.

1. The operation is more economical.
2. The alternative fuel, firewood is a readily available renewable energy source.
3. The life of the crucible is extended.

The same principle may be utilized for melting Zinc and Aluminium too. The NERD Centre has developed galvanizing plants in which firewood based producer gas is used as the fuel.

4.4.4 Cost

The cost of the entire foundry equipment along with the gasifier for melting 40kg. of Brass is Rs. 60,000/- approximately.

4.5 Producer gas engine systems for shaft power

4.5.1 Introduction

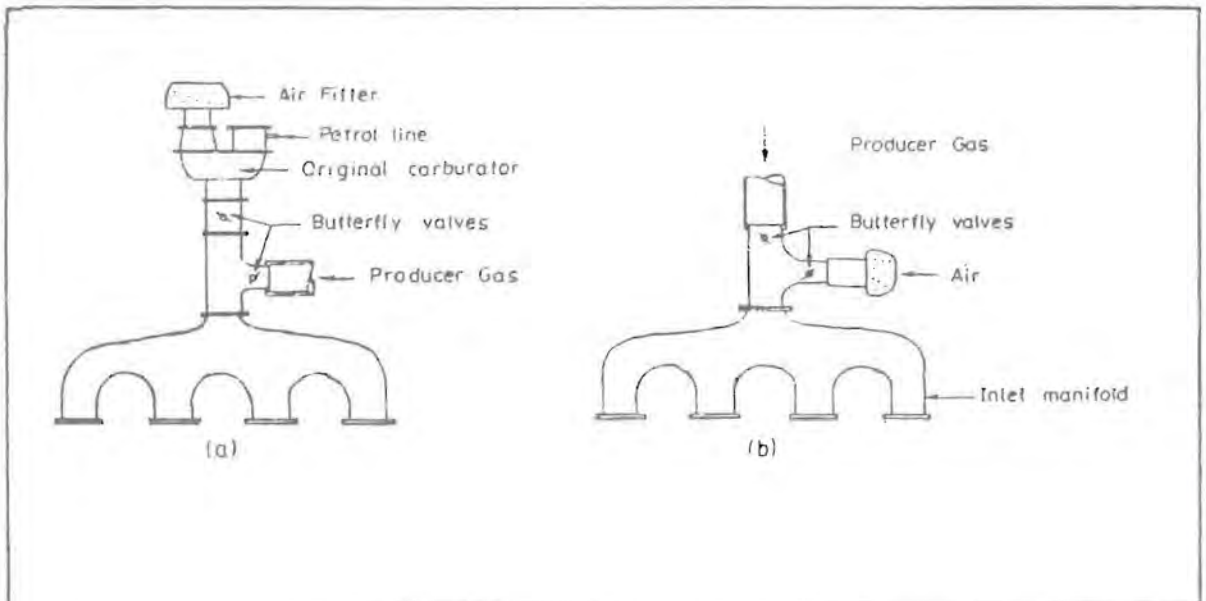
Producer gas is a fuel in gaseous form having low calorific value of 4-5 MJ/Nm³. This gas can be fed into IC engines, after processing the gas sufficiently. Dust, tar, moisture and volatile free clean producer gas is required for IC engine applications. If the above mentioned impurities of the producer gas are not removed, there may be serious damage to parts or the engine such as push rods, valves, nozzles etc. by choking the gas passages, stopping the operation of moving parts and corroding various metallic components. Therefore auxiliary equipment such as cyclone separators, various type of filters, gas scrubbers and gas coolers are required for removal of impurities which are found in raw producer gas, for IC engine applications. Producer gas cooling is essential in order to increase the volumetric efficiency of the engine.

4.5.2 Shaft power applications

Both diesel and petrol engines can be modified to be fueled with producer gas. After a petrol engine has been started, it operates 100% on producer gas. But in the case of diesel engines only up to 80% of diesel can be replaced with producer gas; some diesel is needed for ignition.

Let us consider the necessary changes which have to be done in order to operate a petrol engine with producer gas. Two butterfly valves are installed, one in the producer gas line and the other in the air line, to facilitate the proper regulation of the air/gas mixture which will be admitted to the engine. Petrol engines can be converted to run on producer gas very easily by installing a new system as shown in Figure 4.12a. Here all the effort should be taken to minimize the distance between the inlet manifold and the original carburetor. Since the combustion limits of the producer gas and air mixture lie within a very narrow range, adjustment of the two butterfly valves has to be done very carefully. Anyway there will be 40% - 50% power reduction due to the low calorific value of the producer gas.

Figure 4.12 (a & b) Modification to the I C engines



In the case of diesel engines, the air intake arrangement is removed from the inlet manifold and instead of that a new gas-air mixer is fixed as shown in Figure 4.12b. The reduction of the diesel flow rate to the engine is expected after the conversion. But the reduction has to be done very carefully, after considering the lubricating arrangement of the fuel pump. Some fuel pumps are self lubricated and in such a situation careful regulation is required. 10% - 15% power reduction is experienced with this type of conversion.

For IC engine applications, external blowers are not needed, once the engine is started, it sucks air continuously through the gasifier, generating producer gas. Throughput is regulated by accelerator control in the usual manner.

4.5.3 NERD Centre experience

Several diesel and petrol engines have been converted at NERD Centre for various applications. Among them the following are very significant.

1. Water pumping
 - 2" water pump coupled to a petrol/kerosine 4 HP Robin Engine.
 - 4" water pump coupled to a 1600 CC Mazda Petrol Engine
2. Stand-by electricity generator
 - Cummins Diesel Engine coupled to a 300 KVA generator
 - Kirloskar Diesel Engine coupled to a 22.5 KVA generator
 - Hino Diesel Engine coupled to a 45 KVA generator
 - V-8 Ford Petrol Engine coupled to an induction generator
 - 6 Cylinder Petrol Engine coupled to an induction generator
3. Mobile application
 - Toyota Hiace Petrol Van 1600CC
 - Fiat Diesel Tractor 45 HP
 - Isuzu 3.5 Diesel Lorry

4.6 Development of biogas energy systems

4.6.1 Abstract

The availability of an abundance of raw materials and low cost technology led to research and development for producing biogas from non-conventional materials such as straw, grass and water plants. Straw has a very high potential application due to two seasons paddy (rice) cultivation of large extents of land in all parts of the island. The NERD Centre R & D has resulted in developing a Sri Lankan Dry Batch type biogas generator. It eliminates problems of conventional types of biogas units such as non-availability of raw materials, scum formation and poisoning of units due to long retention time.

In addition to promoting this method for individual family use for fuel and fertilizer, a programme has been implemented to serve villages of about 100 families with low power fluorescent lighting and operating radios and TVs via charging of batteries with electricity generated from biogas.

4.6.2 Introduction

The Chinese method of biogas production started earlier was found to be satisfactory and introduced into farms in the Livestock Development Board as well as to farmers connected to the National Livestock Development Board. A subsidy scheme was introduced to construct those units, with all the required materials given by the government, and labour only supplied by the farmer (Figure 4.13).

Most of the farmers do not have mains power supply. Cooking and heating water for various purposes can be done with biogas. In some instances biogas is being used for power generation and for pumping water.

Several biogas units donated by India have been installed in some farms of the Livestock Development Board. Due to non-availability of trained personnel for proper maintenance some of these units, and some Chinese Units are not functioning or are abandoned (Figure 4.14).

4.6.3 Biogas production at NERD Centre

R & D activities at NERD Centre were firstly on the Chinese method. Although the original Chinese biogas generator used a masonry structure, NERD Centre tried out several units made of precast components. Due to the high pressure developed in the digester making the unit gas tight was a problem. These precast concrete units were constructed with cylinders of 6' diameter and 12" height. They were placed one on top of the other and the joints sealed by cement mortar and a bituminous glue.

But the joints were not satisfactory. In addition the lid of the unit also was of precast concrete and the joint of the lid to the well also was not satisfactory as in the high pressure Chinese system.

Later the system of using the precast units for the Chinese system was abandoned, and the same system with low and constant pressure, Indian method was started. The gas holder was made of fibre glass and it was resting on several concrete blocks and allowed to float on a guide when that is filled with gas.

On the experience gained from India in addition to the fibre glass holder, a ferrocement gas holder also was tested. But that was not gas tight even for the low pressure. Handling of that gas holder posed big problems due to the weight. Therefore we concentrated mainly on the precast digester and the fibre glass gas holder.

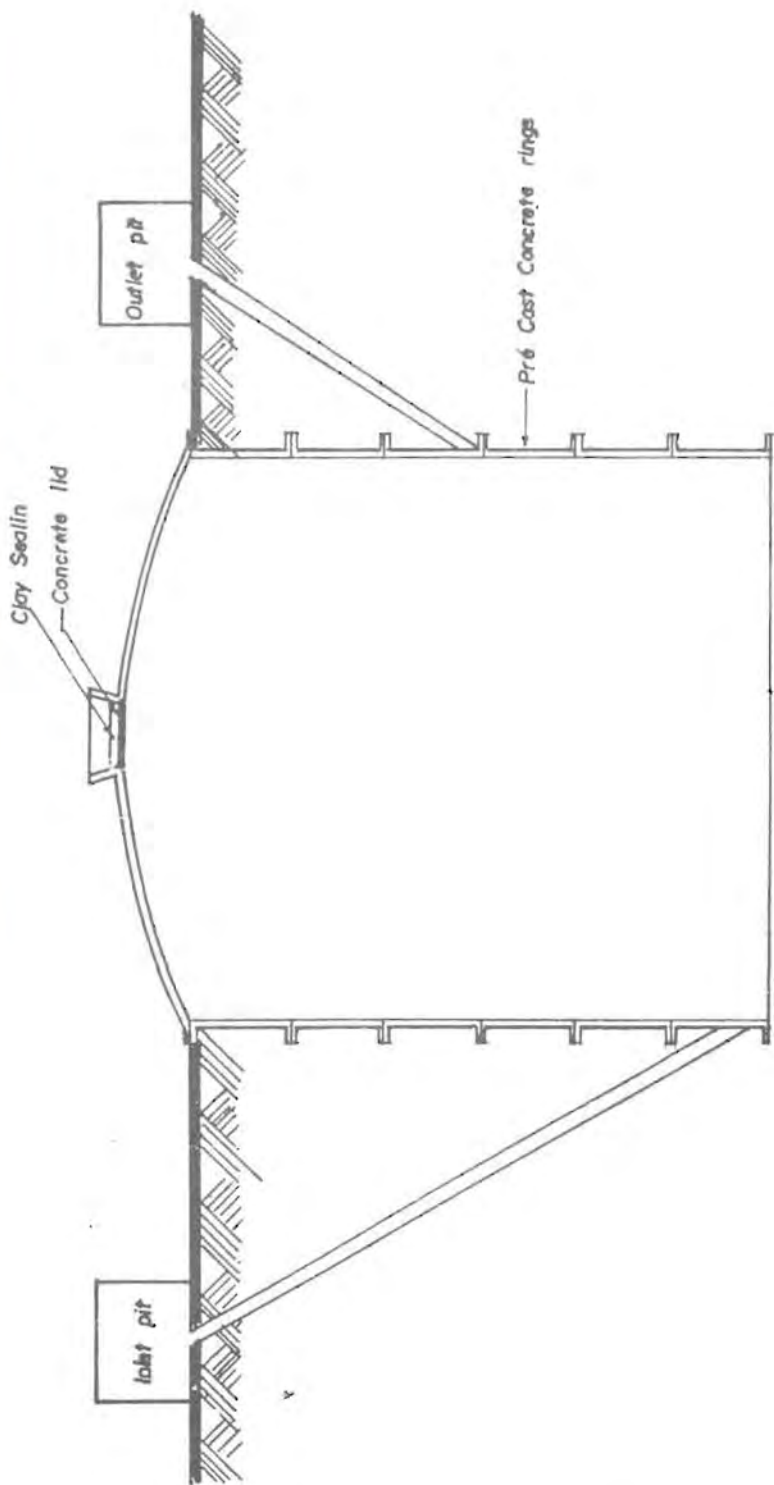
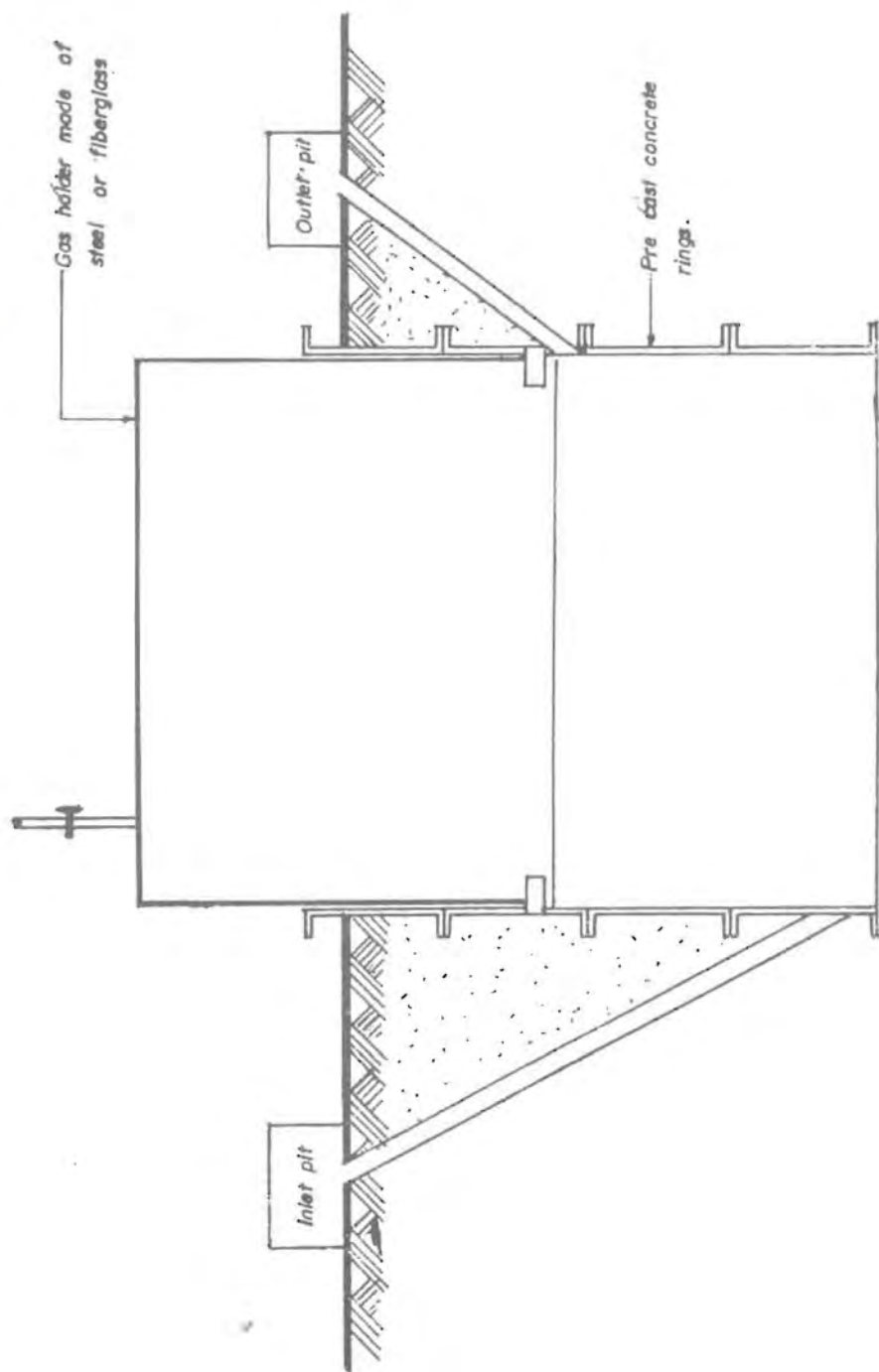


Figure: 4.13

CHINESE TYPE
B10 GAS Generator made of
P. C. Concrete rings



INDIAN TYPE
BIO GAS Generator made of
P.C. Concrete rings.

Figure: 4.14

This method of gas production was successful and attempts were made to introduce the method to farmers who had several head of cattle or pigs. Except for scum formation when cattle dung is used it went smoothly. But to operate a unit of family size one needs at least three head of cattle to get sufficient feed materials. In Sri Lanka the number of farmers owning three or more head of cattle is very small. As such the benefits of biogas technology was limited. The cost of constructing a biogas unit too was high for poor farmers who could benefit from the biogas units.

4.6.4 Emergence of straw biogas unit

It was understood that due to the reasons mentioned popularization of biogas in Sri Lanka was difficult. Therefore the Chairman of the NERD Centre Vidya Jyothi Dr. A N S Kulasinghe looked into the possibility of producing biogas from vegetative materials, instead of animal wastes as the feed materials.

A series of bottle experiments was initiated. The materials used mainly are straw, coir dust, saw dust, coconut leaves, banana leaves, water hyacinth, gliricedia leaves, salvinia etc. To make the C:N ratio narrow i.e. 25-30:1, a Nitrogen rich material or urea was added to the mixture.

To get the initial culture medium, a little cowdung or culture from an old digester was also added. Water for the mixture was kept at a minimum level that is to make the medium wet only to enhance the growth of bacteria. The sample was sealed and made gas tight as shown in the diagram (Figure 4.15).

These samples gave very satisfactory results. Gas production was as high as 2 litres of gas per kg. of biomass per day at the peak. Gas production of various materials are shown in the diagram. It was revealed that straw, the material abundantly available in almost all parts of the island, was the best for biogas production. The gas yield varies from place to place depending on the climatic conditions. On average the gas production was about 1 lit./kg./day.

While monitoring the gas yield, the amount of CH_4 in the mixture also has been tested. Although from the very first day there is gas it is not combustible, as it is mainly CO_2 . The action of CO_2 forming bacterial comes first, while the methanogenic bacteria act a little later. Therefore to get a reasonable flammable gas it takes about 7 days to 10 days depending on the materials and mixture and the temperature.

BIO GAS-BOTTLE EXPERIMENTS

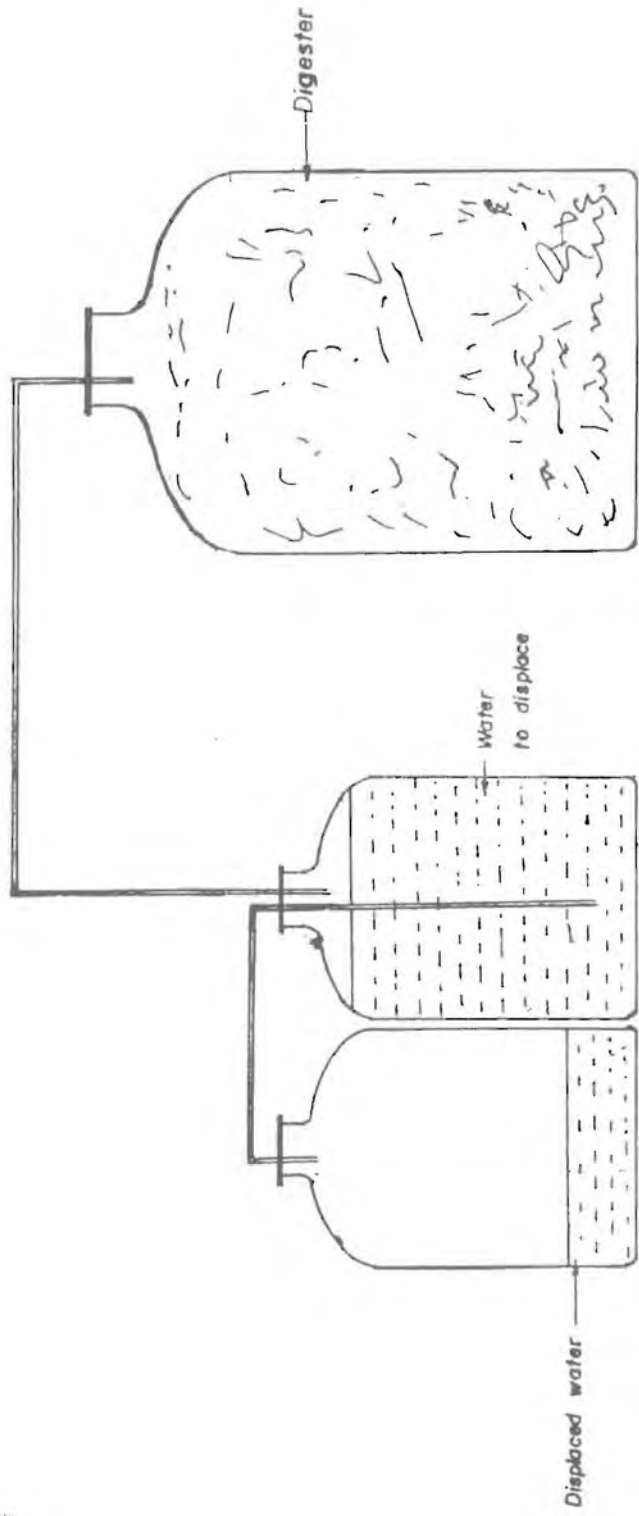


Figure: 4.15

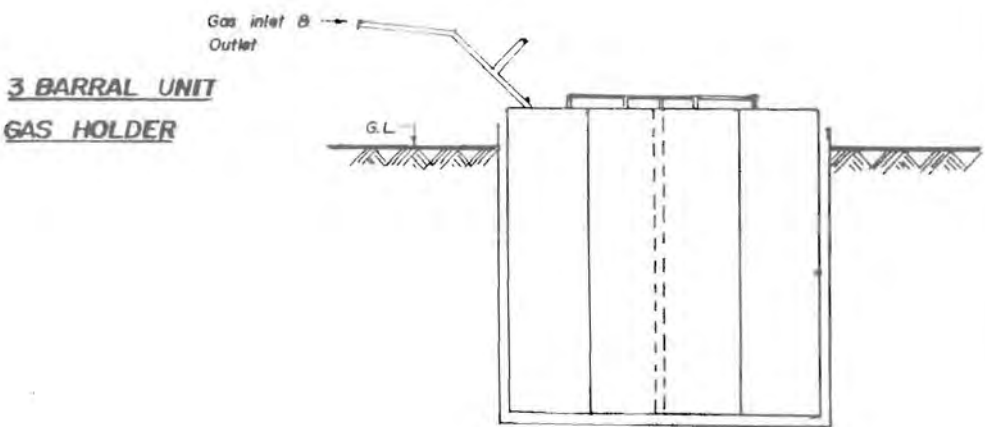
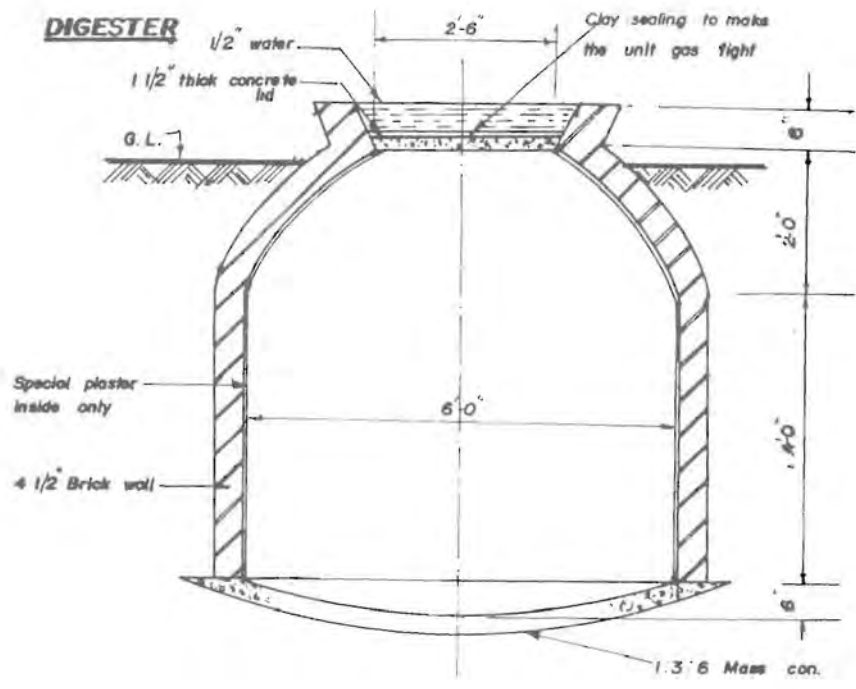


Figure: 4.16

BATCH TYPE
STRAW BIO GAS GENERATOR

NERD CENTRE
 CE/82/31-01

In 7 to 10 days time there is at least 40% of Methane in the biogas. As in the case of other biogas generators it improves upto 70% of Methane. Although the gas production drops a little by that time, the calorific value of gas is higher than at first as there is more Methane towards the end of digestion.

After the successful bottle experiments several prototype digesters were built at the NERD Centre (Figure 4.16). The results were very promising. Although in the use of bottle experiments, higher quantity of gas can be obtained during day time, from the field unit we could obtain more gas during night. This was an additional benefit as the usage of gas is higher in the morning than during day time.

Bottle experiments were continued for 2 yrs. and it was found from the samples that gas can be produced even for a period of 2 years. However, since the fertilizer value of the digested material is double that of the energy produced it is always advantageous to recharge the unit after 6 months and use the digested material as fertilizer. There was no difficulty in finding feed material for the digester as most of the farmers do double cropping.

4.6.5 Special benefits of straw biogas generator

Application of chemical fertilizer to the field, can be altogether eliminated so that bacteria which fixes atmospheric Nitrogen would re-appear to sustain reasonably good yields over long periods of time. Addition of Nitrogen fertilizer prevents natural fixation as the bacteria was inactive or killed.

Although the amount of Nitrogen is smaller in the biogas slurry or the digested material, this residue when applied to the field does not kill the bacteria available in the soil. It enhances the activity of the bacteria, and enhances the moisture retaining capacity, and other physical properties of the soil that is beneficial to crops.

This biogas unit can produce gas for cooking and other uses while producing valuable organic fertilizer for a season. The maintenance is minimal, charging being done once in six months. The demand for the unit is likely to be very large. As the price of cooking fuel and fertilizer is escalating the value of the biogas unit has increased considerably.

As the demand for the biogas unit is increasing, several training programmes were conducted on construction and fabrication of simple biogas cookers, biogas lamps, connections, maintenance etc. Some participants were from NGO's who were engaged in rural community development, who can popularize the technology among rural people who cannot afford mains power supply for lighting and cooking, at the same time producing a good fertilizer for the farmstead.

4.6.6 NERD battery charging centre

The Battery Charging Centre consists of six family size digesters with two nos. of gas holders. The quantity of gas produced is sufficient to charge about 10 batteries at 5 amp. for 8 hrs. a day (4 hrs. in the morning and 4 hrs. in the evening). The charging unit consists of a low cost induction generator with control and rectifying devices (A 3 HP engine is coupled to a 1.5 HP motor and it produces D.C. power through a transformer capacitor). The power generated can be adjusted by the gas flow and can be kept at a constant depending on the number of batteries charged at a time. The conversion of the kerosene engine to work on Methane can be done very easily through the air inflow manifold. This is the cheapest possible generator to charge batteries.

It is produced by the NERD Centre at a cost of 50% of the cost of a conventional generator and battery charging unit.

This set of battery charging equipment and the digesters cost about Rs. 60,000/- in Sri Lanka and it can serve about 100 families. It is associated with the D.C. lighting system which is also a product of the Centre known in Sri Lanka as 'Prashakthi'. The proposal to extend this facility of battery charging was forwarded to the Government and has been accepted. Now the implementation stage is in progress.

ANNEX 5

5. LOW - COST BUILDING TECHNOLOGY

5.1 Introduction:

Low cost high quality building technologies were developed at the NERD Centre, for a variety of applications, of which housing is a priority area. Other applications include factory buildings, schools and hospitals. When Dr. Kulasinghe took over as Chairman of NERD centre in 1978 at the special request of the then Minister of Industries, Hon. Cyril Mathew, he asked for and obtained a block of land at the Industrial Estate at Jaela. The first building was built in 1978 to enable the NERD Centre to make a start at the new site.

5.2 Laboratory building

Tenders were next called for construction of a laboratory building 20 ft wide and 150 ft long. The lowest tender was twice the amount of money available for this building. It was then decided to make this an R and D project for a low cost laboratory building. The solution adopted had a timberless roof made of asbestos cement sheets held together at the base by high tensile steel wire, forming a tied arch. This had been subjected to theoretical analysis and load tests before the prototype roof was built. For the walls, a reinforced concrete frame was built which was covered with an outside cladding with an impression of brick work on it, and a plain finish cladding on the inside. These claddings were made of Kohutex sheets, a cement bonded coconut fibre dust product developed previously at the State Engineering Corporation under Dr. Kulasinghe. Thus the first laboratory building was built at a very low cost, approximately about half the cost using conventional building techniques at the time.



Inside, view of laboratory building showing ceiling

5.3 Workshop

Following this, the next building to be constructed, a Workshop building with a clear span of 40 ft and 140 ft long was also treated as an R & D project. Here the solution adopted was a reinforced concrete framed building with 40 ft long vierendiel type reinforced concrete roof trusses post-tensioned with parabolic high tensile steel cables at ground level and jacked up to roof level. The roof trusses were placed at 20 ft centres along the length of the building, and the 20 ft. was spanned with the asbestos cement sheets forming tied arches as in the first building described previously.



Workshop building under construction

5.4 Civil engineering building

The next building constructed at the NERD centre was a 20 ft span by 140 ft long building for the Civil Engineering Department. Once again the corrugated asbestos cement tied arch was used for the roof. The walls of this building were built using a new slip form technique, patented and used for low cost housing later. In this system, 4" x 4" prestressed concrete columns were placed in pocket foundations 2 ft square, at 10 ft centres, along the length of the building, in two rows 20 ft apart. Plinth beams were cast at ground level between adjacent columns along the length of the building, and for gable end walls. These plinth beams were 12 inches deep with 2 1/4 inch diameter bars at the bottom. The walls were built on the plinth beams using a slip form between adjacent columns, with a mortar mix of 1: 12 cement and quarry dust, and a small amount of random coir fibre to provide green strength. Reinforced concrete door and window frames were incorporated in walls where necessary. Other buildings were later constructed using this technology for the walls.



Civil Engineering building under construction

5.5 Auditorium

A new technology was once again developed for construction of an Auditorium for the NERD Centre. This is a 100 ft diameter circular building with a tension shell roof, supported only at the perimeter, giving an unobstructed space underneath. However, for purposes of better utilisation of the large space available, non-load-bearing partitions have been introduced to create different rooms in this beautiful and functional building. The cost of this building when it was constructed was Rs. 300 per square ft. whereas a 100 ft clear span building of whatever ground plan would have cost about Rs. 600 per sq. ft. for the same quality of finishes.

The method of construction of this unique building was as follows. The roof was built at ground level and jacked up in stages. First, the 100 ft. outer ring and the concentric 10 ft diameter inner ring were built on the ground in reinforced concrete. The two rings were connected together with a number of 5 mm. diameter high tensile wires in a radial pattern. Weights were placed on the inner ring, and the outer ring was jacked up to 5 ft above ground level, being the final difference in elevation between the outer and inner rings. A second set of high tensile wires was tensioned to take the circumferential stresses in the inner ring, after which the radial wires were tensioned in stages. After tensioning was completed, the roofing material was placed on the mesh of high tensile wires, starting at the outer end adjacent to the outer ring.

This membrane consisted of a fibre reinforced concrete of thickness varying from 5/8 inches to 1/2 inch. As headroom was needed when placing the membrane towards the centre, the outer ring beam was jacked up, lifting the inner ring beam with it. Also as the membrane load was placed from the outer end, the pre-load on the inner ring was removed to keep the total load constant. The final height of the outer ring beam was 15 ft. above ground level, and the inner ring beam was 10 ft above ground level. A polystyrene layer was pasted on the concrete as a finish.

This unique structure was described in a paper presented to the International Symposium on Innovative Applications of Shells and Spatial Structures, in Bangalore, India, in 1988.

5.6 Hydraulics laboratory

The hydraulics engineering laboratory building which is 40 ft wide by 100 ft long was designed like the Workshop building. However, in this case the 40 ft vierendiel roof trusses, together with the tied arch corrugated asbestos cement sheets spanning between adjacent trusses, were all built at ground level. The complete roof was then jacked up to roof level using the same hydraulic jacks that were used for the construction of the Auditorium roof. Another feature of this hydraulics laboratory is the mezzanine floor built using another new technique. Precast prestressed concrete beams were placed at two foot centres and a two inch thick concrete slab with a 5 mm. g.i. two inch square mesh as the only reinforcement, was cast in situ. Formica faced forms were used which were struck after 24 hours giving an excellent finish that did not require any further finish to the soffit.

In a similar manner prestressed clay purlins have been used with a two inch cast in situ concrete slab to form the pitched roof of a building which is cost competitive with conventional tiled roofs, and uses no timber at all.

5.7 Low cost housing

Low cost high quality housing was developed at the NERD Centre, making use of many of the research based technologies developed for constructing the NERD Centre buildings as described here. Two model houses are on permanent display at the Centre, as well as different stages in the construction such as the slip-form technique for building walls. These houses cost between 50% and 60% of the cost of equivalent houses built with conventional techniques, with comparable quality of finishes. The added advantage that has to be taken into consideration is the speed of construction compared to conventional building techniques. In general, this may be taken as half the time required for construction using conventional techniques.

NERD Centre trains workers in the use of the new technologies for low cost high quality housing. Licenses have been issued to a number of local entrepreneurs who are in business as building contractors. A number of Provincial Councils have also adopted the new technologies for new housing and building schemes, the new technologies being very useful specially for construction of school buildings.

A local entrepreneur has exported the new housing technology to Indonesia, where a project for construction of 5000 new houses has been started, under license from the NERD Centre which gets a Royalty payment for this. The possibilities are really very great to use this unique low cost high quality technology for construction of houses in South Asian countries.

His Excellency President Ranasinghe Premadasa galvanised world opinion a few years ago with his dynamic approach to solving the housing problem. The UN 1987 International year for Housing was a result. Now the whole world is watching his million houses program with great interest. NERD Centre technologies will make an important contribution to that program.

