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R. P. F. III

FINAL REPORT

1. Institute Code No. Tech. XVI (231)

2. I. C. A. R. Code No.

3. Name and Address of Research Institute/Centre: Central Plantation Crops Research Institute, Kasaragod, Kerala.

4. Project Title: Design and development of a smoke free 1000 nuts copra dryer.

5. Name and Designation of Project Leader: T. Vidhan Singh, Scientist (FM & P)

6. Name(s) and Designation(s) of Project Associates including Project Leader and work to be done:

Sl. No.	Name and Designation	Time spent	Work done
	T. Vidhan Singh Scientist (FM&P)	60%	Design, development, Fabrication & testing and final report.

. Location of Research Project with complete address (Division/Section/Sub-Centre)

Pre and post Harvest Technology division, CPCRI, Kasaragod - 671 124, Kerala.

8. Date of start

May 1996

9. Date of termination

May 1998

10. (a) Objectives (Not more than 150 words)

1. To design and develop a dryer to dry coconuts in 24-36 hours using coconut shell as fuel.

2. To design and develop a burner to generate clear heat at controlled rate, continuously and safely for several hours.

(b) Practical Utility including background information (Not more than 150 words)

Dryers are available in the market for drying copra but the production of higher quality copra with low moisture content free of smoke, molds and dirt is the key to the viability of dry production of cooking oil. When high quality copra is processed the oil obtained is light in colour and very low FFA. This dryer will be able to fulfil the above repairements which in turn will be of great help to small farmers.

13. Approximate expenditure incurred in the Project: (Give reasons for variation, if any, from original estimated cost)

Rs. 12,000/-

14. Publications and material (one copy each to be supplied with this proforma)

a) Research papers — Submitted to JPC for publication

b) Popular articles

c) Reports

d) Seminars and workshops (Relevant to the Project) in which the Scientists have participated:

Nil

e) Material developed (such as new varieties of crops or breeds of farm animals, implements, products, etc.)

Copra dryer to dry copra in 24 hrs.

15. Details (Nos. etc.) of Field/Laboratory Note books and final material and their location

Pre and post harvest Technology division, CPCRI, Kasaragod - 671

16. Comments/suggestions of Project Leader regarding possible future line of work that may be taken up arising of this project:

Larger size dryer upto 10,000 nuts can be developed with the same technology.

17. Signatures with name of Project Leader and Associates:

(T. Vidhan Singh)

18. Signature (with comments, if any) of Head of Division/Section/Station:

Dr. V. Rajagopal

19. Signature (with comments, if any) of Director:

Dr. K.U.K. Nampoothiri

Final report

INTRODUCTION

In India, coconut is broken transversely into two cups and is then generally sun-dried. About seven days are needed to reduce the moisture content to about 6% from the initial 45 - 55%. During rainy season, when conventional practice of sun drying is not possible, drying by artificial method is the only possible solution for processing the produce (Annamalai, 1985). The existing direct type kiln dryers are not desirable as the product becomes inferior in quality due to smoking and improper drying (Grimwood, 1975). Copra which has been smoke dried using coconut husk or wood is often more highly contaminated with high polycyclic aromatic hydrocarbon than that dried using coconut shell. Hence, most copra produced is relatively of poor quality, principally caused by inadequate drying techniques. Smoke contamination can be avoided by using heat exchangers to heat the drying air indirectly (Areculeratne, 1976). The common quality defects are:

- high free fatty acid (FFA) content.
- extensive fungal contamination, notably by *Aspergillus spp.* which may produce carcinogenic aflatoxins.
- high polycyclic aromatic hydrocarbon (PAH) content particularly in directly smoke dried copra (Drew, 1992)

Aflatoxins are produced due to inadequate or lengthy drying (Nagler, 1991). Coconut oil and copra cake thus produced can contain unacceptably high levels of aflatoxin (Conning and Lansdown, 1983; Samarajeewa and Arseculeratne. 1983). Copra should be dried to 5-6 percent moisture content (MC) before storing and should have an oil content of about 65 % free from dirt, smoke contamination and moulds and insect infestation (Ernesto, e.t.a.l. 1995). The production of high quality copra with low moisture content, is the key to the viability of fresh dry production of cooking oil (Ernesto,e.t.a.l. 1993). A dryer using agricultural waste as fuel, suitable for small holders was developed at Central Plantation Crops Research Institute, Kasaragod which takes about 33 hours to dry copra (Patil, 1982). A natural convection type dryer suitable for medium plantation holdings (>5 ha), which takes about 3 days to produce copra was also developed at Central Plantation Crops Research Institute, Kasaragod (Annamalai, 1985). The main objective to develop this dryer was to reduce the total time of drying, so that copra can be produced at faster rate to suit medium size plantation crop holders and those engaged in the production of copra for oil extraction with low free fatty acid.

MATERIALS AND METHODS

The dryer parameters like size of the drying chamber, size of burner, shape of heat exchanger, ventilation holes etc. have been designed taking into consideration, factors like psychometric and heat transfer principles (Mc Adams,1954). This dryer uses only broken coconut shell as fuel and no other fuel can be used as this dryer is unique in the sense that it does not have a chimney. The dryer is designed to hold 1000 coconuts of all sizes. The factor of safety is greater than two i.e. upto 2000 nuts can be loaded and the dryer can withstand the load without failure.

Description:

The dryer consists of a drying chamber, a unique burner, a heat exchanger and ventilation holes. This dryer was fabricated using locally available materials such as asbestos cement sheet, galvanized iron sheet, mild steel angle and fire resistant plywood. Asbestos cement sheet has been provided only at that place where the copra does not come into direct contact. The contact areas (sides) with copra is provided with heat resistant plywood. The shape of the heat exchanger is designed to avoid the flue gas coming into direct contact with the copra.The heat exchanger is fixed to the main frame using nuts and bolts. The details of the dryer is shown in Fig.- 1. The overall dimensions of the dryer are 2m (length) x 2m (breadth) and 2m (height) and it requires a housing shed of $8m^2$ area. The support frames are joined using nuts and bolts. The frames can be dismantled and the dryer can be collapsed at the time of transportation. The heat exchanger has an area of 2.8 m^2 and the drying chamber has $2.6m^3$ volume. Ventilation doors are provided all along the bottom of the dryer (Fig - 1, part No: 11) and just above the heat exchanger of size 20 cm x 6 cm. The main function of the bottom ventilation door is to regulate the flow of air to control the burning of the fuel. This door is generally kept open so long the temperature is maintained (75°-90^{0}). If there is rise in temperature the ventilation doors are closed to cut the supply of air and the temperature is maintained. One side of the drying chamber is hinged, which can be opened for loading and unloading copra. Galvanized iron weld mesh is provided just above the heat exchanger which is supported on angle iron frame of size 40 mm X 40 mm X 6 mm. The heat exchanger does not have any perforations but the corners are cut open for uniform flow of hot air through the bed of copra (Fig.1).The heat exchanger is placed at about 20 cm below the drying platform. The weld mesh for stacking copra is made of 10 gauge, 25 mm X 25 mm size. The burner has a conical shape. The advantage of this is that when the fuel is loaded fully the clearance between the burner and heat exchanger is about 25 cm which goes on increasing as the fuel is consumed there by increasing the quantity of fuel to maintain the temperature in the drying chamber. The overall dimension of the burner are, bottom diameter - 505 mm, top diameter - 315 mm, height - 685 mm (Fig.1, part No: 9) The size of perforations were - 15 mm ϕ (spacing 100 mm). The burner has

1"thick fireclay lining. The cleaning and ventilation window (Fig.1, Part No:4) has an opening of 200 mm X 60 mm and is generally kept open. The overall view of the dryer is shown in Fig.- 2.

Fuel preparation: Dry coconut shells are broken into small pieces of approximately 1"x 1" size with the use of a wooden hammer. For a batch of 1000 nuts, about 60 - 80 kg shell is required. This will consume about 3 man-hours.

Firing the dryer: The dryer's burner holds about 20 kg of broken shell. A small amount of kerosene is added onto a piece of cotton waste, which is put on the top of the fuel pack and ignited using a match stick. After about 15 minutes, when smoke emission is sustained, the burner is placed below the heat exchanger. One burner load will produce heat for 5 -6 hours with a temperature of about 55 - 95° C. Generally after about 6 hours, when the temperature drops below 55° C, the burner is removed from the dryer, cleaned and refilled with fuel, refired and replaced below the heat exchanger. About 4 loads of fuel is required to dry the copra to about 6% moisture content. The heat generated by the burning of the fuel heats the heat exchanger. The air in between the heat exchanger and the drying chamber gets heated up and moves upwards through the layers of fresh coconut kernel and fresh air enters through the ventilation holes provided at the top and bottom (Fig.1. Part No 4 &11.). This phenomena helps in the natural convection of the air through the drying bed which can be controlled by using the ventilation doors.

Testing the dryer: The dryer was tested for production of copra two times in April 1997 and three times in January 1998 and the important observations are presented in table.-2. Hourly observation of various parameters like drying air temperature at the corners and at the center were recorded using a thermometer. Moisture content was recorded on hourly basis using a moisture meter (Madhavan. 1985). The relative humidity was measured using Barigos hygrometer. For making copra, the coconuts were broken into two halves and kept inverted for 4 - 5 minutes in order to drain the water. After the coconut water is completely drained, the cups are stacked in the drying chamber, layer by layer in such a way that in the first two layers, the inside of the cup faces upwards and in the subsequent layers, the inside of the cup faces downwards. The cups in adjacent layers are stacked in a brick-laying-fashion, one overlapping the other. Drying was carried on continuously for 24 hours by firing the burner four times at intervals of approximately 6 hours. To achieve this, coconut shell was broken into pieces and kept ready before the testing started.

The thermal efficiency of the drying was calculated using the formula given below. (Patil, 1982.)

$$\eta_t = \frac{\varphi\lambda(Mo - Mf) \times 100}{WC(100 - Mo)}$$

Where,

η_t = Thermal efficiency of the dryer in %

Mo = Initial moisture content (%, wet basis)

Mf = Final moisture content (%, wet basis)

φ = Quantity of the final dried product at Mf moisture content kg.

λ = Latent heat of vaporization in kcal/kg.

W = Quantity of fuel used in kg.

C = Calorific value of fuel used in kcal/kg

The latent heat of vaporization is assumed to be 540 kcal/kg and the calorific value of shell as 3500 kcal/kg (Annamalai 1985). The dryer performance data is presented in table-1 and Fig-3. The average thermal efficiency was found to be about 31.25%.

RESULTS AND DISCUSSION

In assessing the performance of the dryer the following parameters were evaluated.

(i) air temperature :

The burner is placed below the heat exchanger after the smoke emission is sustained. Thermometers were fitted at all the four corners and at the center of the drying chamber. The air temperature profile is presented in Table - 4. from which it is evident that the mean temperature at the corners was 90° C and 75° C at the center after about 2.5 hours. After about 5 hours the mean temperature started coming down to about 72.9 ° C and at the end of 6hours it falls to about 55.8° C. The burner produces heat without tending as coconut shell burns layer by layer under controlled atmospheric conditions there by giving sufficient time to the labourer to do other works like breaking shell into pieces etc. The temperature at the corners is more than that at the center because of the opening in the corners of the heat exchanger there by allowing more hot air through the sides than at the center. The burner could produce heat for about 5 hours without tending (Table-4) The third and fourth firing should be done with three fourth of fuel and the ventilation slots kept open for free circulation of air and to see that the temperature does not go beyond 75°C. This dryer was fired 4 times to obtain the moisture content of 6 % which is best for maximum oil extraction and storage of copra (Erensto, 1995). The shell was removed after about 10 hours of firing. Testing of copra with 1000 nuts was done five times. The advantage of this dryer is that it does not require frequent fuel loading as in the case of other dryers developed (C.P.C.R.I, 1994). Precaution should be taken to see that the shell pieces are uniformly loaded and packed properly, other wise flame of high magnitude will be produced. Normally it takes about 7 days for drying copra on bright sunny days where as in this dryer it is possible to dry in 24 hours .This dryer can be used to dry copra in a continuous spell of 24 hours or on daily 8 hours of operation depending upon the availability of labour and requirement of copra. Generally during rainy season this dryer is very useful as it produces copra in 24 hours where as sun drying is impossible. The thermal efficiency of the dryer is 31.25% which is an indication of proper utilization of the heat produced. This is about 10% higher than other dryers developed.

(ii) kernel drying rate:

The initial average random moisture content was about 50%. The reduction in moisture content of the produce during drying is shown in Fig.-3. It is evident from Fig.-3 that the rate of removal of moisture from copra was rapid in the initial 8 - 10 hours due to free moisture available in the produce and subsequently the moisture removal was gradual. The mean relative humidity varied from 75% to 85% during the testing.

(iii) Product quality:

The produce was randomly tested for moisture content and it was found that the entire produce has an average moisture content of 5.7 %.(Wb). The quality of copra obtained is of high quality without any fungal infection. The analysis of the oil extracted form the produce has free fatty acid value- 0.012%, peroxide value- 0.43 milli. eq. acid value-0.352 (mg KOH/g), saponification value-250.3 which is below the normal values and the oil is off white in colour without any bad odor. (Table-3). (Sadasivan, 1992). The design of this dryer can be used to fabricate higher capacity dryers up to 10,000 nuts using multiple burners.

(iv) drying cost:

The cost of the dryer was estimated as Rs. 12,000 and the expected life is 10 years. The use of the dryer for copra can be at a minimum of 200 days. Accordingly, about 100 batches of 1000 coconut can be dried in one year. Straight line method of depreciation was adopted for calculating annual depreciation. Interest rate is assumed to be at 10% per annum and annual maintenance cost as Rs. 250/- (This is only for replacing the fire clay of the burner).

Cost of dryer	:	Rs 12,000.00
Fixed Cost		**(Rs)**
Annual depreciation	:	1,200.00
Interest @ 10% per annum	:	1,200.00
Maintenance cost	:	250.00
Total fixed cost	:	2650.00
Fixed cost / batch (Assuming that the dryer will be operated for 100 batches in a year.)	:	26.50

Variable cost per batch

Average cost of nuts @ Rs 5.00/nut (Farm gate price)	-	5000.00
Dehusking charge for 1000 nuts	-	240.00
Labour charges for 3 shifts @ Rs.120.00/day	-	360.00
Total variable cost	-	5600.00
Total cost (Fixed cost + Variable cost) per batch.	-	5626.50
Or say	-	5627.00

Returns

Revenue from sale of 175 kg of copra @ Rs. 33.00/ kg		5775.00
Value of husk	-	100.00
Value of 50% shell		75.00

(50 % Shell being consumed as fuel)

Total revenue / batch	-	5950.00
Net income/ batch	-	323.00
Net additional revenue obtained by sale of copra per batch	-	323.00
Net additional revenue that can be realised by dryer in one year	-	32,300.00
Cost of drying one kg of copra-		1.80

Economic viability of the dryer: The cost of drying one kilogram of copra works out to be Rs.1.80. By operating the dryer for one year the farmer will get a profit of Rs 32,300. Even if the farmer pays rent for housing the dryer he will earn Rs. 25,000. per annum. If the dryer is operated for continuously in rainy season then the profit can be increased.

CONCLUSION

Copra can be dried to about 6% moisture content from the initial 50% within 24 hours using the smoke free dryer. This dryer has a unique burner which can produce heat for more than 5 hours without tending using coconut shell as fuel. The analysis of the oil extracted form the produce has free fatty acid value- 0.012%, peroxide value- 0.43 milli. eq. acid value-0.352 (mg KOH/g), saponification value-250.3 which is below the normal values and the oil is off white in colour without any bad odor. (Table-3). The cost of drying is Rs.1.80 per kilogram and the average thermal efficiency of the dryer is 31.25%. The design of this dryer can be used to fabricate higher capacity dryers up to 10,000 nuts using multiple burners and similar technology.

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Table.1: Details of item numbers shown in Fig.-1

Item No:	Description
1	Weld mesh for stacking copra - 10G, 25 mm x 25 mm; supporting frame - 20 mm x 3 mm M.S flat
2	M.S angle support for resting the weld mesh - 40 mm x 40 mm x 6 mm
3	G.I Sheet Baffle - 18G (Without perforations)
4	Cleaning & Ventilation Window - 200 mm x 60 mm opening
5	Main frame - 40 mm x 40 mm x 6 mm M.S angle
6	Asbestos sheet - 4 mm thick
7	M.S flat - 40 mm x 6 mm
8	Door for handling the burner
9	Burner having 1'' thick inside lining with fire clay Overall dimensions: bottom diameter - 505 mm top diameter - 315 mm height - 685 mm perforation size - 15 mm ∅
10	M.S angle rail for supporting the burner
11	Fresh air inlet

Table. 2 :Dryer Performance data.

Sl.No.	Produce./ Mean	Quantity.	Average drying air temperature. # °C	Average initial moisture content. (w.b.)* %	Final average moisture content (w.b.)* %	Total drying time Hrs.	Quantity of final product Kg.	Fuel used	Quantity of fuel used Kg.	Thermal efficiency %
1	Copra[ψ]	1000 nuts	55-95	48	5.8	24	178	Shell	80	27.85
2	Copra[•]	1000 nuts	55-95	52	5.6	24	172	Shell	74	34.66
3	Mean	1000 nuts	75	50	5.7	24	175	Shell	77	31.25

ψ -Average of 2 trials , •- Average of 3 trials, #- Average of 50 observations, *-Average of 75 observations

Table. 3 : Analysis of oil extracted from copra

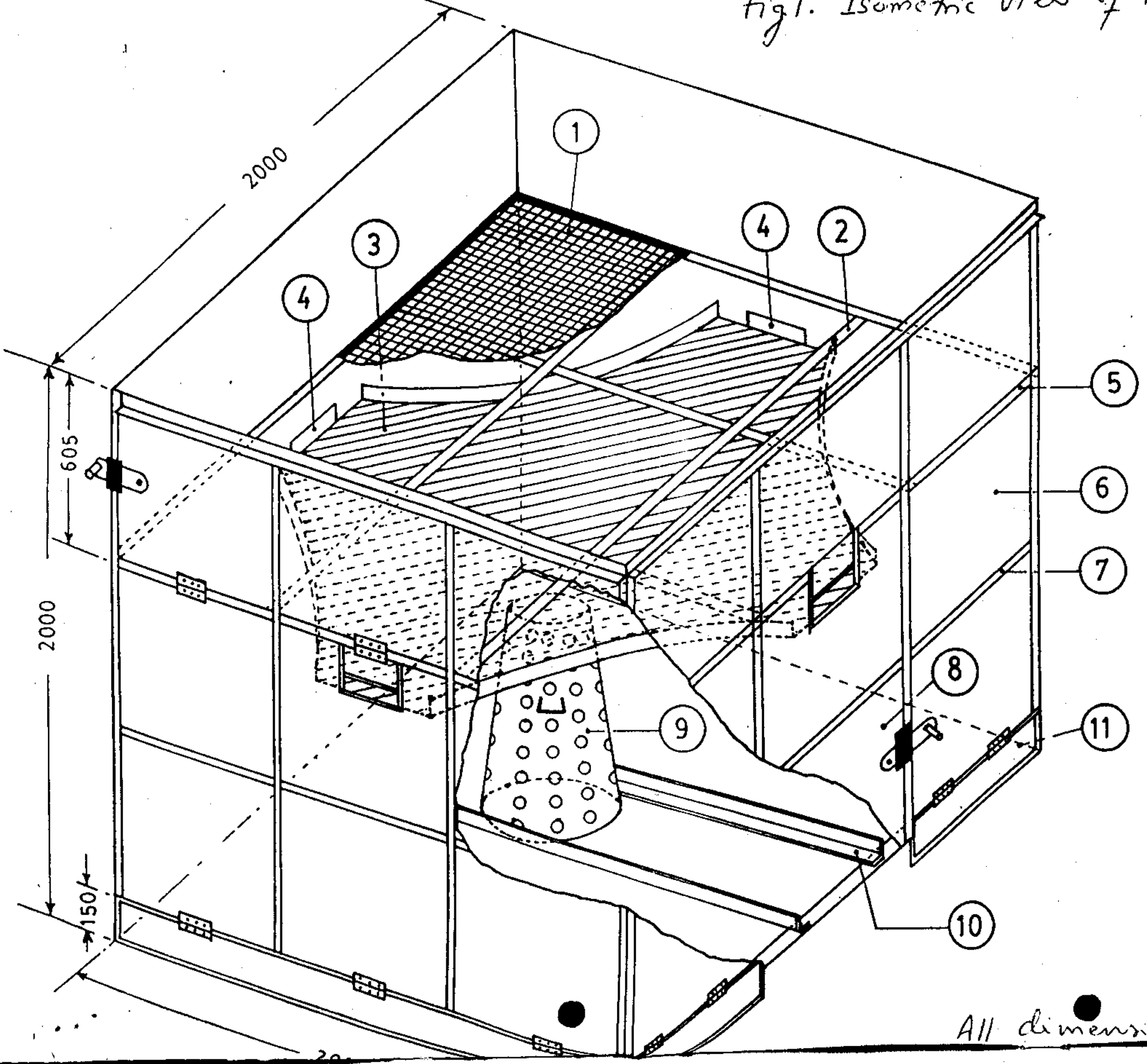
Oil Sample*	Free fatty acid %	Peroxide Value (milli.eq. peroxide/Kg sample)	Acid Value (mg KOH/g)	Saponification Value.
Random Sample, 1	0.012	0.43	0.3502	251
Random Sample, 2	0.011	0.42	0.3501	250
Random Sample, 3	0.012	0.43	0.3503	251
Random Sample, 4	0.014	0.43	0.3502	250
Random Sample, 5	0.012	0.42	0.3503	250
Mean Value	0.012	0.43	0.3502	250.3
Standard value	< 1.0	< 1.0	Max-2 %	250-257

*** Test procedure. (Sadasivam,1992)**

Table-4: Temperature profile of the burner.

Time (hours)	Average Temperature (At the corners of dryer) ^{0}C	Average Temperature (At the Center of dryer) ^{0}C	Mean Temperature (Drying chamber) ^{0}C
O	32.5	32.5	32.5
0.5	55.2	50.8	53.0
1.0	65.6	58.4	60.0
1.5	74.8	65.2	70.0
2.0	85.7	73.3	79.5
2.5	93.8	75.3	84.5
3.0	95.1	75.3	85.2
3.5	94.6	75.1	84.8
4.0	94.1	74.2	84.1
4.5	89.3	72.1	80.7
5.0	80.7	65.2	72.9
5.5	70.1	55.7	62.9
6.0	61.4	50.2	55.8

Fig 1. Isometric view of the dryer.



All dimensions are in mm