WOOD/BAMBOO (PIPE) PROJECT

MAIN FINAL REPORT

PLANNING AND PROJECT PREPARATION DIV.,
WOOD/BAMBOO PROJECT,
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1979-01-08

FINAL REPORT - WOOD/BAMBOO PROJECT FOR WATER SUPPLIES AND IRRIGATION

1 Introduction

This report represents a Summary of the investigations on the use of Wood and Bamboo in Tanzania Water Supplies and Irrigation Works carried out by Ndugu T. N. Lipangile of the Ministry of Water Energy and Minerals as directed by PARTY AND GOVERNMENT.

2 Purpose of Investigation

The purpose of investigation consists of three aspects which shall be dealt in a logical manner.

2.1 Use of Local Materials

The present Policy of Tanzania is to stress the use of local materials wherever possible. The main idea behind this policy is self reliance, and the saving of scarce Foreign Currency reserves. Civil Engineering works offer numerous possiblities for the use of indigenous resources for current construction in lieu of imported materials. In this connection, the transport of water is a most interesting subject, since in the establishment of water supplies, the pipelines, tanks and transport, form about 65 % to 90 % of the total costs. Also the construction of Domestic points and cattle troughs etc; should be utilization of local materials in a less sophisticated manner.

2.2 Non-Availability of Currently Used Materials

Present water supplies construction experience demonstrated that delays in implementation are often attributable to the non-availability of pipes. In addition of what is available at the time, in spite of the fact that the original design usually represents the most economical solution.

In this connection the ever rising costs of cement, transport and non-availability of sophisticated technical manpower for Civil Engineering, construction must also be mentioned as a reason to investigate alternatives.

2.3 Explosive Rise of Price and Rapid Inflation

Last but not least, should be mentioned the alarming inflation of material costs. Especially for petroleum based materials such as P.V.C. and Polyethylene, prices have doubled. Also in the procurement of Ductile Iron and Galvanised Steel, the Ministries have been confronted with considerable price increase.

2.4 Future

It is not expected that the circumstances mentioned in ad. 2.2 and 2.3 will improve substantially in the near future. On the contrary, it is more likely that the scarcity of materials will grow worse and the rise in prices continue for materials imported.

<u>EVEN IN FUTURE IF PLASTIC PIPES ARE MADE LOCALLY WITH LOCAL MATERIALS THEIR COSTS WILL NOT DECREASE AS COMPARED WITH CURRENT PRICES NOR WILL THEY COMPETE IN PRICES WITH WOODEN PIPES</u>

2.5 Conclusion

The situation as given in section ad. 2 justifies the effort to make greater use of National Resources, in this case wood and bamboo for Tanzania Water Supplies and Irrigation Works. In fact wooden pipes and tanks are currently being utilized by developed Nations in Europe as well as CANADA, AMERICA and INDIA.

Bamboo pipes have been used and are still used in many Tropical countries. Brief details of this will be defined at a later stage.

3 <u>Phases of Investigation</u>

3.1 Mwanza

In December, 1974 investigations started in Mwanza to make more use of local materials for Rural Water Supplies and Irrigation Works.

Four sites were selected for experimental purposes. These sites were NANSIO PUMP HOUSE, UKEREWE DISTRICT; MABATINI AREA, MWANZA DISTRICT, and PASIANSI SABA SABA GROUND, MWANZA DISTRICT. The experiments were conducted utilizing wood and bamboo as water pipes.

The first attempt at all these locations showed some relatively encouraging results. Contracts were also made with some overseas Institutes and Tanzania Medical and Fores' Division. More promising informations towards the progress of the project were received.

3.2 Songea

Resulting from Government decision to continue with further investigations some more interesting and positive results were found during the construction of LIKUYUFUSI Village in Songea District Ruvuma Region. In this village many aspects were studied such as the laying of bamboo pipes, the effect of termites and weather, smell in bamboo pipes, type of bamboos suitable for water supplies and cost studies. During construction various literature received from abroad was also consulted. A Technical report on designs and construction of wooden pipes and tanks was also received from Tanzania Wood-Industry Corporation. This Corporation is a parastatal of Tanzania Government under Forest Division.

Monthly follow-up reports for the operation of LIKUYUFUSI Village Water Supply were also established.

The results and experience gathered during construction of LIKUYUFUSI Village together with the literature received locally and from abroad, confirmed that there is enough Technical evidence to justify the TECHNICAL VALIDITY of the project for both wood and bamboo systems.

3.3 Abroad

Canada

Through Office of the Canadian High Commissioner in Tanzania, we received substantial Technical information relating to wood stave pipes and tanks, their manufacture and construction, which are applicated in CANADA and U.S.A.

Norway

We also received more information regarding manufacture and construction of wood stave pipes and tanks from Norway through Tanzania Wood Industry Corporation (TWICO), SAO HILL SAW MILL, near Iringa.

This information is related to countries which are currently using this method of technology, supplies from Norway Factories. Such countries are NORWAY, SWEDEN, FINLAND, ICELAND, ENGLAND, CENTRAL AMERICA and AUSTRALIA.

Sweden

We received information regarding datas, installation of pipe lines and tanks.

India

From Forest product Research Centre of India we received a technical document regarding designs, manufacture, construction and maintenance of wood stave pipes and tanks.

4 Literature

4.1 Wood Stave

From many countries of the World we received much Technical Literature in connection with design, construction and maintenance of wood stave pipes and tanks.

The main contents of this literature have been retained in our records.

In an exhibit form we shall produce some of this literature in an additional file of this report.

Among the countries from which we received literature concerning wood stave pipes and tanks are:

CANADA (EXHIBIT NO. 1, 2, 3, 4, 5, 6)

a) CANBAR PRODUCTS LTD
P.O. Box 280 Canbar Street
WATERLOO ONTARIO
Canada M2J - 4 A 7

b) PACIFIC COAST PIPE LTD
550 Pacific Street
VANCOOVER, BRITISH COLUMBIA
Canada

c) CANADIAN FORESTRY SERVICE
WESTERN FOREST PRODUCT LAB
6620 N.V. Marine Drive
VANCOOVER, BRITISH COLUMBIA
Canada V6T - 1 2

d) CANADIAN FORESTRY SERVICE
EASTERN FOREST PRODUCT LAB
800 Montreal Road
OTTAWA ONT
Canada XIA - OW5
CITY OF SAIN JAIN - Canada

INDIA (EXHIBIT NO. 7)

FOREST PRODUCT RESEARCH CENTRE
VAN ANUSANDHAN SANTHAN AVAM MAHAVIDYALA
P.O.M. W Forest
DEHRA DUN
India

UNITED STATES (EXHIBIT NO. 8)

a) NATIONAL TANK AND PIPE CO.
2301 N. Columbia Boulevard
P.O. Box 17158
PORTLAND OR 97217

b) NATIONAL WOOD TANK INSTITUTE
848 Eastman Street
CHICAGO Illinois 60622
United States

NORWAY (EXHIBIT NO. 9, 10, 11, 12)

TUBUS A/S
TRERR FABRIKK-GREA'KER
Post Boks 48 - Central 6251
SARPSBORG - Norway

SWEDEN (EXHIBIT NO. 13, 14, 15)

BOXHOLM AKTIEBOLAG
BOXHOLM Sweden

TANZANIA (EXHIBIT NO. 16, 17, 18, 19)

a) Messrs, TANZANIA WOOD INDUSTRY CORPORATION
(Use of Wood stave pipes flumes, water tanks and storage silos for grains) by D.D.S. SCORER

b) MINISTRY OF NATURAL RESOURCES
FOREST DIVISION
UTILISATION SECTION
Box 10
MOSHI

4.2 Bamboo

HOLLAND (EXHIBIT NO. 20, 21 A)

a) UNIVERSITY OF TECHNOLOGY
EINDHOVEN Holland

b) TECHNICAL CORPORATION OF OVEREAS DEVELOPMENT

ETHIOPIA (EXHIBIT NO. 22)

MEZANI TEFER REGION
Ethiopia

SOUTH AFRICA (EXHIBIT NO. 23)

SOUTH AFRICAN SUGAR TECHNOLOGISTS ASSOCIATION

FAR EAST COUNTRIES

1) JAPAN (EXHIBIT NO. 24)
2) CHINA (EXHIBIT NO. 25)
3) INDONESIA (EXHIBIT NO. 26 A)
4) TAIWAN (EXHIBIT NO. 26 B)
5) THAILAND (EXHIBIT NO. 26 C)

LATIN AMERICA

COLUMBIA (EXHIBIT NO. 27)

5 Results

5.1 Pilot Projects on Wood Stave Pipes and Tanks

Having collected much important information which could be useful regarding the manufacture of wood stave pipes and tanks small and big diameters for Rural Water Supplies and Irrigation it was decided to request a private corporation to manufacture.

a) Wood Stave Tanks capacity 140 gallons Photographic Exhibit No. 28 A

b) Wood Stave Pipes one each 300 mm, 150 mm and 100 mm, length one meter Photographic exhibit 28 B

c) Square wood pipes one each 50 mm and 14 mm, length one meter Photographic exhibit 28 C

d) Irrigation flume one in number 450 mm, length one meter Photographic exhibit 28 D.

The tank proved to be water tight for a period of more than four months while under observation. The joints which were used for construction of this tank were of tongue and groove type.

Big tanks are now being manufactured by M/S SAO HILL SAW MILLS near Iringa.

Wood Stave pressure Pipes were also tried and successfully managed to carry water pressures up to six atmospheres. PHOTOGRAPHIC EXHIBIT NO. 29. The proto-type wood stave pipes and tanks were manufactured by M/S J. S. Saggu Contractor of Iringa.

./. The complete Engineering and Forestry Technical reports on wood stave pipes and tanks is shown in appendix 1 and 2. Wood Stave Pipes and Tanks are made out of timber pieces size (150 mm 150 mm) and (100 mm 50 mm). The timber pieces are milled to the true circumference of the pipe and tank to be made, each timber having a side groove and a side tongue for jointing purpose. Staves are jointed together by means of steel hoops. Pressures are determined by spacing the hoops. The cost of wooden tanks and pipes is about 1/3 to 1/2 of normal traditional pipes and tanks which are made by concrete, steel and plastic, (see Exhibit No. 30). The life expectancy of Preserved Wooden Pipes and Tanks when continuously saturated with water is indefinitely and under normal conditions about 30.5 years.

The following species of timber have been confirmed as durable and available in Tanzania: NON TREATED

Mninga - Phecocarpus angolensis
Mvule - Chlorophora excelsa
Mkunya - Ficus
Mtambara - Cephalophela usambarensis
Muhama - Borassus aethiopum
Mkangazi - Khaya nyasica
Mgwina - Adina microcephala

TREATED - PINE - CYPRESS and PODO

The main use of wood stave pipes and tanks are for:

a) Water Supplies (Municipal and Rural)
b) Irrigation
c) Sewage Disposal
d) Hydro Electric Power Development
e) Drainage
f) Paper and Pulp Plants
g) Chemical Industry and Mine Ducts
h) Grain Silos

See Exhibit No. 1 and 7.

5.2 Pilot Projects on Bamboo Pipes

a) KAYENZE

The purpose of the Kayenze Water Supply Pilot Project was to apply the knowledge and experience which was obtained during investigations at Mwanza and also some information which we received from abroad.

Another purpose of the scheme was to show that the indigenous Natural Resources of Tanzania can be used to substitute in many constructions more expensive materials currently imported from abroad that are often difficult to obtain.

Set Up of Kayense Pilot Project

It was decided to start on small scale. The following applications of wood/bamboo pipes were to be tested:

a) Domestic use
b) Irrigation

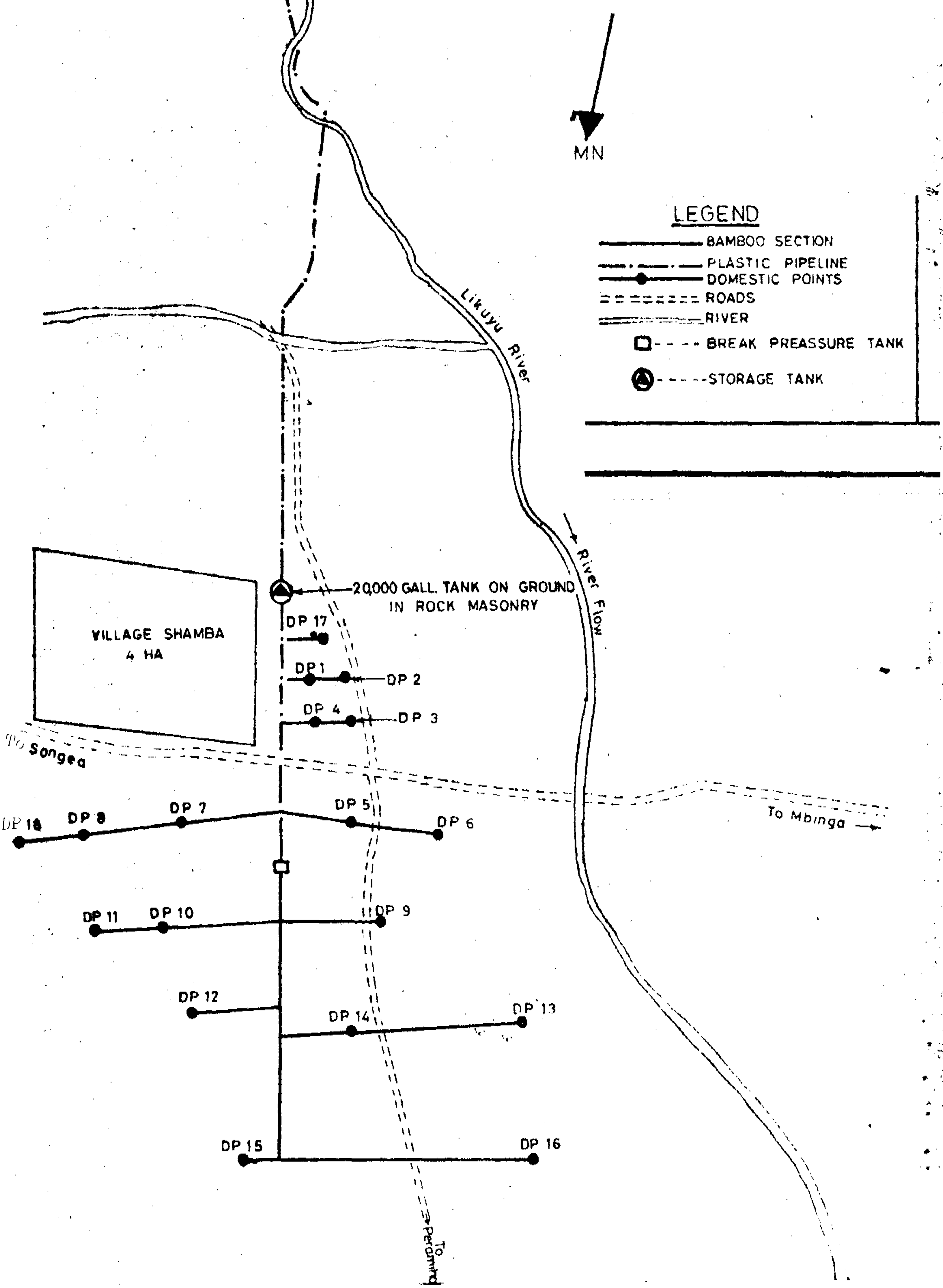
Location

A small village was selected in which the possibility of irrigation existed. The choice was Kayenze, Magu District, Mwanza Region. The Village is situated on the shores of Lake Victoria at Longitude 33° 0.6 and Latitude 2° 0.8. Means of access is either via the Airport Road about 25 km beyond Mwanza aerodrome, or either Mwanza/Musoma Road where there is a turnoff to the left 1 km beyond Kisesa, this cross road is leading to Kayenze.

Description of the Village

Kayenze is a small village with about 1 500 people having a School, a market and a large irrigation rice field. Means of lively hood: Agriculture, fishery and cattle. (For layout see sketch on next page.)

LAYOUT LIKUYUFUSI WATER SUPPLY



Design

Design was done with the following data:

a) Number of people: 1 500
   "- teachers: 8
   "- students: 250

b) "- cattle: 400

c) Size of irrigation scheme: 50 acres approx. 200 m^3/h.

The idea was to have a pump flow of 193 m^3/h in the initial stage pumping for two hrs/day, since most of the water was destined for irrigation purposes and only a small part of the irrigation area could be irrigated.

Then as the irrigation system was extended, the number of pumping hours would be increased accordingly up to 10 hrs/day.
The water for irrigation purpose was being pumped through Mihama wooden pipes. Bamboo Water Supply System was provided with a separate small pump which was running for about 6 hrs/day.

Suction - Arrangements

Three 200 mm Ø P.V.C. pipelines leading the water into a wooden pump by Gravity from Lake Victoria. These lines were provided with strainers at the end. 150 mm Ø and 100 mm Ø suction mains leading into the pumphouse as suction.

Pumphouse

Two pump units a capacity of 135 000 l/h or 135 m^3/h and 90 000 l/h or 90 m^3/h respectively were installed. In addition a temporary mobile pump unit was installed with a separate suction and a connection to the Bamboo Pipe System. The capacity of this plant was about 18 000 l/h or 18 m^3/h.

Distribution System

A 50 mm distribution system to eight delivery points was constructed in bamboo pipes of a total distance of 1 500 metres. The joints used for bamboo pipes were of two types:

1) Polyethylene tubes applied with paste of tangit

2) Bamboo to bamboo caulked with cotton wool

The pressure in the whole system ranged from $1\frac{1}{2}$ atmospheres to 2 atmospheres.

The Green and Yellow type bamboo were used in this project. The bamboo pipes were not treated except for an external layer of bitumen coating.

The rising main to the irrigation field was constructed as a 300 mm Mihama wooden pipe of about 300 metres in total length. The joints of these pipes were of flange type made out of Mihama pipe themselves. Mihama wood pipes are naturally durable and as such were not treated.

Cost of the Scheme and all Investigation Works Up to First Pilot Project

The overall cost for all investigation activities including the construction of the first pilot project as reported by the Mwanza Regional Water Engineer is said to be in the region of Shs. 240 000/= (Sw Cr 140 000).

Performance

Since the opening of the scheme in November, 1975 the station was operating satisfactorily up to July, 1976. Unfortunately the Mwanza Regional Commissioner (Ndugu Lawi Sijaona) and the Regional Development Director (Ndugu C. Y. Mpupua) - who were the key top Government Officials and interested in the development of the project - were then transferred to other regions outside Mwanza area. The transfers were of normal exchange of responsibilities in the civil service. The Regional Water Engineer who was heading the investigation activities was also transferred even before the completion of his investigations at Mwanza. These transfers much hampered the progress of the Kayenze Pilot Scheme.

New Government Officials were appointed in Mwanza Region. None of these Officials including other Government Technical Officials who were outside Mwanza Region became positive to the development of the project.

As a result of these transfers the Kayenze Pilot Scheme started to deteriorate in a very bad manner.

The station was not provided with fuel to run the pump for the period between September, 1976 and March, 1977 resulting to major damage of bamboo pipes. Since the pipes were left to dry they started decaying because of fungi growth. A smilar situation occurred again for a period between October, 1977 to present time.

In second incident it is reported that the portable pump which was supplying water to the bamboo system broke down. No repairs or pump replacement took place.

As the bamboo pipes were not treated they could only extend their life time by continuously being saturated with water and so we believe that all 1.5 km of bamboo pipes by now have encounted a total failure.

We believe that Mihama wooden pipes however are still in good order since they are naturally durable and can survive (under any condition) whether saturated or not saturated. Mihama pipes are thus not affected by a failure of fuel supply. The following points of interest were noted during the operation of the project and afterwards:

Bambo Pipes

a) Water coming from bamboo pipes showed to have an unpleasant smell

b) Joints proved not to be efficient

c) Bamboo to bamboo joints proved not to be efficient

d) Fungi decay was noted

e) Effect of termites was also noted.

Wooden Pipes

No problems were experienced.

An improvement of the performance of bamboo pipes system has been made in the second pilot project at Likuyufusi water supply Songea in Ruvuma Region.

Technical Conference

During the Water Engineers' conference which was held in Dodoma in April, 1977 a paper titles "REVIEW OF KAYENZE AND WOOD PIPE PILOT SCHEME" was presented to the conference by the Ministry of Water Development Minerals and Power. In its comment the paper stated that all leaks have been rectified since January. It was noted also that the bitumen coating had come off some of the pipe pieces giving access to attack by white ants. Samples of these defected bamboo pipe pieces are shown in the photographs. Some of the pipes have started to rot. Frequent bursts, cracks, slippage of joints are experienced. So frequent are the repairs that the villagers are now fed up with the fact that this scheme is perpetually under repair. They themselves have hinted to the effect that these bamboo pipes be replaced with other more durable pipes. Water from bamboo pies is smelling. Relatively little trouble has been met with as far as the wooden pipes are concerned. The paper also showed some costs comparison figures. All quoted prices for bamboo pipes were based from investigation works and wild Mihama tree pipes not made in timber pieces. During the confernece section no suggestions were given regarding the improvements of the problems as presented. Not any member of Ministry of Water, Minerals and Energy suggested as to how to overcome the reported failures.

Visitors - Kayenze Pilot Project

Ndugu Lawi N. Sijaona R. C. Mwanza, Region, Ndugu Timothy Apiyo Principal Secreteray President's Office, Ndugu F. K. Lwegalulila P. S. MAJI under instructions from TANU Headquarters.

b) LIKUYUFUSI PILOT SCHEME

In September, 1976 The Then Tanganyika African National Union our Nationalist Party and Tanzania Government directed that the Wood/Bamboo Project must continue.

It was then decided to start another Pilot Project at Likuyufusi Village Songea District, Ruvuma Region. This Village is located 13 miles from Songea Town (near Peramiho Mission). It has a population of approximately 1 200. The means of livehood is mainly Agriculture. For layout see sketch on the next page.

Set Up of Likuyufusi Pilot Project

Having experienced problems and some failures of Kayenze Pilot Project it was considered to select a village where it would be simpler and more convinient to ulilize bamboo in the water supply.

System and which could also serve as our research base for bamboo and wood activities.

The main advantage of Likuyufusi Village were:

a) The whole investigation team was stationed together at Likuyufusi. The crew was also receiving lecturers. Photographic Exhibit No. 31.

b) The proposed Water Supply System was of Gravity ensuring a continuous flow of water in the bamboo water supply system.

c) Regional Government Officials were interested in the construction of a bamboo water supply system.

Investigation Activities

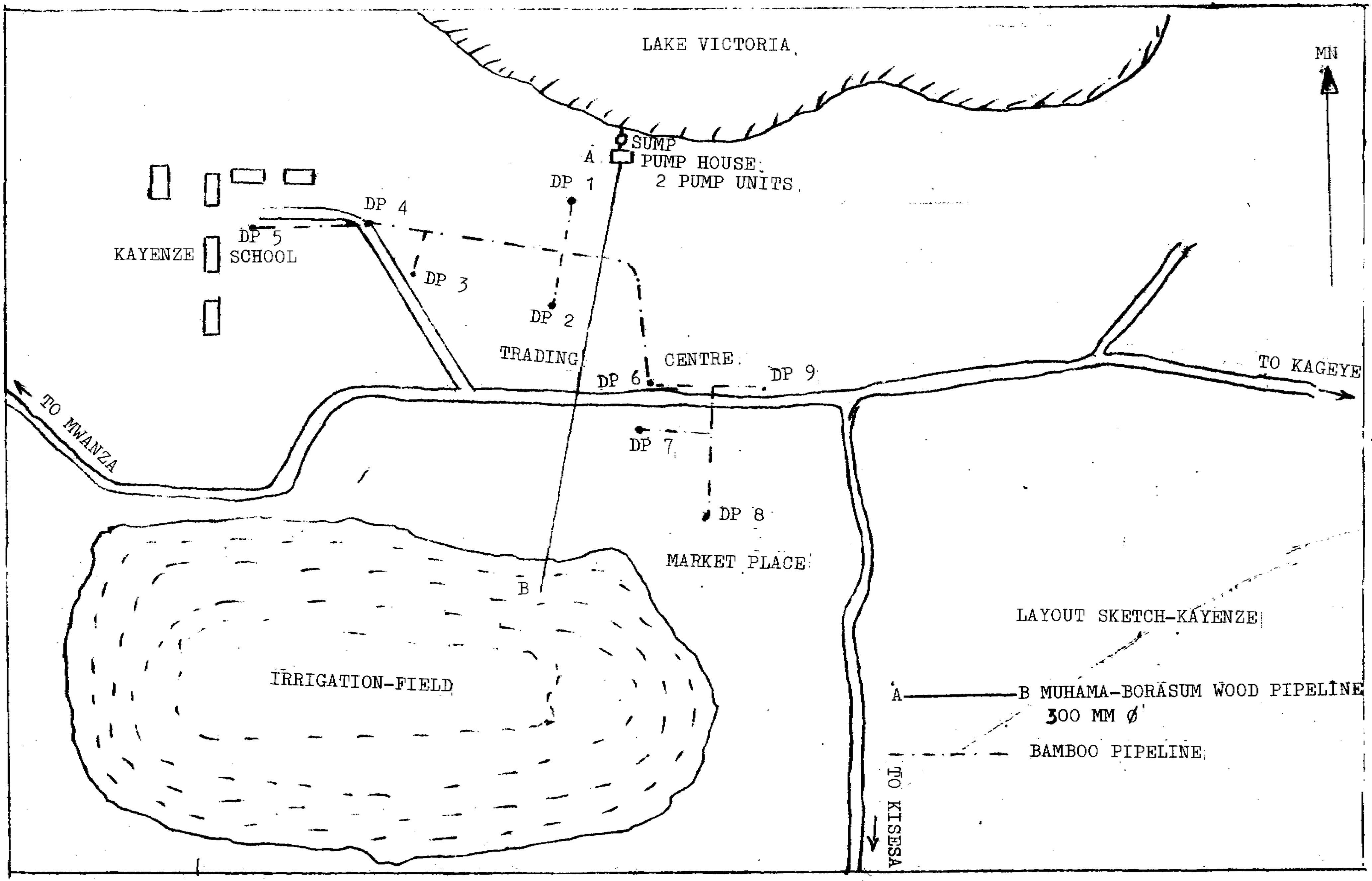
From Kayenze Pilot Project the following problems were noted during operation of the bamboo system:

a) Water coming from bamboo pipes showed to have an unpleasant smell

b) Joints proved not to be efficient

c) Effect of termites was also noted.

A result of studies of the above problems and other which were noted during Likuyufusi Construction works is the following. This has proved to be the present solution for the problems.


LAKE VICTORIA
MN
SUMP
A
PUMP HOUSE:
2 PUMP UNITS
DP 1
DP 4
DP 5
KAYENZE
SCHOOL
DP 3
DP 2
TRADING
CENTRE
DP 6
DP 9
TO KAGEYE
TO MWANZA
DP 7
DP 8
MARKET PLACE
B
IRRIGATION-FIELD
LAYOUT SKETCH-KAYENZE
A——B MUHAMA-BORASUM WOOD PIPELINE
300 MM Ø
BAMBOO PIPELINE
TO KISESA

13

Effects of Smell

The smell originates from the interior part of bamboo as it makes first contact with water.

The smell is very strong.

It was discovered that by submerging the bamboo pipes in flowing water when already bored for a period of about six to eight weeks they were given a sound wash of this smell. This treatment is suitable for green bamboos only.

In Yellow bamboos with small green strips, the smell can not be removed by this method. The smell in this type of bamboo can however be removed by putting them in chlorinated water of strong concentration for a period of about 24 hours. Chlorine treatment could also be used to green bamboos.

Hot water can also give good results in removing the smell coming out of bamboo pipes. Bamboos are submerged in hot water fo a period of about 2 hrs and hot water is left to cool while the bamboos are still in the hot water tank to avoid cracking.

Best Joints

Polyethylene pieces with Tangit paste (a PVC cement) wound with wire band has proved to be the best joint up to present time. It is highly reliable in gravity water supply system where bamboos are continuously saturated with water. The joints stand pressures over eight atmospheres. In future, timber pieces will be tried as sockets for connecting bamboo pipes. Also bends and tees will be tried out in timber.

Fungal Decay

The problem of fungal decay is being solved by saturating bamboos with water continuously. Gravity water supply has proved to be the best solution for this problem for the time being.

Forest Division is experimenting alternative treatments for fungal decay. The first results are promising. If this alternative treatment is successfull, bamboo pipes can be used in pump supply system as well.

Effect of Termites

Soil treatment has proved to be the best solution. Chemical used are Chlorodox and Andrudin. The pipes are laid in the trench ensuring that they are surrounded with non treated soil. The pipe must contain water flowing under pressure to avoid external contamination.

Other experiments are going on for alternative treatment on termites.

Pressures

Yellow/Green bamboo stand pressure of five atmospheres without reinforcement. Green bamboo stand pressure up to 2 atmospheres without reinforcement. Green reinforced bamboo can stand pressure of eight atmospheres (when re-inforced) for technical details (see appendix 1). Exhibit No. 31 is a Photograph of a green reinforced bamboo taking a pressure over eight atmospheres.

Costs

A cost study for bamboo pipes was conducted at Likuyufusi construction site. A follow-up procedure for costing statements was laid down. Every member of the crew, who was assigned to perform a certain activity during construction, was instructed to maintain a proper record showing time consumed, material used etc. Such a person was being supervised with a Senior Official. Both employees were Voluntarily requested to endorse their signatures in the costing record note book.

The following is the outcome of the bamboo pipe cost study as it was done at Likuyufusi.

Costs are made per running metre.

Cost Summary

Bamboo Forest Location	Pressures 3.5 ATM.	Pressures 8 ATM.	Not Reinforced 2 ATM.
Bamboo forest outside Region	4.73	5.49	-
Bamboo forest inside Region	4.39	5.15	-
Bamboo forest inside District	4.22	4.98	-
Bamboo forest inside Village	3.88	4.64	2/53

The length of bamboo pipe ranges between 3.5 metres to 4 metres in uniform diameter. Fore break down see ENGINEERING REPORT, appendix 1.

Cost Summary

Bamboo Forest Location	Not Reinforced Bamboo Pressure 2 ATM.	Reinforced Bamboo Pressure 3.5 ATM.	Reinforced Bamboo Pressure 8 ATM.
Outside Region	-	4.73	5.49
Inside Region	-	4.39	5.15
Inside District	-	4.22	4.98
Inside Village	2/53	3.88	4.64

The cost of polythene Ø 50 mm Diameter together with transport from Dar es Salaam to Likuyufusi is about 18/60 per running meter as in June, 1977. The cost of 50 mm steel pipe at Government stores Songea is Shs 31/70 Exhibit No. 32A - 32B - 32C is a front cover and first pages of the costs records.

Design and Construction of Likuyufisi Village

The intake was constructed by concrete weir and also a stone masonry storage tank having a capacity of 80 m^3. The gravity main from Intake to the Storage Tank was laid in Polythene 50 mm Ø. The distribution mains were 75 mm and 50 mm of a total distance of 3,050 metres all of bamboo pipes. Few metres of 100 mm and 75 mm P V C pipes were laid from the storage tank linking with bamboo distribution system. In additional there were 19 domestic points installed in the distribution system.

The pressure in the distribution system was about 1 ½ atm.

All bamboo joints were of Polythene pieces.

Soil treatment was applied throughout the distribution system.

Performance

During the first operation of Likuyufusi water supply system two severe problems were encountered.

a) Bamboo bursts

b) Termites

Bamboo Bursts

Mainly Green bamboos were used at Likuyufusi. This type of bamboo is very weak in shear strength. Water hammer showed to be the main reason for bursting of these bamboos. A short length of bamboo pipe showed a considerable number of bursts in a few hours while Domestic Points were in operation. The problem of bursts was solved by reinforcing bamboos with wire wounds.

Termites

Bitumen coating proved to be ineffective as a preservative for termites. About 200 metres of bamboo pipes were effected by termites within a week after all bamboos were buried.

Soil treatment has proved to be a satisfactory solution to this. The system of Likuyufusi is now reported to be in a satisfactory operational condition.

a) The water is free from any trace of smell

b) Joints are free from leaks

c) Bursts are very infrequent and are being counted to count nil

d) No existence of fungal decay

e) Termites have absolutely disappeared.

Spares

Spares consumed for a period of the first eight months were as follows: three bamboos and very little cotton wool for scaling four minor joint leaks. Exhibit No. 33 A.B.C.D.E are true monthly performance records as observed by our station attendant. Exhibit No. 34 is a photo of one of kiosks dispensing water at Likuyufusi village bamboo water supply system. We believe that even better results on performance will come out from ongoing projects which are currently being constructed in Iringa and Rukwa Regions. All are four projects, Mgama Water Supply, Nyakipambo Water Supply, Lupalilo Water Supply - Iringa Region, Usie Water Supply - Rukwa Region.

Villagers of Likuyufusi are satisfied with the system.

Exhibit No. 35 is a true copy of the letter received from the village Chairman. The Chairman argues for all extensions of the bamboo lines to areas where plastic pipes have been promised to be laid. The system is operating directly under our own control.

Visitors

The following Higher Government Officials have paid a visit to Likuyufusi Water Supply Station.

1) Ndugu Edward Sokoine - The Prime Minister

2) Ndugu Lawrence Gama - The Regional Commissioner-Ruvuma Region

3) Ndugu Hassan Nassoro Moyo - Minister for Home Affairs

4) Ndugu Ole Saiburi - Minister for Natural Resources and Tourism

5) Ndugu Kuhanga - Minister for National Education

6) Ndugu R. N'gitu - Junior Minister, Office of the Prime Minister

7) Ndugu Chimsala - Regional Chairman CCM Ruvuma Region

8) Father Chengula - N.E.C. Member Ruvuma Region

9) Ndugu G, Mapunda (M.P.) Songea

Appreciation

We also received a letter of congratulation from Chama cha Mapinduzi (C.C.M.) Headquarters Dodoma after the completion of Likuyufusi water supply village. The letter was copied to the Principal Secretary, Office of the President and Minister of State Office of the Prime Minister. Exhibit No. 36.

Conclusions: Result of Bamboo Project

Bamboo Project represents village technology (Intermediate Technology). It is suitable for small scale water supplies for a population ranging from 500 to 2 000 people. In a combined system with wood stave pipes it can serve as a distribution system of any scale at the village level. Bamboo water system could also serve for a small rural irrigation scheme. Green bamboo pipes with reinforcement stand pressure over 8 atmospheres. Green bamboo pipes without reinforcement stand pressure up to 2 atmospheres. Yellow/Green bamboo pipes stand pressure up to 5 atmospheres without reinforcement. Bamboo pipes for 5 to 8 atmospheres are used in the high pressure system.

Bamboo pipes of 2 atmospheres are used in a non pressure system (constant speed flow).

WHEN PROPERLY HANDLED BAMBOO PIPES ARE AS STRONG AS PLASTIC PIPES IN STANDING PRESSURE.

The cost of bamboo pipe system is about 1/6 to 1/3 of our normal traditional water supply system using plastic and steel pipes. See page 13, 14, and Exhibit No. 30. The life expectancy of a bamboo pipe system is over 15 years when properly preserved and reasonably saturated with water, and less than four years when not technically treated. Exhibit No. 2A and 2B.

About 1 000 bamboos are sufficient to cover a village water supply scheme.

Bamboo forests are plenty in Tanzania. Vast bamboo forests have been found in Iringa, Mbeya, Morogoro, Kigoma and Lindi Regions. These forests could provide bamboo pipes to a number of villages at an initial stage. Other forests can be grown to maturity in three years.

6 Final Technical Reports

Appendix 1 is a complete Engineering report covering both wood stave pipes, tanks and bamboo projects. The report has been checked and passed by Messrs P. Jacobs and Nils Lundborg Civil Engineers of Ministry of Lands and Tanzania Wood Industry Co-operation respectively.

Appendix 2 is a complete Forestry report for both Wood Stave and Bamboo Projects. The report has been compiled and made by the Director of Forest Division.

From studies and facts in our possession we are of the opinion that the project is technically valid from both aspects.

7 Implementation Construction Water Supply Projects

For construction purpose tenders were invited from Messrs Tanzania Wood Industry Co-operation (TWICO) and Messrs J. S. Saggu Contractor of Iringa.

Both tenders were quoted for high pressure water pipes and tanks.

Messrs J. S. Saggu has quoted for construction of water tanks as well.

Both tenders have showed to be cheaper than the cost of the same materials produced by the Ministry of Water, Energy and Minerals, and Government Stores. For instance the Ministry of Water, Energy and Minerals is selling at DSM Port, one meter of steel pipe 600 mm diameter at the rate of Shs. 1160/60 per meter without transport, pipes are very heavy occupying a big volume of the vehicle without the required materials.

Messrs TWICO has quoted ex factory for the same materials at the rate of Shs. 450/- per meter. Timber pipes will be in stave pieces, very light in weight - and occupy the whole volume of the vehicle.

Messrs Saggu has quoted ex factory for the same materials at the rate of Shs. 430/- per meter.

b) These steel pipes are now being constructed in Dodoma Capital Project.

Messrs J. S. Saggu is the only present firm able to manage construction works of big capacity on Wood Stave Projects.

Tenders from Messrs TWICO are shown on exhibit No. 37A.

Tenders from Messrs J. S. Saggu are shown on exhibit No. 37B.

Scale prices from Ministry of Water, Energy and Minerals are shown on Exhibit No. 37C.

Irrigation Projects

Messrs MECCO DSM is selling a 1 200 mm diameter reinforced concrete pipe ex DSM factory at the rate of Shs. 550/- per meter while Wood/Bamboo (pipe) Department can make for Shs. 340/- per meter, sale prices for Messrs MECCO and Wood/Bamboo department is shown in exhibit No. 37D.

From the above tenders wood stave pipes and tanks have proved to be consierably cheaper - against steel, plastic and concrete pipes.

For bamboo construction we can train local villagers to manage the projects themselves whereever possible.

Four villagers can manage the construction of a village water supply.

In comparison costs if bamboo forests are available in a Region/District bamboo pipes are considerably cheaper.

The cost of 50/75 mm of bamboo pipe including transport in a Region/District is Shs. 3/50 per meter. Exhibit No. 37E.

The cost of 50 mm plastic pipe from Maji Stores DSM is Shs. 18/60 per meter including transport to Songea. Exhibit No. 37F.

The cost of 50 mm steel pipes is Shs. 31/70 per meter at Government Stores Deports. Exhibit No. 37G.

We conclude that both wood stave and bamboo pipes are economically feasible.

7.1 Factories Woodstave Construction

The following factories for manufacture of woodstave pipes and tanks are available in Tanzania and others are in the process of being developed:

1) Messrs Sao Hill Sawa Mill (TWICO) near Iringa. Exhibit No. 38A.

2) Sikh Saw Mills Tanga (TWICO). Exhibit No. 38B.

3) Forest Utilisation Section (Sawa Mill) Moshi (Forest Division). Exhibit No. 38C.

4) Messrs J. S. Saggu Sawa Mill Iringa. Photographic Exhibit No. 38D.

8 <u>Medical Aspects</u>

Both Projects Woodstave and bamboo are bound to make contact with water in motion or at rest.

For health reasons chemical analysis was necessary.

The following Government Laboratories and overseas agencies were consulted:

a) Office of the Tanzania Government Chemist

b) Maji Ubungo Laboratory

c) University of DSM Laboratory

d) Messrs Hickson's Timber Impregnation Co. (GB) ITD. Castleford, West Yorkshire, ENGLAND

Results

a) The Principal Chemist and Maji Ubungo Laboratories have agreed that all natural timber species are safe as water conductors

b) The Principal Chemist has agreed that untreated bamboo pipes are safe as water conductors

c) The Principal Chemist has agreed that water passing in untreated bamboo pipes is safe

d) The Maji Ubungo Laboratory has approved that water coming out of treated bamboos through soil treatment

e) The Principal Chemist and Maji Ubungo Laboratories have detected leaching preservatives from timber pieces treated with Copper Chrolomine Arsenic (C.C.A.). Forest Division are repeating the exercise

f) The University of DSM has approved the use of C.C.A. in drinking water and Irrigation works. Exhibit 38E

g) Messrs Hickson Company is recommending the use of C.C.A. in Water Supply as applicated in Norway and other Scandinavian countries today

f) Forest Division has reported that C.C.A. treatment is not hazard when leaching at admissible levels

i) Forest Division has approved the use of C.C.A. treatment timbers in the Irrigation projects first, until further experiments

Conclusion

To start with, we shall use natural durable non treated timbers for water tanks and bamboo pipes with soil treatment for water supplies. Treated timber will first be used in the Irrigation farms until more treatment trials for water supply purpose is safely confirmed.

Appendix III is a full medical report as confirmed by our local Government laboratories and overseas firms.

We are therefore concluding that both projects are medically acceptable.

9 Party and Government Directives

In September, 1975 the Mwanza Regional Development Committee under the Chairmanship of Ndugu Lawi Nangwanda Sijaona, Regional Commissioner directed that Wood/Bamboo pipes investigation works continue.

In June, 1976 the then Tanganyika African National Union, our Nationalist Party directed that Wood/Bamboo Project must continue.

TANU instructed three Senior Party Officials from Dodoma Capital to visit Kayenze Project, Ndugu K. R. Kalubu Chairman of Social Services of the Central Committee of the Party, Ndugu R. Kapinga and F. P. Muro both were members of the Secretariate.

TANU directed the Central Government to take up the project and continue with investigation works.

On 16th September, 1976 the then Prime Minister Rashid Kawawa directed the Ministry of Water, Energy and Minerals and Regions for Wood/Bamboo Projects to continue. Exhibit No. 39. This meeting was attended by the then Minister of Water, Energy and Minerals.

On 16th August, 1977 the Prime Minister Edward Sokoine directed the Minister of Water, Energy and Minerals, Agriculture and Natural Resources for Wood/Bamboo Project to continue. Exhibit No. 40.

On 22nd October, 1977 at State House D'Salaam Ndugu Timothy Apiyo the Principal Secretary President's Office and Head of Tanzania Civil Service directed the Head of Wood/Bamboo Project Ndugu T. N. Lipangile to prepare a summary of investigations and construction works together with proposals with a view of project implementation.

From all the above directives we are convinced that the project is politically highly desirable.

10 Expertising and Financing Nations

For the purpose of going to implementation on both Projects it was considered essential to contact some Foreign Nations which have already established their Diplomatic Office in Tanzania. These Agencies are normally assisting Tanzania Development Projects. The following Embassies and Agencies have agreed in principle to support the project by assisting on procurement of high level manpower and finance provided they are formally requested by the Tanzania Government:

1) EMBASSY OF NETHERLANDS. Exhibit No. 41

2) ORGANISATION OF NETHERLAND VOLUNTEER SERVICES IN TANZANIA. Exhibit No. 42

3) CANADIAN HIGH COMMISSIONER. Exhibit No. 43

4) EMBASSY OF INDONESIA. Exhibit No. 44

5) EMBASSY OF NORWAY (ON REQUEST BY TANZANIA GOVERNMENT)

6) EMBASSY OF SWEDEN (ON REQUEST BY TANZANIA GOVERNMENT)

7) WORLD BANK: Will consider financing the project after submission of this report. The World Health Organisation report titled "RURAL WATER SUPPLY SECTOR STUDY 1977" (Exhibit No 45) has been misleading. Non of Wood/Bamboo project officials was consulted at any situation it has been reliably learnt that all the contents of the report discussing Wood/Bamboo Project were deliberately made. The intention behind this report was to condemn the project to both possible financers and the World technical bodies. This action was taken locally and later at Washington. The Tanzania Government authorities were well briefed vide our confidential letter reference number WB/C/100/37.

On request by Tanzania Government the above agencies can assist in providing experts for the project and training of Tanzanians locally and abroad.

They will as well consider assisting the project in providing financial grants.

As a result of the above Overseas Nations, Technical and financial supports, we conclude that implementation is going to have a positive approach.

11 Recommendation

We have proved beyond reasonable doubts that the investigation works of Wood stave and Bamboo Projects are complete as confirmed by investigation activities and documents which have been attached to this report as Exhibits and Appendixies.

The present Technical Policy on providing water to Rural population is of a sophisticated kind based on views in Developed Nations of Europe.

With Today's World inflation it is impossible for our poor nation to manage or execute Projects originating from such policies both as regards finance and manpower.

Wood/Bamboo will provide the best solution to MANY UJAMAA VILLAGE WATER SUPPLIES OF TANZANIA NOW AND MANY YEARS AHEAD.

It is recommended that the Project should start implementation in July, 1978 under the title WOOD/BAMBOO (PIPE) PROJECT.

Tanzania is a vast country and the Project is likely to be of demand at any location of the country.

It is not possible with the present manpower, and present availability of bamboo forests to be able to spread the project throughout the Country.

We therefore propose to establish one Central Headquarter with 7 operational Regions where Bamboo Forests and timber is available in abundance and some activities have already started under the following arrangement:

a) Head Office and Central Depot Dodoma Capital

Function: Overall control and implementing Major Projects e.g. IRRIGATION SCHEMES - MUNICIPAL WATER WORKS, SEWERS, DRAINAGE AND GRAIN SILOS Using Wooden conduits

b) REGIONS - STAGE I, IRINGA-MBEYA-RUVUMA-RUKWA-MOROGORO-KIGOMA and LINDI

Function: CONSTRUCTING WATER SUPPLIES TO UJAMAA VILLAGES VIA BAMBOO PIPES AND WOODEN TANK SYSTEM

c) REGIONS - STAGE II, TANGA-KILIMANDJARO-ARUSHA-WEST LAKE

Functions: CONSTRUCTION OF UJAMAA VILLAGES WATER SUPPLIES USING WOODEN TANKS AND BAMBOO PIPES WHEREVER BAMBOO PROJECTS ARE ESTABLISHED AND SMALL WOODEN PIPES PROVES TO BE FEASIBLE

d) REGIONS - STAGE III, DODOMA-SINGIDA-TABORA-MWANZA-SHINYANGA-MARA-COAST-DAR ES SALAAM AND MTWARA

Function: CONSTRUCTION OF UJAMAA VILLAGES WATER SUPPLIES USING WOODEN TANKS AND IF FEASIBLE SMALL WOODEN PIPES

Specialised teams for Irrigation and other activities of using timber conduits and tanks will move from Central Depot to other areas of activities at the request of the Project Authorities concerned.

As more bamboo forests are established in the country, crews will gradually be posted to the project area. (For set-ups see page 25).

Wood/Bamboo Project
MANAGEMENT CHART

PRINCIPAL SECRETARY
OFFICE OF THE PRIME MINISTER

PROJECT MANAGER

CHIEF ENGINEER W/S AND IRRIGATION
- 1 ENGINEER
- 1 CHIEF WATER TECHNICIAN
- 2 SENIOR WATER TECHN. I and II
- 2 WATER TECHNICIANS I
- 4 WATER TECHNICIANS II and IV
- 1 WELDER
- 1 MECHANIC
- 4 DRIVERS
- 1 MESSENGER
- 6 PLANT OPERATORS

1 FOREST EXPERT/WOOD TECHNOLOGIST
- 1 FOREST ASSISTANT

1 TRAINING OFFICER
- 2 ASS. TRAINING OFFICERS

1 ACCOUNTANT
- 3 CLERKS
- 1 MESSENGERS
- 1 WATCHMAN

IRINGA REGION
- 1 ENGINEER (3 REGIONS)
- 1 FOREST EXPERT (3 REGIONS)
- 1 CHIEF WATER TECHN. (3 REGIONS)
- 1 SENIOR WATER TECHN. I
- SENIOR WATER TECHN. II
- SENIOR WATER TECHN. III
- 1 WATER TECHN. I
- WATER TECHN. II AND III
- 1 WELDER
- 1 MECHANIC
- 4 CLERKS
- 2 DRIVERS
- 1 WATCHMAN

MOROGORO REGION
- 1 SENIOR WATER TECHN. I
- 2 SENIOR WATER TECHN. II
- 2 SENIOR WATER TECHN. III
- 2 WATER TECHN. I
- 6 WATER TECHN. II AND III
- 1 WELDER
- 1 MECHANIC
- 2 CLERKS
- 5 DRIVERS
- 1 WATCHMAN
- 1 MESSENGER
- 2 LABOURERS

LINDI REGION
- 1 SENIOR WATER TECHN. I
- 2 SENIOR WATER TECHN. II
- 2 SENIOR WATER TECHN. III
- 2 WATER TECHN. I
- 6 WATER TECHN. II AND III
- 1 WELDER
- 1 MECHANIC
- 2 CLERCS
- 5 DRIVERS
- 1 WATCHMAN
- 1 MESSENGER
- 2 LABOURERS

MBEYA REGION
- 1 ENGINEER (2 REGIONS)
- 1 FOREST EXPERT (2 REGIONS)
- 1 CHIEF WATER TECHN. (3 REGIONS)
- 1 SENIOR WATER TECHN. I
- 2 SENIOR WATER TECHN. II
- 2 SENIOR WATER TECHN. III
- 2 WATER TECHN. I
- 6 WATER TECHN. I AND II
- 1 WELDER
- 1 MECHANIC
- 2 CLERCS
- 1 WATCHMAN

RUVUMA REGION
- 1 SENIOR WATER TECHN. I
- 2 SENIOR WATER TECHN. II
- 2 SENIOR WATER TECHN. III
- 2 WATER TECHN. I
- 6 WATER TECHN. II AND III
- 1 WELDER
- 1 MECHANIC
- 2 CLERCS
- 5 DRIVERS
- 1 WATCHMAN
- 1 MESSENGER

RUKWA REGION
- 1 SENIOR WATER TECHN. I
- 2 SENIOR WATER TECHN. II
- 2 SENIOR WATER TECHN. III
- 2 WATER TECHN. I
- 8 WATER TECHN. II AND III
- 1 WELDER
- 1 MECHANIC
- 2 CLERCS
- 5 DRIVERS
- 1 WATCHMAN
- 1 MESSENGER
- 2 LABOURERS

KIGOMA REGION
- 1 ENGINEER (2 REGIONS)
- 1 FOREST EXPERT (2 REGIONS)
- 1 CHIEF WATER TECHN.
- 1 SENIOR WATER TECHN. I
- 2 SENIOR WATER TECHN. II
- 2 SENIOR WATER TECHN. III
- 2 WATER TECHN. I
- 2 WATER TECHN. I AND II
- 1 WELDER
- 1 MECHANIC
- 2 CLERCS
- 5 DRIVERS
- 1 WATCHMAN
- 1 MESSENGER
- 2 LABOURERS

12 Management of Wood/Bamboo (Pipe) Project

The Project has significant implication in the field of technology as such it is essential that it is managed by approved professional officials.

The Project consists of two Technical fields:

a) CIVIL ENGINEERING (Water Supply and Irrigation)

b) FORESTRY (Wood Technology and Preservation)

It is therefore recommended that the Project will be headed by an official appointed by the President under the rank of PROJECT MANAGER assisted by two Chief Experts, a Civil Engineer and a Forester or Wood Technologist.

The later two Experts, are chief Aids to the Director or Manager of the Project on day to day activities.

Regions will have professional counterparts to those established at the Head Office.

Gradually more responsibilities will be decentralized from Headquarters to Regional, District and Village Level. (Management is shown on page 25).

13 Facilities and Equipments

The Wood/Bamboo Project requires Buildings, Vehicles, Plants and Office Equipments.

The first phase requirements is shown on next page. Experts, Personnel and equipments for the first five years 1978/79, 1979/80, 1980/81, 1981/82, 1982/83.

14 Costs

a) MANPOWER INCLUDING OVERSEAS TRAINING SHS. 746 000/-

b) EQUIPMENT SHS. 817 280/-

The Breakdown is shown on next page (27).

The initial cost of this Project is Shs. 1 628 160/-.

15 Projects Executions

15.1 Wood Stave Pipes and Tanks

TWICO: This is a Tanzania Government Parastatal and its Tenders are Economical. Accordingly we recommend to the Government to accept TWICO as a National Contractor for Wood Stave Pipes and Tanks. M/S J. S. SAGGU CONTRACTOR: This contractor is prominent in Tanzania and has experience in Tanzania Wood Industry and Building construction.

Yearly Engagement of Experts Personnel Plants and Equipment

Item	1978/79	1979/80	1980/81	1981/82	1982/83
Project Manager	1	1	1	1	1
Civil Engineer	4	5	5	8	8
Expert Bamboo Technology	1	2	2 1	3 1	3
Forest Expert	1	2	2	3	3
Training Officer		1	1	1	1
Chief Water Techns	3	3	3	4	4
Senior Water Techns I	2	2	2 1	2 1	2
Senior Water Techns II	4	4 NIL	4 NIL	6 NIL	6
Senior Water Techns III	5	5	5	7	7
Water Techns I	6	6	6 4	9 4	9
Water Techns II	-	-	-	-	-
Water Techns III Carpenters & Masors	11	11	11	24	24
Forest Assistant	1	2	2	3	3
Asst. Training Officer		2	2	2	2
Welder	1	4	4	4	4
Mechanic	1	4	4	4	4
Personnel Secr. Acct.	1	2	2	2	2
Clerical Officer	2	13	13	13	13
Motor Driver	5	16	16	16	16
Plant Operators	1	2	-	2	2

M/S SAGGU has made Tenders for Wood Stave Pipes and Tanks including construction works. Their tender is quite economical and it is the only firm able to carry out construction works in Wood Stave works throughout the country for the time being.

We recommend to Government to accept M/S J. S. SAGGU as an alternative contractor to TWICO.

Priority should be given for his contract to operate in the following Regions which are close to his factory.

a) IRINGA

b) MOROGORO

c) MBEYA

d) RUVUNA

e) RUKWA

f) DODOMA

This Contractor can operate hand in hand with TWICO. In addition his Contract should operate elsewhere in the Country at the Government request.

In order to encourage M/S Saggu to make more Investments on the Project, long term contracts must be considered and awarded.

15.2 Release of Contracts

Construction Drawings and Papers will be prepared by Wood/Bamboo Project Staff.

In case of administrative disputes involving release of contracts for Wood Stave Pipes and Tanks, the office of the Prime Minister will be responsible in deciding such disputes.

15.3 Bamboo Construction

Plans will be prepared by Water Experts.

Construction Works will be carried out by special Crew trained in handling Bamboo Water Projects.

Local Villagers will also participate in construction activities. Maintenance of Bamboo Water System will be carried out by Local Villagers themselves.

Minor allowances of about Shs. 30/- to Shs. 50/- a month can be paid to a villager responsible for maintenance Services. Such allowances are payable to Hydromet Gauge Readers by Maji today.

Two villagers are sufficient to maintain a bamboo village water supply system.

15.4 Bamboo Forests

The demand for bamboo pipes for village water supply will be high. We recommend the Government to establish new bamboo forests up to village level.

15.5 Aids

The following Agencies and Embassies have agreed to support the Project Technically and Financially.

1) NETHERLAND EMBASSY

2) ORGANISATION OF NETHERLAND VOLUNTEER SERVICES TANZANIA

3) CANADIAN HIGH COMMISSIONER

4) NORWAY EMBASSY

5) INDONESIAN EMBASSY

We recommend the Government to make official request to the above Embassies and Agencies in supporting the Project technically, financially, in short and long term.

15.6 Release of Forest Experts

Office of the Prime Minister has approved the appointment of six experts for the Projects ongoing.

We recommend the release of Ndugu P. F. Nangawe of Forest Division to join the Project. Initially he can work on the Project part time.

The Director of Forest Division is willing to take up this decision.

Ndugu Nangawe has been attached to this Project since beginning. Forest Division will provide more trained manpower as we require from time to time.

16 Responsible Ministries

Investigation works started in Mwanza in 1974 and continue to Songea and Iringa in 1976 - 1977 and 1978. Since the beginning there has been a strong rejection from Maji Ministry Staff (on technical side) in accepting and helping the Project.

The Wood/Bamboo Project is REVOLUTIONARY to Maji Ministry as a whole.

The background of this Project and investigation was to assist the Government to provide water to Rural Population cheaply and quickly.

It is therefore recommended for Wood/Bamboo Project to remain UNDER THE OFFICE OF THE PRIME MINISTER until the Ministry of Water, Energy and Minerals accepts the Project and its functions. Maji Facilities such as Vehicles, Plants should be equally shared. Maji staff who are interested to join the Wood/Bamboo Project should be given free hand to join.

The Project has capacity to accomodate irrigation works as well.

Normal co-operation with Ministry of Agriculture will be made during Planning and Implementation of irrigation works.

17 Special Recommendations

17.1 Subversive Activities

During investigation works we experienced many unpleasant incidents which were aimed at frustrating and under-mining the Project.

Such incidents were exposed to the authorities concerned. 26 different incidents were noted and recorded.

Below is a text of one of the letters which was being used actively to undermine the Project.

SWAHILI 1977-04-23

Ndugu, ???
REGIONAL WATER ENGINEER

MAJI KIJIJI

Nimeonana na Ndugu, ambae amenieleza maendeleo ya kazi pale Kijijini nimepata pia taarifa ya, kuhusu matumizi ya mianzi kama bomba na nimekatishwa tamaa.

Hivyo nimependekeza kwa: ???

a) Matumizi ya mianzi yaachwe

b) Wafadhili wapewe taarifa ya, na waombwe kuidhinisha matumizi ya P.V.C. tu ili kuondokana na matatizo makubwa baadae kwa w.nakijiji. ??? wamesema na wakuu wa Serikali huko Mkoani na Wilayani wenye uwezo wa kusimamisha Mradi wa mianzi kama wanaridhika na taarifa hiyo. Tafadhali ongea na RDD, DDD na AC ili kwa kauli moja muiarifu Office ya Waziri Mkuu kuwa Mradi huo hautufai na uachwe kabisa. Uamuzi huo utawapa nguvu ??? KUBADILISHA kauli yao ya kuusaidia Mradi wa Mianzi.

Nisalimie wote huko, na Kijijini

Jina???

Cheo???

Swahili to English Translation

Ndugu,
REGIONAL WATER ENGINEER

WATER AT??? VILLAGE

I have met Ndugu??? who has given me the development progress at the village. I have also been given the report from??? Concerning the use of bamboo as water pipes. This has discouraged me.

Thus I have suggested the following:

a) The use of bamboo should be abandoned

b) The DONOR COUNTRY should be given a report??? and should be asked to approve the use of P.V.C. pipes only. So as to avoid big problems to the villagers which might arise in future. ??? have already discussed with the Regional and District Government Officials, these have the ability to stop the Bamboo Project if at all they agree with the report.

Please discuss with R.D.D, D.D.D, and R.C. so that you all have one and joint decision and inform the PRIME MINISTER'S Office that the Project does not suit us and should be completely abandoned.

Such a decision will give ??? strength to change the decision of supporting the Bamboo Project.

Greetings to all??? and at the Village.

Name???

Designation???

The Origination of this letter is from a very senior member of Government.

We believe such incidents might continue when the Project is at the implementation stage.

We request the Government to take all the necessary measures against any person who might in future attempt to carry out activities which might affect the Project during implementation.

17.2 Promotions

During investigation works a lot of problems and hardship occasions were encountered by members of Investigation crews e.g. working in rain, very cold weather and camping in locations which were extremely hard to live.

All this effort and energy has resulted to fruitful results for the success of the Project.

Accordingly it is recommended for the following staff to be promoted to Senior Positions of the Project as their reward.

All are non-professional grades:

Posts of Chief Water Technicians

1) E. MWAKAFWILA
2) R. ZIMBWE
3) O. NGOI

Post of Senior Water Technician, Grade I

1) L. NDALLO
2) O. SALUMU

Post of Senior Water Technician, Grade II

1) M. LUKUWI
2) S. BWAHAMA
3) J. MALASA
4) C. TUNDURU

A SHORT OVERSEAS OR LOCAL COURSE IS SUFFICIENT TO HELP MANAGE THEIR WORKS

Post of Senior Water Technician III

1) S. BAKARI
2) A. O. JUMANNE
3) E. LUGAGALA
4) C. MKAMA
5) M. MUSSA

A SHORT FIELD COURSE IS SUFFICIENT FOR THEIR PROMOTION

Post of Water Technician I

1) A. IBRAHIM
2) K. MWAKISALE
3) E. SAMSON
4) P. KIFARU
5) M. KAZI
6) A. MOHAMED
7) Y. AMIDU
8) K. CHAPALAMA
9) CHRISTANTUS R. NDIWE

Promotions should take effect immediately after fulfilment of managing field training as recommended.

17.3 Appreciation

The following Overseas Experts who have Voluntarily assisted the Project to come to success by providing the technical materials essential for investigation works are worthy mentioning.

1) Mr. C. N. LANDMAN (Photograph on last page left hand side to Ndugu Lipangile) C/O ORGANISATION OF NETHERLANDS VOUNTEERS IN TANZANIA, P.O. BOX 9421, DAR ES SALAAM

2) Mr. D. D. S. SCORER (E.K.I.O.B. - A. I. M. WOOD T) (Photograph right hand side to Ndugu Lipangile) C/O TANZANIA WOOD INDUSTRY CORPORATION (TWICO), P.O. BOX 9160, DAR ES SALAAM

LOCAL EXPERT: NGUGU P. F. NANGAWE, C/O UTILISATION SECTION, FOREST DIVISION, P.O. BOX 10, MOSHI

Finally, as the Head of Project I must give my sincere thanks to Ndugu - LAWI SIJAONA - THE THEN MWANZA REGIONAL COMMISIONER (M.P.) TIMOTHY APIYO - PRINCIPAL SECRETARY TO THE PRESIDENT, JACKSON MAKWETA MINISTER OF STATE OFFICE OF THE PRIME MINISTER AND NDUGU P. P. MURO OF C.C.M. HEAD-QUARTERS for their encouragement and strong support of the Project since beginning up to now.

Submitted by:

T. N. LIPANGILE
HEAD OF PROJECT
WOOD/BAMBOO

cc The Principal Secretary
President's Office
DAR ES SALAAM

cc The Executive Secretary General
C.C.M. Headquarters
DODOMA

cc The Principal Secretary
MAJI
DAR ES SALAAM

cc Principal Secretary
KILIMO
DAR ES SALAAM

cc The Principal Secretary
Maliasili
DAR ES SALAAM

WOOD/BAMBOO PROJECT

APPENDIX I

ENGINEERING REPORT ON WOODSTAVE PIPES AND -TANKS AND BAMBOO PIPES

Peter Jacobs
Nils Lundborg

August 1978

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1979-01-24

ENGINEERING REPORT ON WOOD STAVE PIPES AND -TANKS AND BAMBOO PIPES

This report looks upon the technical and civil engineering aspects of the use of wood and bamboo in the Tanzania Water Supplies.

Dealt will be with:

1) Wood specified after the following items:

1.2 wood stave pipes (small - square)

1.3 wood stave pipes (bigger - round)

1.4 wood stave tanks

2) Bamboo: Possibilities of using it as pipe material.

Applications

Woodstave Pipes for:

- Irrigation schemes (Rising main)
- Rural and Urban Water Supply
- Drainage and Sewage purpose

Woodstave Tanks for:

- Irrigation schemes
- Rural and Urban Water Supply
- Industrial purposes

Bamboo Pipes for:

- Rural Water Supply
- Irrigation Schemes (Branches)

1 WOOD

1.1 Introduction

1.1.1 General Data

This part of the appendix is mainly based on the report "Feasibility study on the use of wood in water-works" from Mr C N Landman, which was submitted by Mr T N Lipangile in March 1977.

The set up is changed and new findings have been added.

We will deal with the following wood stave constructions:

1.2 Woodstave pipes, square from 5 x 5 cm^2, 12,5 x 12,5 cm^2 (2" x 2" - 5" x 5").

1.3 Woodstave pipes, with diameters of 15 cm (6") and onwards.

1.4 Woodstave tanks, with capacities varying from 1 000 to 100 000 l (about 220 - 220 000 gallons).

For pipes two methods of woodstave constructions can be distinguished:

The Continuous Stave System

- stave (planks) are machined in the factory
- assembled in the field
- lenght of staves (planks) can be at random

Factory Made Pipes

- conventional idea: pipe made in the factory
- complete in fixed lengths
- joint necessary

Both systems have advantages. For Tanzania circumstances the continuous stave type is regarded more suitable, mainly because in this system the pipes are transported as loose staves. This is a considerable advantage in transport. In this report attention will be given to the continuous stave system only.

1.1.2 Advantages of Wooduse in Waterworks

The use of wood in waterworks has quite some advantages compared to the conventional materials such as PVC, Galvanised Steel, Ductile and Concrete Pipes. These advantages are listed in sequence of importance:

- The imported materials content is very low in woodstave constructions. This gives an extra dimension when comparing prizes.

- Wood in waterworks increases employment.

- The transport costs are very favourable for the woodstave construction because they are transported to the site in knocked down condition and assembled over there. No or little breakage during transportation of the staves provided these are bundled and handled with some care.

- Long life and low maintenance. Especially when treated properly, the modern woodstave constructions require little or no care to ensure long, uninterrupted service.

- Easy and economical to install. The constructions are assembled in place from individual, precut staves. No heavy equipment and compared to steel and concrete works little skilled labour is needed.

- The friction losses are fabourable and won't increase with age.

- Wood provides effective insulation against outside temerature changes.

- No electrolysis: since wood is a non conductor of electricity, no cathodic protection is necessary.

1.1.3 Availability of Wood

The total wood production in Tanzania is per year about 170 000 m^3. The coniferous species (softwoods) supply up to now only a small part (40 000 m^3) of the year production. About 10 % of the total production is exported, in figures: 13 000 m^3 hardwood and 4 000 m^3 softwood.

In the near future (5 years) the availability of the softwoods will improve, but the situation for the hardwoods will be worse because no replantation is taking place.

The not-exported wood is used for the following purposes (figures 1970):

- Furniture	38 %
- Joinery	35 %
- Construction	21 %
- Shuttering	4 %
- Crates	2 %

1.1.4 Durability of Wood

<u>Lifetime without Treatment</u>

The lifetime of not treated wood is depending on the wood species and the environmental conditions (dry, wet insects).

Lifetime

	Under the ground	Above the ground
Durable wood	More than 15 years	More than 25 years
Perishable wood	0,5 - 1 year	1 - 5 years

Treatment Methods

Certain timber species especially of the softwoods can be treated to extend its lifetime. Such a treatment should be done after machining.

The best method of wood treatment is pressure impregnation.

- Impregnated are salts, containing copper - chrome - arsenic (CCA - Salts)

- The two major brands in Tanzania are Tanalith C and Celoure A

- Pine is very suitable for this kind of treatment

- There are pressure impregnating plants in Arusha, Mafinga, Tanga, Tabora, Moshi, Dar es Salaam, Bukoba and Mbeya.

Other possibilities of wood treatment are

- Dipping or emerging in preservative, if the timber is heated and left to cool down in the preservative, reasonable good results are obtained.

- Brushing of painting, which seldom is very effective against insect attack

- Sap displacement for poles and dip diffusion for sawn timber, the sap in the green timber is replaced by a preservative in about one week by means of osmosis, lifetime in the ground: more than 10 years

- Soil treatment, which is effective against subterranean termites (see also the Bamboo part).

Life of Softwood when Pressure Impregnated

The average lifetime of softwood when pressure impregnated is supposed to be well over 30 years and probably reaching 50 years (from Preserving Timber by N Lundborg in an information pamphlet from TWICO.

1.1.5 Health Aspects

None of the species which are suitable for woodstave construction, are containing any poisonous parts, which could effect the quality of the water.

Sometimes a chlorination treatment has to be applied to avoid colouring of the water. After a short flushing of the treated wood, no harmful effect have to be expected. See for the way of chlorination treatment and the health aspects, the Bamboo part. Durable hardwood species can be used to make wooden pipes and tanks.

Pressure impregnated softwood timber containing CCA - salts has to be checked on leaching. Through abroad for already more than 20 years good results have been attained - also in drink water supplies - leaching of the salts was found by the Ubungo Laboratory of Maji. The Ubungo Laboratory was testing some samples, which were pressure impregnated by TWICO (Sao Hill Mill Ltd). Experts from TWICO suggested that the leaching was due to the taking of tests on recently treated wet samples. The wood has to be dried after treatment for about 3 - 6 weeks (depends on the weather conditions).

The Chemical Department Laboratory of the University of Dar es Salaam is carrying out more tests on the leaching of the CCA - salts.

More tests have to be carried out and only after a clarifying with the laboratories concerned (Government Chemist and Ubungo), we will start to use the CCA - treated wood for drinkwater purposes.

For irrigation projects the Forest Division has already confirmed the safe use of CCA - treated wooden tanks and pipes (medical report, page 7).

1.2 <u>Woodstave Pipes, Square 5 up to 12,5 cm^2 (2 - 5 sq inch)</u>

These woodstave pipes are assembled from 4 planks and held together by bolts and nuts. See for such a kind of pipe fig 1. The composing parts are put together at random and no joints like we know them from the conventional pipes are needed.

A comparison of the prises between these pipes and PVC pipes can be made, if we take the working pressure, the area, the C valve and the kind of jointing in account. If we take thus comparable pipes we will find that the small square pipes (5 x 5 cm^2) are about 10 % more expensive and the biggest square 12,5 x 12,5 cm^2 are about 35 % less expensive than the PVC pipes.

An open type of square woodstave pipes (only 3 planks) could prove to be very suitable for irrigation purposes.

Investigations will teach us more about the possibilities of this pipe construction.

1.3 Woodstave Pipes with Diameters of 15 cm (6") and Onwards

A woodstave pipe is assembled out of a number of staves, which are machined to form a circle. The staves are kept in place by means of metal bands, galvanised wire or strapping material. For the sizes, mentioned in this chapter, metal bands are used, which can be loosed or tightened by a nut, attached to the threaded end of the band. During assembly, these nuts are fixed loose-tight and the moisture content of the wood is approximately 15 %. When water is flowing in the pipe the wood saturates and tightens itself firmly against the metal bands by swelling and thus eventual leaks in the pipe will disappear after 1 or 2 days, see fig 2.

We distinguish the following types of wood - stave pipes.

Pressure Woodstave Pipe for:

- Rural and Urban Water Supply

- Irrigation pipes (Rising mains)

- Non-pressure woodstave pipes

Closed Pipes for:

- Irrigation purposes

- Culverts

- Drainage and sewage pipes

Flumes or Open Pipes (see fig 3) for:

- Irrigation works

- Drainage pipes

The three kinds of pipes are generally discussed, if necessary additional remarks are made on differences.

1.3.1 Techniques

Seasoning

Fresh cut timber or green timber has a moisture content higher than 20 %. To assure an easy machining and a good swelling when the pipe is put into service, the moisture content has to be lowered to 15 - 20 % (= seasoning).

In Tanzania the air drying of timber is performed sticker stacked where between every piece of sawn timber stickers are placed. The pile of timber is then covered to keep the sun and rain away. A rapidly decreasing moisture content often results in a twisting of the timber. It has to be noted that some species always will twist.

The thickness of the stickers (e g 1 cm) and the environmental conditions determine the period of seasoning. Generally it takes 2 - 4 months for the softwoods and 4 - 6 months for the hardwoods.

Selection

A minimum (no) leakage can be reached when selecting the wood or the following items.

- Only fresh knots if any

- No splits

- Not effected by fungi or live borers

- For softwoods the distance between the annual rings should be limited; the fast grown central part of the tree avoided

- No bark or resin pockets.

Composing Parts of the Pipes

Stave

Although the internal pressures are taken by the steel bands, wound around the pipe at regular intervals the thickness of the wall (the staves) is important.

Diameters (mm)	Sizes (mm^2)	
150 - 225	25 x 30, 38 x 30	(1½" x 1", 1½" x 1½")
250 - 375	38 x 50, 50 x 50	(2" x 1½", 2" x 2")
400 - 500	50 x 75	(3" x 2")
525 - 1 200	50 x 100	(4" x 2")

Four conditions are influencing the shape, to be given to a stave:

a) The outer circumference of a pipe should be round, thus to enable the steel band to be in touch with the woodsurface over its entire lenght.

b) The inner surface is in continous contact with the water, so the roughness of this surface is determining the C-value of the pipe.

c) Some shape must be given to the sides of a stave, to make the pipe leakage free.

d) During construction, before the banding is done, the staves should not fell apart.

According to these conditions, the shape has to be machined as follows (see also fig 4):

a) The side of the stave, which will form part of the outer circumference should be machined to have the correct external radius.

b) The internal surface of a stave should be planned as smooth as possible.

c) The sides of the stave should form a tight joint with the adjoining stave throughout their lengths.

d) To facilitate the assembly, a small bump and indent on alternate sides should be machined.

Winding Materials

Mainly four types of winding materials can be used, varying with the requirements.

a) Galvanised wire: for small diameters.

b) Round iron bars: 3/8", $\frac{1}{2}$" and 5/8" (10, 12, 14 mm).

c) Flat bars, $\frac{3}{4}$" x 1/8", 1" x $\frac{1}{4}$" (10 x 3, 25 x 3, 25 x 6 mm).

d) Strapping material, galvanised. b) and c) to be used for bigger diameters.

Shoes

A simple, locally made construction is manufactured to be to tie each band sufficiently. One end of the band is fastened to a shoe - see fig 5, the other end is threaded and the same thread is machined in the ferrule of the shoe -. A nut is attached to tie or loosen the band.

Reinforcement/Pressure

Spacing for Non-Pressure Pipes

For the use as irrigation-pipes culverts, sewage pipes and drainage-pipes the pressure normally will be zero. The spacing of the bands can be at regular intervals of 300 - 500 mm (12" - 20").

Spacing for Pressure Pipes

For pressure-pipes the safest method is to calculate the spacing in such a way, that the total internal water pressure is taken up by the bands. Some engineers use a system, whereby both wood and steel bands are taking this pressure; the pipe can be more economical but the play is small, we prefer to stick to the first method.

The spacing can easily be calculated with the following formula:

$$L = \frac{2 \times F}{P \times D}$$ See figures 6 and 7

Whereby: L = Spacing between two lands
F = Internal force, which can be taken by one band
P = Waterpressure and D = diameter of the pipe

An example is given for a 150 mm pipe, which will have to carry 4 atm. The steel band is a round steel bar, diam 6 mm.

The working tension in this steel is 1 400 kgf/cm^2.

$$L = \frac{2 \times F}{P \times D} = \frac{2 \times (\frac{1}{4} \times 3{,}14 \times 0{,}6 \times 1\,400)}{4 \times 15} = 13 \text{ cm}$$

Fig 8 is a spacing chart on which the spacings of the different sizes of steel band are indicated for several diameters under varying pressures.

Jointing

Longtudinal Joints

For a continuous stave the longitudinal joint is important, there are mainly three solutions, of which the last one will be recommended.

a) Galvanised steel or plastic tongue joint (see figure 9).

b) Malleable iron but joint (see figure 10)

c) Double tongue-finger joint (see figure 11)

The advantage of the latter one is, that practically nothing can go wrong during installation. In case of neglect the inserting of the other two can be forgotten, or wrongly applied. The difference in cost is small, but c) will be the cheapest.

Junctions/Fittings

The connection of a woodstave line to a dam, surge tank or power house is normally made to steel thimbles the outside diameter of the steel being equal to the inside diameter of the woodstave pipe. A layer of candle wicking is carefully wrapped around the steel and then the woodstave pipe is built over it and cinched tightly with extra bands.

Saddles for small take-offs, drains, air and vacuum release valves can be installed by means of cast iron or steel weldments.

New Connections

New connections are also made by means of the steel thimbles. The pipeline is cut with a saw on the part where one wants to make the new connection and build together again like is described above by inserting the steel thimble and by building the shortened wood-staves over it.

Design Details

- Lines should be laid out for a radius of curvature not less than 60 pipe diameters

- Air release valves should be installed at all high points in the line where air will collect

- Vacuum release valves of adequate capacity should be installed at high points

- Drain and wash-out fittings should be installed at low point in lines for emptying and cleaning

- In large lines conveniently located manholes should be installed to allow access for internal inspection

- Surge tanks must be installed when required by the hydraulic operating characteristics of the system

- Wood stave surge tanks will be found most economical in many situations

- Fittings for the above requirements sometimes have to be especially designed and fabricated to fit the particular pipe line being built. Try to avoid this by an adapting of the pipelines to the available thimbles.

Laying Operations

General Remarks

Woodstave pipes are laid above the ground for maximum life and easy of maintenance. The gradient requirements are therefore simple and economical. A gradient levelled to within 2,5 cm (1") of sill bottom elevation and ballasted with suitable gravity is all that is required. This prepared gradient will also serve as a roadway for the distribution of pipe components.

The pipe can be built to horizontal and vertical curves, the gradient can follow the natural contours closely.

Expensive fabricated elbows and turns, are not required. The use of these smooth, easy curves instead of sharp angle bends also eliminates the necessity for long concrete anchorages.

Tools

The working tools required for the erection of wood-stave pipes are illustrated in fig 12 and are as follows:

1) Oak driving bar

2) 10 pound sledge hammer

3) Building chisel

4) Crowbar

5) 2½ lb black hammer

6) Brace wrench

7) Ratchet wrench.

Laying Pipe

When the pipe staves are distributed along the pipelines, they should be placed in piles containing the number of staves required to form the circle. The staves in each pile should be approximately the same length so that the finished pipe will have the joints staggered in about the same location around the pipe.

There are many types of building forms that can be used; however, those shown in fig 12a and 12b are now considered standard for the smaller sizes of pipe. They are made of iron pipe bent to the pipe circle and can be produced by any blacksmith or plumber. These forms are used to hold the staves in position until a few bands are placed around the pipe.

The driving bar is used to avoid marring or damaging the ends of the staves when they are being driven into position. The driving bar should be about 120 cm long and made of oak or other hardwood that will withstand considerable hammering, and it should have a steel reinforcing band around one end. The building chisel is used to guide the staves into their proper position.

As soon as a section of pipe is build, a few bands should be placed around it about 0,60 - 0,90 m apart. These bands can be placed without regard to their final position.

The bands are used to hold the pipe staves in position so that the building forms can be moved forward and the next section of pipe built. The remainder of the bands can then be placed on the pipe.

The bands should be placed perpendicular to the axis of the pipe with the shoes placed so as to bear quality, as nearly as possible on two staves. The shoes should be placed alternately on opposite sides of the pipe in a uniform manner. There should be two or more rows of shoes on each side of the pipe, which gives a uniform bearing on a number of staves.

After the band is placed around the pipe, the pipe shoe is slipped over the button-head and the crowbar is used to place the threaded end of the band with the nut and washer into position in the pipe shoe. The brace wrench is used to run the nuts down on the thread and give the band its initial tightening.

The ratchet wrench is used to give the pipe bands their final cinching. These ratchet wrenches have removable parts that can be replaced when worn out, and heads to fit several sizes of bands can be furnished for one handle.

After all bands are in position and tightened, they should be cinched again to produce uniform tension throughout the pipeline. All kinks in bands should be carefully hammered out, using the $2\frac{1}{2}$ lb blacksmith hammer for this purposes. Bands should not be cinched too tightly, just enough so that they will not move on the stave when lightly tapped sidewise with the $2\frac{1}{2}$ lb hammer.

If necessary, bands may be hammered during the cinching process in order to remove irregularities and to insure proper seating. Extreme care should be exercised at this point to prevent bruising or breaking of the wood fibers. After erection, all metal work should be retouched. Where necessary, with a suitable paint of asphalt mastic.

Cradles

Cradles are required not only to support the pipe on the grade but also in larger lines to prevent the pipe from distorting. This distortion is particularly dangerous when large lines are being filled or are operating under very low head. The cradles are placed on 2,4 - 3 m (8 - 10 ft) spacing.

Timber cradles are practically always pressure impregnated. They are completely shop fabricated, shipped knocked down and assembled in the field. See fig 2.

Testing

Whenever possible, water should be admitted to the pipeline gradually, allowing time for the swelling of the staves before full pressure is applied. The pipe should then be tested to full operating pressure and any running leaks appearing under such pressure closed.

Repairs

Replacing Lengths

On the spot where one wants to replace the stave, the pipe is cut with a saw. The woodstave are taken out and replaced. Again a steel thimble is inserted and the new staves built over the thimble.

Small Leaks

The wood pipe will leak slightly when the water is turned on, but wedges should not be used until the pipe has had time to soak thoroughly. If seam leaks appear drive thin wedges under the iron bars. Never drive them between the stave because this only results in a spoild joint.

Another good method of closing small seam leaks that do not swell tight is to make a shallow out with a chisel about 3 - 6 mm (1/8 - ½") away from the seam and drive in a softwood wedge. This bends to pinch the seams together.

1.3.2 Hydraulics

Friction

The inside smoothness of the woodstave pipes is in the Hazen-Williams formula expressed by the value C. This value for woodstave pipes is 120. The corresponding friction losses are about the same as the losses in concrete pipes, about 50 % higher than in PVC pipes and about 30 % less compared to cast iron pipes.

Pressure

The size and the spacing of the winding material determines the pressure a woodstave pipe of a certain diameter can take. See Reinforcement/Pressures on page 8 and fig 8.

Non-Pressure Pipes

A non-pressure pipe needs winding material at intervals of 30 - 50 cm. This type of pipe can be built in every desired diameter.

Pressure Pipes

Woodstave up to 600 mm (24") can take pressures of at least 10 atm depending on the size and spacing of the bands. To take for instance 10 atm (142 psi) a 300 mm (12") pipe needs steel bars of Ø 10 (3/8") and a 600 mm (24") pipe bars of Ø 14 (5/8") for both the required spacing is 7 cm. The pressures for bigger dimensions are easy obtained from the formula on page 9 for instance a 1 800 m (72") woodstave pipe can take about 5 atm. (71 psi) (Ø 14 spacing 5 cm).

1.3.3 Costs/Economy

The prices of non-pressure woodstave pipes are about 20 % cheaper than concrete pipes. Compared are woodstave pipes made by a contractor and Mecco concrete pipes. See for the actual prices exhibit 37 D.

Plastic steel pipes compared to concrete pipes prove to be more expensive (ex-factory) and thus far more expensive than woodstave pipes. (6 times more expensive e.g. for 24" pipes.)

Woodstave pipes which can take 6 atm (88 psi) are at least 50 % cheaper as comparable plastic and steel pipes (6 atm). See exhibit 37 A and B.

The compared prices are ex-factory. Added must be transport to the site and the laying of the pipe in line.

- Transport; the transport of woodstave pipes, which go unassembled to the site, will be very much less per meter than any of the other types which go complete. Woodstave pipe is one quarter of the weight of steel or concrete and about 1/10th the volume. Plastic pipe is lighter than wood but the volume is the same as for steel or concrete. The transport of wood pipes would be 1/3rd of that of steel or concrete and ½ that of plastic.

- Laying of the pipe, whether on the surface or in a trench is always cheaper with woodstave pipes, because no heavy lifting equipment is needed (concrete and steel) and a minimum of foundation is needed (concrete), which gives a further saving in transport.

- The woodstave pipe is built by unskilled labour with a minimum of supervision and equipment. Per day 30 - 90 m (100 - 300 ft) can be built. Especially compared to concrete this saves skilled labour.

Also the savings in foreign exchange should be mentioned, when using wood pipes instead of steel and plastic pipes. On this item, the following remarks: In relation to the wood project it is often heard that the shortage of wood in Tanzania does not allow any expansion of the wood use. Noted should be that only a relative small quantity of wood is needed when building woodstave pipes, for instance 35 m^3 wood for a pipe line of a diameter of 150 mm (6") length 1 000 m (3 280 ft) or 60 m^3 for a 300 mm (12") pipeline per 1 000 m or 115 m^3 for a 600 mm (24") pipeline per 1 000 m.

If in future some bigger schemes are going to be implemented, where pressure woodstave pipes are used instead of plastic or steel pipes it possibly can be decided to reduce the export of wood, in favour of these schemes. This if it would turn out to be that there is too little wood available on the local market. Of course on one hand this will reduce also the income of foreign currency, but on the other hand no steel pipes or rough material for plastic pipes have to be imported. This prices are at least twice that high as the amount of money that is involved when reducing the export of wood.

1.3.4 Application

Woodstave pipes can be used in the following cases:

- Impregnated softwoods: 1) Irrigation pipes (closed pipes and flumes), 2) Drainage and sewage pipes, 3) Culverts.

- Hardwoods: 4) Rural and Urban Water Supply, 5) The under softwood mentioned cases (1 - 2 - 3).

Impregnated Softwoods

The woodstave pipes made from impregnated softwoods should be always filled or at least half filled. If not, already after $1\frac{1}{2}$ week (pinc) cracks will appear. These cracks will close again after refilling, butthey will lead to severe losses of leaking water for 1 - 2 weeks. For this reason the woodstave pipes made from impregnated softwood should preferably be used on gravity lines. When on well set-up bigger schemes the management is in good order, impregnated softwood can be used to serve also pumped water supplies.

1) Irrigation pipes. Probably in the near future some bigger irrigation schemes will be implemented in Tanzania. It will be of very big interest to investigate what role woodstave pipes can play in these schemes. Special attention has to be drawn to the possibilites of the opening of woodstave pipes (flumes).

2) Drainage and sewage pipes. Especially on bigger lines and the woodstave pipes will prove their suitability.

3) Culverts. Not of current interest because culverts of corrugated iron sheets (ARMCO culverts) are far more cheaper and can be used for the same purposes.

In the near future when the use of impregnated softwood for domestic water supply purposes will be approved by the authorities concerned, especially on the bigger schemes important savings can be made (50 % or more).

Hardwoods

The problem of the cracking of hardwood pipes is much less than on softwood pipes and the pipes can serve gravity and all pumped supplies.

4) Rural and Urban Water Supply. Hardwoods are 50 - 100 % more expensive, compared to softwoods, while also the machining is a bit more expensive. It has to be investigated what species of hardwood could be economically used for the domestic water supply.

1.4 Woodstave Tanks

In principle the idea behind the woodstave tank is very much the same as for woodstave pipe. It can be constructed in sizes varying from 1 000 - 100 000 l (about 220 - 220 000 gallons). The sizes up to 2 000 l (440 gallons) can be produced at village level. The woodstave tank is circular, and the walls are consisting of a number of vertical staves. The internal pressure of the water in the tank is taken by steel hoops wound horizontally around at distances, varying with the internal pressures at a certain height. These bands are adjustable, they can be tightened or loosened by a nut. Fixed on the threaded end of the band. The foundation of the tank is made out of concrete of wood; the advantage of concrete foundation is, that it can serve as bottom of the tank as well.

1.4.1 Techniques

Seasoning and selection as mentioned under 1.3.1.

Composing Parts

Relation capacity/dimensions. In the USA the following standard sizes of water tanks are applied:

Gallonage (Nom US)	Liters	Dia m	Height m
500	1 892	1,57	1,22
1 000	3 785	1,83	1,83
5 000	18 925	3,35	2,44
10 000	37 850	4,15	3,05
15 000	56 775	4,72	3,66
20 000	75 700	5,47	3,66
25 000	94 625	5,49	4,27

We have kept as maximum capacity 25 000 gallons but actually there is not a technical limitation. Woodstave tanks have been built with capacities up to 2 000 000 gallons.

For the range, mentioned above the finished thickness of 50 mm (2") will do. Using 75 mm (3") staves the diameter of the tank can go up to 22 m. (72') for 100 mm (4") up to 37,50 m (123').

Hoops

Hoop spacing is calculated according to the liquid pressure of the tank contents and varies from a necessarily close spacing at the bottom to a maximum spacing of 45 cm (15") at the top. Mild steel bars is the appropriate material for the hoops, though stainless steel can be used as well. Each hoop section has at least 15 cm (6") of cold rolled thread on one end and 5 cm (2") on the other. A heavy hexagon nut provides a sufficient fastening. The ends of hoops sections are connected by iron shoes see fig 5.

Example of Spacing

Given: Woodtank 10 000 G. Height 3,05 m diam. 4,15 m.

Hoops: Mild steel bars 12 m.

Pressure at bottom 3,05 m water colomn = 0,305 atm

Take the 10 cm nearest to the bottom. Average pressure: 0,3 atm kgf/cm^2.

According to the example for spacing in woodstave pipe we got:

$$2 \times F = \text{Diam} \times 10 \text{ cm} \times 0{,}3 \text{ kgf/cm}^2$$
$$F. = \frac{1}{4} \text{pi } (1{,}2)^2 \times 1\ 400 = 1\ 568 \text{ kgf}$$
$$2 \times 1\ 568 = 415 \times 10 \times 0{,}3$$
$$3\ 143 = 1\ 245$$

Second attempt: we take the lowest 20 cm; now the average water pressure =

0,295 atm
$$3\ 143 = 415 \times 20 \times 0{,}295$$
$$3\ 143 = 2\ 743$$

The difference is smaller, and can be seen as a safety-factor.

Conclusion

A 12 mm bar can take the pressure of the lowest 20 cm in a 10 000 g tank. We space the hoops at this interval over the lowest metre and sequencly make the calculation again.

Construction

Based on the information, received from the USA a 45 000 l storage tank on groundlevel is designed.

Further are in our possession drawings with all kind of details on floor wall, roof and erection-procedures.

1.4.2 Costs/Economy

In exhibit 30 page 3 the costs of wooden tanks on ground level are given. This tanks are assembled from impregnated softwood by a contractor. In the same exhibit also the prices of stone masonry/concrete tanks on groundlevel are given. The woodstave tanks are 10 - 30 % (50 000 - 10 000 gallons) cheaper compared to the masonry/concrete tanks.

If the tanks are made from a cheap hardwood like Mtambara the contractor price will rise with 30 %. This results are not competitive prices for these wood tanks against masonry/concrete tanks.

1.4.3 Application

Woodstave tanks made from impregnated softwoods can be economically oonstructed for irrigation purposes (savings 10 - 30 %).

In the near future when the application of impregnated softwoods is approved, woodstave storage tanks can serve the Rural and Urban Water Supply.

Woodstave tanks made of hardwoods are in the domestic Water Supply not competitive with masonry/concrete, tanks. The future of these tanks has to be searched in the storage of special liquid (high temperatures chemical and corrosive materials) for manufacturing purposes. Also the impregnated woodstave tanks should be taken in consideration for this purposes.

2 BAMBOO

2.1 Introduction

2.1.1 General Data

From botanical view bamboo is any member of the tribe Bambusae, a subfamily of the grasses. The plants included in this group are of extremely variable nature, ranging from small inconspecious species to the largest species of grass known, some having slender erect stems approaching a hundred feet (30 m) in height. All these grasses are characterized by jointed hollow stems having solid nods. In some regions the people have become to depend almost entirely on bamboos, so numerous are its uses. The hollow stem may serve as pipes for conducting water, or as containers for storing water and other substances. The stems are used for the construction of shelters, boats and furniture, further the stalks of certain species become an important foodstuff (Van Nostrand's scientific Encyclopedia, 1968).

The stem consists of sections of uniform length (25 - 90 cm or 10 - 36"), with membranes or nodes in between.

Bamboo is one of the most rapidly growing plants in existence. Generally it is fully mature in 3 - 4 years.

2.1.2 Availability in Tanzania

For the examinations two species of bamboo are used: the green bamboo and the yellow bamboo with green stripes. (See fig 13).

Green bamboo (oreobambos buchwaldii) has weak, hollow green stems up to 18 m (60') height and is forming dense patches or solitary clumbs in more open parts of ever-green rainforest, ranging from 450 to over 2 000 m (1 500 - 6 600 ft) altitude.

From the green bamboo stem a pipe of about 3 m 9'10" with a nearly uniform inner/outer-diameter can be obtained. This part is situated between 1-4,0/5. 0m (3'4" - 13'2"/16'5") above the roots.

The uniform inner diameters are ranging from 3,75 - 7,5 cm ($1\frac{1}{2}$" - 3"), with a maximum difference of 0,6 cm ($\frac{1}{4}$") between the ends of the pipes.

From the Forest Report (Appendix II) the following data about the availability of green bamboo are extracted:

Region Kigoma	Area in acres
Kibondo District	30 000
Kigoma District	16 280
	46 280 acres
Region Mbeya	
Rungwe and Mbeya	88 000 acres
Region Lindi	
Nachingwea District	23 654
Kilwa District	84 480
Lindi District	11 264
	119 398 acres
Region Iringa	
Iringa District	53 171 acres
Mufindi District	1)
Njombe District	1)

1) Plenty available but quantity is not known.

Region Morogoro

Mahenge District	2)
Ifakara District	2)
Morogoro District	2)
Kilosa	2)

In Iringa district (Dabaga area) the Forest Division was counting 100 mature stems per 400 sq m or 1 000 stems per acre.

If we only take the known acrage in the few regions mentioned (306 849 acres) then this is already leading to an availability of more than 300 million mature stems.

Also in other regions like Kilimanjaro, Tanga, Arusha and West Lake green bamboo forests are existing, but we do not have any detailed information about place and quantity.

Yellow Bamboo with Green Stripes (Oreobambos Vulgaris) has erected straight stems up to 20 m (65'7") height. The structure of its fibres is very compact which results in a heavy and hard bamboo. This foreign bamboo is planted by Forest Division in the bamboo forests of the Government forest reserves and on little scale by local people on an altitude of 1 000 to over 2 000 m (3 300 - 6 600).

From this type of bamboo, pipes of 4 - 5 m (13½" - 16'5") with uniform inner diameters of 5 - 12,5 cm (2 - 5") can be cut. This part is found 1 - 6 m (3'4" - 19'8") above the ground. The inner diameter of one pipe will differ 0,3 cm or 3/8".

Though this bamboo is planted in the Government forest reserves, there are no records which are showing the exact place and the acrage of these bamboo is planted in the Mbeya and Iringa regions for domestic use (baskets) and construction purposes.

The yellow bamboo is included in this report because it can be planted in Tanzania for water supply purposes and then will supply diameters up to 12,5 cm (5") within 4 years.

For practical use right now we are limited to diameters up to 7,5 cm (3") of the green bamboos.

2.2 Techniques

2.2.1 Procurement

The bamboo cut should be:

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2) Available but quantity is not known. (See also fig 14).

- at least three years old, because the younger ones are too moist and insufficient resinous, which creates a poor resistence against insects and moulds.

- straight over the concerned part of 3 - 5 m (9'10" - 16'5"). This to enable an easy removal of the dividing membranes.

The wanted part of the bamboo is cut and cleared from its sprouts by pangas.

While awaiting for transport the bamboos should be kept out of the sun and wind. They should be stored under grass, under water, under soil or in a shed, this to avoid cracking which would appear within 48 hours.

2.2.2 Removal of Nodes

The nodes are removed by hand, using the tools as showed in fig 15.

The boring tools are made in the sizes from 3,75 up to 7,5 cm, step 0,6 cm ($1\frac{1}{2}$" - 3", step $1\frac{1}{4}$"), with a length of 3 m (about 10'). We have the same sizes of cleaning tools, but these have a length of 6 m (about 20').

Procedure (see also fig 16)

- a vise is holding the bamboo in position

- first a boring tool with a diameter 1,2 cm ($\frac{1}{2}$") less than the pipe diameter-removes the inner part of the nodes. Due to the length of the tool this handling has to be carried out from both ends of the pipe

- as above but now with the boring tool with the right diameter

- the cleaning tool removes the remaining parts of the nodes in one go.

2.2.3 Desapping

If the bamboo pipes are not desapped, this will result in a very strong smell of the outcoming water, as the pipes are taken into use.

This smell can be taken away by one of the following measurements:

Green Bamboo

a) Put the bamboos in flowing water or in a pool of water for 6 - 8 weeks or

b) Submerge the bamboos for 24 hours in a chlorine-solution (10 - 20 ppm) and let fresh water flow through the pipes for 3 - 4 hours or

c) Submerge the bamboos in hot water (90 - 95 degr C/ 194 - 203 degr F) and keep the temperature on this level for 1 - 2 hours, cool down to normal temperature while the bamboos remain in the water.

Yellow Bamboo

b) As above mentioned

c) As above mentioned.

2.2.4 Selection

During all mentioned actions cracks may appear. Further the pipes have to be examined on the existence of little spot holes, caused by insects.

The number of spot holes is varying from average 0 up 1 hole per m, this connected to the area of origin of the bamboos (Tukuyu - none, Iringa rather many).

The cracks and spot holes are determined by putting the pipes under a water pressure of 1 - 2 atm (14 - 28 psi). This water-pressure can be obtained by means of a hydraulic test water - pump, but also by making use of the water-pressure of an existing water supply.

The pipes which are showing cracks are to be wasted. Maybe after further investigations on the subject joints, the bigger pipes can be used on this item (see: Joints, page 24).

The spot holes are sealed by using small fibres of bamboo together with sticking cement. These sealings can take 2 atm (28 psi) without further reinforcement. While reinforcing the pipe these sealings have to be wire-wound.

2.2.5 Reinforcement

The green bamboo on itself can take 2 atm (28 psi).

The yellow bamboo however is performing will under a continous pressure up to 5 atm (71 psi) without any reinforcement. It has been investigated how much the working pressure could be increased when reinforcement is applied.

The possibilites in reinforcement are:

a) 3 x 1 mm (1/25") galvanized wire together with bitumen, which are brushed upon to give an extra rust protection to the wire

b) Aluminium, nylon and polyethene pine strings

c) Sisal rope.

Up to now only the galvanized wire is used in practice. The three wires are turned together so that they perform one (3 string) wire, then the wires are fastened by means of turning the ends together with pliers on relative spacings of 3,75 or 7,5 cm (1½" or 3"). Every wire wound needs about 90 cm (3') wire. Instead of 3 x 1 mm also 1 x 2 mm (1/12") wire can be used.

During tests nylon strings proved their ability of re-inforcement purposes, but the nylon strings and the other materials mentioned in b) have a lower elasticity modulus (E) and thus require more reinforcement material. An advantage would be that no brushing of bitumen is needed, but still compared to the method a) these materials are far more expensive and not of interest for reinforcement purposes. Sisal ropes may prove to be an alternative solution in reinforcing bamboo. The first theoretical findings are promising. For instance a 3 mm (1/8") sisal bundle on a 1,3 cm(½") spacing can take under wet conditions (unfavourable) at least the occuring forces of a pressure of 6 atm in a 7,5 cm (3") diameter pipe. The required length per m will be about 25 m and the costs per m about Shs 1/25. The sisal bundles can be impregnated, which makes the applying of bitumen superfluous.

In Mwanza and Songea tests were carried out to determine the pressures that bamboo pipes can take when reinforced with galvanized wire.

The tests were performed by means of hydraulic test water-pump. The shown figures are the results of each time testing about 20 pipes a length of 4 m (13'1") up to bursting. The diameters of the green bamboo pipes were between 5 and 6,25 cm (2" - 1½"), the diameters of the yellow bamboo pipes were between 6,25 and 7,5 cm (2½ - 3).

Results	Waterpressures in atm		
	Minimum	Maximum	Mean value
<u>Green bamboo</u>			
Spacing 7,5 cm (3")	3,5	6,0	3,5
Spacing 3,75 cm (1½")	7,0	9,5	8,0
<u>Yellow bamboo</u>			
Spacing 3,75 cm (1½")	6,0	7,0	6,0

Remarks:

- Cracks were having a length of minimum 7,5 (3") up to maximum 15 cm (6").

- The wire wounds of the green bamboo loosened on the spot where the bamboo bursted, but the wire wounds of the yellow bamboo didn't loosen at all.

- The reason that the green bamboo is taken more pressure than the yellow one has to be searched in the fact that the green bamboo is more flexible. Because the material is more flexible, a tighter wire wound is possible, which results in a better cooperation between the bamboo material and the wires when the water pressure forces are taken. The yellow bamboo on the other hand exists of hard material which is difficult to compress by means of handmade wirewounds. This leads to an insufficient cooperation between the wires and the bamboo material. An indication for this is the cracking of the bamboo without the loosening of the wire wounds.

- Investigations have to be made how to improve the tightening of the wire wounds on the yellow bamboo.

2.2.6 Jointing

Longitudinal Joints

Bamboo pipes with an external diameter up to 7,5 cm (3") are jointed by means of a piece of plastic, polyethene (PE) pipe. See fig 17.

The bigger bamboos can be jointed by means of plastic polyvinyl chloride (PVC) pipe (see fig 18). Up to now no good joint with PVC pipe is developed. Probably for this bigger diameters, but also for the smaller ones, rubber joints can be applied. The prices of rubber joints are about the same or cheaper compared to PE and PVC joints. Because the rubber material will be more elastic, possible no sticking material will be needed, further investigations will be carried out.

A further future development is the method of jointing where bamboo forms also the jointing material. The external diameters of the bamboo pipes (green bamboo) have to be made equal to the internal diameter of the jointing piece (yellow bamboo). When the line is filled the jointing parts will swell a bit more and the joint will be free of leaking, without the use of any additional materials. Investigations have to prove the suitability of this joint and further if this joint can be made in the villages.

Branches and Valves Connections

Bamboo pipe at branches and valves are up to now made in the same way as plastic pipes, by using adaptors and T-branches. For details see fig 20.

In the near future these connections are going to be implemented in wood. See fig 19 and 21.

2.2.7 Pressure Relief Chambers

In case the anticipated pressure along the bamboo pipeline is higher than the working pressure of the bamboo pipes, pressure relief chambers are installed at appropriate locations. See fig 22.

Pressure Relief Devices against Waterhammer

Waterhammer has a serious drawback to bamboo pipes. In practice it has been found useful to install a small surge cussion device below the public water point to prevent additional pressure, resulting from abrupt shutoff of water. See fig 23.

2.2.8 Laying Operations

A trench is excavated of about 75 cm deep and 60 cm wide (2'6" - 2').

Treatment with Aldrin or Chlordane solution (see also fig 24).

- The insecticides are sprayed in an amount of 5,6 litre/ha (5 lb/acre). Example: 1 litre of 50 % insecticide to 220 litre (drum) of water, results in a 0,227 % solution. This amount of solution can treat about 500 m (1 640 ft) of bamboo pipeline.

- The solution is spread by means of a watering-can on the bottom of the trench

- Then 15 cm (6") of untreated soil is placed on the treated area

- The bamboo pipe is laid in the untreated soil insuring that flow pipe is not in contact with treated soil in any direction

- Backfilling with untreated soil up to 15 cm (6") above the pipe

- Another layer of solution treatment is applied on top of this untreated soil and on both (slope) sides

- The final back fill (about 35 cm or 14") is again done by means of untreated soil.

Pipes are laid one after another by pushing a bamboo pipe in one side of the polythene tube or PVC pipe. PVC cement on the outside of the ends of the pipes provides a sound sealing of the joint. A stone hammer and a piece of plank is used to push the bamboo into joining position. See fig 25. To secure a water-tight joint, a wire wound is made outside the polythene tube.

Bamboo pipelines are operated at no pressure for a period of 24 hours to ensure that the bamboos are saturated. Any abrupt pressure charge will result in serious bamboo bursts if bamboos are not saturated with water for a long period.

2.2.9 Repairs

Procedure

All soils including treated soil is first removed at the portion where repairs are to take place. Pipes are replaced by opening 2 joints and a new piece of bamboo pipe is replaced. For short cracks a piece of polythene tube can be inserted.

Water is turned on to wash out the pipeline this to clear turbidity and any trace of (possible) treated soil which may have entered during repair activities.

The wash out is shut leaving the pipeline under normal working pressure. Leaks and cracks are observed at the repair point. If no leaks are visible backfilling works start with normal procedure of replacing layers of treated and untreated soil.

Bamboo pipeline repairs can be done by two men.

Spares

Bamboo pipes for repair purposes and extensions are kept submerged in a nearby river or a pool built at the river for this purpose. One lorry of bamboo pipes is enough for repairs and extension works for about 10 years.

A few meters of polythene tubes, Tangit Paste, wires for reinforcement, spare taps, tees, elbows, union pipe spanners, vice and pliers are kept for repair purposes.

2.3 Durability

If bamboo is put in the ground it will decay becuse of biological attack, that is by insects and fungi. Fungies need material of a certain moisture content, usually between 20 - 30 %. The best way of preventing fungal attack will thus be keeping the bamboo above or beyond this moisture content. Another solution is an impregnation of the bamboo.

The insect attack has to be expected from the subterranean termites. Effective protection is reached by impregnating the bamboo or by means of a treatment of the soil which is surrounding bamboo or by means of a treatment of the soil which is surrounding the bamboo.

2.3.1 Lifetime of Bamboo without Treatment

The literature gives for untreated bamboo pipes lifetimes which are varying from three up to seven years. The following reasons can be put forward to explain the big differences in life-expectations:

- Different kinds of bamboos are used

- Several bamboos are most probably not always kept out of the dangerous 20 - 30 % moisture content, which is leading to fungal attack

- Variation in termite-infestation.

From our own experience we found out that particularly the latter matter is of big importance. In Songea we discovered that bamboo pipes were attacked severely by termites after two weeks. While in Mwanza only after two years only two attacks were notified.

It will be clear that bamboo pipes without any treatment for water supplies are not feasible on village level.

2.3.2 Treatment Methods

Practical applied up to now:

Soil Treatment

The soil around the bamboo pipe is treated against termites. A solution of an appropriate insecticide is spread in an amount of 0,56 - 5,6 litre/ha (0,5 - 5 lb/acre).

Used are the following insecticides:

- Aldrin solution or

- Chlordane solution.

Both are almost insoluble in water and not easy to be leached out. The chemicals are cheap and always easy to be obtained. See for details under laying operations.

Continuous Saturation of the Pipes

Soil treatment is solving the problem of the insect attack, which leaves us with the fungal attack. When applying soil treatment, fungal decay is to be avoided by keeping the bamboos always filled with water (and their moisture content above 30 %. This continuous saturation of the bamboo pipes also prevent the pipes from cracking.

To assure this saturating of the bamboos, we deal for the time being only with gravity water supplies, if in the future the pumped supplies prove to be more reliable, also the pumped water supplies can be served by a bamboo pipe net work.

Future possibility:

Impregnation of the Bamboo

On-going tests are examining the possibility of impregnating bamboo by means of the pressure and sapdisplacement methods. These examinations are performed by Forest Division together with Government Laboratories. If the tests prove to be successful, they will enable us to implement water supplies without soil treatment, because the impregnation is protecting against both insect and fungal attacks.

Impregnated are salts containing copper-chrome-arsenic (CCA -salts). In Tanzania these salts are available under the brand names: Celcore A and Tanalith C.

Abroad copper-napthene has proved to be a good alternative for the CCA-salts.

2.3.3 Lifetime of Bamboo when Treatment Methods are Applied

Soil treatment together with the everlasting saturation of the bamboo pipes is extending the life expectance to 15 years (Forest Division).

The exact lifetime will obvious depend on:

- Amount of leaching of soil treatment chemicals which will be determined by the soil (porous or not), the rainfall (heavy or not) and the topography (hilly or not)

- The level of termite infestation in the area

- The possible negligence when repairs are performed and the backfill is done without an appropriate treatment.

The impregnation of the bamboo will result in a lifetime over 20 years (Forest Division in exhibits 21 B).

2.4 Hydraulics

2.4.1 Friction

The friction of a bamboo pipe is depending on the two following factors

- smoothness of the wall

- irregularities in the pipe.

Remarks:

- The degree of the inside smoothness of a pipe is in the Hazen Williams formula expressed by the value C. The friction head in feet of water per 100 feet due to the roughness of the wall is:

$$f_w = 0{,}283 \times (100/C)^{1{,}852} \times \frac{g^{1{,}852}}{d^{4{,}8655}}$$

C = constant for the inside smoothness of the pipe
g = flowing gallons per minute
d = inside diameter of pipe in inches

- Irregularities are caused by nodes and joints. The friction losses are expressed in velocity heights or $v^2/2G$.

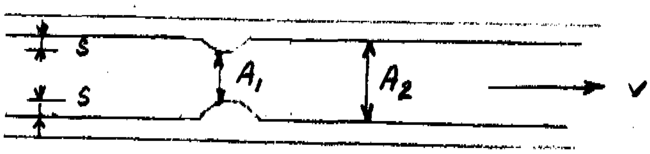
$v^2/2G$ = velocity height in m or ft
v = velocity of the flowing water in m/sec or ft/sec
G = acceleration caused by the attractive power of earth in m/sec2 (= 9,81 m/sec^2) or in ft/sec2 (= 32,185 ft/sec2).

In the notations as used for fw:

$$v = 4{,}9057555 \ . \ 10^{-3} \ . \ g/d^2 \text{ ft/sec}$$
$$v^2/2G = 3{,}7387615 - 10^{-3} \ . \ (g/d^2)^2 \text{ ft}$$

- Nodes are causing friction because of a narrowing on this place. The friction will depend on:

- The degree of narrowing/expension, which depends on the quality of the removal of the membranes



Per node the loss will be:

$$f_{node} = ((A_2^2/A_1^2) - 1)^2 \times v^2/2G$$

- We qualify s = 0,1 cm (1/25") as good work and s = 0,5 cm (1/5") as bad work

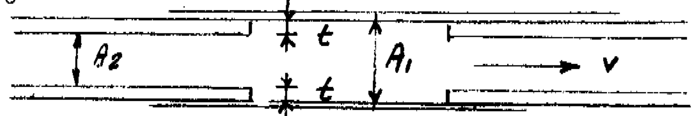
- The amount of nodes varies from 40 - 45 - 50 per 100 feet for green bamboos of a diameter 6,25 - 5,0 3,75 cm (2½ - 2 - 1½) up to 85 nodes per 100 feet for the several diameters of the yellow bamboo

- $f_{nodes}/(v^2/2G)$ per 100 feet

Inside diam Bamboo pipe	Good removal s = 0,1 cm	Bad removal s = 0,5 cm
3,75 cm (1½")	0,67	36,94
5,00 cm (2")	0,32	14,24
6,25 cm (2½")	0,18	6,96

- A joint is causing friction losses because of the widening of the diameter on this spot

  - per joint the loss will be:



$$f_{joint} = (1 - (A_2^2/A_1^2)^2 \text{ x } v^2/2G$$

  - The amount of joints varies from 11 per 100 feet for d = 3,75 cm to 10 per 100 feet for d = 5,00 and 6,25 cm of the green bamboos, and from 6 - 9 joints per 100 feet for the bigger yellow bamboos.

- Inside diam bamboo pipe	Wall thickness t	$f_{joints}/(v^2/2G)$ per 100 feet
3,75 cm (1½")	0,85 cm (0,33")	3,05
5,00 cm (2")	0,9 cm (0,35")	2,11
6,25 cm (2½")	1,0 cm (0,39")	1,82

  - Friction losses of nodes and joints together:

Friction losses of nodes and joints per 100 ft/(v^2/2G)

Inside diam bamboo pipe	Good node Removal	Bad node Removal
3,75 cm (1½")	3,72	39,99
5,00 cm (2")	2,43	16,35
6,25 cm (2½")	2,00	8,78

- C value of bamboo pipes

  - Several tests were done to determine the C value of bamboo pipes. Also the influence of the node quality is investigated.

  - It was found that the C value of the wall of the bamboo pipes is 75. When the influence of the nodes and joints is included, we get a C value of 72 for pipes with good nodes and a C value of 60 for pipes with bad nodes.

  - One should strive after a good quality of node removal (s = 0,1 cm), which will allow a C value of 70. When the removal of nodes is poor (s =0,5 cm), the C value will be 60, which means 33 % higher friction losses and a 15 % lower discharge under the same head.

  - If we compare bamboo pipes (C = 70) to plastic pipes with a C value of 150, we can draw the following conclusions:

- the friction losses in bamboo pipes are 4,1 times that big as those in plastic pipes of the same diameter and the same flow.

- the discharge of plastic pipes is 2,1 times that big, compared to that in bamboo pipes of the same diameter under the same head.

- the friction losses and the flows in plastic and bamboo pipes will be the same, when the bamboo diameters are chosen 1,34 times the size of the plastic pipes.

2.4.2 Pressure

To determine the possible working pressures for the several bamboos it is necessary to introduce some statistics. This statistical tackle is dapted from the paper: The strength properties of Tanzania Timbers, by J. M Bryce, Utilisation Officer from the Utilization Section of the Tanzania Forest Division in Moshi, published August 1966.

Two points of this article are for our determination of importance:

1) Variability within the material

2) Long term loading.

Long term loading is actual in our schemes, this is reducing the pressure with 10 %.

The 2 reductions on the main values as they were found by testing the bamboos (see page 2) are leading to the following derived value:

	Mean value in atm	Derived value in atm
<u>Green bamboo</u>		
No reinforcement	2,0	1,1
Spacing 7,5 cm (3")	3,5	1,9
Spacing 3,75 cm (1½")	8,0	4,3
<u>Yellow bamboo</u>		
No reinforcement	5,0	2,7
Spacing 3,75 cm (1½")	6,0	3,2

To come to the working pressure we have to take in account the symptom of water hammer.

Remarks on water hammer:

- Waterhammer is causing a sudden rise of the pressure in a pressureline due to a sudden decreasement of the velocity of the flowing water.

- The pressure impact is moving through the line with a speed c

$c = 1/\sqrt{R/K + RD/TE}$

c = velocity of the pressure impact through the pipeline in m/sec

R = density of the water: 1 000 kg/m^3

K = modulus of compression of water: $2{,}10^9$ N/m^2 (other notation: $2{,}10^4$ kgf/cm^2)

D = inside diameter of the pipeline in m

T = thickness of the pipewall in m

E = modulus of bamboo, perpendicular on the fibres.

- The maximum rise of pressure height is H_h

$H_h = c \cdot v/g$

H_h = maximum pressure rise in m due to waterhammer in m

v = sudden decreasement of the velocity of the flowing water in m/sec

G = earth acceleration: 9,81 m/sec^2

- E modulus of bamboo pipes

  - Tests were done to determine the E modulus of the bamboo

  - This determination was implemented by observing pressure rise due to water hammer in a bamboo pipe of a known diameter, wall thickness, discharge and static head

  - By means of the above mentioned formulae it is possible to determine the E modulus of the bamboo

  - The E modulus of bamboo, perpendicular on the fibres is $E = 5 - 10^8$ N/m^2 (or $5 \cdot 10^3$ kgf/cm^2)

  - It is clear that the E modulus of the bamboo pipes, which are reinforced and which are not reinforced will differ, while these diffrences in E modulus will result in different pressure impacts due to water hammer.

- Pressure relief devices

  - Pressure relief devices absorb pressure impacts due to water hammer

  - For safety reasons we assume that the pressure relief devices only take 75 % of the pressure impact.

- Pressure impacts H_h due to water hammer

D	c m/s	Without pressure relief device v=0,5 m/s	v=1,0 m/s	v=1,5 m/s	With pressure relief device v=0,5 m/s	v=1,0 m/s	v=1,5 m/s
1½"	327,50	16,69	33,38	50,08	4,17	8,35	12,52
2"	293,47	14,96	29,92	44,87	3,74	7,48	11,22
2½"	277,35	14,14	28,27	42,41	3,54	7,07	10,60

Working Pressures in Bamboo Pipes

Without Pressure Relief Devices - Green Bamboo

Green bamboo No pressure relief devices	Derived value in atm	Working pressure in atm v=0,25-0,5 m/s	v=0,5-1,0 m/s	v=1,0-1,5 m/s
Not reinforced	1,1	-	-	-
Reinforced (3")	1,9	-	-	-
Reinforced (1½")	4,3	2,6	1,0	-

When Pressure Relief Devices are Applied - Green Bamboo

Green bamboo pressure relief devices applied	Derived value in atm	Working pressure in atm v=0,25-0,5 m/s	v=0,5-1,0 m/s	v=1,0-1,0 m/s
Not reinforced	1,1	0,7	0,3	-
Reinforced (3")	1,9	1,5	1,1	0,6
Reinforced (1½")	4,3	3,9	3,5	3,0

2.4.3. Capacity

The discharge of the bamboo pipes depends on the available head per unit of length. The heads per unit of length (in %) together with the several sizes of the bamboo pipes and the matching discharges are shown on chart 26.

2.4.4 General Remark

It has to be noted that all figures, which are given in the chapter Hydraulics are tentative, because they are obtained from not very accurate gauges.

The Civil Engineering Department of the University of Dar es Salaam has shown interest in the project and will help us in obtaining accurate figures on friction losses, water hammer and working pressures.

The Production Engineering Section of the University will probably look upon the possibilities of the bamboo joint and upon the reinforcing of bamboo pipes by means of sisal rope.

2.5 Health Aspects

To check all cases where health aspects could be of concern, we will go through the first three points of this report and discuss the relevant items.

- Bamboo is not containing any poisonous parts (see appendix II, page 2, sample 6)

- Desapping of the bamboos. Some remarks on the method of seasoning where bamboos are submerged for 24 hours in a 10 - 20 ppm chlorine solution

  - After flushing the pipes for 3 hours no chlorine can be smelled or tasted

  - In the drink water supply the maximum amount of chlorine to be added is 5 ppm. This water is easy to be distinguished by smell and taste as being chlorined

  - Conclusion: After flushing of the pipes the chlorine parts in the water will for sure be less than 5 ppm and thus harmless.

- Soil Treatment.

  Aldrin

  - This insecticide is effective against soil insects at rates of 0,56 to 5,6 litre/ha (0,5 to 5 lb/acre)

  - Aldrin is surrounding the pipes on average distance of 0,2 m (8"). But even if it would be spread on the pipes it never can get to the water as long as the pipes are under pressure

  - Problems could be expected when a pipe is bursting and has to be replaced.

  We assume the following situation:

    - A pipe with a length of 5 m bursts and has to be replaced

    - All insecticide spread over the length of 5 m is entering the pipes downstream. The amount will be: 5x 2,1 x 10,4 x 5,6 = 0,006 litres

    - The pipe is replaced and the pipe is slushed by a flow of 33 l/min for 1 hour or 1 990 l per hour (33 l per min = 7,28 gallons per min = flow in 3,75 cm pipe when watervelocity is 0,5 meter per sec.

  - If the insecticide is washed away after one hour flushing then the outcoming water was containing average 3,0 ppm (Aldrin 0,006 x 10^6/1 990).

So if it takes a longer time for the Aldrin to be washed out, for sure the quantity of leaching Aldrin will be less than 3,0 ppm.

Tests on the toxity of Aldrin showed that a dietary level of 5 ppm Aldrin for two years did not harm rats at all, 25 ppm was resulting in liver damage.

Chloridane

- This insecticide is used in the same way and in the same amounts as Aldrin

- As the amounts and the way of handling are the same as mentioned under Aldrin, also the given example for indicating maximum possible leaching figures is valid for chloridane

- Tests on rats for two years showed that a dietary level of 150 ppm didn't result in higher mortality, though the liver was attacked severely.

- Impregnation of the bamboos

  - The first tests on impregnated bamboos showed leaching of the CCA-salts

  - The tests are on-going

  - No impregnated bamboos are going to be taken into use before the right procedure of impregnating is found and then only after approvement by the Government Chemist.

2.6 Costs

This chapter is divided up in two parts, the first part is an estimation on the costs of a bamboo pipeline per m, ready on the spot, including material costs, joints and soil treatment, as this is performed up to now.

The second part is looking upon the saving that can be made when in the near future some cheaper methods of pipeline building are going to be applied.

2.6.1 Costs of Bamboo Pipeline per Meter

General data

- 1 labourer per day Tsh 17/-
- 1 night allowance Tsh 40/-
- a 7 tons lorry per km Tsh 2/70
- load of 7 tons lorry = 1 600 m bamboo
- 1 kg galvanized iron wire (1 mm) Tsh 3/-

- 1 liter bitumen Tsh 2/-
- Tangit PVC cement (128 gr) Tsh 13/25
- 3"PE pipe per m Tsh 17/-
- Aldrin per liter Tsh 42/-
- Chloridane per litre Tsh 48/-.

Buying Bamboo

- L = 3 - 5 m
- Price = 0/25 - 050

— 0/05 - 0/16 Tsh/m

Cutting Bamboo

- 2 labourers night allowance
- 3 days
- 1 600 m

— 0/21 Tsh/m

Transport Bamboo (see fig 14)

- 1 lorry
- 2 labourers (outside district)
- 125 - 250 km per day

Bamboo forest location	Average distance from village and back in km	Transport costs per m bamboo	Labour costs per m bamboo
In the village	-	-	-
In the district	200	0/34	-
In the region	250	0/42	0/09
Outside region class I	450	0/76	0/09
Outside region class II	1 000	1/68	0/24

- 1 m of 3" polythene pipe
- 5 joints
- 1 joints - Tsh 3/40
- 3,5 m - 1 joint

— 0,97 Tsh/m

Joints (longitudinal - labour costs)

- 1 labourer
- 1 day
- 42 choppings
- 3,5 m/2 choppings

— 0/23 Tsh/m

Soil Treatment (material costs)

- 5,6 litre chlordane ha
- per m pipe - 2,1 m^2
- per m pipe - 1,2 10^3 litre

- 0/06 Tsh/m

Resuming

Not Reinforced Bamboos, Bamboo Forest Near to the Village

	Material costs per m	Labourer costs per m	Total costs per m
Buying bamboos	0/17	-	0/17
Cutting bamboos	-	0/22	0/22
Removal nodes + seasoning	-	0/24	0/24
Selection	-	0/12	0/12
Joints	1/29	0/23	1/52
Soil treatment	0/06	0/23	0/06
	1/52	0/81	2/33

Reinforced Bamboos - Spacing 7,5 cm (3")

Bamboo forest location	General costs per m		Reinforcement costs per m		Total costs per m		
	Material	Labour	Material	Labour	Material	Labour	Material Labour
In the village	1/52	0/81	0/48	1/07	2/99	1/88	3/88
In the district	1/86	0/81	0/48	1/07	2/34	1/88	4/22
In the region	1/94	0/90	0/48	1/07	2/42	1/97	4/39
Outside the region class I	2/28	0/90	0/48	1/07	2/76	1/97	4/73
Outside the region class II	3/20	1/05	0/48	1/07	3/68	2/12	5/80

Reinforced Bamboos - Spacing 3,75 cm (1½")

Bamboo forest location	General costs per m		Reinforcement costs per m		Total costs per m		
	Material	Labour	Material	Labour	Material	Labour	Material Labour
In the village	1/52	0/81	0/70	1/61	2/22	2/42	4/64
In the district	1/86	0/81	0/70	1/61	2/56	2/42	4/98
In the region	1/94	0/90	0/70	1/61	2/64	2/51	5/15
Outside the region class I	2/28	0/90	0/70	1/61	2/98	2/51	5/49
Outside the region class II	3/20	1/05	0/70	1/61	3/90	2/66	6/56

Costs of Additional Items

- Pressure relief chamber size ⌀ 0,90, h = 0,90 m	- Tsh 1 200/-
- Pressure relief device	- Tsh 45/-
- T-branches + 2 connectors	- Tsh 155/-
- Valve + 1 connector	- Tsh 140/-
- Air valve 1"	- Tsh 375/-

Costs of Laying

Six labourers can lay under normal conditions 200 m bamboo pipeline per day.

This laying of pipes include soil treatment and jointing labour. This is about Tsh 0,51/m.

On self help base two labourers - four local people can do the job which is decreasing the costs to Tsh 0,17/m.

The digging and filling up of the trenches is done on selfhelp base. One man can dig a trench of 10' x 2½' x 2' a day and he can fill back five times that amount a day. If one wants to include this against the Tsh 17/- a day rate, this makes Tsh 6,80/m.

2.6.2 Savings, when Cheaper Methods of Bamboo Pipeline Building are Applied

This estimation is looking upon the savings which can be made by alternating some implementations most given items have already proved their ability.

Reinforcement

- Instead of 3 x 1 mm wire now 1 x 2 mm wire. The material costs will be 33 % higher but labour 25 % less.
Spacing 7,5 cm (3") - cheaper Tsh 0,06/m.
Spacing 3,75 cm (1½") - cheaper Tsh 0,12/m.

- Instead of galvanized wire in future probably impregnated sisal rope is going to be used. (See page 20.) The savings have to be mainly searched in foreign currency, because no galvanized wire and bitumen are needed anymore for this purpose.

Rubber Joints

- Material costs of rubber joints are about the same as joints made of PE and PVC pipes

- A rubber joint does not require any sticking material, this will be Tsh 0/32 per m cheaper.

Connection

- T-branches can be implemented in wood (see fig 21) then you don't need the two connectors per branch: Tsh 112/50 less expensive

- The connection valve - bamboo pipe can also be made out of wood. (See fig 19.) This will save Tsh 55/-.

Pressure Relief Chamber

- Wooden pressure relief chambers will be about Tsh 300/- cheaper than the concrete ones.

Example

If we want to interprete these savings in the price per m, we have to assume an average village-scheme. For instance:

- Total length of bamboo pipeline 5 000 m (16 400 ft)

- Half of the line has a galvanized iron wiring of 3,75 cm (1½") spacing and the remaining part is half not reinforced and the other half has a reinforcement spacing of 7,5 cm (3")

- The number of T branches and valves will be ten

- Further we suppose two pressure relief chambers.

Savings in Figures

Reinforcement with 2 mm wire	Tsh 375
Wooden T branches and valves	Tsh 1 675
Wooden pressure relief chambers	Tsh 600
Per 5 000 m	Tsh 2 650

The savings per m bamboo pipeline Tsh 0/53

Together with the savings which can be achieved by applying rubber joints this will be about Tsh 0/85 per m.

Central Processing of Bamboo Pipes

If in the future the bamboo pipes are centrally processed in the neighbourhood of big bamboo forests, prices will decrease because of the continuous production and the better equipment (tools + machines). A lowering of production costs of the pipes of 10 % can be easily reached the maximum will be about 25 %.

The production of the pipes will be made to correspond to the early demand. Then the pipes can be delivered out of stock.

An extra advantage when centralizing the processing of the bamboo pipes is the possibility of applying the method of jointing by means of a piece of bamboo. This kind of jointing will perform well without PVC cement. The joints nowadays are costing Tsh 1/52/m, the bamboo joint/m at least 40 % less. This will result in pipelines which can be per m at least Tsh 0/60 cheaper.

If we assume a lowering of the production costs of 10 % and a Tsh 0/60 per m cheaper bamboo pipe because of the bamboo joint, the price will decrease with about Tsh 1/- per m.

2.7 Economy

If we want to make a technical comparison between a bamboo pipeline and a PVC pipeline we have to assume a certain situation (size and location scheme) and then consider the following items:

- PVC - PE pipes can perform under a higher working pressure which saves pressure relief chambers but increases the friction losses.

- Compare flowing quantities (not diameters) and do so on equal situations, including transport joints etc.

- Lifetime and repairs.

Without going too much in details the following remarks can be made:

- A bamboo pipe of 6,25 cm (2½") diameter and with a 3,75 cm (1½") spacing will cost in the Iringa district about Tsh 5/- per m. A PE pipe of 5 cm (2") in Iringa District will cost Tsh 12/55 or 60 % more (expressed in % of PE pipe).

Plastic pipes cost about 45 % of the total investment costs at surface gravity supplies. When the bamboos are applied, the schemes will be 27 % cheaper, which means that instead of three conventional schemes, four schemes in bamboo can be implemented.

- The lifetime of a bamboo pipeline reaches up to 15 years, the lifetime of plastic up to 30 years.

The interpretation of these lifetimes, together with the 60 % higher initial costs of the plastic pipes and the fast increasing prices of plastic in amounts of money as well as the foreign exchange factor, is a very complicated task, which we preferably leave to economists.

A very important matter of consideration is the question if after 15 years, a water supply based on the water-kiosks system, still will meet the villagers wants. It is very likely that after this period of time the standards of living have risen that high, that the villagers are not satisfied anymore by this system, and that they want to get water in their houses by means of private connections to the domestic water supply.

Such a situation will require a complete new set-up of the water supply, also because of the much larger water amounts to be conducted.

- Known is that the prices of bamboo pipes for sure not will rise in the first years to come but much more likely will decrease possibly with 30 % (see 2.6.2). Also known is that the prices of plastic pipes have increased considerably last years and it is only to be expected that this rapid increase will continue.

Especially the critical period of shrinking oil-stocks which is expected between 1985 - 2000 (by dr Alexander King and many others), will accelerate this process of rising prices.

- In future, cement pipes will prove to be more and more economical against plastic pipes, although the cement pipes are heavy and thus expensive in transport, and have a high breakage rate.

If we talk about small cement pipes, we think of pipes made of a cement sand mixture, reinforced with artificial fibres or natural fibres (for instance sisal).

The rise of such a new cement pipe, will be possible because of the rising prices of plastic and the improvement of the new reinforcement techniques.

Compared to bamboo however the prices will remain very high, because of the high cost of cement, the production costs and the transport. The transport will be far more expensive because of the heavy material and the high breakage rate.

A final remark on the position of the foreign currency and the labour employment. Plastic pipes are made in a not - labour intensive full mechanized process out of rough materials which nearly all have to be imported from abroad. Bamboo pipes have only small requirements of imported materials and are made labour intensive.

2.8 Application

In the first stage of implementing bamboo schemes we are restricted to villages with a population of about 1 000 - 1 200 inhabitants and a length of th rising main of maximum 3 km at a general slope of minimum 0,75 %.

As soon as the rubber joints have been found suitable for the bigger bamboos, or when the square and round woodstave pipes have been taken into production, we can implement all gravity schemes, which are at the moment implemented in plastic pipes.

2.9 Conclusion

In Tanzania it is foreseen that about 17 % of all water-supplies will be served by surface gravity systems. The development costs of these schemes are estimated at Tsh 230/- per capita (Government goal: Tsh 220/- per capita).

The development costs of bamboo schemes will be about Tsh 168/- per capita.

This new technique should be strongly supported, so that a new cheap way of bringing water to the people can be established.

Prepared by Mr Peter Jacobs - Civil Engineer, Ministry of Lands, Housing and Urban Development, Iringa. August 1978.

Checked and passed by Mr Nils Lundborg - Civil Engineer and Wood Expert, Tanzania Wood Industry Cooperation, Dar es Salaam. September 1978.

FIG. 1

BOX TYPE, EQUIVALENT TO A Ø 3" (75 mm) PVC PIPE

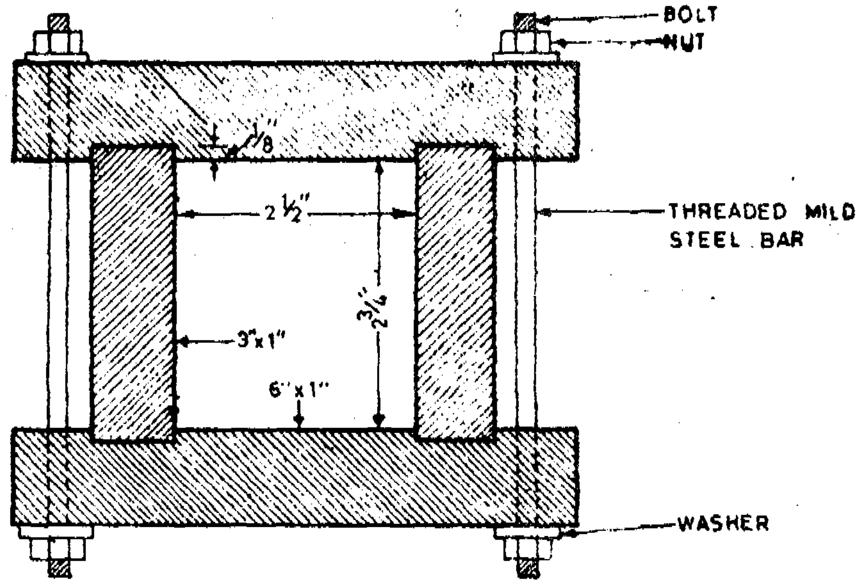


FIG. 2

PRINCIPLE OF WOOD STAVE PIPE

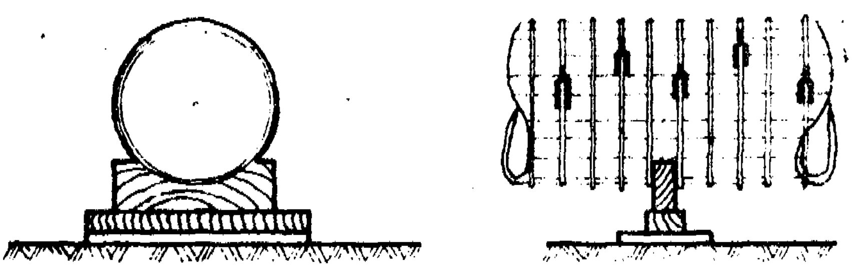


FIG. 3

WOOD STAVE FLUME

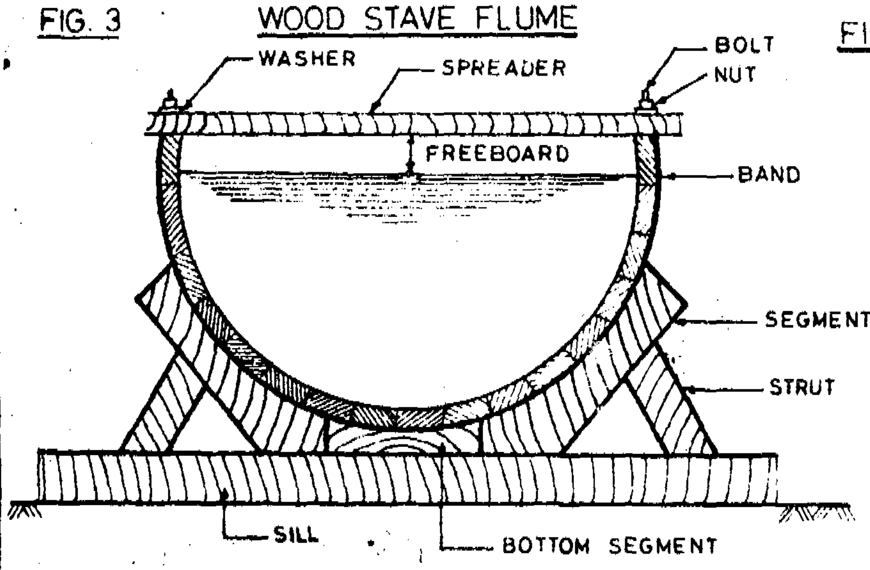
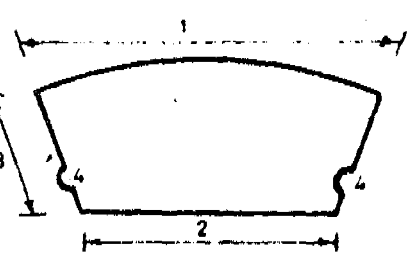


FIG 4

SHAPE OF WOOD STAVE



1. EXTERNAL SHAPE TO FIT IN WITH CIRCULAR EXTERNAL CIRCUMFERENCE
2. PLANED
3. TO FORM A LEAKAGE-FREE SURFACE
4. LOCATING BUMP AND INDENT

FIG. 5

DETAIL SHOE

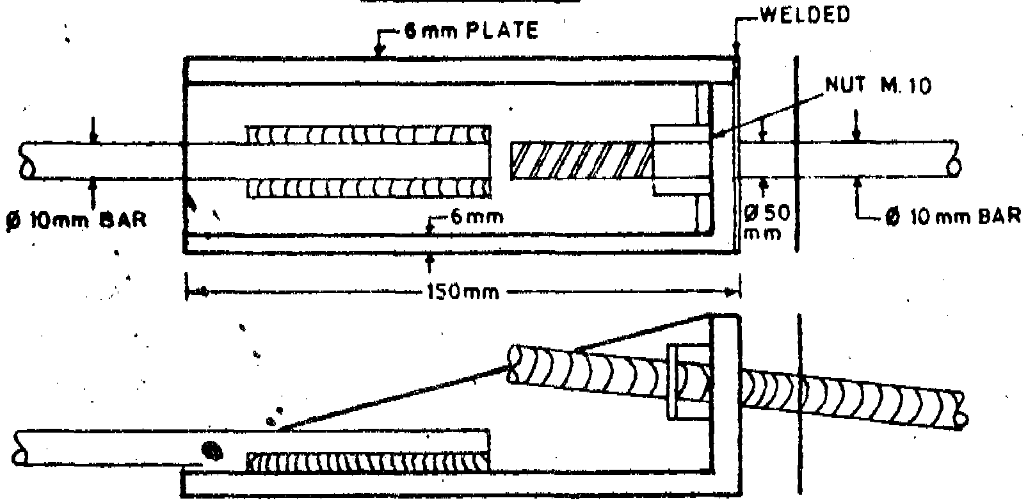
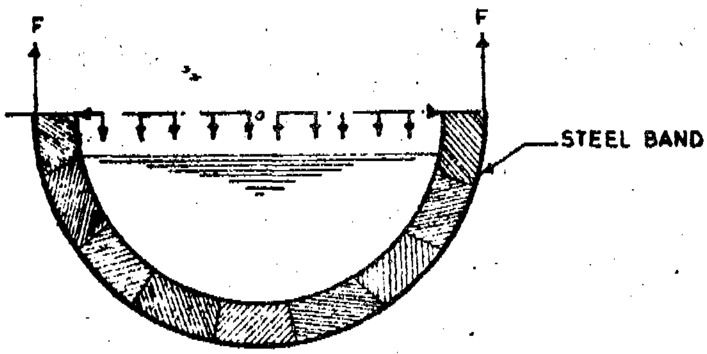


FIG. 6

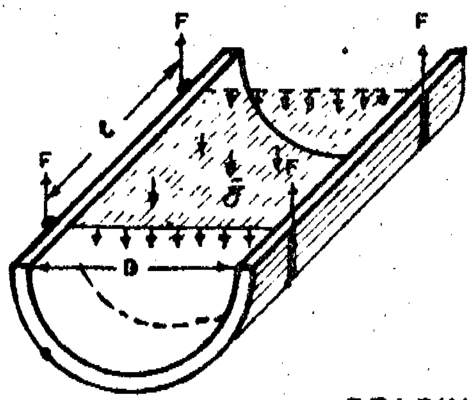


BALANCE BETWEEN FORCES IF

$$2F = \bar{\sigma} D$$

PER UNIT OF LENGTH PIPE

FIG. 7



BALANCE BETWEEN FORCES IF

$$2F = \frac{\bar{\sigma} \times D \times \ell}{2}$$

$$\text{OR } \ell = \frac{2 \times F}{\bar{\sigma} \times D}$$

FIG. 8

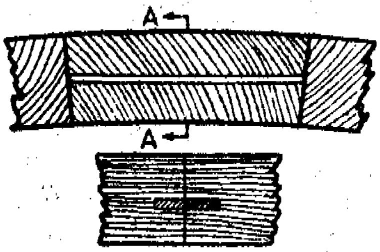
SPACING CHART

DIA. →	150mm Ø 6"		200mm Ø 8"		250mm Ø 10"			250mm Ø 12"			450mm Ø 18"			600 mm Ø 24"		
STEEL ATM	Ø 6 mm	Ø 8 mm	Ø 6 mm	Ø 8 mm	Ø 6 mm	Ø 8 mm	Ø 10 mm	Ø 6 mm	Ø 8 mm	Ø 10 mm	Ø 8 mm	Ø 10 mm	Ø 12 mm	Ø 8 mm	Ø 10 mm	Ø 12 mm
1	M*	M	M	M	M	M	M	26	M	M	M	M	M	23	M	M
2	26	M	20	M	16	28	M	13	23	M	16	24	M	12	18	26
3	17	M	13	24	10	18	29	9	16	24	10	16	24	8	12	17
4	13	23	10	17	8	14	22	6	12	18	8	12	18	6	9	13
5	10	18	8	14	6	11	17		9	14	6	10	14		6	10
6	8	15	6	11		9	15		8	12		8	12			9

* = MINIMUM 30 CM.

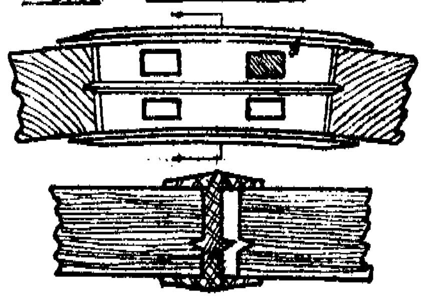
EXAMPLE: IF A Ø 10MM STEEL BAND IS USED FOR A 300MM (Ø 12") WOOD PIPE, AND THE WORKING PRESSURE WILL BE 4 ATMOSPHERE, THE SPACING BETWEEN 2 BANDS IS EQUAL TO 18 CM.

FIG. 9
GALVANIZED STEEL TONGUE JOINT



SECTION A - A

FIG. 10 BUTT JOINT



SECTION A - A

FIG. 11 DOUBLE TONGUE FINGER JOINT

FIG. 12 PIPE WORKING TOOLS

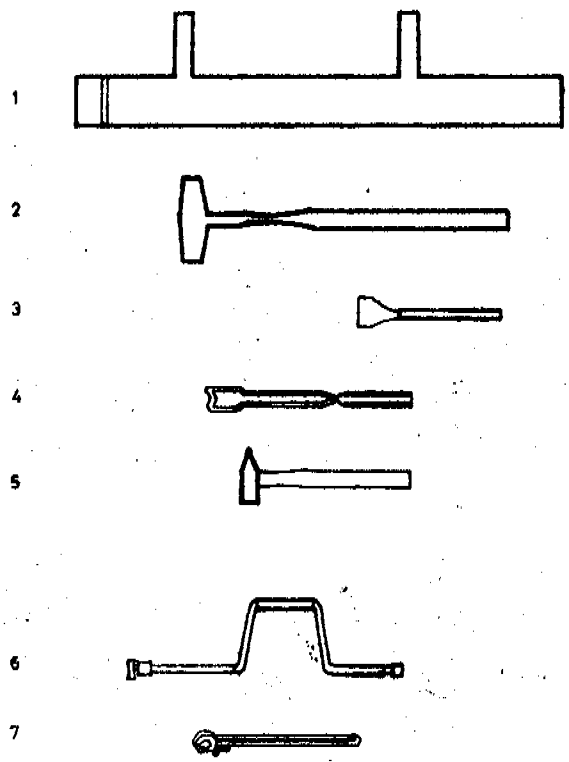
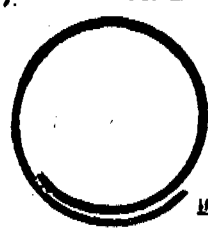


FIG. 12a BUILDING FORMS (IRON SHEETS). FIG. 12b

OUTSIDE FORM



INSIDE FORM

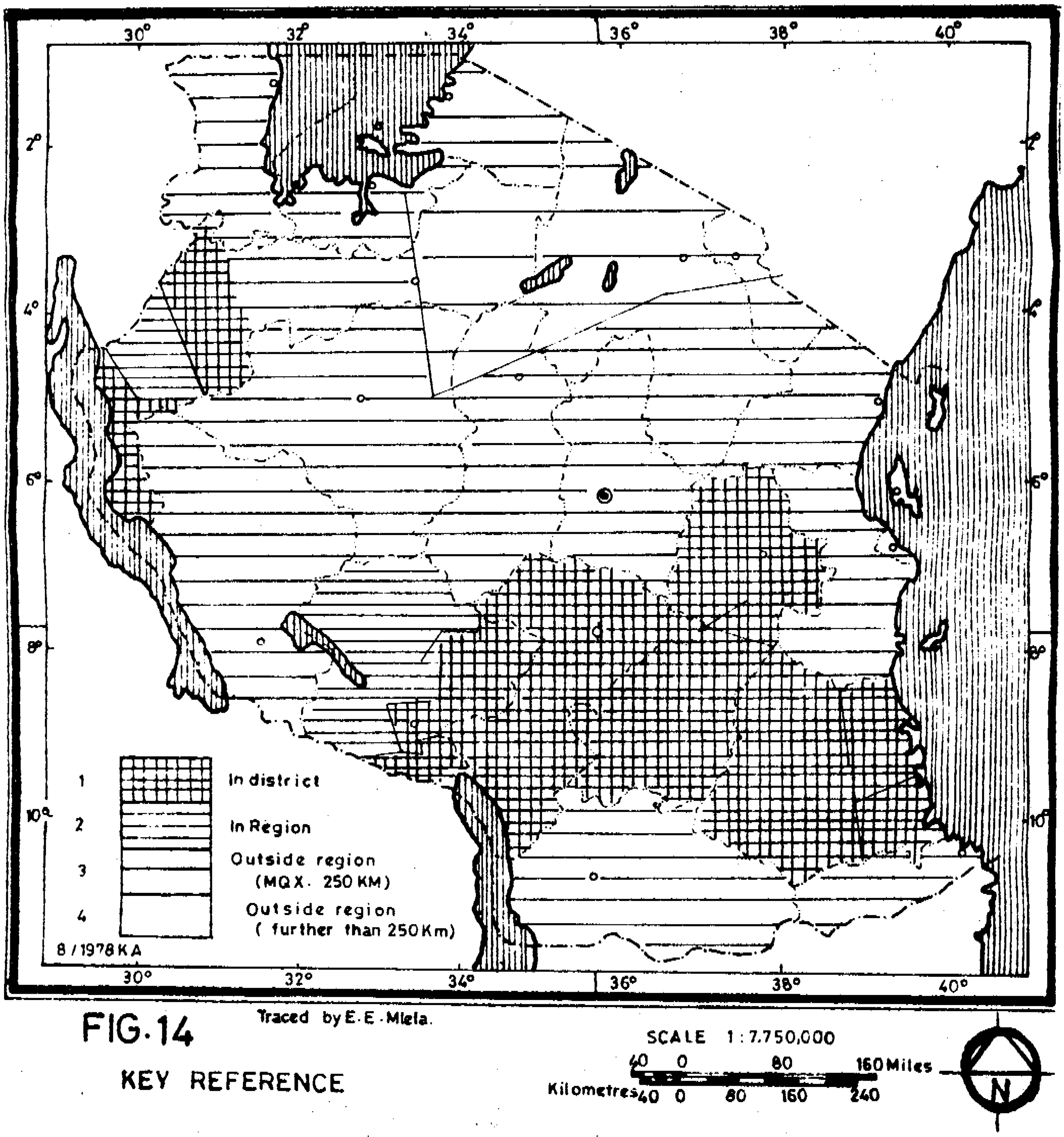


FIG. 14

Traced by E. E. Mlela.

KEY REFERENCE

FIG. 15 BORING AND CLEANING TOOLS.

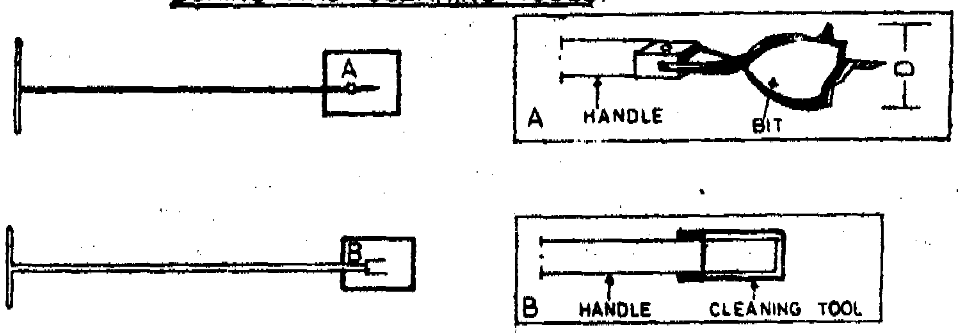


FIG. 13 X-SECTION THROUGH A BAMBOO STEM

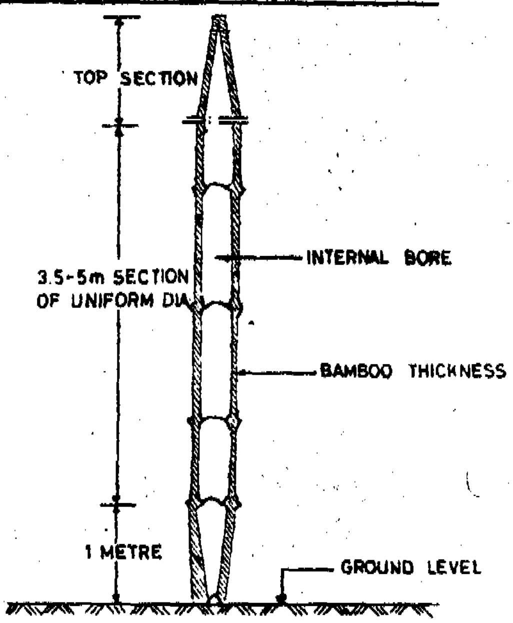


FIG. 16 BORING OPERATION

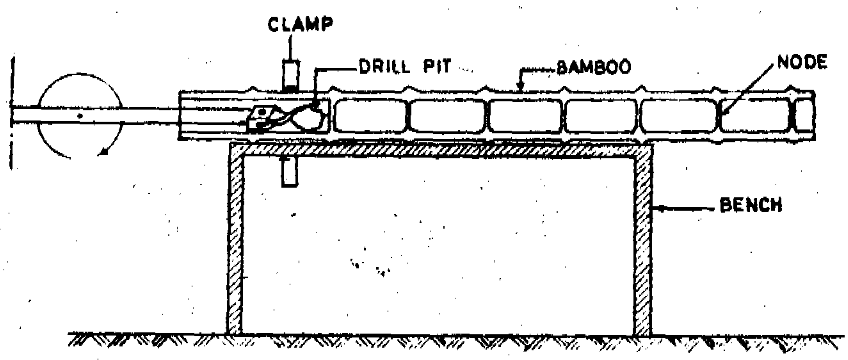


FIG. 17 P.E. JOINT.

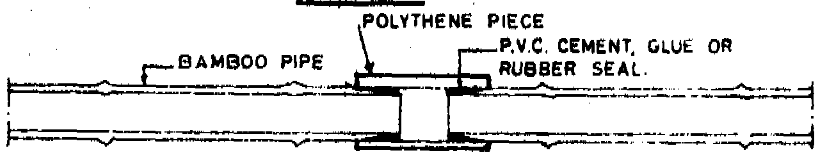


FIG. 18 P.V.C. JOINT

FIG 19 WOODEN CONNECTOR AND VALVE.

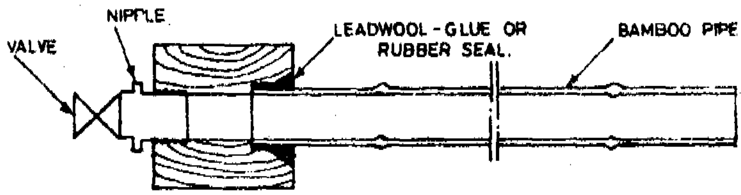


FIG. 20 G.S. TEE AND CONNECTOR

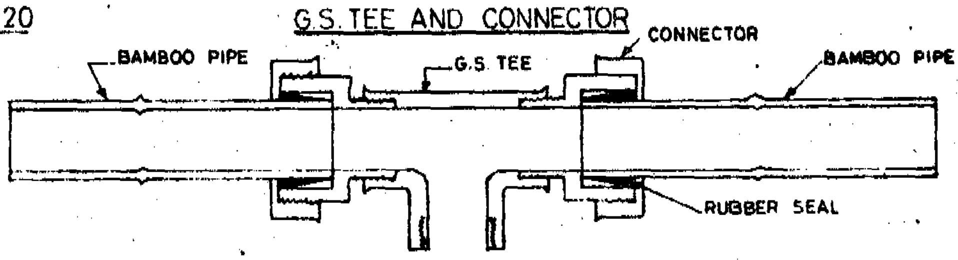


FIG. 21 WOODEN TEE

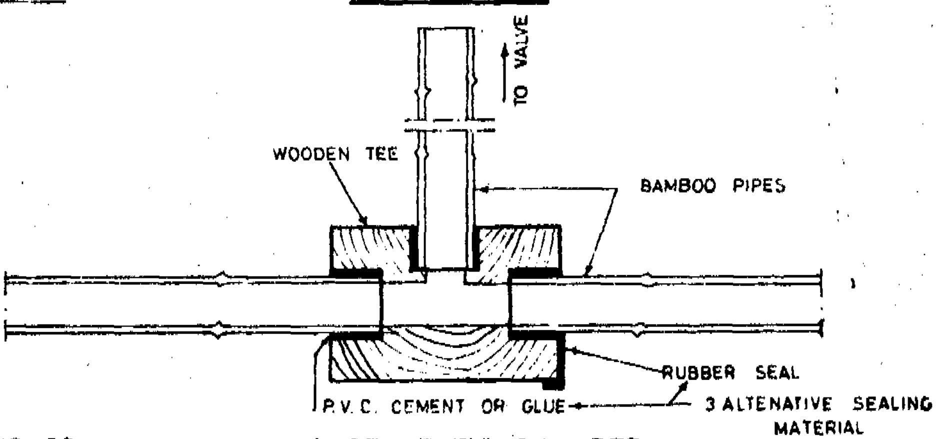


FIG. 22 PRESSURE RELIEF CHAMBER

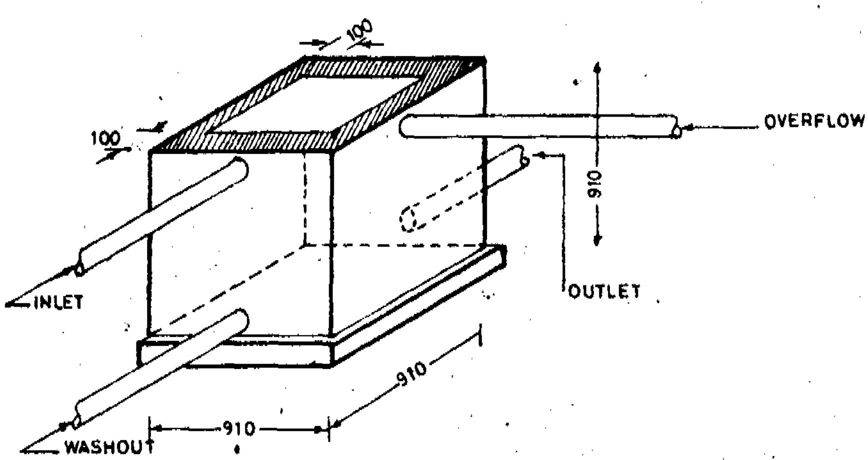


FIG 23 WATER HAMMER CONTROL DEVICE

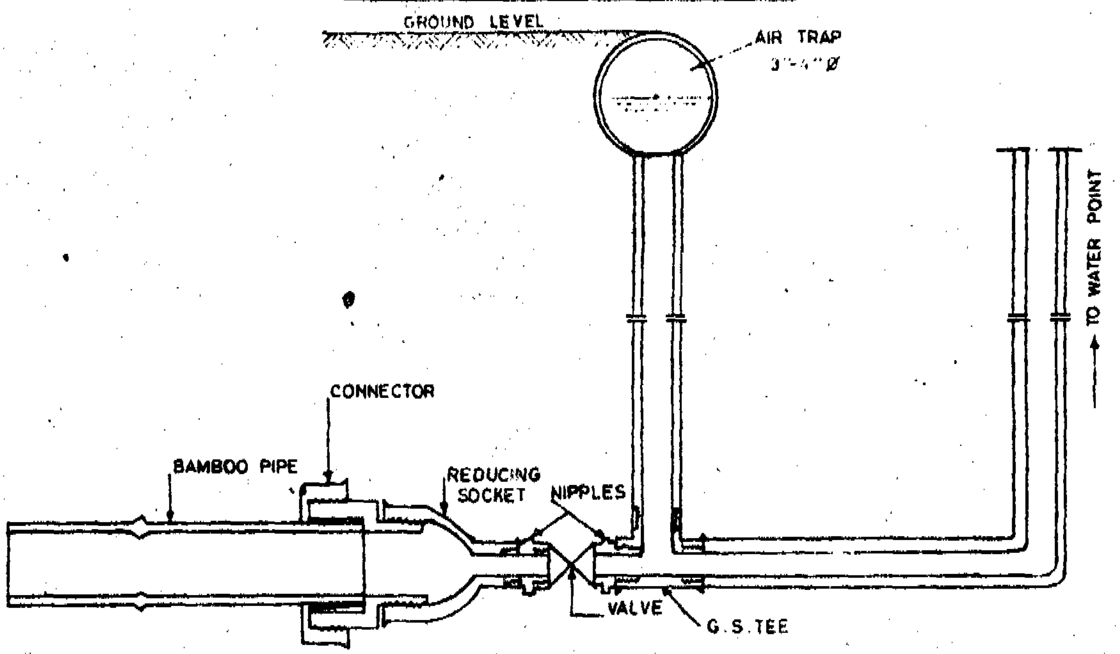


FIG 24 X-SECTION THROUGH PIPE TRENCH, TREATMENT AND BACKFILLING

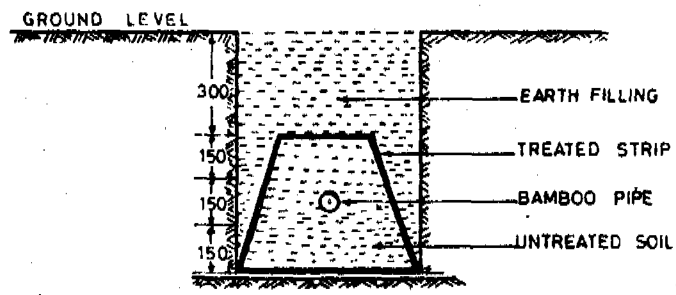
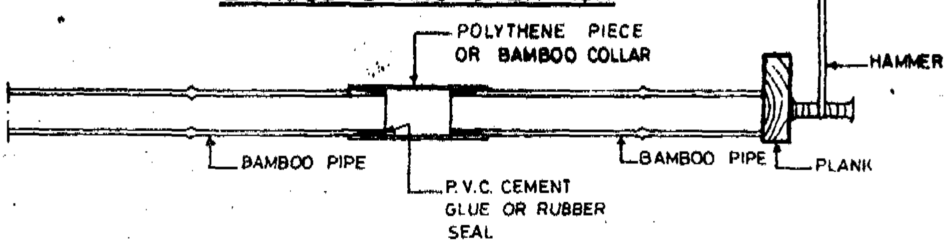


FIG 25 BAMBOO LAYING OPERATION



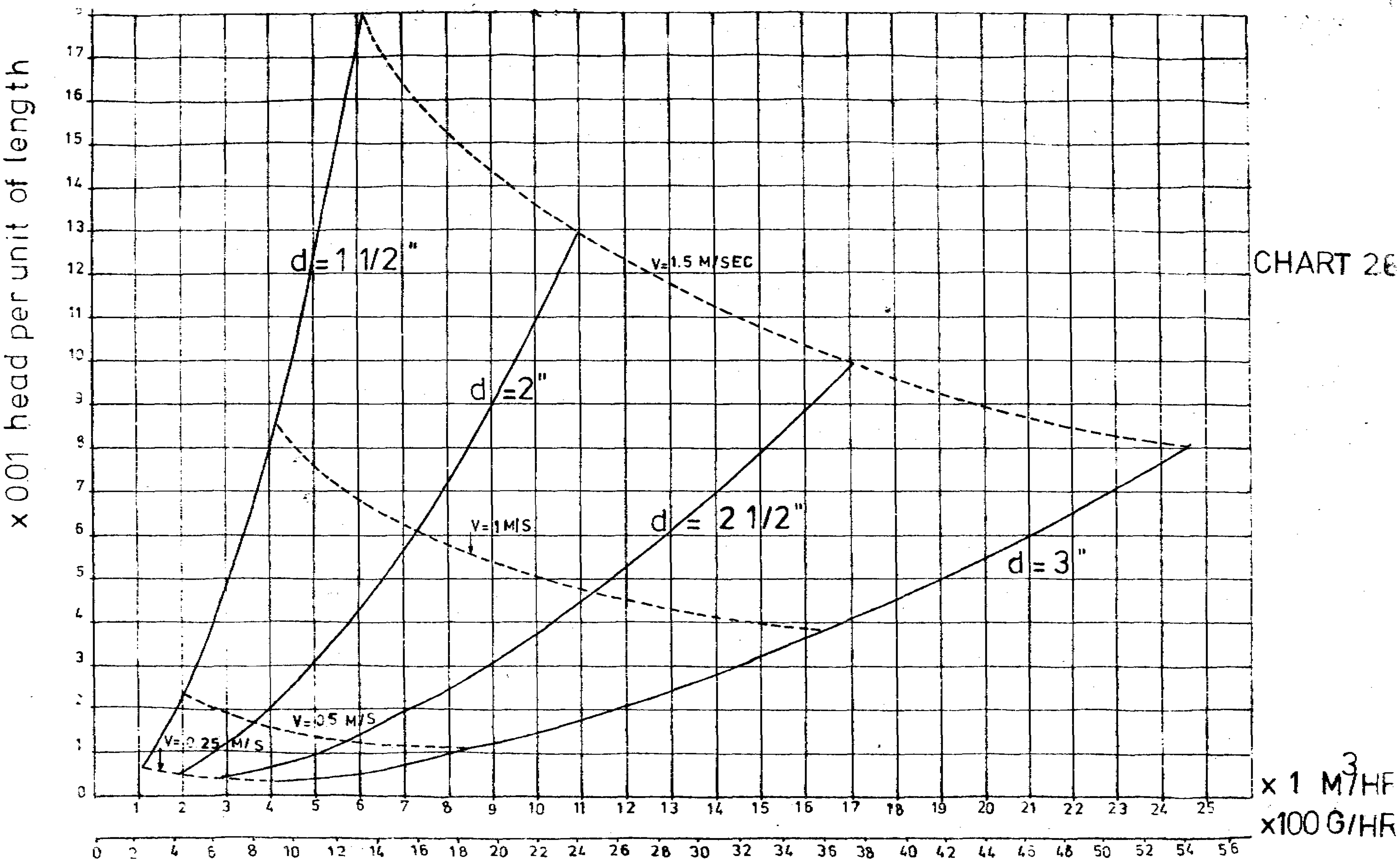

x 0.01 head per unit of length
d = 1 1/2"
d = 2"
d = 2 1/2"
d = 3"
V = 1.5 M/SEC
V = 1 M/S
V = 0.5 M/S
V = 0.25 M/S
x 1 M3/HR
x100 G/HR

CHART 26