**COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH- FOOD RESEARCH INSTITUTE (CSIR-FRI), ACCRA, GHANA**

# REPORT ON COST ESTIMATION OF DRYING COCOYAM SLURRY PER HOUR USING THE ANDRITZ GOUDA CONTACT DRUM DRYER


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# 1.0 INTRODUCTION

## 1.1 Cocoyam

Cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) is a perennial crop grown in the subtropical and tropical regions of the world. It belongs to the Araceae family. On average, the height of the plant is 2m. The length and breadth of its broad leaves range between 20cm-85 cm and 20cm-60 cm, respectively (Balami *et al.,* 2016). The plant has corms above or a little beneath the surface of the soil. The corms of cocoyam are usually spherical in shape. Averagely, the corms have major, intermediate and minor diameters of 7.43 cm, 4.10 cm and 3.90 cm, respectively (Balami *et al.,* 2014). The corms have appreciable amounts of starch (25% wet weight basis) as well as fibre (Owusu-Darko *et al.,* 2014). Cocoyam contains proteins and essential amino acids (Lewu *et al.,* 2009).

## 1.2 Uses of cocoyam

Cocoyam provides food for people and livestock. The corms of cocoyam are boiled, served with sauce or pounded into a paste popularly known in Ghana as 'fufu' served with soup. Cocoyam corms are processed into value-added products including cocoyam chips and high quality cocoyam flour. Processed cocoyam corms can be used as an industrial raw material in the manufacture of alcohol and drugs (Okwuowulu *et al.,* 2002)

## 1.3 Processing of cocoyam corms into flour

The high moisture content of cocoyam corms after harvesting exposes them to rapid deterioration under ambient conditions during natural storage. Long-term storage of the cocoyam corms after harvest becomes difficult if measures are not put in place to reduce their moisture content to safe storage moisture content. Postharvest losses are therefore heavy, and transportation costs are high (Balami *et al.,* 2016).

Drying of cocoyam corms is an efficient way of reducing the moisture content of cocoyam corms to safe moisture content to enable long-term storage of the cocoyam. Different drying methods can be employed in drying of the cocoyam corms depending on the desired end-product and or end-use. These drying methods include direct sun drying, solar drying and drum drying among others.

Direct sun drying of cocoyam corms is very easy to carry out. The harvested cocoyam corms are sorted to remove immature corms and foreign materials. The cocoyam corm are peeled with knife and washed to remove sand and dirt. The washed peeled corms are cut into round chips of uniform sizes, blanched in water bath at 100℃ for 5 minutes. The blanched chips are spread in stainless steel trays and sun dried for seven days to a low moisture level. The dried chips are then milled using milling machine, sieved and the flour is packaged into polyethylene films (Iwe and Egwuekwe, 2010). However, sun drying of cocoyam corms is dependent on ambient conditions. Unfavourable ambient conditions such as low temperatures and high relative humidity do not permit effective sun drying of the cocoyam corms.

Drum drying of cocoyam is one of the fastest methods in drying of cocoyam especially if the desired end-product is flour. Cocoyam corms are milled into slurry and then dried into thin solid films by the drum dryer.

# 2.0 METHODOLOGY

## 2.1 Study area

Drying of cocoyam slurry using the Andritz Gouda Contact drum dryer was carried out at the Pilot Plant Complex of Council of Scientific and Industrial Research-Food Research Institute, Accra.

## 2.2 Materials

Cocoyam corms of weight 4.15kg and clean potable water were used for the study.

## 2.3 Equipment/Instrument/Tools

a. Electronic balance
b. Andritz Gouda Contact drum dryer
c. Electric steam boiler
d. Scraper
e. Plastic cup with handle
f. Measuring cylinder
g. Plastic strainer
h. Two plastic bowls
i. Sharp knife
j. Transparent plastic bags
k. Gloves

## 2.4 Preparation of cocoyam slurry

Cocoyam corm samples were peeled using a clean sharp knife. The peeled cocoyam corm samples were cut into small pieces and weighed using an electronic balance. The weighed samples were placed in a plastic strainer (sitting in a plastic bowl) and washed with potable water. The plastic strainer was removed from the plastic bowl after washing of the cocoyam

samples to allow the excess water to drain off the cocoyam. The weight of the cocoyam after washing was measured using electronic balance. The washed cocoyam samples were placed in a transparent plastic bag. The plastic bag was tied up immediately to prevent moisture absorption by the cocoyam samples as well as contamination of the samples until milling. The cocoyam samples were milled together with two litres of clean water to get cocoyam slurry.

**2.5 Cocoyam weight measurement**

Weight of cocoyam peels, $W_{cp} = 1kg$.....(1)

Weight of cocoyam after peeling, $W_{ap} = 3.15kg$.....(2)

Weight of cocoyam after washing, $W_{aw} = 3.3kg$.....(3)

Weight of cocoyam slurry after milling $W_s = 4.15kg$.....(4)

**2.6 Cocoyam slurry-water mixing ratio**

A mixture of cocoyam slurry and water was obtained using a mixing ratio of three kilograms (3 kg) of cocoyam slurry to two litres of water. The mixture was then fed onto the drum dryer to obtain dried product.

**2.7 Drum drying of cocoyam slurry**

Prior to drying of the cocoyam slurry, the drum dryer was started by rotating the drum at 25rpm. Steam of pressure 10 bars generated by the electric steam boiler was passed through the drum until the surface temperature of the drum reached 170±1℃. The cocoyam slurry was then continuously fed equally over the length of the drum between the applicator rolls. Within one rotation of the dryer, the cocoyam slurry dried up into thin solid film which was scraped off by the knife mounted close to the drum surface unto a retaining chute collector. The dried cocoyam was removed from the collector and placed in transparent polythene bag and tied up.

Figure 1: Drying of cocoyam slurry using the Andritz Gouda Contact drum dryer

**2.8 Equipment required during drum drying process**

**2.81 Electric steam boiler**

The electric steam boiler consists of water feed pump, boiling chamber, steam pipe as well as other accessories.

Figure 2: Electric steam boiler

### 2.82 Andritz Gouda Contact drum dryer

The Andritz Gouda Contact drum dryer is made up of one horizontally mounted hollow cylinder (drum) with overhead applicator rolls, a supporting frame, chute and auxiliaries.


Figure 3: Andritz Gouda Contact drum dryer

# 3.0 RESULTS

## 3.1 Drum drying cost components

The cost of operating the drum dryer for one hour in drying a specific amount of a sample can be estimated using the following input parameters:

A. Cost of total power consumed per hour ($P_t$)**:**
    i. Electric steam boiler power consumption, $P_s$
    ii. Drum dryer motor power consumption, $P_m$
B. Cost of water used by electric steam boiler
C. Depreciation of Andritz Gouda contact drum dryer and Ross electric steam boiler
D. Cost of Labour
E. Profit margin

### A. Cost of total power consumed per hour ($P_t$)

### i. Electric steam boiler power consumption, $P_s$

Power consumed by electric steam boiler ($P_s$) is given as

$$P_s = 50kW \quad \text{.....(5)}$$

### ii. Drum dryer motor power consumption, $P_m$

Power ($P_m$) consumed by the drum dryer motor is given as

$$P_m = I \times V \quad \text{.....(6)}$$

$$P_m = 8.6A \times 380V$$

$$P_m = 3268W$$

$$P_m = 3.268kW \cong 3.268kW$$

Total power consumed by drying per hour ($P_t$) is given as

$$P_t = P_s + P_m \quad \text{.....(7)}$$

$$P_t = 50kW + 3.3kW$$

$$P_t = 53.3kW$$

Total power consumed by drying cocoyam slurry with the drum dryer in 1h is 53.3kW. According to the Electricity Company of Ghana tariff dated 1st July, 2016, under the Non-Residential Section, 51units = 51kWh = GH₵ 72.35. The total power consumed (53.3kW) in hour is a little above 51kWh. However, it is assumed that the amount of money charged for consuming 53.3kW of power in one hour is equivalent to that charged for consuming 51kW of power in one hour. Therefore, the cost of power in running the drum dryer for one hour is GH₵ 72.35.

**B. Cost of water used by the electric steam boiler**

**Water capacity of the electric steam boiler:**

The amount of water ($C_w$) used by the electric steam boiler per hour in generating steam to heat the drum of the drum dryer is $78L$ according to the Ross steam boiler catalogue for the boiler model (RSBE-50).

$$C_w = 78\,L/h \quad \text{.....(8)}$$

According to the Ghana Water Company tariffs, the cost of consuming thousand litres (1000L) of water is GH₵11. Therefore the cost ($W_{c)}$ of using seventy-eight litres (78L) of water is given as:

$$W_c = \frac{78 \times GH\,\not\subset 11}{1000L} \quad \text{.....(9)}$$

$$W_c = GH\,\not\subset 0.858 \cong GH\,\not\subset 1$$

Therefore, the cost of using 78L of water by the electric steam boiler in generating steam to heat the drum dryer is GH₵1 for every hour.

**C. Depreciation of Andritz Gouda contact drum dryer (AGCDD) and Ross electric steam boiler (RESB)**

Depreciation is the method of calculating the cost of an asset over its lifespan.

Depreciation using the Straight Line Method

Purchase price of AGCDD = GH₵ 2,830,000

Purchase price of RESB = GH₵ 60,000

Total purchase price of AGCDD and RESB, $P_t$ =GH₵2,830,000+ GH₵60,000= GH₵2,890,000

**Assumptions**

Salvage or scrap value, $S$ = 15% of Total purchase price of AGCDD and RESB

Salvage or scrap value, $S$ = GH₵ 433,500

Life span of AGCDD and RESB, $N$ = 10 years

Number of working months in a year, $N_m$ = 12

Number of working days in a month, $N_d$ =27

Number of working hours in a day, $N_h$

Depreciation per annum = $D_a$

Depreciation per month = $D_m$

Depreciation per day = $D_d$

Depreciation per hour = $D_h$

Depreciation per annum, $D_a = \frac{P_t - S}{N}$ .....(10)

$$D_a = \frac{GH\not{c}\ 2{,}890{,}000 - GH\not{c}\ 433{,}500}{10}$$

$$D_a = GH\not{c}\ 245{,}650$$

Therefore the depreciation cost per annum of AGCDD and RESB is GH₵ 245,650.

Depreciation per month, $D_m = \frac{D_a}{N_m}$.....(11)

$$D_m = \frac{GH \not\subset 245{,}650}{12}$$

$$D_m = GH \not\subset 20{,}470.83$$

Therefore the depreciation cost per month of AGCDD and RESB is GH₵ 20,470.83.

Depreciation per day, $D_d = \frac{D_m}{N_d}$.....(12)

$$D_d = \frac{GH \not\subset 20{,}470.83}{27}$$

$$D_d = GH \not\subset 758.18$$

Therefore the depreciation cost per day of AGCDD and RESB is GH₵ 758.18.

Depreciation per hour, $D_h = \frac{D_d}{N_h}$.....(13)

$$D_d = \frac{GH \not\subset 758.18}{8}$$

$$D_d = GH \not\subset 94.77$$

Therefore the depreciation cost per day of AGCDD and RESB is GH₵ 94.77.

**D. Cost of Labour**

The cost of labour factors in the number of persons required to operate the drum dryer and the amount of money each person charges per hour during drying operation according to their ranks. The number of persons needed in operating the drum dryer during processing is three. One Principal Technical Officer, one Technical Officer and one Factory hand are needed in the operation of the drum dryer.

**Amount charged by Principal Technical officer per hour:**

Monthly salary of Principal Technical officer = $PTo_m$ = GH₵ 1,893.02

Number of working days in a month = $N_d$ =27

Number of working hours in a day = $N_h$ =8

Amount charged per day or daily wage by Principal Technical officer = $W_{dpto}$

$$W_{dpto} = \frac{PT_{om}}{N_d} \quad \text{.....(14)}$$

$$W_{dpto} = \frac{GH\ \not{c}\ 1{,}893.02}{27}$$

$$W_{dpto} = GH\ \not{c}\ 70.11$$

Amount charged per hour by Principal Technical officer = $W_{hpto}$

$$W_{hpto} = \frac{W_d}{N_h} \quad \text{.....(15)}$$

$$W_{hpto} = \frac{GH\ \not{c}\ 70.11}{8}$$

$$W_{hpto} = GH\ \not{c}\ 8.76$$

Therefore, the amount charged by Principal Technical officer per hour for operating the drum dryer in drying any product is GH₵8.76.

**Amount charged by Technical officer per hour:**

Monthly salary of Technical officer = $To_m$ = GH₵1,599.36

Number of working days in a month = $N_d$ =27

Number of working hours in a day = $N_h$ =8

Amount charged per day or daily wage by Technical officer = $W_{dto}$

$$W_{dto} = \frac{To_m}{N_d} \quad \text{.....(16)}$$

$$W_{dto} = \frac{GH\ \not{c}\ 1{,}599.36}{27}$$

$$W_{dto} = GH\ \not{c}\ 59.24$$

Amount charged per hour by Technical officer = $W_{hto}$

$$W_{hto} = \frac{W_d}{N_h} \quad \text{.....(17)}$$

$$W_{hto} = \frac{GH \not\subset 59.24}{8}$$

$$W_{hto} = GH \not\subset 7.40$$

Therefore, the amount charged by Technical officer per hour for operating the drum dryer in drying any product is GH₵ 7.40

**Amount charged by processing hand per hour:**

Monthly salary of **processing** hand = $Fh_m$ = GH₵ 916.97

Number of working days in a month = $N_d$ =27

Number of working hours in a day = $N_h$ =8

Amount charged per day or daily wage by **processing** hand = $W_{dfh}$

$$W_{dfh} = \frac{Fh_m}{N_d} \quad \text{.....(18)}$$

$$W_{dfh} = \frac{GH \not\subset 916.97}{27}$$

$$W_{dfh} = GH \not\subset 33.96$$

Amount charged per hour by **processing** hand = $W_{hfh}$

$$W_{hfh} = \frac{W_d}{N_h} \quad \text{.....(19)}$$

$$W_{hfh} = \frac{GH \not\subset 33.96}{8}$$

$$W_{hfh} = GH \not\subset 4.25$$

Therefore, the amount charged by **processing** hand per hour for operating the drum dryer in drying any product is GH₵ 4.25. The **total amount of money charged ($T_a$)** by the Principal

Technical officer, Technical officer and **processing** hand per hour in operating the drum dryer is the sum of the individual charges per hour for each rank.

$$T_a = W_{hpto} + W_{hto} + W_{hfh} \quad \text{.....(20)}$$

$$T_a = GH \not\subset 8.76 + GH \not\subset 7.40 + GH \not\subset 4.25$$

$$T_a = GH \not\subset 20.41$$

Thus, cost of labour in operating the drum dryer per hour is GH₵ 20.41.

### E. Profit margin

The amount of money to charge as profit is at the discretion of management or administration.

Table 1: Summary of drum drying cost components per hour

| **No** | **Component** | **Cost (GH₵)** |
|---|---|---|
| 1. | AGCDD and RESB power consumption | 72.35 |
| 2. | Cost of water consumption | 1.00 |
| 3. | Depreciation of AGCDD and RESB | 94.77 |
| 4. | Cost of Labour | 20.41 |
| 5. | Profit margin | - |
| | **Total** | **188.53** |

## 4.0 CONCLUSION

The total cost of using the Andritz Gouda Contact drum dryer for drying cocoyam slurry for every hour is estimated at **GH₵ 188.53** (excluding profit margin which is assigned at the discretion of the institute). The total cost of drying per hour is applicable to other food products (apart from cocoyam slurry) that can be dried using the Andritz Gouda Contact drum dryer. The total cost of drying per hour is also subject to change in the event of changes in utility tariffs (water and electricity) and cost of labour.

## 5.0 REFERENCES


1. Balami, A. A., Dauda, S. M., Mohammed, I. S., Agunsoye, J. K., Abu, H., Abubakar, I. and Ahmad, D. (2016). Design and fabrication of a cocoyam (Colocasia esculenta) peeling machine. *International Food Research Journal* 23(Suppl): S65 - S70.
2. Balami, A. A., Chukwu, O., Gbabo, A. and Idris, R. D. (2014). Determination of some engineering properties of cassava tubers grown in northern Nigeria. *Lautech Journal of Engineering and Technology* 8(2): 35-39.
3. Owusu-Darko, P. G., Paterson, A., Omenyo, E. L. (2014). Cocoyam (corms and cormels)—An underexploited food and feed resource. *Journal of Agricultural Chemistry and Environment* 3(1): 22-29.
4. Lewu, M .U., Adebola, P. O. and Afolayan, A. J. (2009). Effect of cooking on the proximate composition of the leaves of some accessions of Colocasia esculatenta (l) Schott in Kwazulu-natal Province of South African. *Journal of Biotechnology*, 8(8): 1619-1622.
5. Okwuowulu, P. A., Asiegbu, J. E. and Nnado, W. F. (2002). Effect of row intercropping of cocoyam minisett on tuber/gari yield and productivity in South Eastern Nigeria. *Journal of Sustainable Agriculture and Environment* 2: 214-225.
6. Iwe, M.O. and Egwuekwe, E.I. (2010). Production and evaluation of cookies from Xanthosoma sagittifolium and Colocasia esculenta blends. *Nigerian Food Journal* 28(1): 145-153.
7. Vallous, N. A., Gavrielidou, M. A., Karapantsios, T. D. and Kostoglou, M. (2002). Performance of a double drum dryer for pregelatinized maize starches. *Journal of Food Engineering* 51: 171-183.

## APPENDICES

## Appendix A: Electricity Company of Ghana electricity tariff

| ELECTRICITY COMPANY OF GHANA | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELECTRICITY TARIFF RECKONER EFFECTIVE 1ST JULY, 2016 | | | | | | | | | | | | | |
| July 2016 | RESIDENTIAL | | | | | | NON-RESIDENTIAL | | | | | | |
| Units (kWh) | Energy Charge | Street Light | Nat'al Elect Levy | Service Charge | TOTAL THIS MONTH | Net Charge after Re-alignment | Energy Charge | Street Light | Nat'al Elect Levy | Service Charge | VAT & NHIL | TOTAL THIS MONTH | Net Charge after Re-alignment |
| 0 | 0.00 | - | - | 2.13 | 2.13 | 2.13 | 0.00 | - | - | 10.55 | 1.85 | 12.40 | 12.40 |
| 1 | 0.34 | 0.02 | 0.02 | 2.13 | 2.51 | 1.85 | 0.97 | 0.05 | 0.05 | 10.55 | 2.01 | 13.63 | 13.58 |
| 2 | 0.67 | 0.03 | 0.03 | 2.13 | 2.86 | 2.16 | 1.94 | 0.10 | 0.10 | 10.55 | 2.17 | 14.86 | 14.76 |
| 3 | 1.01 | 0.05 | 0.05 | 2.13 | 3.24 | 2.49 | 2.90 | 0.15 | 0.15 | 10.55 | 2.33 | 16.08 | 15.93 |
| 4 | 1.34 | 0.07 | 0.07 | 2.13 | 3.61 | 2.81 | 3.87 | 0.19 | 0.19 | 10.55 | 2.49 | 17.29 | 17.09 |
| 5 | 1.68 | 0.08 | 0.08 | 2.13 | 3.97 | 3.13 | 4.84 | 0.24 | 0.24 | 10.55 | 2.65 | 18.52 | 18.27 |
| 10 | 3.36 | 0.17 | 0.17 | 2.13 | 5.83 | 4.76 | 9.68 | 0.48 | 0.48 | 10.55 | 3.45 | 24.64 | 24.14 |
| 15 | 5.03 | 0.25 | 0.25 | 2.13 | 7.66 | 6.36 | 14.52 | 0.73 | 0.73 | 10.55 | 4.26 | 30.79 | 30.04 |
| 20 | 6.71 | 0.34 | 0.34 | 2.13 | 9.52 | 7.98 | 19.36 | 0.97 | 0.97 | 10.55 | 5.06 | 36.91 | 35.91 |
| 25 | 8.39 | 0.42 | 0.42 | 2.13 | 11.36 | 9.59 | 24.20 | 1.21 | 1.21 | 10.55 | 5.86 | 43.03 | 41.78 |
| 30 | 10.07 | 0.50 | 0.50 | 2.13 | 13.20 | 11.20 | 29.04 | 1.45 | 1.45 | 10.55 | 6.67 | 49.16 | 47.67 |
| 35 | 11.75 | 0.59 | 0.59 | 2.13 | 15.06 | 12.83 | 33.88 | 1.69 | 1.69 | 10.55 | 7.47 | 55.28 | 53.54 |
| 40 | 13.42 | 0.67 | 0.67 | 2.13 | 16.89 | 14.43 | 38.72 | 1.94 | 1.94 | 10.55 | 8.27 | 61.42 | 59.43 |
| 45 | 15.10 | 0.76 | 0.76 | 2.13 | 18.75 | 16.06 | 43.56 | 2.18 | 2.18 | 10.55 | 9.08 | 67.55 | 65.31 |
| 50 | 16.78 | 0.84 | 0.84 | 2.13 | 20.59 | 17.66 | 48.40 | 2.42 | 2.42 | 10.55 | 9.88 | 73.67 | 71.18 |
| 51 | 17.45 | 0.87 | 0.87 | 6.33 | 25.52 | 23.13 | 49.36 | 2.47 | 2.47 | 10.55 | 10.04 | 74.89 | 72.35 |
| 60 | 23.51 | 1.18 | 1.18 | 6.33 | 32.20 | 29.09 | 58.07 | 2.90 | 2.90 | 10.55 | 11.49 | 85.91 | 82.92 |
| 70 | 30.25 | 1.51 | 1.51 | 6.33 | 39.60 | 35.69 | 67.75 | 3.39 | 3.39 | 10.55 | 13.09 | 98.17 | 94.68 |
| 80 | 36.98 | 1.85 | 1.85 | 6.33 | 47.01 | 42.30 | 77.43 | 3.87 | 3.87 | 10.55 | 14.70 | 110.42 | 106.44 |
| 90 | 43.71 | 2.19 | 2.19 | 6.33 | 54.42 | 48.90 | 87.11 | 4.36 | 4.36 | 10.55 | 16.31 | 122.69 | 118.21 |
| 100 | 50.45 | 2.52 | 2.52 | 6.33 | 61.82 | 55.50 | 96.79 | 4.84 | 4.84 | 10.55 | 17.91 | 134.93 | 129.95 |
| 110 | 57.18 | 2.86 | 2.86 | 6.33 | 69.23 | 62.11 | 106.47 | 5.32 | 5.32 | 10.55 | 19.52 | 147.18 | 141.70 |
| 120 | 63.91 | 3.20 | 3.20 | 6.33 | 76.64 | 68.71 | 116.15 | 5.81 | 5.81 | 10.55 | 21.13 | 159.45 | 153.47 |
| 130 | 70.64 | 3.53 | 3.53 | 6.33 | 84.03 | 75.30 | 125.83 | 6.29 | 6.29 | 10.55 | 22.73 | 171.69 | 165.22 |
| 140 | 77.38 | 3.87 | 3.87 | 6.33 | 91.45 | 81.92 | 135.51 | 6.78 | 6.78 | 10.55 | 24.34 | 183.96 | 176.99 |
| 150 | 84.11 | 4.21 | 4.21 | 6.33 | 98.86 | 88.52 | 145.19 | 7.26 | 7.26 | 10.55 | 25.95 | 196.21 | 188.74 |
| 151 | 84.78 | 4.24 | 4.24 | 6.33 | 99.59 | 94.17 | 146.15 | 7.31 | 7.31 | 10.55 | 26.11 | 197.43 | 189.91 |
| 160 | 90.84 | 4.54 | 4.54 | 6.33 | 106.25 | 100.48 | 154.86 | 7.74 | 7.74 | 10.55 | 27.55 | 208.44 | 200.47 |
| 170 | 97.58 | 4.88 | 4.88 | 6.33 | 113.67 | 107.51 | 164.54 | 8.23 | 8.23 | 10.55 | 29.16 | 220.71 | 212.24 |
| 180 | 104.31 | 5.22 | 5.22 | 6.33 | 121.08 | 114.53 | 174.22 | 8.71 | 8.71 | 10.55 | 30.77 | 232.96 | 224.00 |
| 190 | 111.04 | 5.55 | 5.55 | 6.33 | 128.47 | 121.53 | 183.90 | 9.20 | 9.20 | 10.55 | 32.37 | 245.22 | 235.76 |
| 200 | 117.78 | 5.89 | 5.89 | 6.33 | 135.89 | 128.56 | 193.58 | 9.68 | 9.68 | 10.55 | 33.98 | 257.47 | 247.51 |
| 210 | 124.51 | 6.23 | 6.23 | 6.33 | 143.30 | 135.58 | 203.26 | 10.16 | 10.16 | 10.55 | 35.59 | 269.72 | 259.26 |
| 220 | 131.24 | 6.56 | 6.56 | 6.33 | 150.69 | 142.58 | 212.94 | 10.65 | 10.65 | 10.55 | 37.19 | 281.98 | 271.02 |
| 230 | 137.97 | 6.90 | 6.90 | 6.33 | 158.10 | 149.60 | 222.62 | 11.13 | 11.13 | 10.55 | 38.80 | 294.23 | 282.78 |
| 240 | 144.71 | 7.24 | 7.24 | 6.33 | 165.52 | 156.63 | 232.30 | 11.62 | 11.62 | 10.55 | 40.41 | 306.50 | 294.55 |
| 250 | 151.44 | 7.57 | 7.57 | 6.33 | 172.91 | 163.63 | 241.98 | 12.10 | 12.10 | 10.55 | 42.01 | 318.74 | 306.29 |
| 260 | 158.17 | 7.91 | 7.91 | 6.33 | 180.32 | 170.66 | 251.65 | 12.58 | 12.58 | 10.55 | 43.62 | 330.98 | 318.03 |
| 270 | 164.91 | 8.25 | 8.25 | 6.33 | 187.74 | 177.69 | 261.33 | 13.07 | 13.07 | 10.55 | 45.23 | 343.25 | 329.80 |
| 280 | 171.64 | 8.58 | 8.58 | 6.33 | 195.13 | 184.69 | 271.01 | 13.55 | 13.55 | 10.55 | 46.83 | 355.49 | 341.55 |
| 290 | 178.37 | 8.92 | 8.92 | 6.33 | 202.54 | 191.71 | 280.69 | 14.03 | 14.03 | 10.55 | 48.44 | 367.74 | 353.30 |
| 300 | 185.11 | 9.26 | 9.26 | 6.33 | 209.96 | 198.74 | 290.37 | 14.52 | 14.52 | 10.55 | 50.05 | 380.01 | 365.07 |
| 310 | 193.84 | 9.69 | 9.69 | 6.33 | 219.55 | 219.55 | 300.67 | 15.03 | 15.03 | 10.55 | 51.80 | 393.08 | 377.87 |
| 320 | 202.58 | 10.13 | 10.13 | 6.33 | 229.17 | 229.17 | 310.97 | 15.55 | 15.55 | 10.55 | 53.56 | 406.18 | 390.71 |
| 330 | 211.32 | 10.57 | 10.57 | 6.33 | 238.79 | 238.79 | 321.27 | 16.06 | 16.06 | 10.55 | 55.31 | 419.25 | 403.51 |
| 340 | 220.06 | 11.00 | 11.00 | 6.33 | 248.39 | 248.39 | 331.57 | 16.58 | 16.58 | 10.55 | 57.07 | 432.35 | 416.35 |
| 350 | 228.80 | 11.44 | 11.44 | 6.33 | 258.01 | 258.01 | 341.87 | 17.09 | 17.09 | 10.55 | 58.83 | 445.43 | 429.16 |

**Appendix B: Ross Boilers catalogue**

ROSS

PROCESS HEAT EXPERTS

# ROSS BOILERS

## WE ARE THE HEAT SOURCE

STEAM BOILERS

HOT WATER GENERATORS

HOT AIR GENERATORS

THERMIC FLUID HEATERS

EDIBLE OIL HEATERS

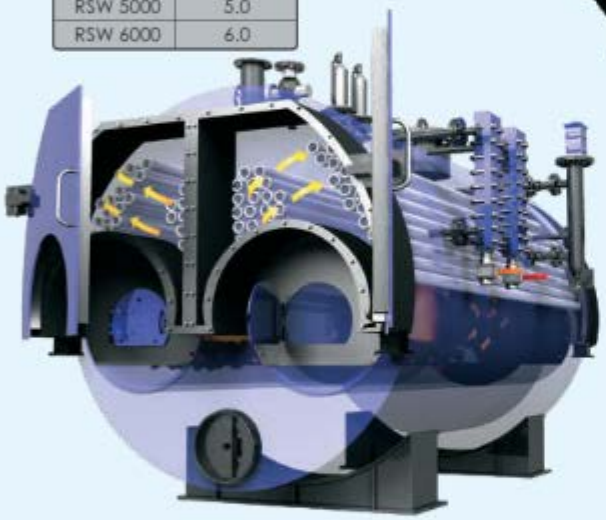
# STEAM BOILERS

## RSW Series

### Solid Fuel Fired Shell Type Flue Tube Steam Boiler

| Model | Capacity (TPH) |
|---|---|
| RSW 1000 | 1.0 |
| RSW 1500 | 1.5 |
| RSW 2000 | 2.0 |
| RSW 2500 | 2.5 |
| RSW 3000 | 3.0 |
| RSW 4000 | 4.0 |

| Model | Capacity (TPH) |
|---|---|
| RSW 4000 | 4.0 |
| RSW 5000 | 5.0 |
| RSW 6000 | 6.0 |



### Solid Fuel Fired Twin Furnace Three Pass Steam Boiler

- High thermal efficiency due to twin furnace design.
- Hinged doors for quick and easy cleaning of tubes.
- Easy to operate and maintain.
- Can fire a variety of fuels, such as coal, wood, agrowaste, etc.
- Rugged design
- Has high steam and water storage to cater to fluctuating steam demands.

## RSBE Series

### Electric Steam Boilers

- Space saving designs
- Fully automatic operation
- Clean & quiet operation
- Fully packaged unit, minimizes site work
- No fuel tank & chimney required

| Model | Capacity (kg/hr) |
|---|---|
| RSBE 10 | 15 |
| RSBE 15 | 23 |
| RSBE 20 | 30 |
| RSBE 35 | 55 |
| RSBE 50 | 78 |
| RSBE 65 | 100 |
| RSBE 130 | 200 |
| RSBE 165 | 250 |
| RSBE 200 | 300 |
| RSBE 260 | 400 |
| RSBE 320 | 500 |
| RSBE 390 | 600 |
| RSBE 450 | 700 |
| RSBE 520 | 820 |
| RSBE 640 | 1000 |