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Sudan.

DEMONSTRATION PROGRAMME ON USE OF INDIGENOUS BIOMASS RESOURCES FOR MEETING ENERGY NEEDS

RP/RAF/85/627

SUDAN

Technical Report*

Mission 1 November to 31 December 1985

Prepared for the Government of the Democratic Republic of the Sudan

by the United Nations Industrial Development Organization

acting as executing agency for United Nations Development Programme

Based on the work of Mr. Albert Zorge,

Charcoal Expert

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Vienna

52

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Director Renewable Energy Research Institute (RERI)

1. SUMMARY

Within the UNIDO-sponsored project RP/RAF/85/627 - Demonstration Programme on the Use of Indigenous Biomass Resources for meeting Energy Needs - identification and construction of equipment for simple kilning techniques were performed.

In Section III of this report the major problems as well as possible solutions are presented.

In Section IV identification of the equipment is carried out by following an extensive narrowing-down process to the chosen design.

Preparations for the construction of a prototype as well as the construction of the kiln itself are recorded in Sections V and VI.

Analysis of the cotton stalks feedstock for the manufacture of charcoal - "cotton coal" as expressed in a previous survey - follows in Section VIII.

After the preparations for the kilning trial runs, tests and demonstrations are analysed in Section IX.

The results of the tests - Section X - justify the recommendations in Section XII to proceed without delay with a number of field tests in a simple pilot project in the Rahad scheme shortly after 1986 harvest season.

II. TABLE OF CONTENTS

ILLUSTRATIONS

III. INTRODUCTION

1.0 The major problem

1.1 Deforestation

Due to the very high consumption of firewood (45%) and charcoal (30%) for cooking - in the Sudan, 75% of the total energy per annum, representing roughly 2 million tons of forest reserves, large-scale deforestation takes place.

Also great damage has been and is still being caused by clearing vast forest areas in order to obtain land for mechanized farming in years to come. Almost all the wood in these areas has been burnt on the spot.

This situation is not uncommon for countries in the Third World and in the Sudan it is expected that in 5 years the forest resources, supplying the populous mid belt of the country with domestic fuel, will have disappeared completely. Forest boundaries in the Kassala province, due east of Khartoum, and Blue Nile Region, south of the capital are receeding at 15 to 20 km per year. Due to the ever increasing distances between producer and consumer, higher transportation costs cause the prices of charcoal and fuelwood to steadily rise.

1.2 A possible solution

This very grave situation has to be stopped, but millions of families, thousands of bakeries and many small-scale industries, badly need this type of fuel, day after day.

The production techniques in the manufacture of charcoal in the Sudan have been so highly developed that no savings at this beginning of the "fuel-pipeline" can be expected.

The Renewable Energy Research Institute (RERI) worked out two main objectives to reduce fuelwood- and charcoal consumption:

- introduction of alternative fuel sources such as agricultural residues
- introduction and promotion of energy (fuel) saving stoves.

2.0. Alternative fuel sources are found in the utilization of biomass, especially agricultural residues.

In the Sudan, in the irrigation schemes of Gezira and Rahad, both situated in the river triangle south and south east of Khartoum, over 1 million tons of cotton stalks are available annually.

A considerable part is already used by farmers as a cooking fuel during harvest time, but transportation and storing of larger quantities are prohibited. Danger of spreading plant diseases during transport and storage is considered to be very high. All cotton stalks remaining at the field are burnt at the latest by 30th May every year - a gigantic waste of biomass energy.

This is not a serious problem as far as the tenants (farmers) are concerned. The only nuisance is the clearing of fields, amounting up to £S10,- per feddan. As the average tenant cultivates 10 feddans, an amount of £S100,- has to be paid every year.

UNIDO consultants suggested the use of cotton stalks as an alternative fuel source.

2.1 Utilization of cotton stalks

Several broad studies were performed by various institutions, followed by a final project formulation: "Carbonization of the cotton stalks to obtain an alternative fuel for household purposes".

When this project is accepted by the consumers of charcoal, a major victory should be gained in the struggle to roll-back deforestation. The large quantities of charcoal and fuelwood now used could be substitued by cotton-coal (charcoal made from cotton stalks).

3.0 Introduction and promotion of improved stoves

Early in 1983 the Sudan Renewable Energy Project, an activity of the Energy Research Council, introduced new and fuel saving stoves, known as canun el duga, ("duga" = small pieces of charcoal).

These charcoal fines, till then useless and generally thrown away, make up a large percentage of a charcoal sack contents - up to 30 percent, depending on the quality of the charcoal.

Current production/sales rates are over 500 stoves per month.

IV. IDENTIFICATION OF EQUIPMENT

1.0. Types of carbonization systems

1.1. Generally there are two methods for the production of charcoal:

- external heating of a horizontal oven or RETORT
- internal heating in a vertical oven or KILN

The first method is not applicable for the carbonization of cotton stalks, for this system requires

a) a permanent plant of a substantial size
b) high investment costs
c) high operating costs
d) a continuous supply of feedstock.

As such a plant means centralized production, the cotton stalks are to be collected, transported and stored, which would include high phytosanitary risks and is therefore prohibited by law. Moreover, the high investment costs would lay an unbearable burden on the Sudanese economy, whilst at the same time skilled labour would cause high operating costs. The supply of enormous quantities of feedstock would require a vast transport organization to be built up and maintained at high cost.

In both the Decon-study, phase II, page 70-72, and the report of Ulrich Graf "Small scale carbonization of cotton stalks", page 7-9, a much smaller retort unit is discussed together with tests, recently demonstrated for RERI, but both installations have the disadvantage of not being transportable, so collection and transportation will still be necessary.

The second method could be applicable to the carbonization of cotton stalks, provided that only mobile units should be used.

1.2 Fixed kilns:

- pit; a hole in the ground (Philippines, Indonesia)

- earth kiln, wood, covered with leaves and earth, with a smokestack or smokeports (Sudan, Somalia etc.)

- charring stack; with smokestack or -ports (Eastern Europe)

- "Brick-Beehive" kiln for the production of charcoal for the iron- and steel industry (Brazil)

- "Missouri", concrete and steel kiln (United States).

These are NOT appropriate for the carbonization of cotton stalks, because the supply of feedstock causes high phytosanitary risks.

1.3 The process of narrowing down has to be followed even further, but by doing so, it should be considered that a choice among types of mobile charcoal kilns should be based on an analysis of

a) availability and cost of materials

b) availability and cost of skilled labour for construction and operation.

The portable kilns are of the following types:

- the drum kiln
- the Uganda Mark II kiln
- the Cusab kiln
- the "Cuve basculante de Carbonisation pour tiges de coton", prototype C.E.E.M.A.T.

1.3.1. The drum kiln, the cheapest, is widely used in the developing world. Ulrich Graf demonstrated recently (August 1985) very successfully with a drum kiln the carbonization of cotton stalks at the research centre of the RERI in Soba near Khartoum.

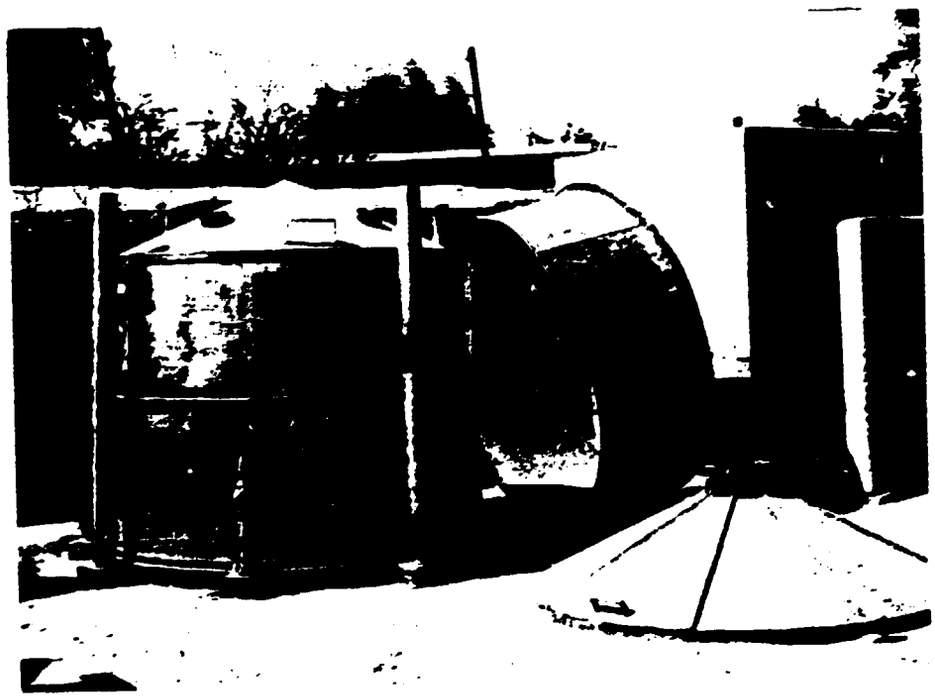
He stated, however, in his report "It must be proved however, if it is really necessary, to weld oil drums together to get larger units instead of using just the adequate number of single drums." (underlining by the author).

1.3.2. Although the Uganda Mark V Kiln (modified) is large compared to the drum kiln, because it is designed for the manufacture of wood charcoal, this type was not judged appropriate due to the high investment costs - up to approximately £S4,000 - requiring also skilled operation techniques

1.3.3. For the same reason, the Cusab kiln, designed to carbonize especially bushy materials such as cotton stalks, is considered disadvantageous.

Moreover, the charging of the material through the top opening is, because of the heat radiation for the operator, quite difficult if not hazardous.

1) drum kiln



2) Uganda Mark V kiln (modified)

1.3.4. The "Cuve basculante de Carbonization pour tiges de coton" is a French design, of which a prototype is being used in the cotton-areas in South Mali. Being also 2m high but with a diameter of only 1m, this kiln seems to have a good chance but is still in a developing phase and adequate information is not available yet.

It is believed furthermore that this type could have two disadvantages: relatively high investment costs and difficult filling of the drum.

In the already quoted report of Ulrich Graf it is described on page 7, paragraph 2.3.2. "Filling of the retort", that a 2-drum-volume encounters difficulties for "it (the cotton stalks) never slips in easily so it is necessary to remove the retort from the fireplace to be able to apply more force".
And on page 4, paragraph 2.2.2, "Filling the drum", it is stated: "The bundle does not slip in easily, therefore the drum has to be bumped on the ground."
The author is of the opinion that this would be difficult in practice.

2.0. Both parties involved, the Sudanese counterpart RERI, represented by Dr. Ahmed Hassan Hood, and the UNIDO-expert, agreed upon a new design.

The new kiln should be larger than the drum but smaller than the Mark V and measuring 1.70 diameter (drum 0.57m, Mark V 2.32m) and height 0.87 (drum 0.90m, Mark V 2.32m

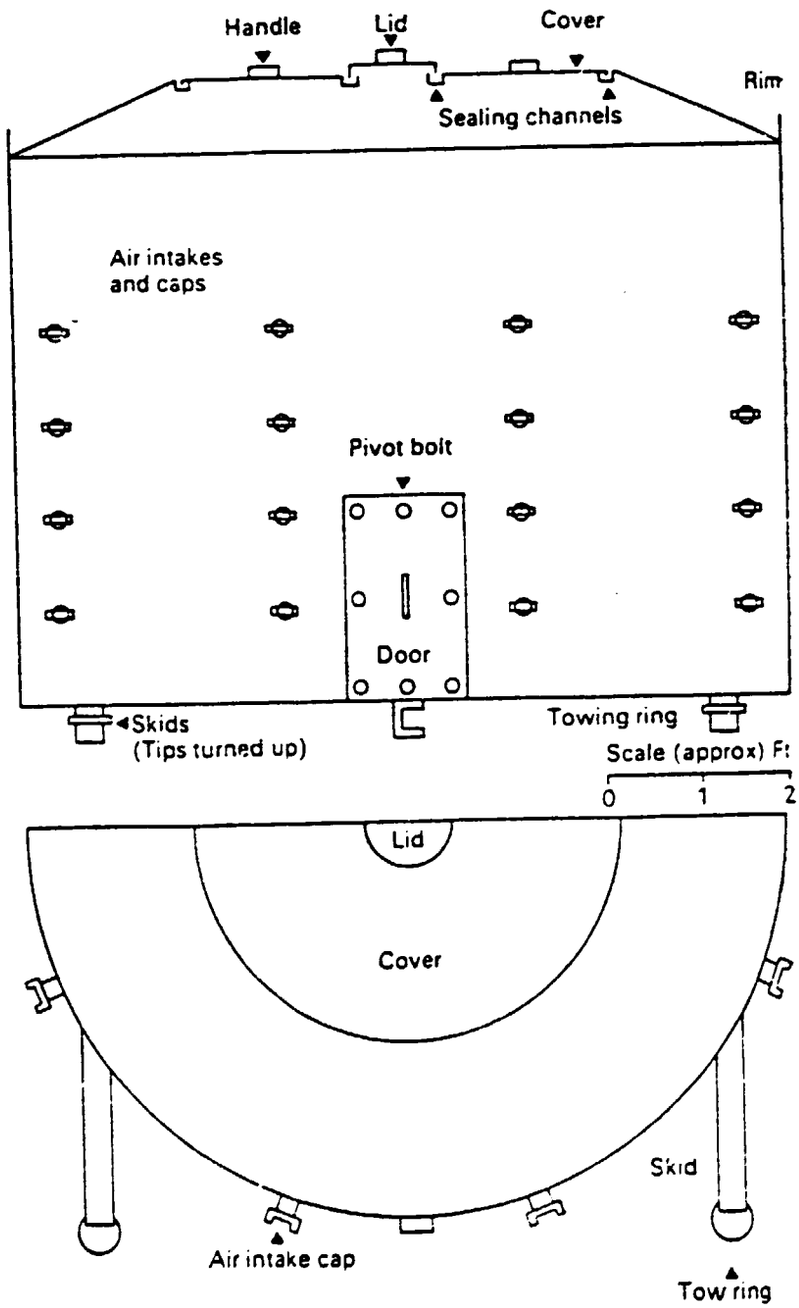
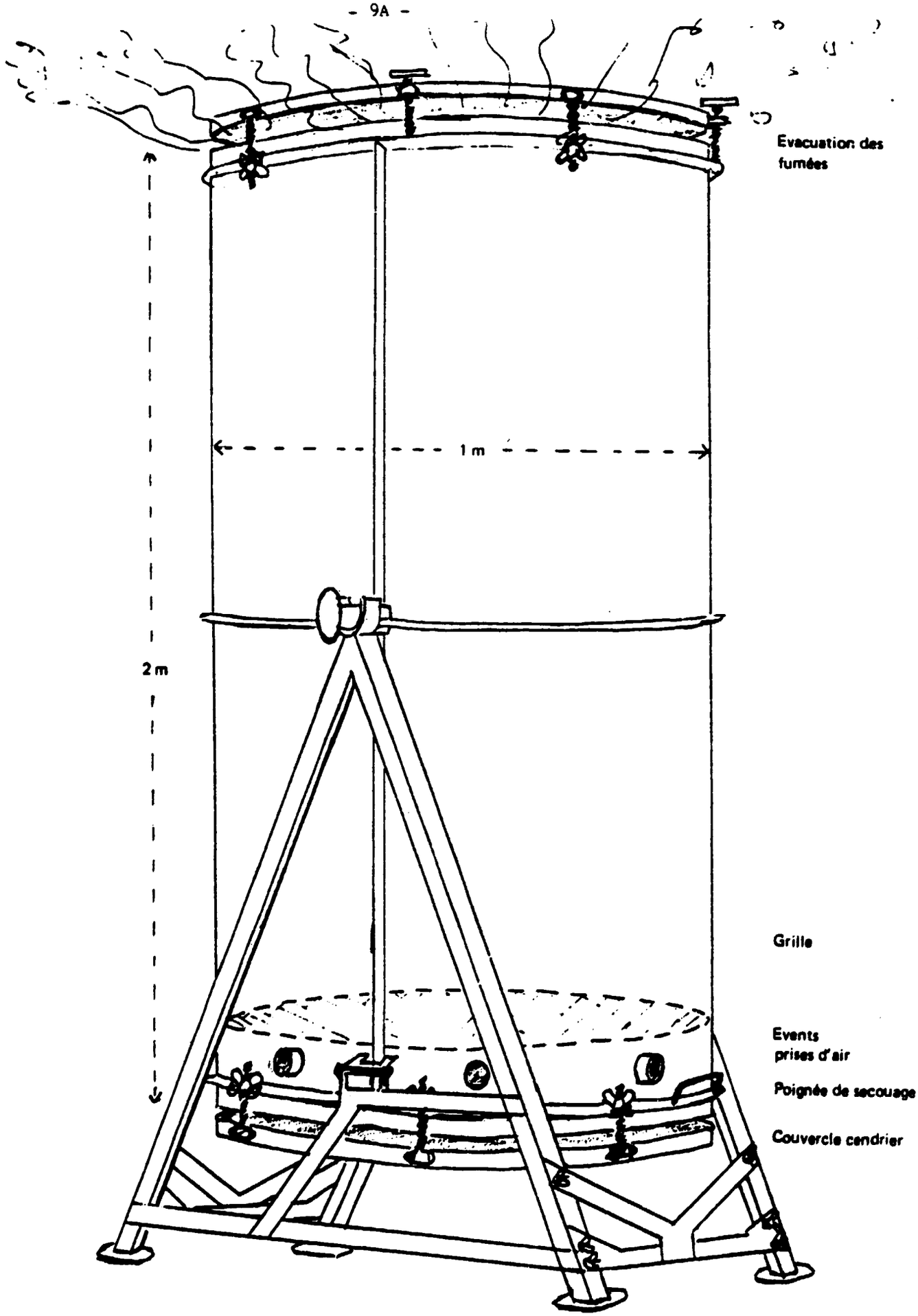


FIG. 1. The CUSAB kiln. In elevation (above); plan (below).



CUVE BASCULANTE DE CARBONISATION POUR TIGES DE COTON

Prototype C.E.E.M.A.T.

the top). Opened and then flattened drumwalls, welded together, should form the cylindrical hull, whilst the material for the conical cover could be possibly also obtained from drums. Bottom and top of the cylinder to be strengthened by steelangle 1/2". The volume was calculated to be ten times more than a single drum and it was hoped to achieve a higher bulk-density than 90kg/m³ (Graf - report page 5, para. 3.2.4.). The construction should be carried out at the workshop of RERI at the Soba site.

This decision was based on mainly three reasons:

a) to find out whether the construction would basically be difficult for an ordinary workshop.

b) to calculate the costs of the construction

c) to have the opportunity to alter/improve the design during the construction. These facilities were not expected to be available in a larger construction firm.

V. PREPARATIONS FOR CONSTRUCTION

1.0. Purchase of materials

El Sagana market, where many merchants, dealing with metal hardware, have their business, was visited. Prices of several kinds of materials from potential suppliers were compared and no great differences could be established, due to sound competition.

Five empty drums were ordered at a price of £S35.- each. The merchant offered to flatten the drumwalls for a price of £S5.- per barrel, which was accepted. Later it was discovered that this was not necessary.

Also two steelangles 1" of lengths 6m each and one flat iron (6m), thickness 4mm, were purchased at a price of £S44.-. Welding electrodes were obtained for £S17.- . Transport costs, the next day, from El Sagana to Soba amounted to £S35.- . Material for the conical cover was still not decided upon.

So, for a total of £S296.-, construction could start. (See Section XIII Annexes)

IMPORTANT: During a seminar with the American consultant for briquetting, Ben James Jr., information was given that larger workshops or construction works in which future production of kilns has to be planned, NEVER work with scrap metal as drums are considered to be. They just work exclusively with new metal sheets.

2.0. Tools

At the workshop of the RERI at the Soba site, following necessary equipment for the construction of the kiln

was available:

- one electric welder
- one acyteleńe/oxygen welder (soon to run out and therefore not used)
- hammers
- tongs
- stakes
- grinding machine
- electric steel shear.

VI. CONSTRUCTION OF THE KILNS

1.0. The Materials

As it was decided to use flattened drumwalls for the construction of the kiln cylinder, a circumference of 537cm was calculated, total length of 3 drumwalls. Thickness 1.1mm. To strengthen the cylinder and prevent it from collapsing during carbonization or rolling to other locations on top and bottom, steel-angle rings 1" were designed.

The calculation of the conical cover encountered some difficulties. It was assumed that the cover could also be constructed from flattened drumwalls, but after several calculations it became clear that at least three additional drumsheets were necessary. Moreover, the flattening, though more or less skillfully executed by the supplier, caused however some small holes in the sheets. These holes had to be closed by welding. Also large parts of the sheets should become useless after cutting out the triangle shaped sections.

Using however two brandnew metal sheets, each measuring 122 x 244 cm, the conical cover could be constructed in one piece, after welding both sheets to become one plate.

1.1. The construction of the cylindrical section

The construction started with the bending of the bottom steelangle ring. A short tube was welded on a joist and by placing the steelangle in the tube and simultaneously heating it, it could be bent bit by bit. But, it turned out that the intended circle was far from well-shaped, so a circle was drawn on the ground and iron pickets

placed accordingly. The steelangle was laid around the pickets and welded lightly onto each stake and by·doing so at the same time being brought into the correct shape.

As the top ring should be formed to a hollow rim, this steelangle had to be bent the other way, "inbound", as accordingly was done by the chief of the workshop and his assistants. Welding the flat iron around the top of the section and then attach the steelangle against the flat iron, a hollow rim was obtained.

During the work it became clear, that:

a) flattening of the drum walls had not been necessary. The two bulged rings in the drum are there to prevent collapse of the drumwalls and even these rings should be used in the kiln section for the same reason. By doing so, holes in the drumwalls caused by the flattening process will be avoided. Only 1cm of each end of a drumsheet should be accurately flattened to get a fine link between two sheets.

b) bending of steelangle can be achieved by using the circular posted stakes as was done later

c) the hollow rim on top of the section can be constructed more easily by bending the steelangle in the same way as the bottom ring and then welding the flat iron on to the steelangle.

1.2. <u>The construction of the conical cover</u>

For the construction of the conical cover, a circle with a diameter of 2m was drawn on the in para.1.1. mentioned enlargedsheet. Price of the sheets £S130.-, welding electrodes £S33.-, one length offlat iron £S15.-, transport to Soba £S35.-, so a total amount

of £S178.-. In the middle of the circle,a smaller one with diameter 30cm was drawn.

Both circles were cut out using the electric steel-scissors. Then a triangular section of the greatest circle was cut out and both ends of the circle welded together.

A vertical collar was attached to the inner circle, wherein a round metal lid was fitted. To strengthen the cover, a flat iron was welded on the inside under the rim, whereupon the metal sheet was formed round the iron.

1.3. Material and labour costs

All in all 89 working hours were spent on the complete kiln construction, i.e.

22 hrs à £S 1.50/hr = £S 33.00 chief workshop
40 hrs à £S 1.00/hr = £S 40.00 welder
27 hrs à £S 1.00/hr = £S 27.00 student/apprentice

Total labour costs	£S 100.-
Materials kiln section (section V, para 1.0)	£S 296.-
Materials cover (see 1.2)	£S 213.-
Total cost/kiln	£S 609.-

N.B.: Surplus of two flattened drums, £S 80.- in total, to be deducted. So in fact total cost is £S 529.-.

New designs for larger kiln

1.4 General

It was duly considered from the first and second trial that the prototype, the RERI-Kiln, built in the workshop of the National Council for Research at the site of the Research Centre at Soba, was too small.

To carbonize the average yield of cotton stalks per feddan, estimated at 1200 kos, it should require about 8 runs or, operating one charge per day, 8 days. As the tenant cultivates on average 10 feddan with cotton, thus 10 x 1200 kos - 12,000 kos cotton stalks, it would take 80 runs or 80 days to carbonize his complete yield.

Having at the most 60 operating days available between 31st March and 1st of June, it is evident that more voluminous equipment is necessary.

1.5 New design

Calculations showed that constructing three metal sheets, measuring 122 cm width and 244 cm length, to each other lengthwise, a circumfence of about 7.32m and a diameter of 2.30 m would be obtained. By doing so, the volume should be more than doubled compared to the RERI-Kiln, i.e. 5 m^3 to 2.3 m_3.

The idea was discussed with the production manager of Fuel Equipment Ltd. in Khartoum North, It seems that for the time being no construction firm in Sudan is experienced in handling thin - 1.5 mm - metal sheets.

FEL offered to do the job at a price of £S 1.750.-, which was considered too excessive and therefore rejected.

On the same day, the design was discussed with Monawir Engineering Works, also in Khartoum North. Messrs. Monawir and Sanhuri accepted the new design, suggested valuable improvements and proposed to construct a prototype with the desired volume at a price of costs of materials, so no labour costs involved.

Next day the proposal was accepted and it was agreed that the new kiln should be tested in another trial run, whereafter negotiations should begin concerning follow-up orders.

2.0. Construction Monawir-kiln

Construction started already the day after the first meeting, however no agreement yet existed! Within six days the kiln was completed and it was noted that not for the full period of six days the construction took place. The construction and assembling was followed with the camera as can be seen in enclosed and subtitled photographs.

Notable remarks of design and construction:

1. Sheets were seamed to one another, last seam riveted.
2. Steelangle at the bottom outside was riveted.
3. Steelangle on top inside was riveted.
4. Cover was divided in 4 equal segments, each seamed and/or riveted to the next one.
5. A flat riveted iron strengthens the cover all around.
6. The only welding concerns attachment of a flat iron ring around the top opening, which was strengthened with a round bar.

VII. FEEDSTOCK

1.0 Cotton stalks

Since around 1920, cotton has been grown in the triangle south of Khartoum between the White Nile in the west and the Blue Nile in the east. Large areas are irrigated for that purpose every year.

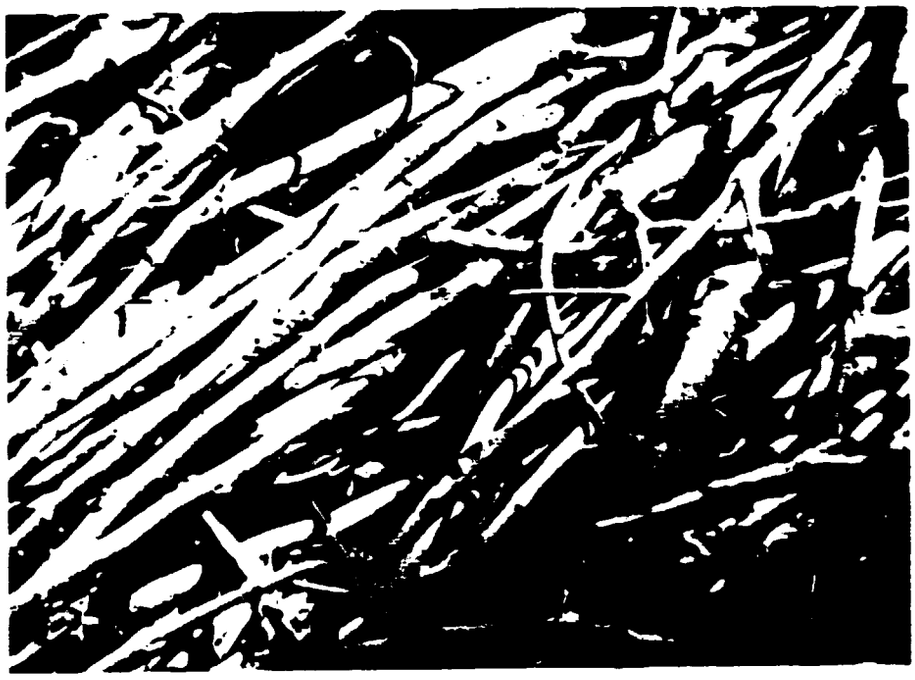
Originally a perennial plant cotton cultivation developed the plant into an annual one which can be harvested up to three times per season. After the last harvest, starting in March, irrigation is stopped and the bushy plant dies and dries within 10 to 14 days.

Until at the latest of 30th May the farmer can clear his land by pulling the plant (stalks plus roots) out of the claysoil in such a special way that the top soil is hardly damaged.

He then must collect and burn the stalks before the above-mentioned date and so contribute to the prevention of spreading the dangerous blackarm disease, which possibly could destroy the whole harvest of the next year.

The burning of the cotton stalks is executed according to a tightly controlled law, however, a certain amount of stalks is transported from the fields to the farmers' houses to be used as a fuel for cooking.

It is assumed - no reliable information in this respect is available - that of the estimated 1 to 1 1/2 million tons of cotton stalks in both the Gezira and Rahad schemes at least 75% is burnt on the fields, a sorrowful



Cotton stalks (enlarged)

loss of gigantic resources.

Stalks and roots of the plant consist mainly of the stems as thick as a thin finger and only a few branches, diameter up to about 8 mm.

2.0 Proposed use of cotton stalks

Since 1982 several studies on the utilization of this bushy waste material have been made, in some cases leading to proposals. None of these projects have been implemented so far.

Analysing the available information, all studies have one significant proposal in common: carbonization of the cotton stalks. After conversion into charcoal, several options for utilization are still open.

In close connection to the shortage of domestic fuel, the Energy Research Council, part of the National Council for Research of Sudan, decided upon utilization of charcoal from cotton stalks as a household fuel, to become a substitute for wood charcoal and firewood.

VIII. PREPARATION FOR KILNING TESTS

1.0. Availability of cotton stalks

The German organization, Gesellschaft für Technische Zusammenarbeit (GTZ) was able to obtain a considerable amount of cotton stalks during last summer. A carload of about 700 kg was transported in spite of some difficulties because of the "cottonlaw" from the Gezira Region to the Research Centre of the National Council for Research at Soba, some 20km south of the capital.

After completing the carbonization tests by Mr Ulrich Graf for GTZ (see Section XIII, 1.4.9), the German organization expressed her willingness for cooperation with the Unido-carbonization project by handing over the remaining quantity of cottons talks to the UNIDO.

2.0. Selection of the raw material

The load of cotton stalks at Soba was dumped at the site.

The stalks were pulled out of the heap by hand, and bundled, but the bundles were not tied.

All bundles were carefully weighed and the figures accordingly registered.

The initial charge of cotton stalks to be carbonized in the first trial run had a total weight of 143kg.

3.0. Filling of the kiln

For the first trial run it was decided to fill the kiln with cotton stalks in horizontal layers. So,

selection and bundling of cotton stalks

weighing of cotton stalks

4.0. Filling of the kiln

On 12.12.1985 filling of the Monawir kiln started. Because of the greater volume the -untied- bundles of cotton stalks could be spread out and pressed far more easily, which resulted in an input of 303 kos cotton stalks. The kiln was then filled for about 85% and all remaining stalks were now used, apart from ca. 40 kos, which were piled up for GTZ on her request.

It can be assumed with some certainty that, once the kiln is completely filled, the input will be near 350 kos cotton stalks. This adds up to a bulk density of 70 kg/m^3, an improvement of 15% compared to the input of the RERI-Kiln.

Also a better chimney in the middle of the kiln could be constructed.

Bundle after bundle was spread out in the uncovered kiln, placed on three bricks, thus forming three large air-inlets at the bottom. The stalks were pressed as much as possible in order to obtain the highest possible filling.

The very light material however showed to be very springy and after much pressing and filling up all the empty spots and holes between the bundles, only a disappointing bulk density of 60.1 kg/m^3 could be achieved.

In the middle of the kiln a plank was placed vertically to create a vertical column to be used as a chimney.

Time of sorting out the stalks, bundling, weighing and filling the kiln was recorded at 50 minutes. The authors and some labourers, the latter only partly, were involved in this activity.

Total input 143 kg.

IX. TESTS AND DEMONSTRATIONS

1.0. First trial run

On the 30th November 1985 the first trial run with the RERI-Kiln was undertaken . Weather conditions were fair, bright with soft S to SE breeze.

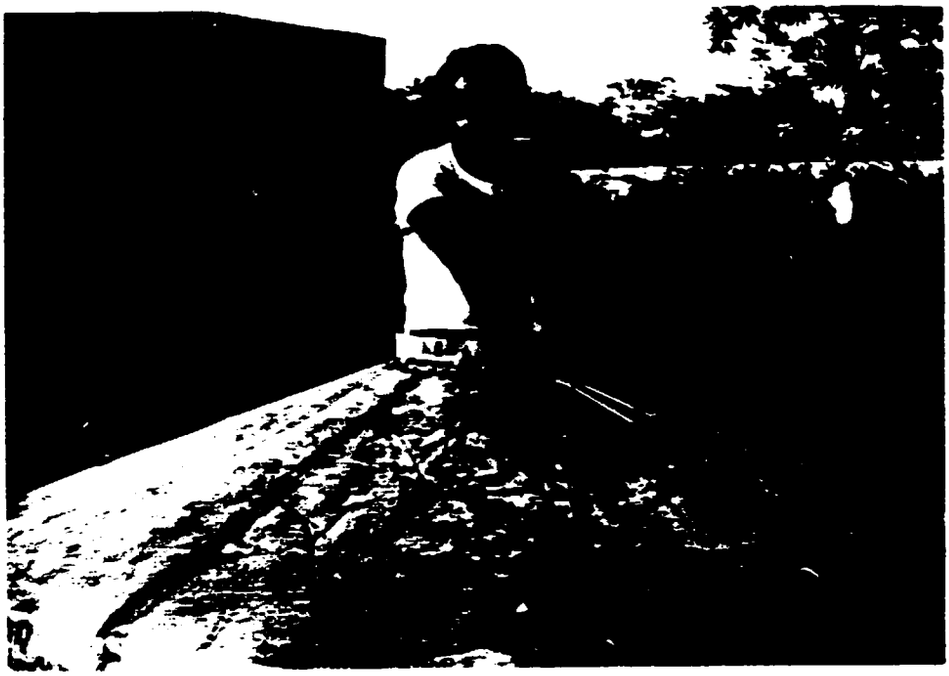
After one minute the lid was placed on the cover and soon enormous clouds of white/yellow smoke were belching from under the cover .

After five minutes carbonization found its way down to the bottom of the kiln, however not through the chimney, but over the cotton stalks downwards along the kiln-wall.

To control the beginning of carbonization, the hollow rim and the lid on the cover were sealed with clay and sand was shoveled to the bottom, closing completely, apart from three air-inlets, the windward and at the same time enabling the heavy carbonization smoke to escape[10)].

Slowly the carbonization went round anti-clockwise and each time sand was stowed to the bottom of the kiln whenever the stalks were observed burning at that spot during several minutes.

Before the kilning operation it was decided that the carbonization process should be controlled more or less "over"cautious because of not knowing exactly how the stalks would react, being stowed horizontally and in a far greater volume than was executed by others before.



start 1st trial run with RERI-kiln

after one minute

After two hours and 28 minutes the carbonization was considered complete, the last smoke outlet was closed and the hollow rim and all possible oxygen inlets on cover and kiln section were sealed with clay .

2.0. The second batch

This time the cotton stalks were piled vertically, a more difficult method of filling in which it was not possible to deliver the maximum pressure when stowing. Moreover, it was necessary to crush with utmost force the cotton stalks into the kiln using the plank as a thresherbat . A total amount of 132 kg was the input, achieving a bulk desnity of 63.8kg/m^3.

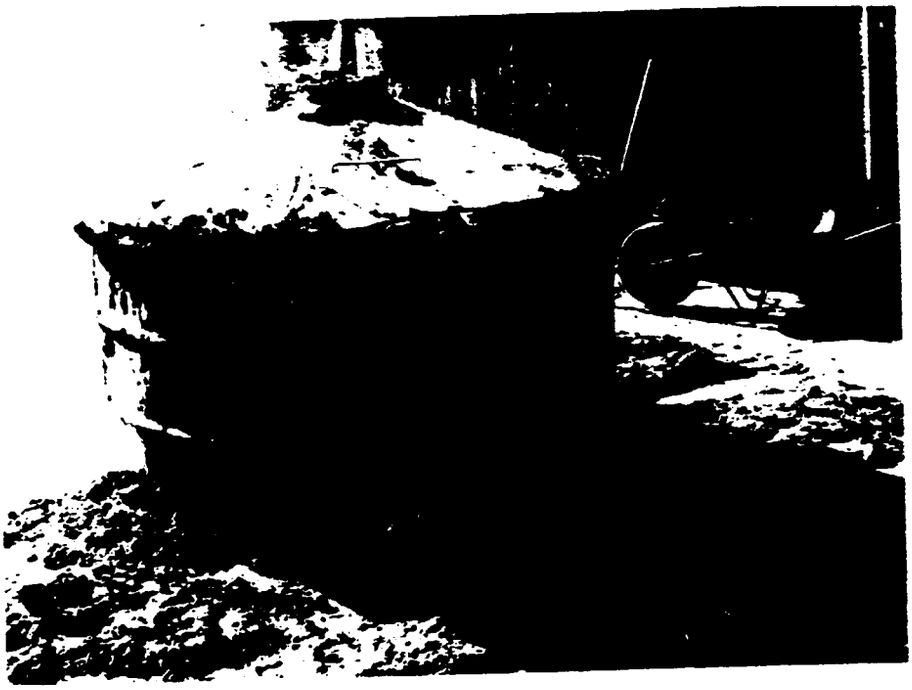
Due to this crushing, the tops of the stalks were smashed and landed at the bottom of the kiln, becoming small brands and a hindrance for charring and sacking afterwards.

Weather conditions were not favourable on this 2nd December 1985; however bright, there was a strong wind blowing from several directions.

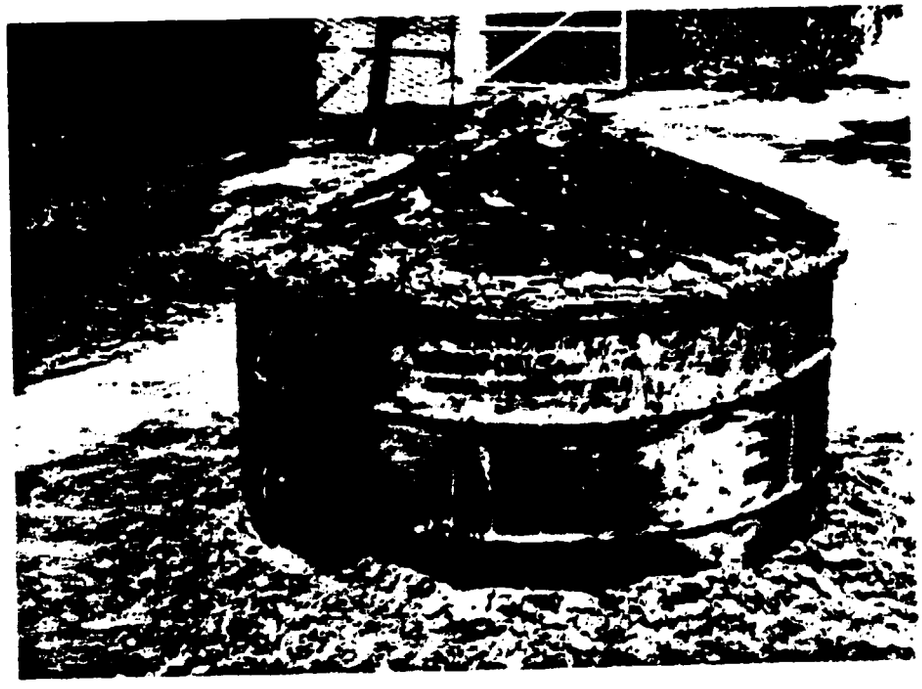
To moderate the unpredictable effects of this light gale, the bottom of the kiln was completely closed with only two small air-inlets and one larger smoke outlet. Beyond that, all measures taken when executing the first trial run were accordingly carried out.

Yet, carbonization went round considerably faster than during the previous batch and also far more inconstant, breaking through and then stopping at one spot and continuing at another.

To be certain that charring was conducted completely, some channels already closed were opened again to



control of carbonization



sealed cover and kiln section

obtain recombustion for a short time.

Finally, after two hours and 4 minutes carbonization was terminated and the kiln clay-sealed as usual.

During both operations cooperation beween counterparts was excellent, each move thoroughly discussed and performed.

Plank as thresherbat

1.0. At 08.30 hrs on 14.12.1985 the third trial was lit. Wheater conditions: temperature 25.2 Centrigrade, humidity 38%, wind velocity 8.39 miles/hr.

Before 8 smoke- and airchannels were constructed radially.

Combustion teached the bottom after 30 minutes, carbonization-heat colored the kiln sheet steelblue and caused a temporary indent .

As the cap was sealed, the carbonization went round clockwise - too fast actually, so two air inlets were closed. As a control on the slowing down process two improvised smokestacks 110 mm diameter were installed in the east and west channels , closing at the same time a third air inlet.

After two hours carbonization was halfway, as was expected, but was obviously hindered by the insufficient escape of carbonization smoke through the smoke stacks. Charring was then ceased and the charcoal removed after a cooling-down period.

On the 20th December after the return from the Rahad mission, carbonization was resumed. The process went by normally and was terminated after 1 hr 48 minutes.

After closing the kiln was ventilated for 30 minutes. The transparent smoke emerging from the top changed from light grey into dark blue .

X. RESULTS

1.0. General

1.1. Both carbonizations were followed by a guarded cooling period of more than ten hours, a period considered more than sufficient.

1.2. The abundant sealing with clay proved to be very effective as not a single airleak was found.

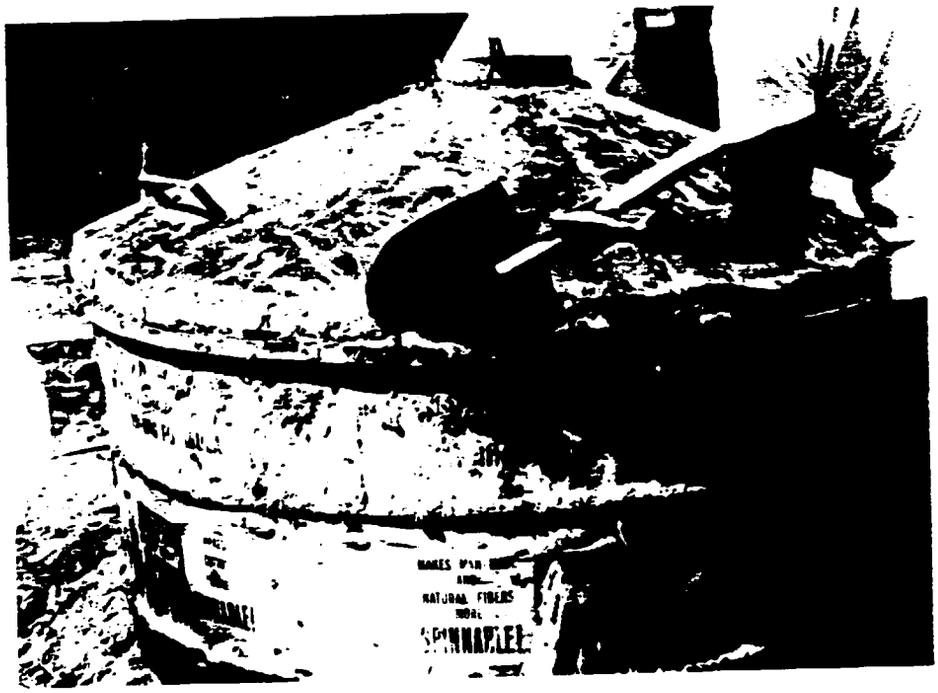
1.3. Warm winds and/or sunradiation are drying the wet clay in no time into a hard crust, which can only be removed with shovel and pickaxe .

1.4. After lifting the kiln it was estimated that the kiln volume was filled up to 60% with cotton coal, regardless of the method of piling.
The amount is far less when manufacturing wood charcoal.

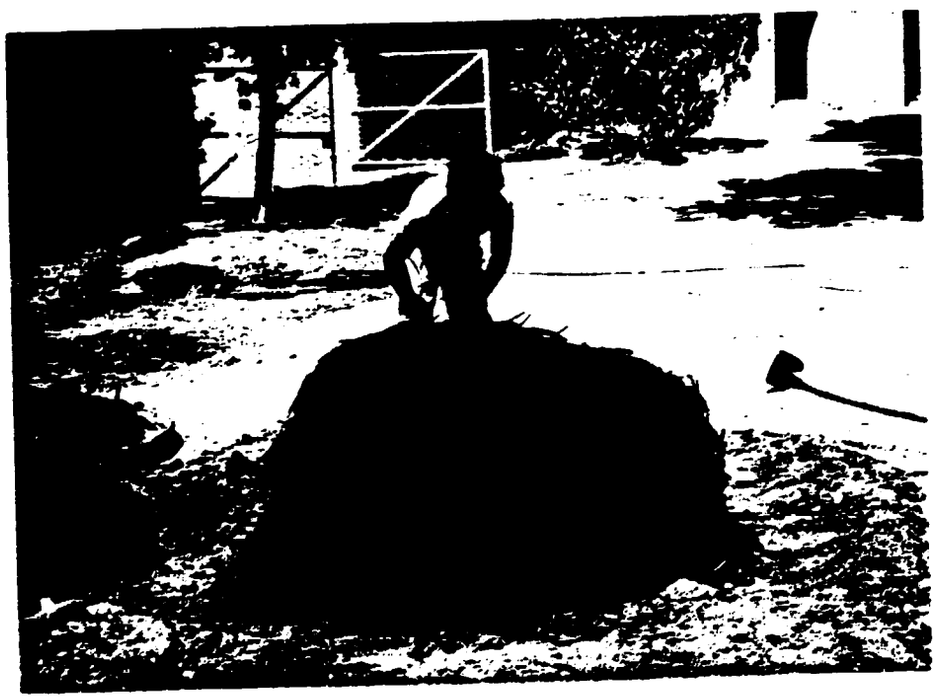
1.5. The stalks kept their original and natural shapes and did not shrink excessively. Sacking was only possible by breaking a bundle of charred stalks at one or two places.

1.6. A thin layer of loose tar covered the stalks on top of the heaps and kiln walls.

1.7. Remarkably few brands (uncharred stalks) were found, (approx. 1%).



removal hard crust of clay



stalks keep their natural shapes

1.8. The percentage of fines - charcoal pieces measuring less than 10mm either length or width - can be judged low.

2.0. Results of first trial run

Input : 143 kos cotton stalks
Bulk density: 68.1 kg/m³
Piling : horizontally
Yield : 46.7 kos cotton coal, gross weight
Packing : nylon sacks 0.7 kos tare
Net yield : 46.0 kos cotton coal = 32%
Brands : 1.6 kos = 1.1%
No fines
Carbonization time: 2 hours 28 minutes
Date of trial : 30.11.1985
Date of opening and sacking: 01.12.1985

3.0. Results of second trial run

Input : 132 kos cotton stalks
Bulk density: 63.8 kg/m³
Piling : vertically
Yield : 47.8 kos cotton coal = 36.2% incl. fines
Brands : 1.2 kos = 0.9%
Fines : 3.5 kos = 2.6%
Carbonization time: 2 hours 4 minutes
Date of trial: 02.12.1985
Date of opening and sacking: 04.12.1985

3.1. Remarks

3.1.1. Carbonization of second batch considered less simple and complete compared to first batch.

3.1.2. Yields of fines second charge due to crushing of the cotton stalks when filling the kiln.

3.1.3. Carbonization time second charge influenced by occurence of strong wind.

All in all: The results of these tests were considered "promising".

4.0 Results of 3rd trial run

Input : 303 kos cotton stalks = 85%
Bulk density: 71.3 kg/m3
Piling : horizontally
Yield : 96.2 kos cotton coal = 32%
Brands : 0.6 kos = 0.16%
Fines : 3.8 kos = 1.3%
Carbonization time: 5 hrs 10 minutes in total
Date of trial: 14.12 and 20.12.1985
Date of opening and sacking: 15.12 and 21.12.1985

XI. CONCLUSIONS

1.0. Carbonization of cotton stalks is feasible as proven in two small-scale and one larger tests, the latter to be recorded in the final report.

2.0. Carbonization of cotton stalks is feasible even if the nature of the soil as favourable as at the site of the Research Centre of the National Council for Research at Soba, provided the soil of future carbonization locations is clayish or sandy.

3.0. The designed and constructed kiln, although proven fully satisfactory, was nevertheless considered too small. Given the average yield of cotton stalks per feddan, estimated at 1200 kg, the kilning equipment has to be large enough to carbonize this quantity in three or four charges. Only then a reasonable production of cotton coal within 60 days is possible.

4.0. Taken this into consideration a larger kiln was designed and constructed within five days by Manowir Engineering Works at Khartoum North. The management of MEW proposed to construct and deliver this kiln as a prototype only at costs of material. This proposal was accepted.

4.1. With this kiln, having a volume of $5m^3$ instead of $2.2m^3$ of the original RERI-kiln, a third trial run was made on 14th December 1985.

4.2 This kiln of simple yet well thought-out design and construction - mostly riveted - will be subject to durability tests, among them pretty rough handling.

5.0 the simplicity of the equipment enabled the kilning techniques to be kept simple.

5.1 A manual for carbonization with this type of kiln in Arab language is desirable and is attached.

6.0 To improve the quality of the "cotton coal" as much as possible, further trial runs are necessary. Due to limited availablity of stored cotton stalks at the Research Centre only three tests were carried out. Use of controlling equipment should help in attaining this objective.

7.0 The rough working plan of 8/11, revised and elaborated on the 25th November, was kept up very strictly in excellent co-operation between counterparts.

XII. RECOMMENDATIONS

1. Order construction of eight more kilns according to Monawir design and/or RERI design.

2. Conduct sufficient demonstrations and field tests in the Rahad schem according to agreed detailed programme, starting March/April 1986.

3. Carbonization to be executed by three categories operators
   a) individual farmers
   b) tenant's union
   c) entrepreneurs

4. Provide adequate controlling equipment for the carbonization process as well as analysis of the charcoal product.

KHARTOUM, Sudan 30 December 1985
DR. A.H.M. Hood

VIENNA, Austria 30 December 1985
A. Zorge

XIII ANNEXES

1.0. Senior counterpart staff

Dr. El Tayeb Idris Eisa
Coordinator Sudan Renewable Energy Project (SREP)
Director, Energy Research Council

Dr. Ahmed Hassan Hood
Researcher Renewable Energy Research Institute
Energy Research Council

Gaafar El Faki Ali
Assistant Coordinator SREP
Energy Research Council

2.0. Materials provided by UNIDO (see also enclosed receipts)

Date	Materials	Price in £S	No. Invoice
11.11.85	1 packet electrodes	17.-	981
	steelangle 1 1/4 2 lengths	29.-	401
	flat bar 1 length	15.-	-
	5 empty barrels	175.-	4
12.11.85	opening + flattening	25.-	5
	transport costs	35.-	3
20.11.85	2 metal sheets 244x122	130.-	1733
	flat bar 1 length	15.-	-
	2 packs electrodes 2 1/2mm	33.-	-
	transport costs	35.-	8
21.11.85	oxygen + acetylene cyl.	120.-	11204
01.12.85	shovel	13.-	-
11.12.85	kiln new design	590.-	989
	transport costs	200.-	1806
16.12.85	labour RERI-kiln	100.-	-

1.

40

مغلق عبدالله مكى

للوازم البناء

بسوق السجانة

№ 000981

تلفون ٤٣٣٩ ص.ب ١٩

التاريخ ١١ / ١١ / ٨٥

مليم	جنيه	البيـــان	ملحوظه
		باكو لحام	
	17	One paeket of welding bars	
		صاكـــــحب	

بسم الله الرحمن الرحيم

مغلق دنقلا من قطاعي المساهمة

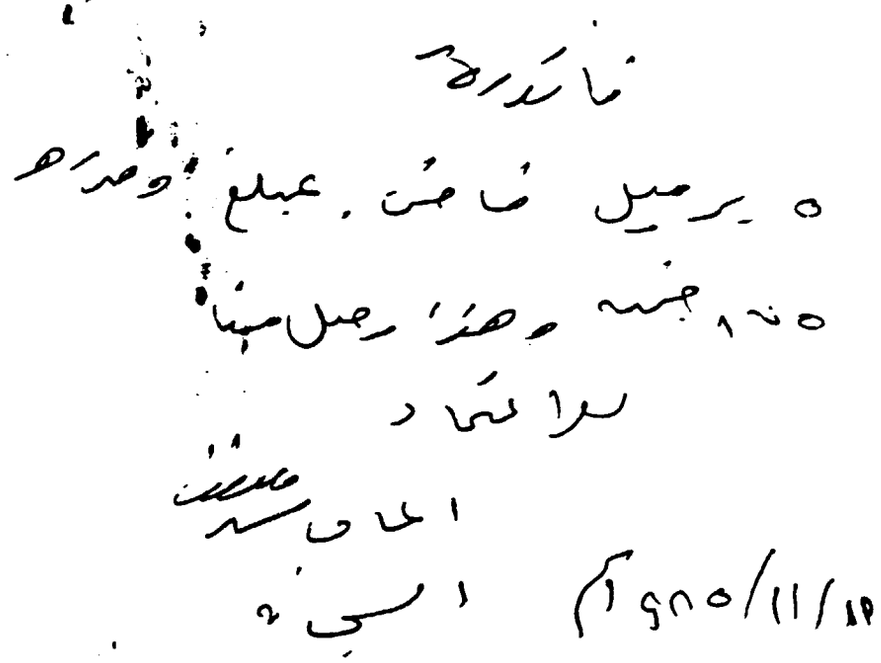
الوازع البقاء

بسوق السمانة

تلفون ٤٤٣٢١ - ص ب ١٩

2

صدر	البيان	عدد	جنيه	ملم
14.5	Angle 1¼	2	29	
15	flat bar	1	15	
	Total		44	



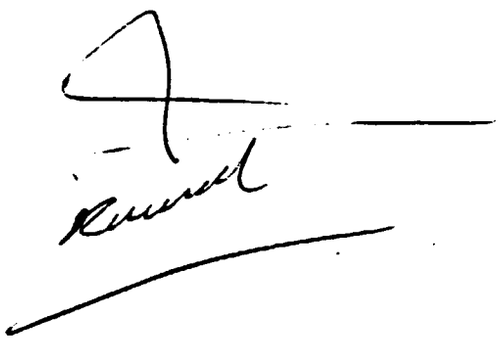
Reciept

empty barrels 5 x 35 ; LS 175
Signed by EL MAHI Mohamed Mustafa
EL SAGANA Market
11-11-1985

[1980/11/12

5

Co



Reciept

Opencing and flatencing 5 empty barrels
5 X 5 = LS 25
Signed by Idris Mohamed
EL Sagana Market
12-11-1985

١٩٨٥/١١/١٢ 3

انا جارالله ابراهيم صاحب السيارة نمرة
نمرة خ ت 7357 قد حملت صديد صابح ونزوى
الى مقر سكن اسرة اسافة بسوبا
بمبلغ قدره (٢٥ ح) خمسة وعشرون
جنيه لا غير

جار الله ابراهيم

Reciept

Transoort of flatened empty barrels

2 angles
1 flat bar
From saqana market to RERI
Site to Soba for the summer of LS 35.
Signed by - GADAHA Ibrahim
Deriver of car No KT 7357
12-11-1985

بسم الله الرحمن الرحيم

مغلق دنقلا للوازم البناء

بسوق السجانه

من انطاعي المسدالله

تليفون ٤٤٣٢١ - ص ب ١٩

التاريخ ٢٠/١١/١٩٨٥ سنة ١٩

المطلوب من حضرة / [illegible] اقرص ١٧٣٣٠٠٠

الخرطوم جنوب

سعر	الصنف	عدد	جنيه	مليم
	الواح صاج ٤×٨	٢	١٣٠	—
	واحد خوص	١	١٥	—
	[illegible] ٣٣	٢	٣٣	
	جملة		١٧٨	
	[illegible]		١٧٨	
	٣٣			
	Metal sheets	2	130	
	Flat metal bar	1	.15	
	Welding bars package	2	33	
	Total		178	

بسم الله الرحمن الرحيم

<u>إيصال</u> ٤/١١/١٩٩٥

أنا احمد محمد مصطفى صاحب العربة تايوتا بوكس رقم خ 6055 اشهد بأني قد رحلت عدد ٢ لوح صاج وواحد قدس من سوق السجانة الى مقر معهد ابحاث الطاقة المتجددة بسوبا بمبلغ قدره -/٣٥ج (خمسة وثلاثون جنيه) 8-

وهذا للاشهاد

احمد محمد مصطفى

احمد محمد مصطفى

Receipt:

Transport of 2 metal sheets and one flat metal bar from Sagana Market to RERI site at Soba.

Cost Ls 35

Signed by: Ahmed Mohd.

Car No: K 6055

47

شركة الاسيتلين والاكسوجين الحديثة المحدودة

THE MODERN ACETYLENE & OXYGEN CO. LTD.

6

تلغرافيا (لحام)
ص.ب ٢٩٢ الخرطوم بحري
تلفونات ٣٤٤٨٧ - ٣٤٦٠٦ - ٣٤٥٩٦

TELEGRAMS : LEHAM
P. O. Box ...
Tel. 34...

الخرطوم بحرى
KHARTOUM NORTH

Date 24-11-85 التاريخ

CASH

No. ______ النمرة

Ref. ______ المرجع

INVOICE № 11204 فاتورة

To جمهورية الطاقة ال

Order No. ______ نمرة الطلب

الكميه Quantity	السعه Capacity	العدد Total Cap	DESCRIPTION البيان	Value القيمه LS.	m/ms	مجموع الكلي Total LS.	m/ms
٢	٦	٦	Oxygen cylinder ٥X 0 1	٣٩١٠		٢٧٣٧	١١٢٩٩
١	٦	٦	Acetylene cylinder AC 0 1	١٢٥٠٠		٨٧٥٠	٣٩٩٠
						١٢٠	٥٠

The sum of [redacted] مبلغ وقدره

Delivered مستلم Returned مرتجعه			Delivered مستلم Returned مرتجعة			Delivered مستلم Returned مرتجعة			Delivered مستلم Returned مرتجعة		
نمرة الاسطوانة Cl. No.	الغاز Gas	ع Cap	نمرة الاسطوانة Cl. No.	الغاز Gas	ع Cap	نمرة الاسطوانة Cl. No.	الغاز Gas	ع Cap	نمرة الاسطوانة Cl. No.	الغاز Gas	ع Cap
			٥X٦			٥X٦					
			١٥٠٨			٥٢٢٣					
			١٥٠٦			١٥٠٦					
			٥٢٤٩			٥٢٢٣					

Received Correct تسلمت كاملا

Received By سلمت بواسطة

امضاء المستلم · Checked ______ دقق ______

M '05

... PARTS

Reciept: 4/12/1985

4 spark plugs Ls 13.50

Car No : 3685

48

Reciept: 1/12/85

1 Shevel Ls 13,00

[redacted]

Monawir Engineering Works

HEAD OFFICE : KHARTOUM NORTH
P. O BOX 2125 KHARTOUM
TEL. 34108—34110

DESIGN & CONSTRUCTION TO B. S.
ASME & DIN STANDARDS
SUDAN

CABLES : MONOSTEEL KHARTOUM
WORKS : KHARTOUM NORTH
TEL. 34108—34110

INVOICE .N: 000989 KHARTOUM 21/12/85

M Energy Research Council Dr.

2 Nos	Steel plate 4×8 Ft × 1.1mm @ 63	126.—
3 "	" " 4×8 Ft × 1.5mm @ 120	360.—
3 "	Angle 30×4×6m long @ 20	60.—
2 "	flat 30×4 @ 22	44
	Total	590.—

(only Five Hundred and ninety Pounds)

No. 30

Paid

E. & O E.

MONAWIR ENGINEERING WORKS

RECEIPT VOUCHER

No. 001806

Date 21.12.85

Received From Energy research Council

	L. S.	m/ms
The sum of only two hundred pounds	200	—
Being Transport of charcoal kit from Wharf to Suba		
TOTAL	200	—

Signature of Cashier [signature]

Approved [signature]

M. 31

3.0. Company visits

02.12.85 Fuel - Equipment Ltd.
Khartoum North
concerning: kiln construction

02.12.85 Monawir Engineering Works
Khartoum North
concerning: kiln construction

Mr. Monawir owner and managing director
Mr. Sanhuri chairman board of directors
Mr. Arbab general manager

4.0. List of references

4.1. "Gasification of Agricultural Residues"
by: Fritz Werner Industrie-Ausrüstungen GmbH.
Geisenheim, West Germany
Draft Final Report
for: United Nations Industrial Organization
Division of Industrial Operations
Ref.: SI/SUD/82/802

4.2. "Utilization of Biomass" (PN 79.2066.3)
Phase I: Literature Survey and Project Proposals
February 1985
Decon-Study for: German Agency for Technical Cooperation
(GTZ) Ltd.
in Special Energy Programme (SEP) Sudan

4.3. "Utilization of Biomass" (PN 79.2066.3) August 1985
Phase II: Results of Field Study with detailed Project
Proposals June 1985
Decon-Study for: German Agency for Technical Cooperation
(GTZ) Ltd.
in Special Energy Programme (SEP) Sudan

4.4. Chaitre X - Preparation du combustible
9.1. Charbon végétal
du Document CEEMAT "Mise au point d'une
cuve carbonisation portative pour tiges
de coton"

4.5. "Charcoal Marketing and Production Economics in the
Blue Nile", August 1985
by: Gaafar El Faki Ali
for: National Council for Research; Energy Research Council
Sudan Renewable Energy Programme; Sponsored by USAID

4.6. "Renewable Energy Assesment for the Sudan" September 1982
by: National Energy Administration
ME & M/USAID Energy policy and planning project
International Science & Technology Institute, Inc.
Energy Development International
for: Ministry of Energy and Mining

4.7. "A Preinvestment Study for Fuel Production from Agricultural Wastes for Power Generation and Household Consumption". Final Report, December 1983
by: SWECO
for: Ministry of Energy and Mining
National Energy Administration

4.8. "Camun El Duga" Improved Charcoal Stoves for the Sudan December 1984
by: Gaafar El Faki Ali, Director Technology Development and Dissemination Unit RERI
Claudia H. Huff, Dissemination Consultant
Georgia Tech. Research Institute
for: National Council for Research, Energy Research Council, Sudan Renewable Energy Project

4.9. "Small scale Carbonization of Cotton Stalks" 1985
by: Ulrich Graf, Bremen
for: Special Energy Programme Sudan
GTZ in Cooperation with Energy Research Council

4.10. A Feasibility Study on the Charcoal Gasifier Project for the Public Works at Isangel, Tanna, Vannatu (New Hebrides) August 1985
by: L.H. Tjeng
Biomass Technology Group
Twente University of Technology
Enschede, The Netherlands

for: The South Pacific Bureau for Economic Cooperation
Suva, Fidji
The Department of Geology, Mines and Rural Water Supply, Port Vila, Vanuatu

4.11. "Family Cooker"
Manual for the fabrication of an energy-saving stove.
November 1982
by: J.C. Overhaart
for: Eindhoven University of Technology
Eindhoven, The Netherlands

4.12. Bioenergy Systems Report
June 1982: Thermochemical Conversion of Biomass for Energy
by: Dean B. Mahin International Energy Projects
Front Royal VA U.S.A.
for: Bioenergy Systems and Technology Project of USAID

4.13. "CHARCOAL" A Report on Charcoal 1974
by: D.E. Earl Andre Mayer Research Fellow
for: Food and Agricultural Organization of the United Nations

4.14. "TDRI Work on improved charcoal production"
Publications by: A.R. Paddon TPI
for: Tropical Development Research Institute U.K.

4.15. Report on The Study of the Utilization of Agricultural Residues as a Source of Energy in the Sudan.
"Cotton Stalks" October 1983
by: Dr. Ahmed Hassan Hood
for: United Nations Industrial Organization

and I read them all.

5.0. Report on meeting with management board at Rahad

On 17th and 18th December a visit was paid to the Rahad Scheme. This area, situated south of the road Wad Medani - Gedaref, is an irrigation scheme installed in 1978 and has a lower population density than the Gezira Scheme.

The Energy Research Council had alloted the Rahad Scheme for the proposed field tests in 1986.

After preliminary talks on the 17th with Mr. Badr El Din, forester, acting as counterpart on behalf of the Rahad Scheme, wherein all aspects of the project once again were thoroughly discussed, a full meeting with the Board was organized on the next morning.

Dr. Hood gave an outstanding dissertation on:

a) conversion of cotton stalks into charcoal during tests and demonstrations at Soba
b) the field tests and demonstrations as intended for March and April 1986 in the Rahad Scheme
c) the equipment used
d) the charcoal from cotton stalks regarding quality and quantity
e) the introduction and use of the new stove design, canun el duga.

Dr. Hood ended with an appeal to the Board for overall support, especially were introduction tc the farmers was concerned.

After the UNIDO-experts had answered a number of questions from all members of the board and given an ample explanation of the photographed carbonization process, the board unanimously promised without any hesitation the overall support as was asked for,

By some lucky chance there was a meeting of representatives of the board with a group of farmers this very morning.
Permission was asked and granted to address the farmers in order to inform them about the workplan for March/April next year. An extensive presentation and demonstration of both the charcoal from cotton stalks and the canun el duga followed. Also a large number of photographs of the carbonization process at the Soba site were shown. All farmers, without exception, listened with sincere interest and much approval to the speech in Arabic of Dr. Hood. At the end they just stated:

"Bring your kilns and show us the techniques, and we'll supply the stalks".

6.0. Manual

General information

The kiln consists of 3 parts:

I the cylinder
II the conical cover
III the little cap on the cover

Filling

1. Place the cylinder on 3 or 4 bricks
2. Place a stem or plank of about 1.50 m height in the middle
3. Fill the kiln with cotton stalks to be spread out horizontally
4. Press the cotton stalks by dancing on them
5. When the kiln is filled completely add more stalks up to 15 cm over the rim
6. Place the cover on the stalks

Carbonization

1. Throw a handful of burning paper/gras/pieces of cotton stalks through the top opening in the kiln
2. When flames are visible in the opening, close the opening with the lid. Yellow/white clouds will emerge from under the cover
3. When the stalks at the bottom start to burn, wait 3 minutes before closing this spot with sand
4. The fire at the bottom will go round. Wait each time 3 minutes before shoveling sand
5. When the fire has gone round completely, control the shoveled sand at the bottom
6. Seal the cover with clay
7. Remove the lid from the top opening. Grey smoke will emerge
8. When the smoke becomes blue close and seal cap

Sacking

1. Control if there is still fire inside by putting a hand on several places of cylinder and cover
2. Remove sand and clay from cap, cover and cylinder
3. Remove cover; inspect the charcoal
4. Lift cylinder and roll cylinder aside
5. Start sacking but put uncharred stalks aside

٦٢

المجلس القومي للبحوث
مجلس ابحاث الطاقة
مشروع انتاج الفحم من سيقان القطن

دليل تشغيل الفرن

١- معلومات عامة :-

يتكون الفرن من ثلاثه اجزاء

أ- اسطوانه

ب- غطاء مخروطي مخرومة من اعلى.

جـ- غطاء صغير

٢- طريقة ملئ الفرن بسيقان القطن :-

١- اضع الفرن فوق ثلاثه اوابعه قطع طوب
٢- اضع عود حوالى ١,٥ متر فى وسط الاسطوانه
٣- ابدأ ملئ الفرن بسيقان القطن بضمها اقيا
٤- اضغط سيقان القطن داخل الفرن (عن طريق اللعب طيها) واستمر فى اضافة سيقان القطن الى ان يمتلئ الفرن .
٥- عند امتلاء الفرن بسيقان القطن حتى الحافه العليا، استمر فى وضع السيقان حتى تكون على ارتفاع ١٥سم من الحافه العليا للفرن .
٦- اضع الغطاء المخروطى .

٣- الكربنه (حرق السيقان الى فحم) .

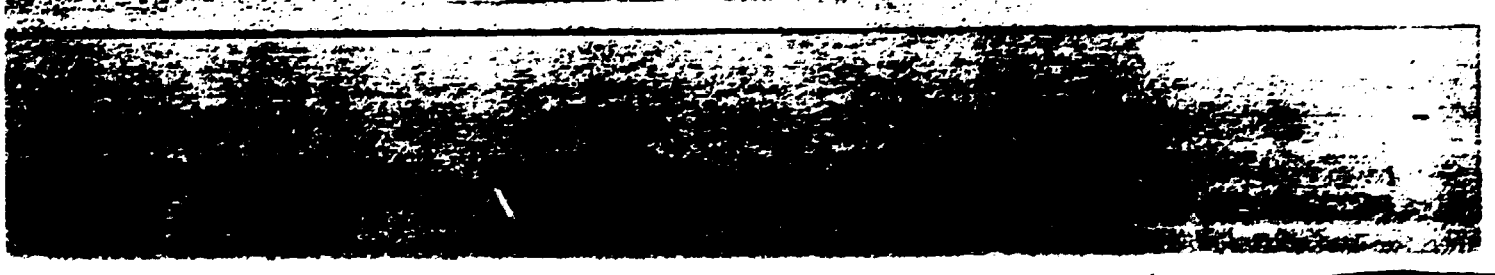
١- اضع قدر من الورق وحشائش او سيقان قطن فى الفتحه العليا للغطاء المخروطى
٢- اشعل الفرن من اعلى وعند ظهور اللهب باقفل الفتحه العليا مستعملا الغطاء الصغير وفى هذه الحاله يخرج سحب من الدخان الابيض او مائل للاصفرار من تحت الغطاء المخروطى.
٣- عليه حرق السيقان الى فحم يبدأ من اعلى الفرن الى اسفله وعندما يصل الكربنه الى اسفل الفرن يبدأ السيقان فى الاشتعال . عندما يظهر اللهب من اسفل الفرن انتظر هذا اللهب لمدة ثلاثه دقائق ثم اقفل الفتحه بواسطة التراب .
٤- ان اللهب فى اسفل الفرن سوف يستمر دائما حول الفرن بعد قفل الفتحه الاولى . فى كل حاله انتظر لمدة ثلاثه دقائق قبل قفل الفتحه بالتراب
٥- عندما يكتمل دوران اللهب فى اسفل الفرن ،تأكد من قفل الفتحات جيدا بالتراب .
٦- تأكد من قفل الفتحات فى الغطاء بواسطة التراب.

٦٣

٧ـ افتح الغطاء الصغير فوق الغطاء الخزفي ـ سوف يظهر دخان وادى
٨ـ عندما يتحول لون الدخان الى اللون اللبنى اقفل الفحم واحكم القفل
با ستعمال التراب ٠

٤ـ التعبئة ٠

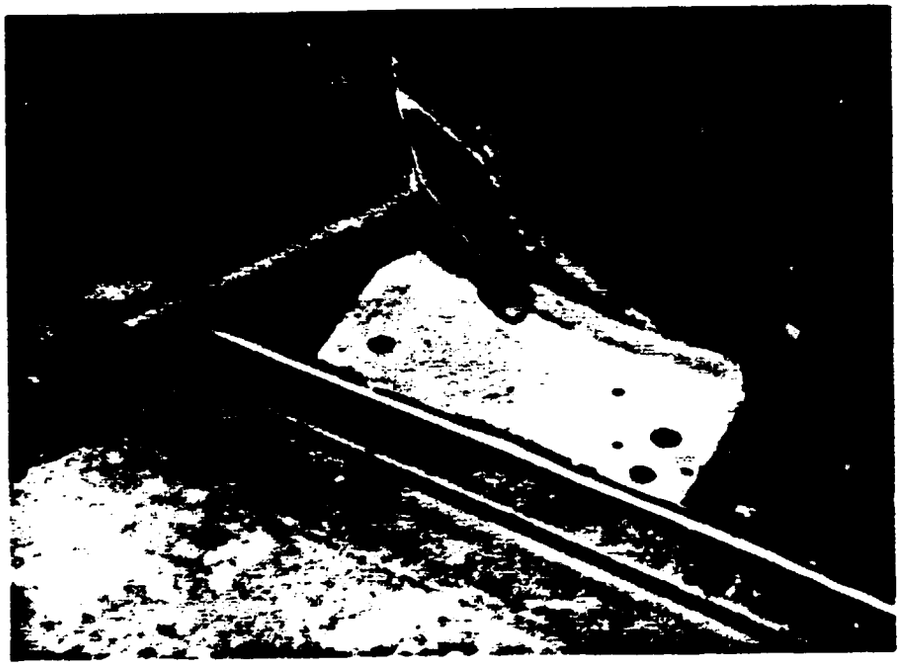
١ـ اترك الفرن لفترة كافيه من الزمن حتى ينخفض درجة حرارته (حوالى عشر
ساعات) ٠ يمكن التأكد من برودة الفرن بوضع اليد فى عدة اماكن
من سطح الفرن ٠
٢ـ انزع التراب من اسفل الفرن والغطاء
٣ـ افتح الغطاء
٤ـ ارفع الفرن واضعه جانبا
٥ـ ابدأ تعبئة الفحم وبكن مثل السيقان غير المحروقة ٠



7.0. Photographs

top- and bottomring Monawir-kiln

seamed metal sheet 122 x 244 cm



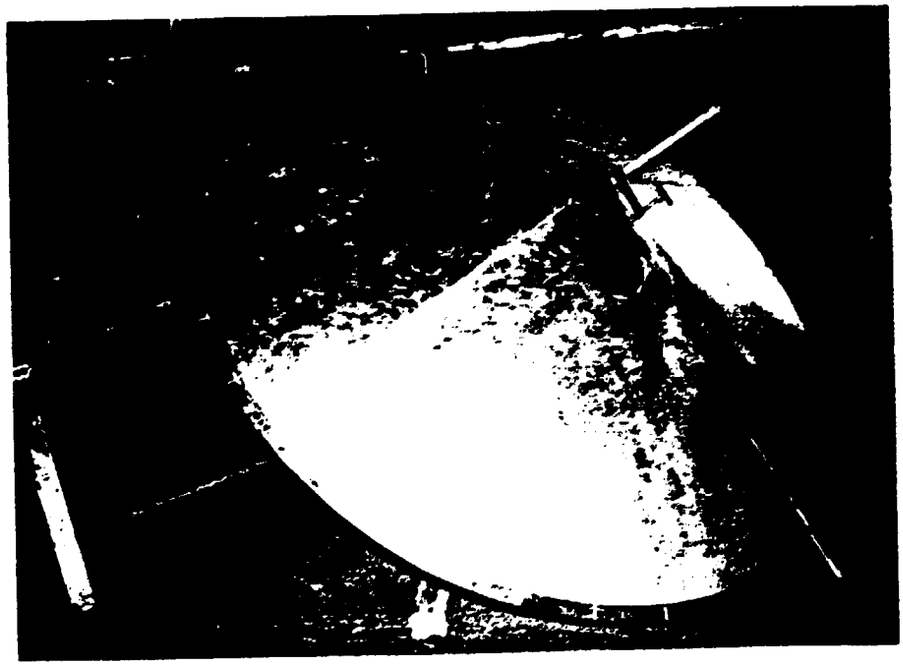
manufacture of a seam

placing the kiln-cylinder in the bottomring

seaming two cover segments

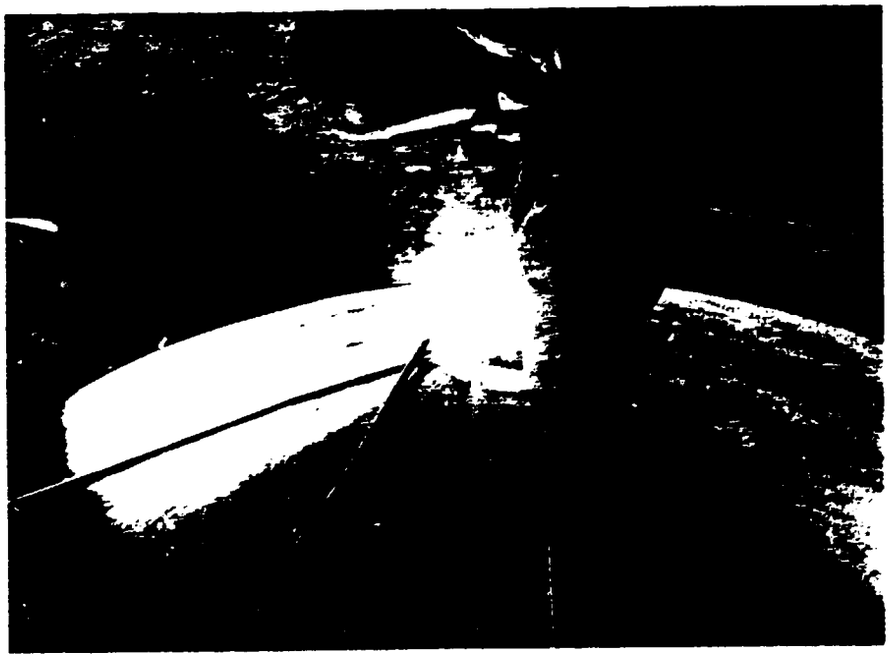
constructing the cover; at left Mr. Monawir

drilling and riveting



Top

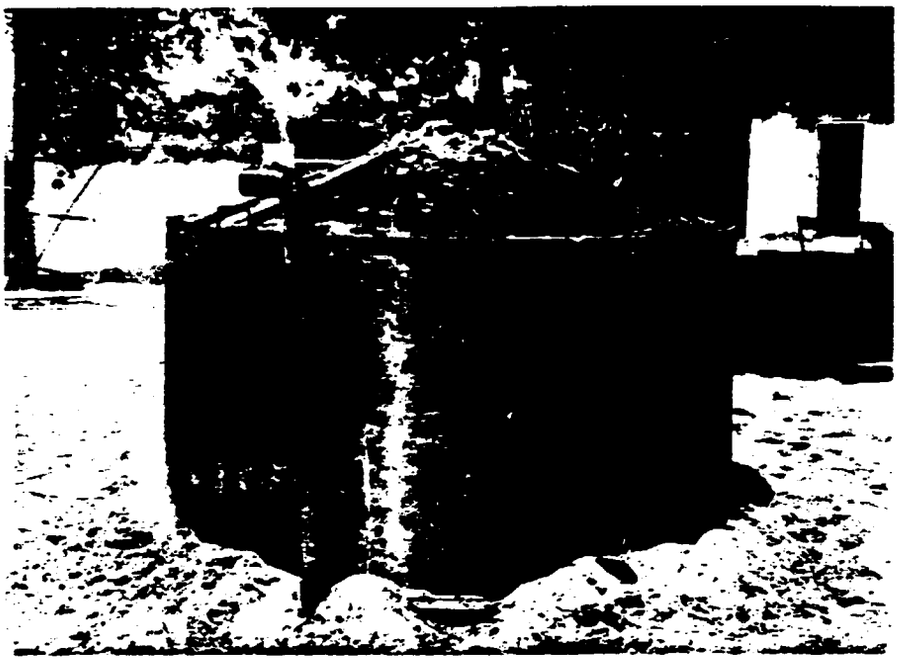
complete kiln section



welding ring round top opening

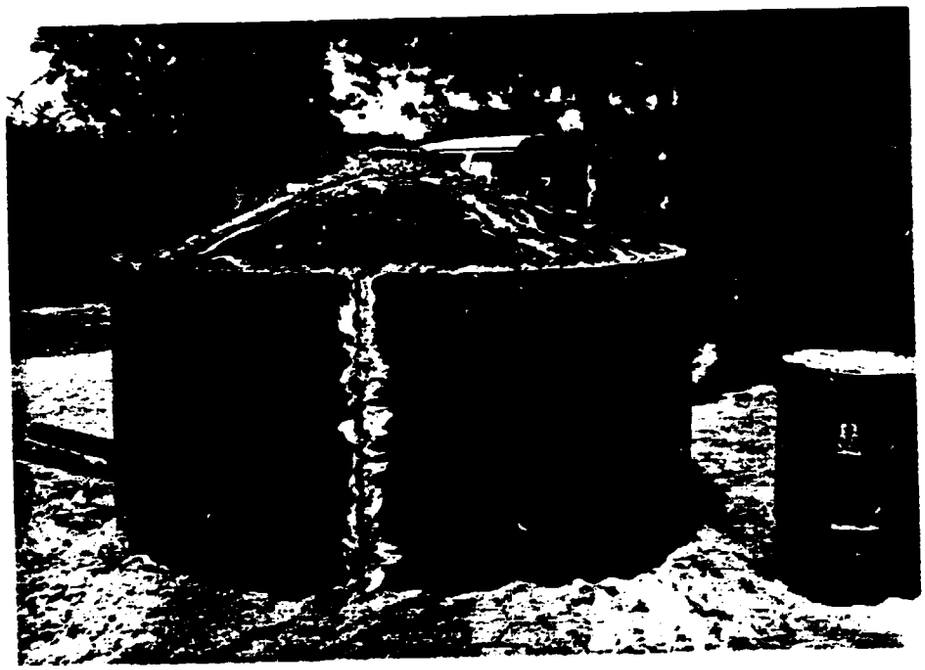
completing the kiln

discoloration of metal sheet



smoke stacks; ineffective

ventilating; blue smoke



operation accomplished