DESIGN, CONSTRUCTION AND TESTING OF A DOMESTIC YAM PEELING MACHINE USING PRESSURIZED STEAM TECHNIQUE

BY

ONORBA, AMOS EMUOBOME

MATRIC No. 2006/24022EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING.

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

FEBRUARY, 2010

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

FEBRUARY, 2010

DECLARATION

I hereby declare that this project work is a design and construction work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from published and unpublished work were duly referenced in the text.

__________________________ ________________________

Onorba, Amos Emuobome Date

CERTIFICATION

This Project entitled "The Design, Construction and Testing of a Domestic Yam Peeling Machine using Pressurized Steam Technique" by Onorba, Amos Emuobome, meets the regulations governing the award of Degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

17/02/2010

Engr. M. A. Sadeeq

Supervisor

Date

17/02/10

Engr. Dr. A.A. Balami

HOD, Department of Agricultural and Bioresources Engineering.

Date

09-02-10

Engr. Prof. G.O. Chukwuma

External Examiner

Date

DEDICATION

This project work is dedicated to my dad, Mr. James. M. Onorba and to my lovely sisters Happy and Agnes Onorba.

ACKNOWLEDGEMENTS

First and foremost, I wish to acknowledge God Almighty for his wisdom, grace and understanding in helping me to successfully complete this work. All glory also to His name for sparing my life all through my program in this institution.

Much gratitude to my project supervisor, Engr. Mohammed Sadeeq, the initiator of this project and the storehouse from where I drew all the inspiration and innovation needed for this work. Despite his busy schedule in doubling also as my level adviser, still found out time to painstakingly read through this project report, proffering corrections where necessary, giving a listening ear to all my questions and supplying appropriate solutions to overcoming every challenge that arose in the course of this project design and construction.

I wish to thank my lecturer and project coordinator, Dr. O. Chukwu, in the fatherly role he played in intimating us on how to prepare a good and acceptable project report. My appreciation goes to all the lecturers in the department especially to Engr. Kehinde and Engr. Fabunmi.

My deepest appreciation goes to my dad, Mr. James. M. Onorba and my lovely sisters, Agnes and Happy Onorba. I am saying a very big thank you to them for the moral advice and financial support they rendered to me.

Finally, to my friends who in one way or the other have affected my life positively, they are Mr. Theophilus Akpotobor, Mr. Jacob Adegbemi and Mr. Afe Peter.

ABSTRACT

The major factor inhibiting the growth of a yam processing industry is the lack of a successful commercial peeling machine since it is required that the yam tuber be peeled before any further processing. In recognition of this problem, a domestic yam peeling machine using pressurized steam technique was designed and constructed. Emphasis was placed on the peeling of *Dioscorea Rotundata* (white yam). The machine consists of a heating compartment where the water is heated to steam; A sprayer located in the peeling chamber and situated just above the tuber and sprays steam on the yam tuber to weaken its bark; The rollers also located in the peeling chamber which rotates the yam tuber to allow for even distribution of steam round the surface of the tuber as well as carrying out the peeling operation; an electrical alternating current motor for rotational torque generation. The machine was designed for yam tubers not more than 30cm in length, not too curved (fairly straight or straight) in shape and built to handle one yam tuber at a time. The machine performance was characterized by peeling efficiency and peeling losses. It peels at an average rate of 0.52mm/sec with a peeling efficiency of 47.8% Test carried out revealed that tubers of lower moisture content offer higher resistance to peeling; hence, lower efficiency while those with higher moisture content offer lower resistance to peeling, hence a higher efficiency. This resistance to peeling would be greatly reduced if the peeling chamber were to be lagged allowing for thorough effect of steam on the total surface area of the bark of the tuber.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Yam belongs to the monocotyledonous family *Dioscoreaceae* and genus *Dioscorea.* They are grown for their tubers or storage organs, which may be subterranean (e.g. *Dioscorea. rotundata, Dioscorea. alata*) or aerial (e.g. *Dioscorea. bulbilifera*), and serve a dual agricultural function as source of food and planting material.

Yams are grown in regions of three continents: West Africa, South America and Asia (Coursey, 1967 ; Alexander and Coursey, 1969 ; Ayensu and Coursey, 1972). In West Africa yams are a major source of nourishment to millions of people, as well as being a crop of prestige and cultural importance (Coursey, 1967 ; Martin and Sadik, 1977). The most important species in West Africa are white yam (*Dioscorea. rotundata*) and water yam (*Dioscorea. alata*). Infact, so important is the white yam that in many regions it is given an almost mystical significance (Apeji, 1993). Of the many species consumed, white yam (Dioscorea. rotundata) is the most important (Ajibola and Onayemi), 1988). Yam tubers can grow up to 2.5 meters in length and weigh up to 70 kg (150 pounds). Yams are grown as annual crops with tubers being planted between February (in the humid forest) and April (in the Guinea savanna) in West Africa. Only one crop cycle is possible per year, restricting supply (Olayide *et al.*, 1972).

Yam is an important food crop especially in the yam zone of West Africa, comprising Cameroun, Nigeria, Benin, Togo, Ghana and Cote d'Ivoire. This zone produces more than 90% of the total world production which is estimated at 20-25 million tones per year

(Sanusi, 2006). Nigeria alone produces above 70% of the world's total (Sanusi, 2006). There are also growing interest in yam production in other African count ries. Available data also shows that yam is one of Nigeria's leading root crops. Comparing its nutritional value with other root crops shows that yam contains a higher value in protein (2.4%), substantial amount of vitamins (Thiamin, Riboflavin and Ascorbic acid) and some minerals like calcium, phosphorus and iron than any other common tuber crops. Yam is also comparable to any starchy root crop in terms of energy (calories) value and the fleshy tuber is one of the main sources of carbohydrate in the diet of many Nigerians. The crop remains the most preferred by millions of people in Africa as a source of carbohydrate. The yam tuber is prepared in several ways for eating. The tuber may be peeled and boiled, and the cooked yam eaten with palm oil or any prepared source. Yam can also be peeled, sliced and fried in oil or made into a pottage. By far, the most popular way in which yam is traditionally eaten is as pounded yam. The peeled yam tubers are cut into pieces and boiled. When cooked, and while hot, the boiled yam is pounded in a wooden mortar and with a wooden pestle. The yam is pounded until it forms a white or slightly yellowish doughy mass; this is eaten with various sources. Peeled yam tubers are cut into pieces, parboiled, and then sundried. The dried pieces are milled into flour which is used to make a black dough called 'amala' (in Yoruba) or 'achicha' (in ibo). These food products were preferred to fufu, garri and cassava flour (lafun) made from cassava. In the southern part of this country, especially south-east and south-south, yam plays vital roles to the cultural, ritual and religious ethics as well as having local commercial affiliations to Nigerians and indeed African people.

1.2 Statement of the Problem

At present, the yam peeling machine and resent work on yam tuber peeling systems are very scarce. Available literature is limited to work which has not gone beyond the four walls of the engineering research workshops (Ukatu,2002). The varying shapes and sizes of the crops are the bottlenecks in developing a yam peeling machine. This important tuber crop at present has little or no place in the international market. This does not mean that it lacks the nutritional values necessary to accord its international recognition. The fact is that the crop has not received the processing necessary to keep it on the shelf internationally. FAO (1990) reported that yam has not been processed to any significant extent commercially. If a crop is processed into various forms, its probability of being consumed by more people becomes higher. The lack of a successful peeling machine has been a major factor inhibiting the growth of the yam processing industry. Peeling which is needed for any form of yam processing, has so far proved very difficult to mechanize and this is mainly due to the varying shapes and sizes of the crop. The use of unpeeled tubers for yam flour production would increase the dietary fibre content of the flour (Akorode, 1987). Adamson (1985) found that the dietary fibre is partially resistant to digestion by secretions of human gastrointestinal tract including carbohydrate compounds such as cellulose, hemicelluloses, mucilage, pectin, gums and non-carbohydrate compounds such as lignin. The presence of peel in yam flour reduces its aesthetic quality and consumers find it unacceptable to eat the flesh along with its peel. Therefore, the need to isolate peels from yam products becomes necessary.

1.3 **Objectives of the study**

The main objective of this project work is the design and construction of a yam peeler that:

- Provides a uniformed peeled yam surface.
- Eliminates accidents arising from knife cut while peeling.
- Would be cheap and easy to operate.
- Would be reliable to peel large number of yams within a short period of time.
- Would peel the yam under a good hygienic condition i.e. take care of contamination which might result by handling with hand.
- Eliminates drudgery encountered in peeling yam.
- Reduces wastage by preventing the edible white flesh being peeled off with the skin.

1.4 **Justification of the Study**

This important tuber crop at present has little or no place in the international market. This does not mean that it lacks the nutritional values necessary to accord its international recognition. The fact is that the crop has not received the processing necessary to keep it on the shelf internationally. FAO (1990) reported that yam has not been processed to any significant extent commercially. If a crop is processed into various forms, its probability of being consumed by more people becomes higher. The lack of a successful peeling machine has been a major factor inhibiting the growth of the yam processing industry.

1.5 Scope of the Study

The design of this machine is limited to the following:

- Sized lot of yam with mass not greater than 2kg.
- Selection of tubers to be peeled i.e. sorting out of the tuber is required. High peeling efficiency could be obtained with the tubers that are less curved.
- Yams with less moisture content like the white yam *(Dioscorea rotundata)*. Yams with high moisture content (water yam) take a considerable long time to peel.

All forms of yam tuber processing activities involving washing, peeling, slicing, cooking, frying, drying and milling demand that the tuber be peeled. Hence, the work presented here was centered on the design and construction of a domestic yam peeler. The vegetable has a rough skin which is difficult to peel, but which softens after heating. The machine therefore, makes use of the principle of steam sprayed on the unpeeled yam for say 5seconds or less so as not to denature the peeled material but to soften its skin which is later removed by the abrasive action of roughened surfaced rollers. On this work, special attention is on *Dioscorea rotundata* (White yam).

CHAPTER TWO

2.0 LITERATURE REVIEW

Over the years, till date, no functional yam peeling machine has evolved because of the difficulties involved with the different shapes and sizes of yam tubers. Shapes and sizes are inseparable in any physical object and both are necessary if the object is to be satisfactorily described (Mohsenin,1986). Sitkei (1986) stated that the functioning of many types of agricultural machines is influenced decisively by the shapes and sizes participating.

Generally, peeling involves the removal of a thin layer called the peel from a stock. Three general method of peeling systems carried out so far are in the area of abrasion action, chemicals and heat. Peeling by the use of chemicals obviously denatures the peeled material. This is due to the reaction of the chemicals with the constituent of the peeled material. Thus, not recommended for yam peeling.

The abrasion method has been used to peel potatoes, ginger and is used in this work on yam tubers. Abrasion peelers for potatoes are theoretically designed to contact uniformly the surface of the potato being peeled with abrasive disc or rollers, in such a way as to remove the peel with as little peeling loss as possible. Agrawal et al. (1983) developed an abrasive brush type ginger peeling machine. The operation of the machine was later optimized by Agrawal et al. (1987). The peeler consisted essentially of two continuous brush belts being driven in opposite directions with a downward relative velocity by a variable speed electric motor. The movement of the two brush belts in opposite direction provided the abrasive action of the ginger passing in between, while the downward relative velocity provided flow of ginger. In the manually operated ginger peeler developed by Charan et al. (1993), brushes made of coconut fibres were used as abrasive materials. A moving abrasive material was mounted on two endless canvas belts. A stationary abrasive surface was also developed with the same brushes, arranging them side by side on a wooden plank of 780 × 240 × 15mm. A uniform gap of 15mm was maintained between the moving and stationary surfaces so as to accommodate ginger pawn between them.

Several methods have been used for peeling onions. The common methods used in modern onion processing industry are lye treatment, flame peeling and mechanical peeling (Srivastava et al.1997). The authors stated that lime and flame peeling methods are harsh and not suitable for many onion products and therefore, recommended the mechanical peeling method (abrasion peeling). For their machine, they made use of four scoring blades as the peeling tool.

The Federal Institute of Industrial Research Oshodi (FIIRO, 1971) in Nigeria has fully mechanized the production of garri. The process involves the utilization of fresh cassava tubers not more than 12hours old. These are chopped and loaded into a rotating vessel with an abrasive lining, which is filled with water. On rotating, the tubers are peeled by abrasion as they come in contact with the lining and as well as with each other. Incompletely peeled tuber pieces are removed by hand. The major disadvantage of this machine is the use of not more than 12hours old cassava and the large volume of water required.

Attempts have been made to develop a functional cassava tuber peeler, using the abrasive action. Odigbo (1976) developed a continuous cassava peeler consisting of a cylindrical knife assembly and a rough cylinder mounted parallel to each other 20mm apart. He reported peeling efficiency of over 95% but only for sized lots of cassava tuber slices. Ezekwe (1979), Odigbo (1983) and Nwokedi (1984) designed and constructed batch cassava peelers that were similar in principle. The peelers rotate a mixture of cassava tubers and abrasive materials in a drum to effect peeling. Ohwovoriole et al. (1988) reported that the peelers work best for sized tubers and have no control on the depth of the peel removed with resulted high losses of cassava flesh.

A batch steam peeler has also been produced. It consists of a cylindrical pressure vessel equipped with a quick opening door and usually mounted on a hollow shaft to permit rotation of the peeler during operation and to allow for admission and discharge of steam. In continuous steam peeler, the machines commonly used consist of a cylindrical pressure chamber with an internal screw conveyor. The continuous stream peelers are preferred to batch peeler because they provide continuous product flow and do not require an operator. The product is admitted and discharged through pocketed rotary valves, which maintain the pressure seal. The steam pressure may be varied as well as exposure time to regulate the depth of heat penetration. For peeling potatoes an exposure time of 35 to 45 seconds is recommended. These machines have capacities up to 12 tons per hour and operate at pressures over 100psi. Potatoes discharge from machine into a barrel washer or dry scrubber for peel removal (Talburt, 1975). Immersing potatoes on hot oil at 150^0 c of to 205^0 c has also been tested for its peel softening effect (Charles and Traver, 1975). Mineral oil impacts undesirable oily odours to the final product when not completely removed. Vegetable oils have been tested also, but the method apparently has little appeal.

Flame peeling utilizes high temperature for removal of peel by actual charring or carbonization. Potatoes are passed through a flame or refracting oven, which subjects all surfaces of the potatoes to about 1095°c for a period of 15 to 30 seconds. (Anon, 1970) The problem of conveying potatoes through the intense heat of the furnace is the principal problem for the builders of the flame peeler. Rotating drums, screw or rolls must be constructed of heat resistant materials and must rotate the potatoes as they pass through the flame or heated area.

In conventional practice in food processing plants, many fruits and vegetables are peeled by dipping them in hot lye (NaOH) solution, and then removing the loosened skin by wiping with rotating, soft rubber discs, or by flushing with jets of water. Although such lye-peeling procedure is effective, it presents several disadvantages. In the first place, high peeling losses occur because the caustic removes a substantial proportion of the softer tissue in the flesh of the fruit or vegetable as well as the peel. It is evident that high peeling losses are economically undesirable. Also, the peeled products do not have an attractive appearance because of removal of some of the flesh. This is, of course, a disadvantage where the product is intended for canning in the whole state. Another disadvantage of lye-peeling is that it yields a waste having a high NaOH content so that it is difficult to dispose of; many communities require that the waste be neutralized prior to releasing it into sewage plants, and even such neutralization, which is a considerable expense, does not alter the detrimental effect of its high sodium content.

The previous works done on the construction of a functional yam peeler have failed to achieve a breakthrough. The work done, using abrasive action, by Ofi (1982) and many others, including students in various tertiary institutions (as research projects) are examples of such work.

However, for all the different peeling methods reviewed above, the abrasive type as well as steam peeling will receive more attention for the purpose of this work because it combines both the abrasion action and steam (heat) to achieve the desired result. If applied extensively and uncontrollably, yam peeling by means of steam is likely to denature the material. With steady increase in applied steam on the yam peel (skin) in a controlled environment could go a long way in softening the texture of its outer skin, hence, ease in its removal by abrasive means.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Material

The materials used in this project work include the following:

3.1.1 **Aluminium Foil:** This is the material that was used for the body work. An aluminium material was selected because of its following properties: (i) it is malleable and therefore can be easily bent or hammered into any shape. (ii) it can be easily sorted for as it is seen everywhere. (iii) it is resistant to rusting. In a work like this where steam is produced and hence moisture coming in contact with the metal, rusting is bound to take place. This is prevented from happening by the use of aluminium sheets.

3.1.2 **Mild Steel:** This metal was used in the construction of the door frame.

3.1.3 **Stainless Steel:** Stainless steel is a good conductor of heat, hence its being used in heating the water to boiling point. It is $0.102m^{2.}$ in volume.

3.1.4 **Pipe:** This is made of copper and also a good conductor of heat. It serves as a means in which high pressure steam is prayed unto the tubers.

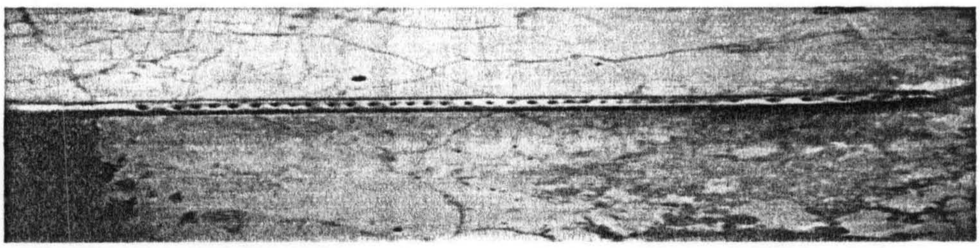

Plate 3.1 Perforated pipe

3.1.5 **Rollers:** These are two in number and coated with a thin aluminium foil. On each of these aluminium foils round the rollers, are bored small holes to serve as roughened surfaces to peel the tuber by abrasive action. Between the rollers is a clearance space of 35mm where the tuber is to sit. One of the rollers has its end attached to the motor (Prime Mover). When switched on, this roller rotates anticlockwise causing the tuber to rotate in a clockwise direction. The clockwise rotation of the tuber in turn causes the second roller to also rotate in an anticlockwise direction.

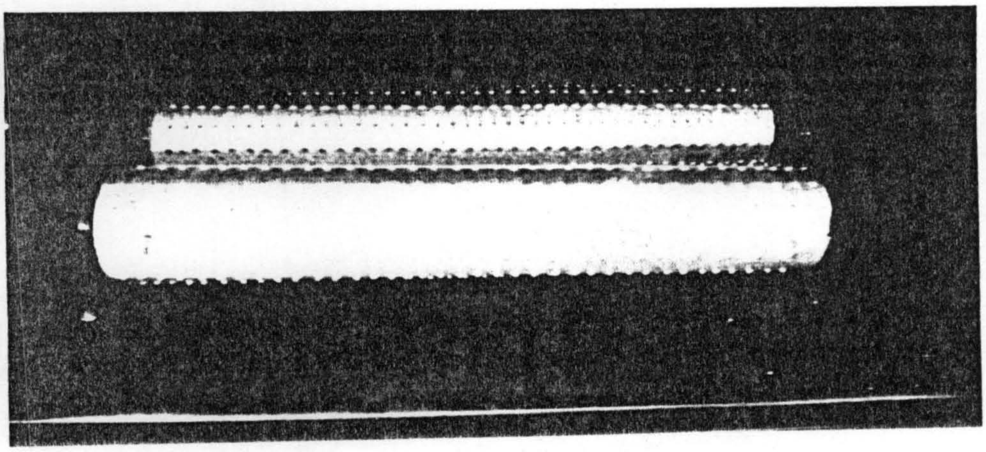

Plate 3.2 Rough surfaced dual rollers

3.1.6 **Roller Support:** Made of mild steel and used for its strength. This is shown in Fig.4. It is positioned in such a way that it just lifts the rollers above the base of the machine. This bottom space is to allow for the cleaning or flushing out of the peels after the peeling operation.

3.1.7 **Motor (Prime Mover):** This supplies the power needed for the peeling operation. It supplies a power of 120Watts, 70 rpm and a torque of 16.37Nm. It converts electrical power into mechanical power in the form of a rotation power that brings about the rotation of the rollers.

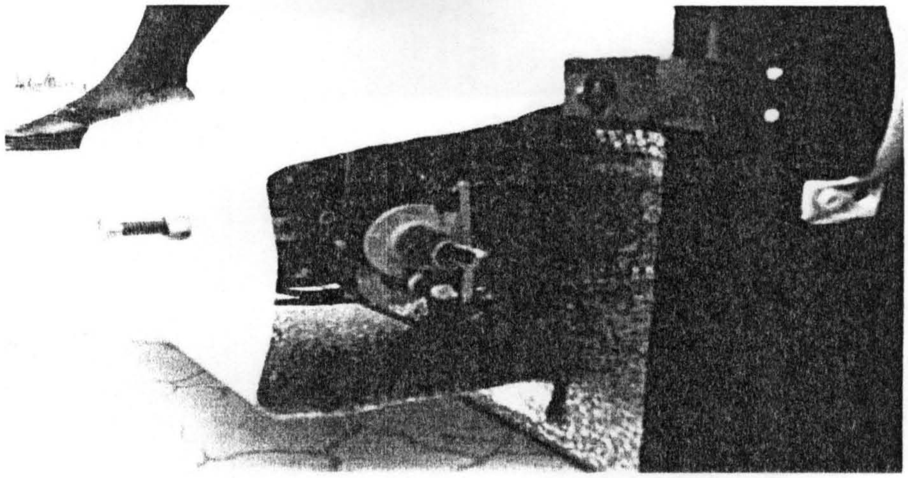

Plate 3.3 Motor

3.1.8 **Heating Element:** The heating element produces the heat required to change the water into steam.

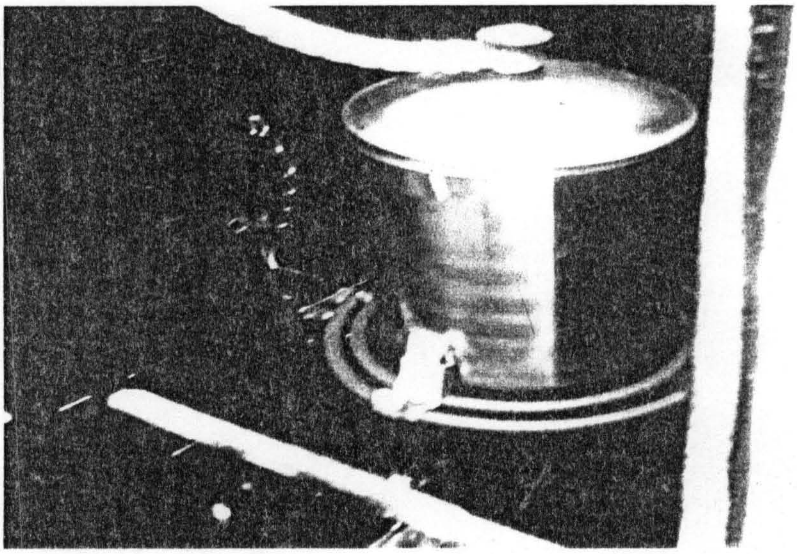

Plate 3.4 Heating compartment

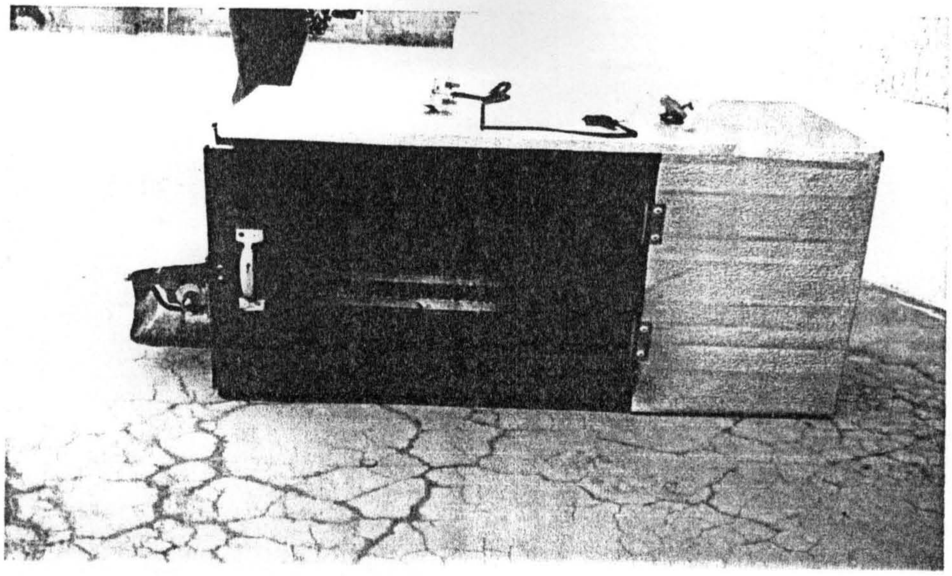

Plate 3.5 The domestic yam peeling machine with pressurized steam technology.

3.2 Method/Operation

The first operation is to heat up the water to steam/vapour state in the heating compartment. The tuber is placed between the two rollers in the peeling chamber and the door closed. The steam produced is then released from the heating compartment through the steam hose to the sprayer by means of the valve. The small perforations on the sprayer increase the pressure at which the steam is sprayed onto the tuber. The spray of steam on the tuber is left for some seconds to reduce or weaken the adhesion between the bark and the whitish flesh of the tuber, hence, allowing easy separation by peeling.

The motor is switched on and the tuber starts to rotate in sympathy with the rotating rollers. The bark of the tuber is removed by the continuous abrasive action of the roughened holes on the weakened bark of the tuber. It should be noted here that the heat produced in the heating compartment as well as the heat used in the peeling chamber is adequately preserved and evenly distributed at the peeling chamber because of the dark coating of the internal portion of the machine. This is from the principle of 'emission and absorption' which states that black surface absorbs heat (Sir. John Leslie).

As peeling progresses, the tuber continues to rotate; hence, exposing all its surfaces to the continuous spray of steam until all its bark is completely removed. The steam condenses to water in this chamber and is relayed out through a vent at the bottom of the chamber. When peeling is completed, the door of the machine is opened and the peeled yam tuber removed. If more than one tuber is required to be peeled, a fresh tuber is once more mounted onto the rollers again and the process continues.

At the completion of peeling, the waste material i.e. the bark is scooped off or flushed from the bottom of the peeling chamber. The roughened holes are also cleaned by removing yam peels that may have fastened onto them. This can be easily done by using a strong metallic brush to scrub the holes on the rollers until all clogged materials have been successfully removed.
Condensed steam is automatically channeled out of the machine through a small vent at the bottom of the machine.

3.3 **Design calculation**

3.3.1 **Area of circles on both sides of the cylinders**

$$\text{Area} = 2\pi R^2 + 2\pi r^2 \qquad (3.1)$$

$$= 2\pi \times (0.06)^2 + 2\pi \times (0.05)^2$$

$$= [2 \times 3.142 \times 0.0036] + [2 \times 3.142 \times 0.0025]$$

$$= 0.0226 + 0.0157$$

$$= 0.0383m^2$$

3.3.2 **Total surface area of the cylinders**

$$Total\ Surface\ Area = 2\pi R(R + H) + 2\pi r(r + h) \qquad (3.2)$$

$$= 0.377(0.06 + 0.12) + 0.3142(0.05 + 0.1)$$

$$= 0.377(0.18) + 0.3142(0.15)$$

$$= 0.0679 + 0.047$$

$$= 0.115m^2$$

3.3.3 **Size of Chamber**

$$2(L \times B) \qquad (3.3)$$

$$2(0.6 + 0.3) = 0.36m^2$$

$$2(0.6 + 0.3) = 0.36m^2$$

$$2(0.3 + 0.3) = 0.18m^2$$

Size of material needed for the construction

$$= 0.0383 + 0.115 + 0.36 + 0.36 + 0.18)m^2$$

$$= 1.0533m^2$$

Therefore, approximately **1.5m²** of material (aluminium sheet) should be used.

3.3.4 **Bending moment,** M_b

For a uniformly distributed load,P, the equation is given by,

$$M_b = \frac{PL^2}{8} \qquad (3.4)$$

But $P = mg$

$$P = 2 \times 9.81$$

$$P = 19.62N$$

$$Therefore, \quad M_b = \frac{19.62 \times (0.32)^2}{8}$$

$$= 0.25Nm$$

Where,

P = weight of material

m = mass of material on rollers/drum

L = length of drum

g = acceleration due to gravity

3.3.5 **Motor torque required, T**

$$P = T \times W \tag{3.5}$$

$$\mathrm{T} = \frac{\mathrm{P}}{\mathrm{W}}$$

$$= \frac{120 \times 60}{2\pi N}$$

$$= \frac{7200}{439.88}$$

$$= 16.37Nm$$

Therefore, shaft diameter is given by,

$$\mathrm{d}^3 = \frac{16}{\pi \mathrm{S_s}} \sqrt{(\mathrm{K_b M_b})^2 + (\mathrm{K_t M_t})^2} \tag{3.6}$$

Where,

$\mathrm{M_b}$ = bending moment

M_t = torsional moment

K_b and K_t = combine shock and fatigue factor applied to bending moment

When the load is suddenly applied,

$K_b = 1.75$ *and* $K_t = 1.5$ (Hall, Holowenko, Laughlin, 1982)

$$d^3 = \frac{16}{\pi S_s}\sqrt{(1.75 \times 0.25)^2 \times (1.5 \times 16.4)^2}$$

$$= \frac{16}{\pi(55 \times 10^6)} \times 115.83$$

$$= 9.2587 \times 10^{-8} \times 115.83$$

$$= 1.0724 \times 10^{-5}$$

$$d = \sqrt[3]{1.0724 \times 10^{-5}}$$

$$= 9.82 \times 10^{-3}\text{m}$$

$$= 9.82mm$$

3.3.6 **Force applied to shaft**

$$F = mg \quad (3.7)$$

$$= 2 \times 9.81$$

$= 19.62\text{N}$

Where;

m = mass of the yam tuber (assume 2kg)

g = acceleration due to gravity, 9.81

3.3.7 **Angular velocity of rotation of cylinder, W**

$$W = \frac{2\pi N}{60} \tag{3.8}$$

$$= \frac{2 \times 3.142 \times 70}{60}$$

$$= 7.33 rad/sec$$

3.3.8 **Motor power required to do the peeling**

$$P = T \times W \tag{3.9}$$

P= 16.37× 7.33

P= 119.99Watts

P = 120Watts

Where,

P= Power

T= Torque

W= Angular velocity

3.3.9 **Stress calculation**

Bending moment, $M_b = 0.25Nm$

Torsional moment, M_t = 16.4Nm

3.3.10 **Determining the maximum bending and torsional stress**

Maximum bending stress, $\delta_{\max} = \frac{M_b}{Z_m}$ (3.10)

Sectional modulus, $Z_m = \frac{I}{y}$ (3.11)

Where,

I = moment of inertia,

y = radius of shaft

$$I = \frac{\pi d^4}{64} \quad (3.12)$$

$$y = \frac{d}{2}$$

$$Z_m = \frac{\pi d^3}{32}$$

$$Z_m = \frac{3.142 \times (0.0098)^3}{32}$$

$$Z_m = 9.24 \times 10^{-8} m^3$$

Where,

d = Shaft diameter

$$\delta_{max} = \frac{M_b}{Z_m}$$

$$\delta_{max} = \frac{0.25}{9.24 \times 10^{-8}}$$

$$\delta_{max} = 2.71 MPa$$

3.3.11 **Maximum torsional stress,** Z_t

$$Z_t = \frac{j}{y} \qquad (3.13)$$

$$= \frac{\frac{\pi d^4}{32}}{\frac{d}{2}}$$

$$= \frac{\pi d^3}{16}$$

$$= \frac{3.142 \times (0.0098)^3}{16}$$

$$= 1.85 \times 10^{-7} m^3$$

3.3.12 **Torsional shear stress,** τ_{xy}

$$\tau_{xy} = \frac{M_t}{Z_t} \tag{3.14}$$

$$= \frac{16.4}{1.85 \times 10^{-7}}$$

$$= 88.6\text{MPa}$$

Alternatively,

Using principal stress theory

$$\delta = \frac{\delta}{2} \pm \sqrt{(\frac{\delta_x}{2})^2 + \tau^2{}_{xy}} \tag{3.15}$$

$$= \frac{2.71}{2} \pm \sqrt{(\frac{2.71}{2})^2 + (88.6)^2}$$

$$= 1.355 \pm \sqrt{1.84 + 7849.96}$$

$$= 1.355 \pm \sqrt{7851.8}$$

$$= 1.355 + 88.6$$

$$= 89.97\text{MPa}$$

3.3.13 **Peeling Efficiency P_e**

$$P_e = \frac{A_{ut} - A_{up}}{A_{ut}} \times 100\% \qquad (3.16)$$

Where;

P_e = Peeling Efficiency

A_{ut} = Surface Area of unpeeled tubers

A_{up} = Total Surface Area of unpeeled patches

From Table 4.1 the over-all machine efficiency can be calculated thus,

$$\text{Overall Machine Efficiency} = \frac{52 + 51 + 49 + 48 + 39}{5}$$

$$= \frac{239}{5}$$

$$= 47.8\%$$

3.3.14 **Peeling Loss**

$$\text{Peeling loss} = \frac{\text{Mass before peeling} - \text{Mass after peeling}}{\text{Mass before peeling}} \times 100\% \qquad (3.17)$$

$$= \frac{1.30 - 1.02}{1.30} \times 100\%$$

$$= 0.21538 \times 100\%$$

$$= 21.54\%$$

3.4 **Bill of Engineering Measurement and Evaluation**

S/N	Material	Quantity	Costs (N)	Amount (N)
1.	Aluminium sheet	1 sheet	1500	1500
2	A.C electric motor	1	1500	1500
3.	Wooden rollers	2	600× 2	1200
4.	Heating Element	1	700	700
5.	Stainless Steel	1	700	700
6.	Copper pipe	1	500	500
7.	Hose	1yard	400	400
8.	Bolts and Nuts	1 dozen	30× 12	360
9.	Cables	2 yards	150 × 2	300
10.	Plug	2	50× 2	100
11.	Rivet pins	20 pieces	20× 5	100
12.	Hinches	2	20× 2	40
13	Door handle	1	30	30
14.	Nails	half kg	50	50

S/N	Material	Quantity	Costs (N)	Amount (N)
15.	$^{3}/_{4}$ Inch square pipe	2 length	600× 2	1200
16.	Mild Steel	1pcs	1000	1000
17.	Roller support	2	200× 2	400
			Total	**N10, 080**

Labour cost = 60% of Material cost

= 60% of 10, 080

= N6, 048

Transportation Cost = N3, 000

Miscellaneous = N1, 000

Total Cost of Project = 10,080 + 6,048 +3,000 +1,000

= **N20, 000**

CHAPTER FOUR

4.0 RESULTS AND DISCUSION

4.1 Presentation of Results

Tests were carried out on two yam tubers of the *Dioscorea Rotundata* which were bought from a local market. These tubers were divided into two groups as can be seen from the Table below. Machine peeling was used on one group while the other group was subjected to manual peeling. Prior to the machine peeling operation, the surface areas of the tubers were determined using the mensuration formulae, $2\pi rh$.

The machine was started with each tuber fed in at a time. The time for peeling each tuber was recorded, using a stopwatch. At the end of the peeling exercise, the areas of patches of peels not removed were measured.

The other five tubers as well as the results obtained from the manual peeling in Table 4.1 and Table 4.2 were extracted from previous work on 'The Development of an Industrial Yam Peeler by Ukatu, 2002.

4.2 Discussion of Results

Table 4.1 shows the comparison of manual and machine peeling with respect to time. In the fourth column, a tuber with length 340mm having a mass of 2.0kg and an average diameter of 83mm is machine peeled for 60secs and trimmed for 70secs. This tuber size is related to the tuber size 342mm, 1.80kg and an average diameter of 76.6mm in the manual peeling row. The difference between machine peeling time as well as trimming time and manual peeling time could be seen to be very wide from table 4.1 below.

However, the more moisture the yam tuber contains, the better its being peeled at a more faster rate. Table 4.2 gives the comparison of losses from the machine peeling method to the manual peeling method. A mass of 1.28kg of tuber before peeling gives a final mass of 1.11kg after peeling with a machine peeling method, hence a peeling loss of 11%. A related tuber of mass 1.30kg before peeling gives a final mass of 1.02kg with a manual peeling loss of 21.54% loss. The losses are computed thus;

Table 4.1 Machine Performance and comparative tests.

	Machine Peeling						**Manual Peeling**				
No	Tuber length (mm)	Mass (kg)	Average diameter (mm)	Peeling time (s)	Trimming time (s)	Peeling efficiency (%)	Tuber length (mm)	Mass (kg)	Average diameter (mm)	Peeling time (s)	Peeling efficiency (%)
1	260	1.19	60.0	450	60	52.00	342	1.8	76.6	202	100
2	275	1.26	72.0	550	69	51.00	150	1.3	77.1	156	100
3	280	1.28	72.0	600	70	49.00	406	1.63	64.8	197	100
4	340	2.00	83.0	600	70	48.00	403	1.7	83.7	190	100
5	300	1.56	66.3	600	70	39.00	375	1.75	80.2	201	100

Table 4.2 Machine and Manual peeling losses.

	Machine Peeling				Manual Peeling			
No	Mass of tuber before peeling (kg)	Mass of tuber after peeling (kg)	Peeling loss (%)	Average diameter (mm)	Mass of tuber before peeling (kg)	Mass of tuber after peeling (kg)	Peeling loss (%)	Average diameter (mm)
1	1.19	1.01	15	60.00	1.80	1.25	30.56	76.6
2	1.26	1.11	11	72.00	1.63	1.23	24.54	64.8
3	1.28	1.11	11	72.00	1.78	1.35	24.16	80.2
4	2.00	1.82	18	83.00	1.30	1.02	21.54	77.1
5	1.56	1.43	13	66.30	1.70	1.38	18.82	83.7

CHAPTER FIVE

5.0 C0NCLUSION AND RECOMMENDATION

5.1 Conclusion

A domestic yam peeling machine using pressurized steam technique which peels by abrasive action has been developed and tested. The machine makes use of rough surfaces that are evenly distributed on the rollers. Their scrubbing effect on the tuber brings about the peeling of the bark from the yam tuber. The major parts of the machine are (i) the heating compartment, where the steam is produced (ii) the peeling chamber, where peeling takes place by abrasion and (iii) the motor power section, to provide the power needed to bring about the rotation of the rollers.

Peeling efficiency of the *Dioscorea rotundata* tuber was obtained to be 47.8 %. Test carried out revealed that tubers of lower moisture content offer higher resistance to peeling; hence, lower efficiency while those with higher moisture content have higher efficiency. The machine peels yam tubers at an average rate of 0.52mm/s.

5.2 Recommendation

Efforts should be made to make the machine operate automatically. In the current work, the valve is manually opened or closed to allow or prevent the flow of steam to the sprayer. Future work on this project should include an in built electrical circuit to allow or resist the flow of steam automatically.

A water heating jug that has its element within the container and directly in contact with the water is strongly recommended as it takes lesser time to completely boil the water by convection principle.

An electrical or relay system is also recommended for the heating element so that it automatically switches on itself to boil the water and cuts off the supply of heat when the water is boiled.

There should be a means of re-circulating the condensed steam in the peeling chamber back into the stainless steel pot for reheating and subsequent re-spraying. This recycling process eliminates the drudgery of constant refilling of the stainless steel pot with water after depletion by evaporation.

To ensure effective use of steam in softening the bark of the tuber in the peeling chamber, I would recommend that the peeling chamber be lagged to prevent or minimize heat losses.

The motor power used in this project work is a 120Watts motor (0.2hp) but I will like to recommend a motor power of 0.5-0.8hp for future work.

The hoses to be used in future work should be well lagged and heat resistant to prevent it from melting when in operation.

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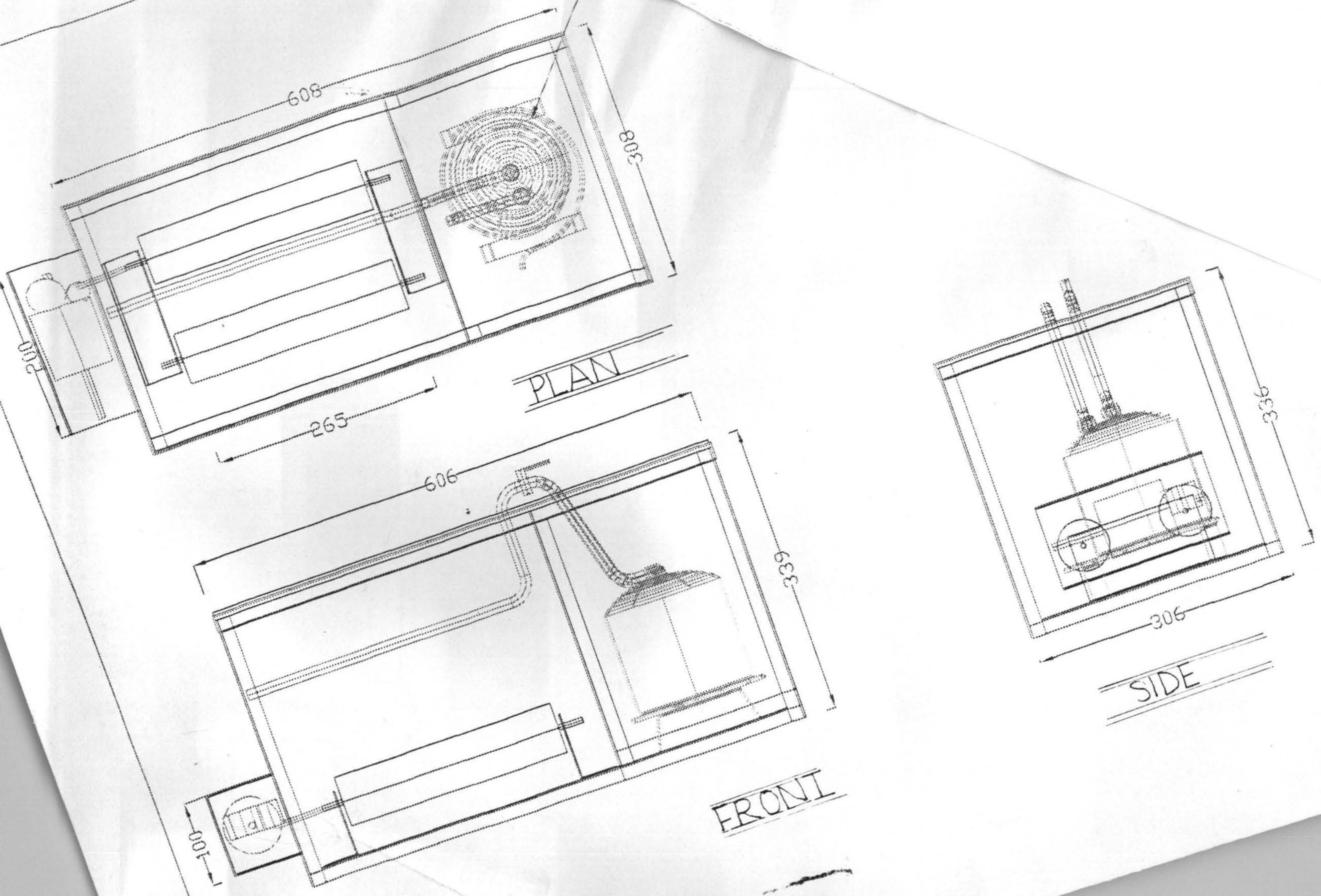

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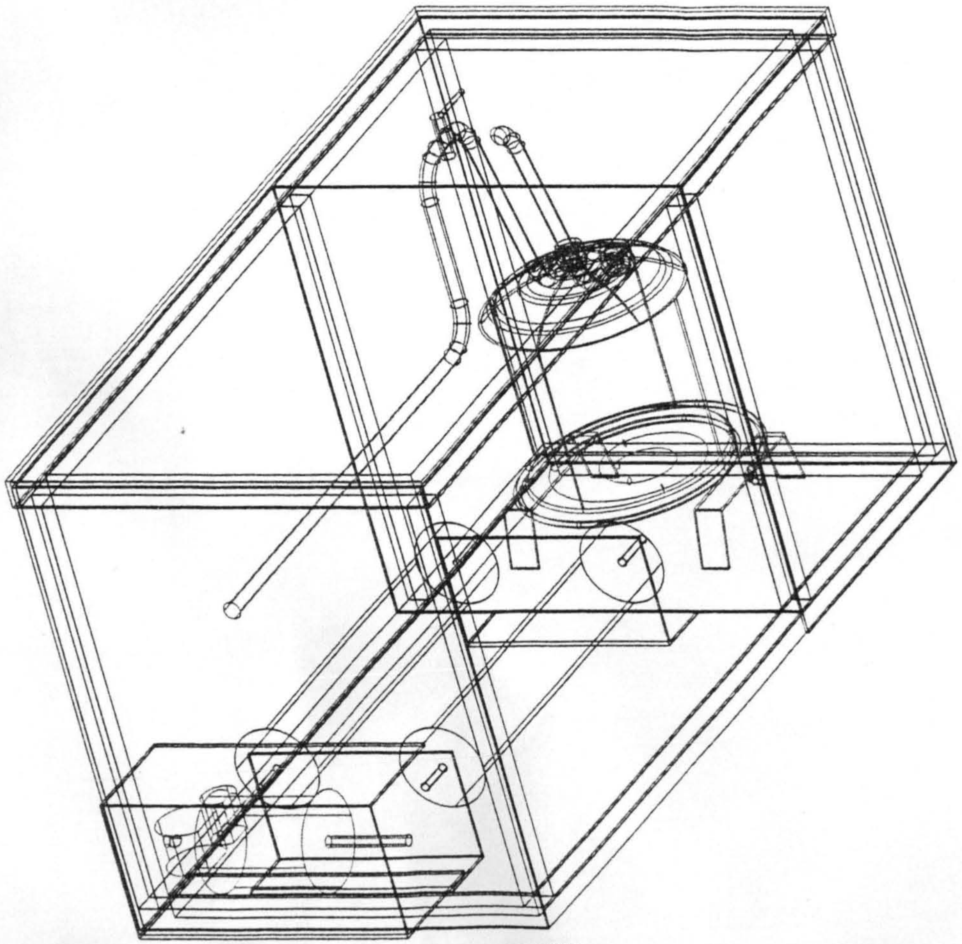

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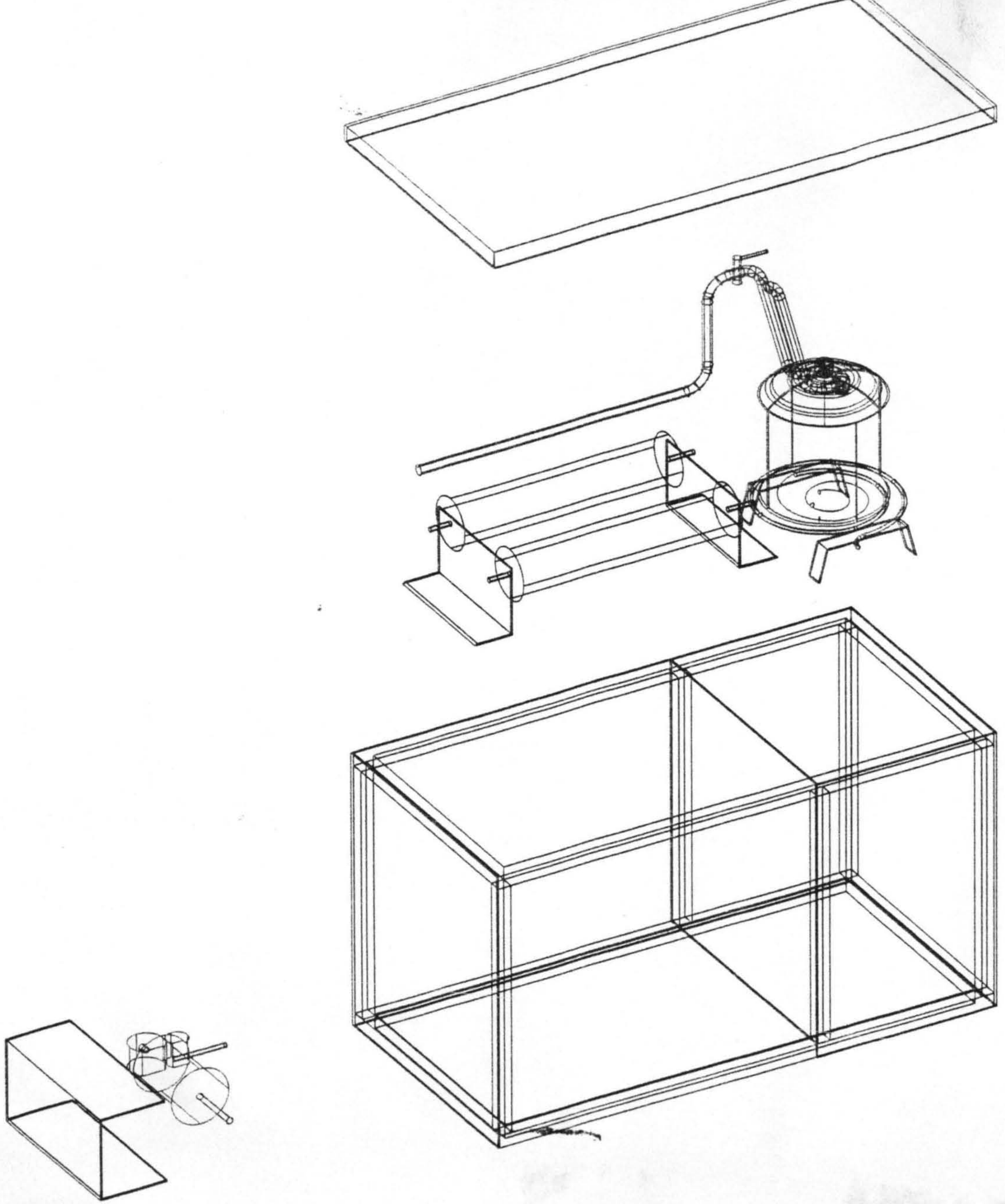

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