11056-BK $ 3.95

Animal-Driven Chain Pump

By A. D. Mast

a VITA publication

ACKNOWLEDGMENTS

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ANIMAL-DRIVEN CHAIN PUMP CONSIDERATIONS

APPLICATIONS:

WATER LIFTING
WATER PUMPING
IRRIGATION

SKILLS/LABOR/TIME:

Construction time and labor resources required to complete this project will vary depending on several factors. The most important consideration in interpreting the time frame given is the availability of the local people interested in doing this project. The project may in many circumstances be a secondary or after work project. This will of course increase the time needed to complete the project. The construction times given here are at best estimations based on limited field experience.

Skill divisions are given because some aspects of the project require someone with experience in metalworking and/or welding. Make sure adequate facilities are available before construction begins.

SKILLED LABOR -- 15 hours
UNSKILLED LABOR -- 21 hours
WELDING -- 4 hours

SPECIAL CONSIDERATIONS:

Advantages:

- Simple to build and maintain.
- Can pump up to 9,000 gallons of water per hour.
- Portable, can be moved from one location to another.
- Can be animal or human-powered.

Disadvantages:

- Differential may be expensive or not available in some areas.
- Water lifting/pumping restricted to 6 meters.
- Rubber gaskets need replacing every 250 hours or operation.

FOUNDRY OR CASTING FACILITIES NEEDED FOR ROLLER CONSTRUCTION

COST ESTIMATE:*

$40 - $200 (US) including materials and labor.

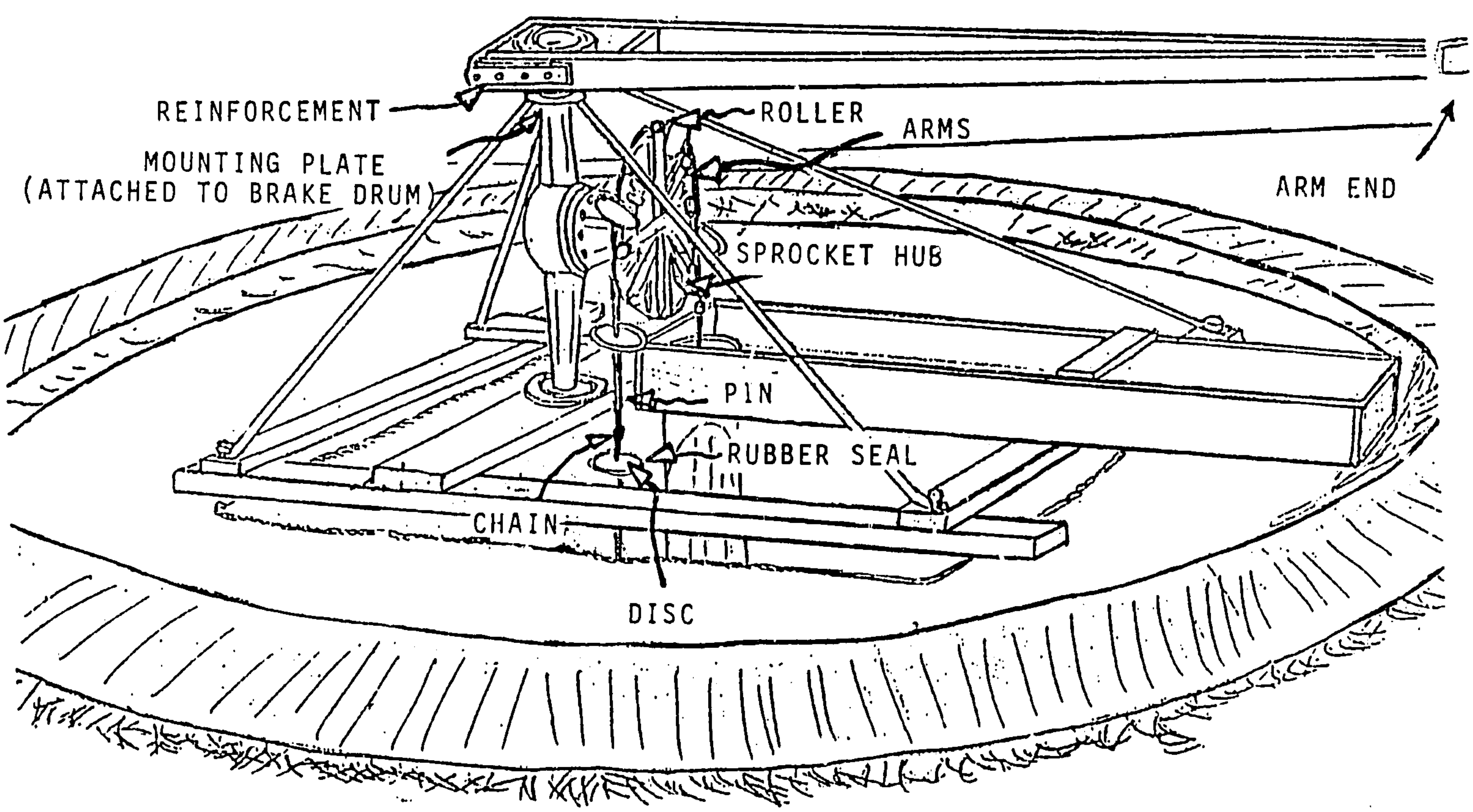
*Cost estimates serve only as a guide and will vary from country to country.

CHAD CHAIN PUMP

I. INTRODUCTION

Draft animals have been a source of power for agricultural operations for thousands of years. Oxen and bullocks are the usual choice because of their adaptability to a variety of climatic conditions and food sources. Horses, camels, mules, etc., are animals which have been and continue to be utilized in plowing, tilling, hauling and cultivating. These animals also provide the farmer with meat, leather, fertilizer, etc.

In many countries livestock symbolize individual or family wealth and are highly prized by their owners. Besides traditional agricultural applications animals may provide power sources for sugar cane pressing, water lifting or a variety of individual processing machines, such as threshers, grinding mills, oil presses and winnowers. With proper gear ratios an animal-driven power device can produce up to 135 revolutions per minute. This output is, of course, dependent on the number and strength of the animals used, but this speed is usually more than sufficient for operating the machinery mentioned above.



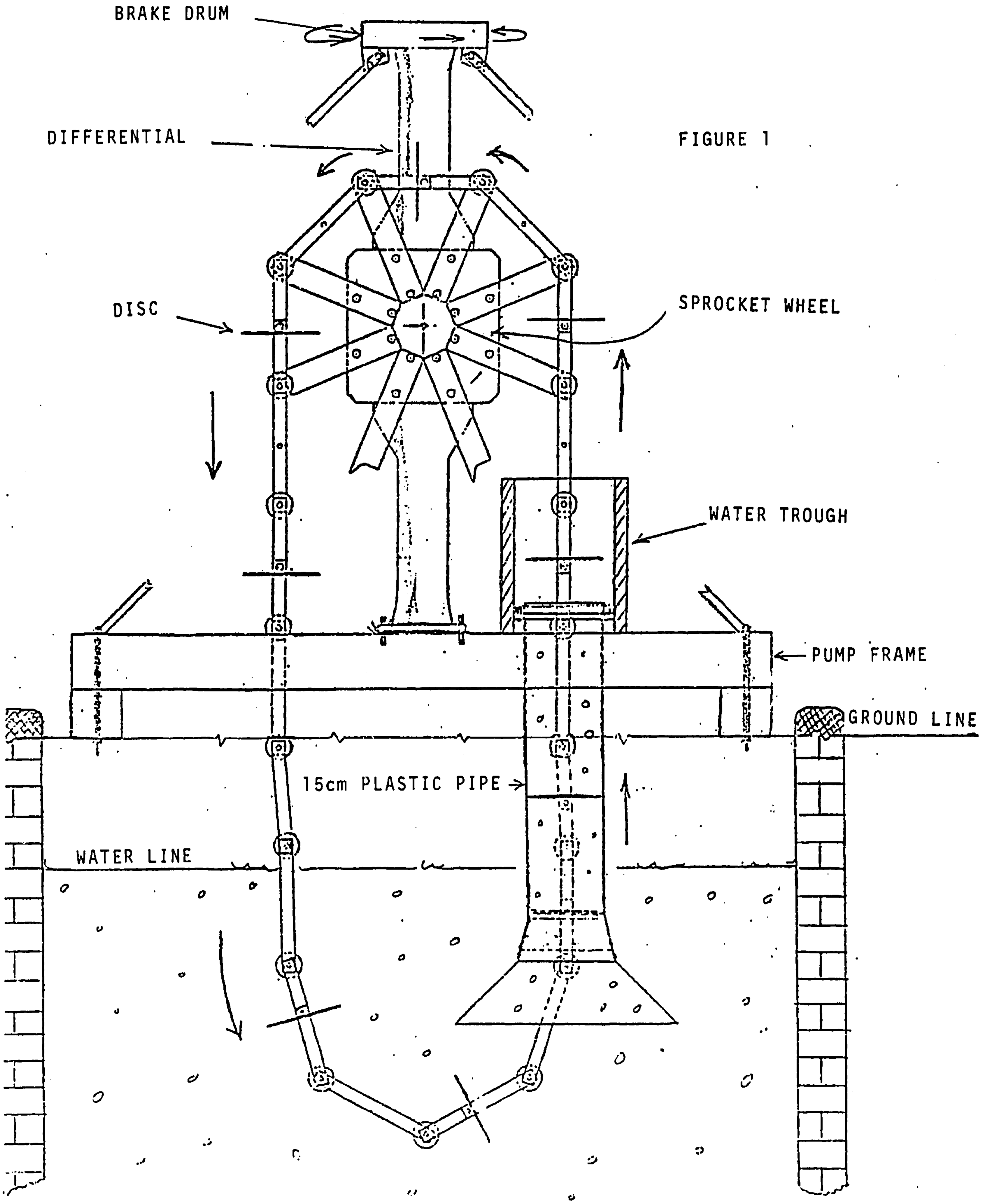
One such animal-driven power device, particularly suited for use with open wells, is a chain pump or water lifting device for depths up to 6 meters (20 ft.). The pump presented here was adapted by Peace Corps Volunteers in Chad from the basic VITA chain pump which appears in the Village Technology Handbook.

The pumping mechanism takes its name from the series of links and rubber metal disks which are attached to form the continuous chain which pulls water up as it revolves around the sprocket wheel. The chain, as shown, lifts water through a 15cm diameter plastic pipe. As the water reaches the surface, it can be emptied into a trough or storage area depending on the purpose or need for which it is being pumped.

When considering this pump for use in a particular area, one should keep in mind that while certain principles involved in the pump's design, construction, and operation are universal and will apply in any situation, local conditions will in all probability require that certain modifications be made.

CHAIN PUMP

FIGURE 1



II. PRE-CONSTRUCTION CONSIDERATIONS

As shown in Figure 1, the finished pump is partially made of sawed lumber. If sawed lumber is not available in the area, logs can be used. Torque arms also can be made from round poles or angle iron depending on materials available. Two optional cross pieces between the torque arms will not affect the stress placed on the torque arm by the animal pushing or pulling the arms. If the pump is to be moved from one well to another the logs should be kept between 7.5cm to 12.5cm in diameter. Four people can carry this frame and pump without a great deal of difficulty. Depending on circumstances, the pump assemblage can be pulled by an animal from one location to another.

Please note on the materials list that quantities are not shown for the rollers, chain links, discs, attaching pins or rubber gasket material. These quantities have to be calculated according to the depth of the particular well(s).

This pump, using 15cm diameter PVC pipe, will deliver approximately 8 to 9 thousand gallons per hour with one animal. The height of the lift does not alter the capacity noticeably. Should a smaller or larger diameter pipe be used, it will be necessary to alter the diameter of the rubber gasket and the metal disc accordingly. It is important that the metal disc be approximately 6.0mm smaller in diameter than the inside diameter of the pipe chosen. The rubber disc, on the other hand, should be 3mm larger in diameter than the inside diameter of the pipe. A funnel-type apparatus is attached to the bottom of the PVC pipe to guide the chain and discs into the pipe. For a 15cm pipe the recommended flanged end of the funnel should be 38cm to 46cm in diameter.

MATERIALS

-- Four-wheel drive vehicle differential with brake drums attached.

-- 8 steel arms 26.7cm x 5cm x 10mm thick steel plate

-- 30.5cm x 30.5cm x 6.0mm thick steel plate (hub)

-- 5cm diameter steel or cast iron rollers*

-- 26.7cm x 2.5cm x 6.0mm thick plate steel* (chain links)

-- 14.6cm diameter steel discs 1.2mm thick* (18 gauge)

-- 15.6cm diameter rubber gaskets 3mm thick* (made from old inner-tube)

-- 10mm diameter steel rods 6.7cm long* (connecting pins)

-- 7 - 35.6cm x 5cm x 5mm thick steel plate (torque arm reinforcement, arm end piece and mounting plates for guide rods)

-- 3cm x 3cm x 3mm angle steel* (guide rods)

-- Scrap steel plate and inner-tube rubber (enough to cover and seal bottom of differential housing)

-- 1 gallon of motor oil (lubrication)

-- cotter pins* (2.5cm length)

-- 24 bolts, 10mm x 2.5cm, with nuts (hub sprocket and guide rod assembly)

-- 12 bolts, 10mm x 8cm, with nuts

-- 4 bolts, 10mm x 14cm, with nuts (torque arm and bracket)

-- 2 bolts, 13mm x 10cm, with nuts (torque arm)

-- 6 - 13mm nuts

-- 12 bolts, 10mm x 22cm, with nuts

-- 15cm diameter PVC pipe*

-- Wood* (trough)

-- 10cm x 10cm wood lumber* (frame)

-- 2 - 5cm x 10cm x 4.5meters wood lumber (torque arms)

-- Miscellaneous - 10mm dia. nails, glue, metal clamps

*Depends on well dimensions or depth of well.

Tools

-- Welding equipment with cutting attachments (cutting steel plates)
-- Knife (to cut gasket materials)
-- Adjustable wrench
-- Hammer
-- Needle-nose pliers (fastening cotter pins)
-- Casting facilities (rollers)
-- Rivet machine
-- Metal drill and bits
-- Ruler
-- Metal hacksaw and blades
-- Compass
-- Pencil
-- Anvil (optional -- read instructions)

III. CONSTRUCTION

This chain pump consists of four major components: 1) chain and disc assembly, 2) sprocket hub and arms assembly, 3) differential and frame assembly, and 4) torque arm attachment. Construction and installation steps follow.

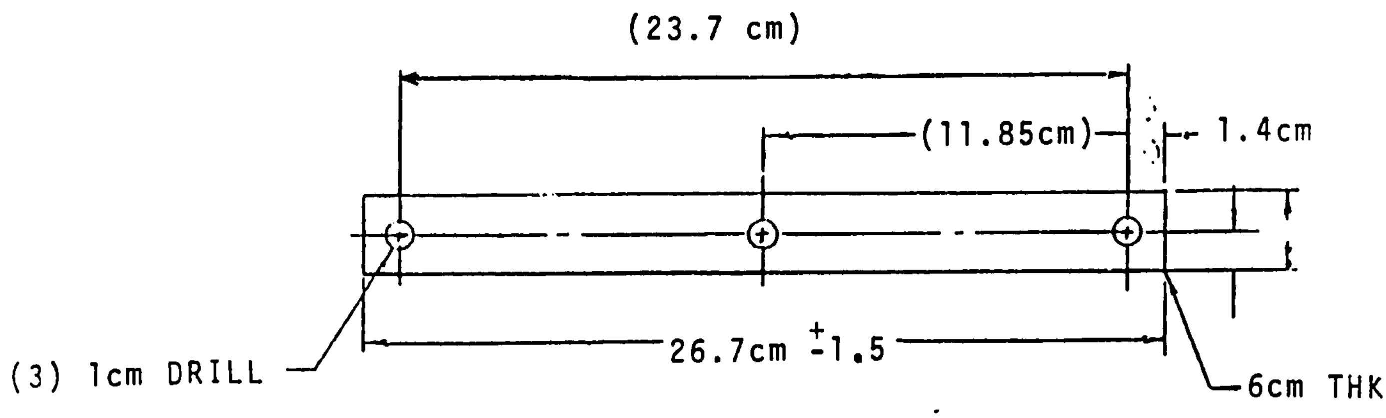
I. PREPARE THE CHAIN AND DISC ASSEMBLY

-- Determine the length of the chain. Attach a large rock to a length of rope and lower the rope into the well until the rock reaches the bottom. This measurement will give the depth of the well and provide a guide to the number of chain links, discs, and rollers needed. Since the chain will be continuous, it has to be two times the depth measurement of the well.

Figure 3 shows the dimensions for the chain links. The link itself is standard. To find the number of links needed for a given well, measure between the end holes (23.7cm) and divide this number into the total length of the chain needed.

-- Cut and drill steel plate 6.0mm thick to the dimensions shown in Figure 3. Make two pieces for each section of chain link.

FIGURE 3



THE DISTANCE BETWEEN THE END HOLES IS MOST IMPORTANT.

CHAIN LINK

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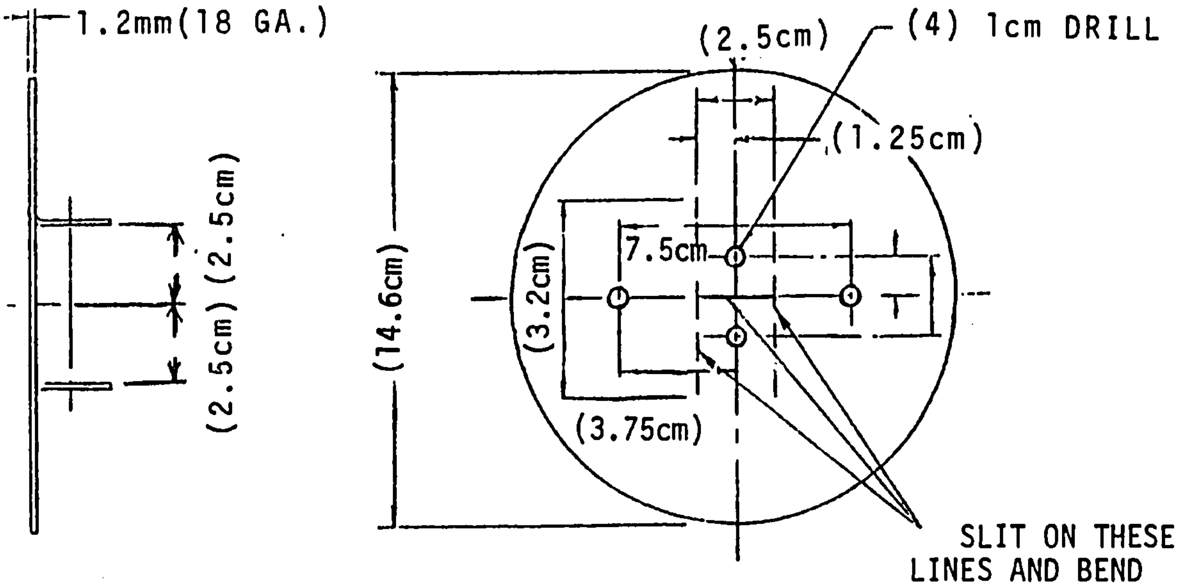
-- Determine the number of discs required by dividing the total number of links by two: there will be a disc for every other link in the chain. Figures 4 and 5 show the two disc components. Figure 4 is a metal disc and Figure 5 is the rubber gasket.

-- Cut the rubber gasket carefully. It is better to start with the holes too small. If the holes are too large, water will escape between the chain link and the gasket.

-- Construct the required number of each component and set aside.

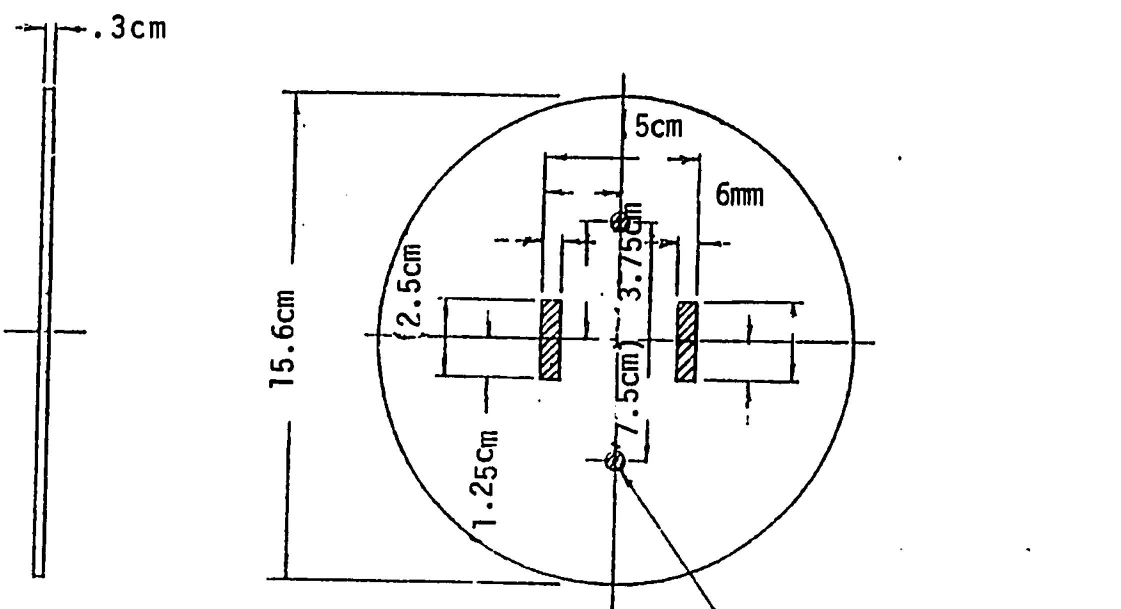
FIGURE 4



HEAVIER MATERIAL CAN BE USED THAN 18 GA.

METAL DISC

FIGURE 5

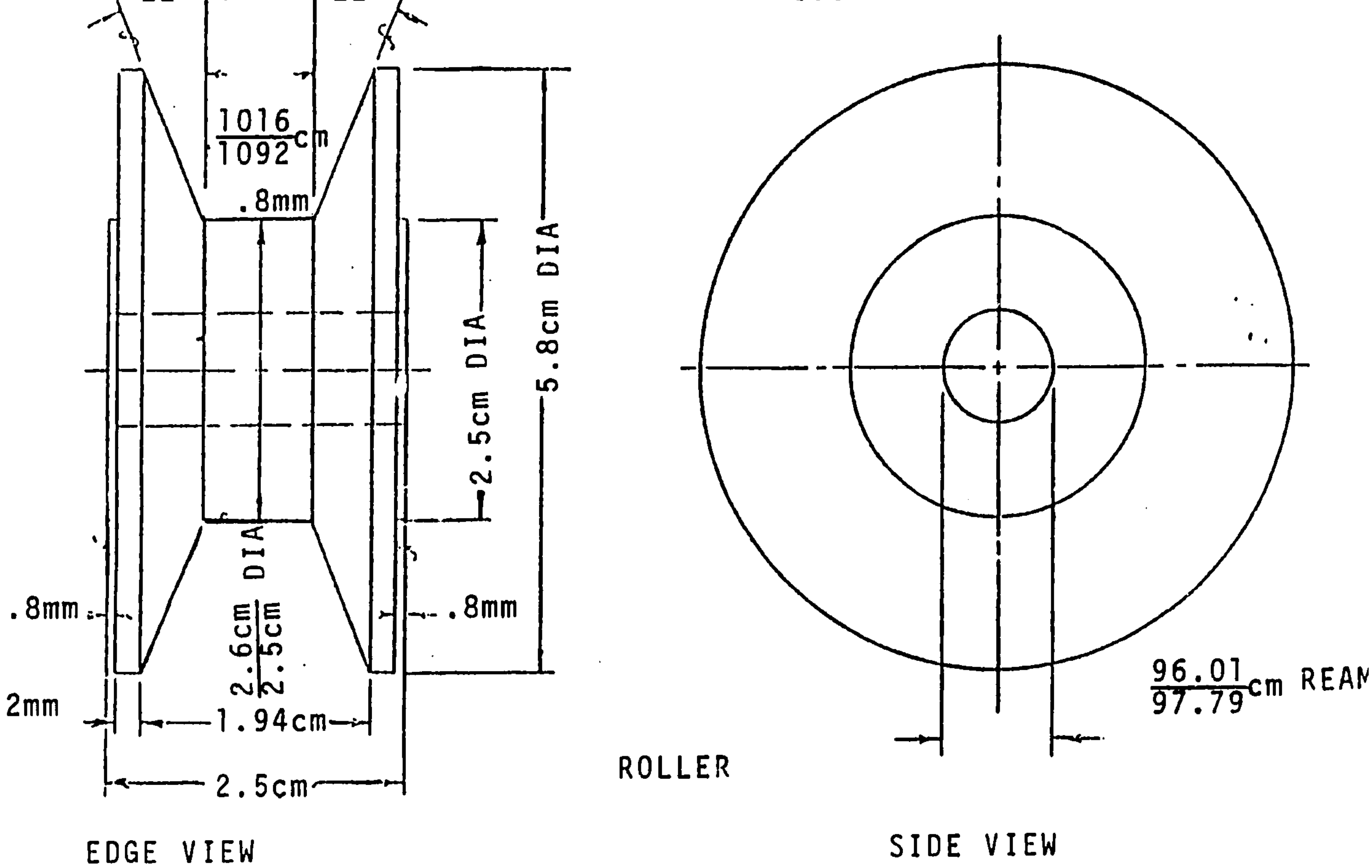


INNER TUBE RUBBER IS SATISFACTORY

RUBBER DISC

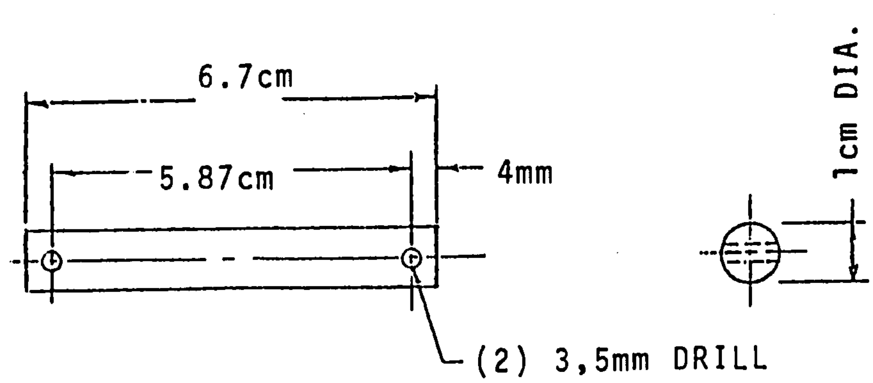
-- Make rollers. The number of rollers needed is equal to the number of links. The rollers are of steel or cast iron. If unavailable locally, it will be necessary to have someone cast them. Dimensions for the rollers are provided in Figure 6.

FIGURE 6



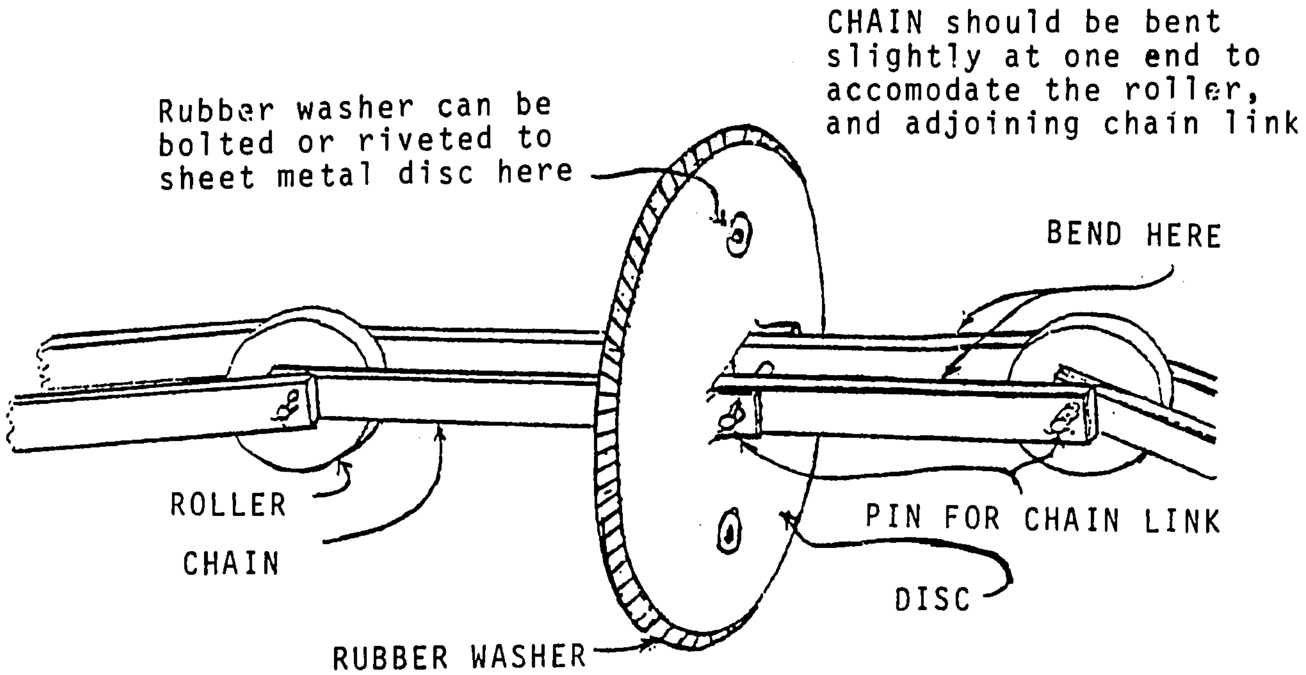
-- Make the connecting pins. The number needed equals the total number of links and discs. Figure 7 shows the dimensions of the pins. Drill two 3.5mm holes in each pin. The pins should be made from cold drawn steel rods for maximum life expectancy. Construct the required number of pins and set aside.

FIGURE 7



-- Assemble the chain as shown in Figure 8. Use the 6.7cm cotter pins to fasten the discs and rollers to the chain link. Remember that the rubber and metal discs are attached to every other link. Do not fasten the last roller and chain link together: this will be done after the chain is pulled through the 15cm PVC pipe (See picture on Operation and Maintenance).

FIGURE 8

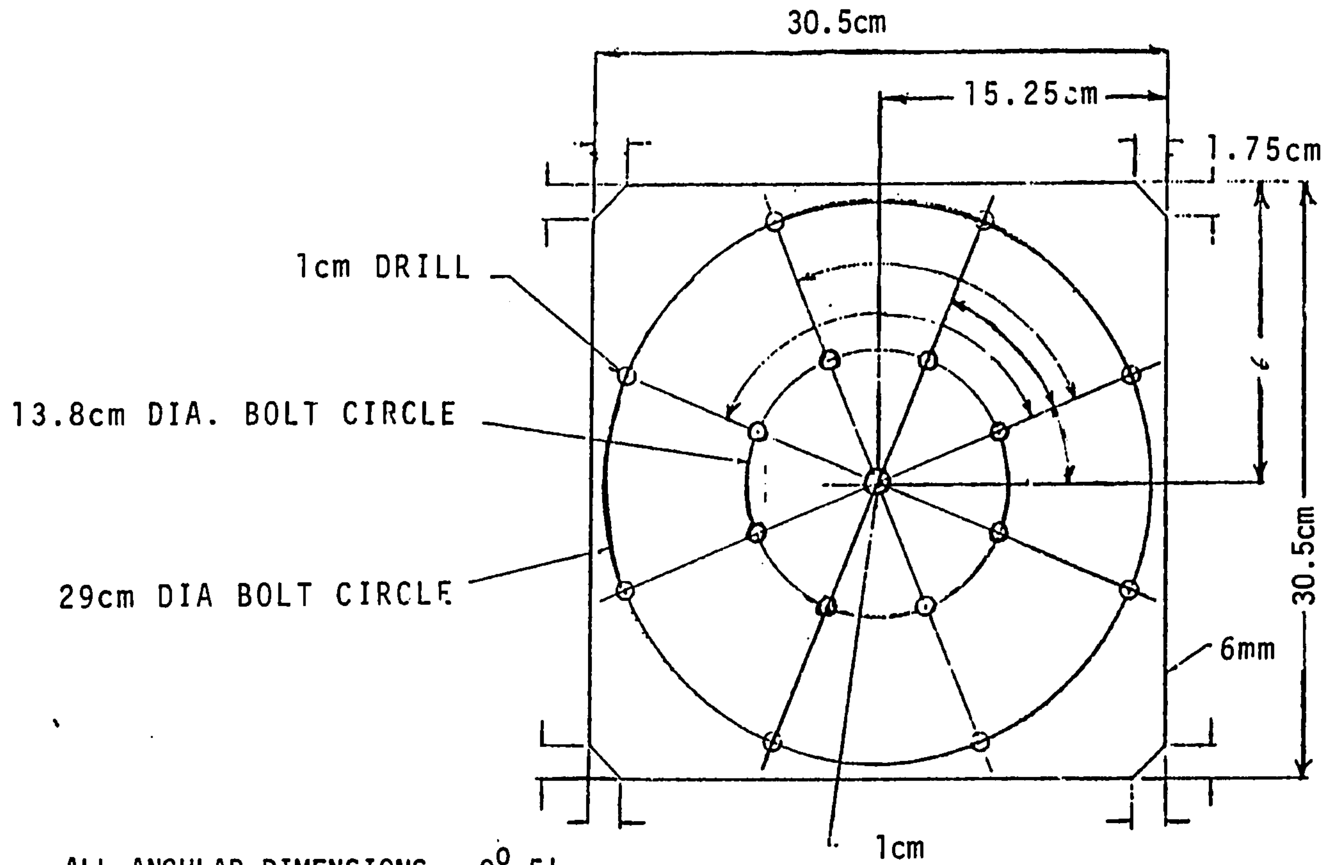


CHAIN ASSEMBLY

II. PREPARE THE HUB SPROCKET ASSEMBLY

-- Construct hub plate from a 30.5cm x 30.5cm steel plate which is 6mm thick following the dimensions given in Figure 9. Follow the measurements exactly. The easiest method of scribing a circle is with a meter stick, a nail, and a pencil. A 10mm diameter nail is nailed to one end of the meter stick; this point is the center of the circle. Measure from the nail the distance of the radius (half the diameter) and drill a hole to fit the pencil at this point. Drill a 10mm hole in the center of the steel plate. Put the nail in the hole and with the meter stick and pencil draw the circle. A compass is then used in determining the exact spacing of the arms which will be attached later.

FIGURE 9

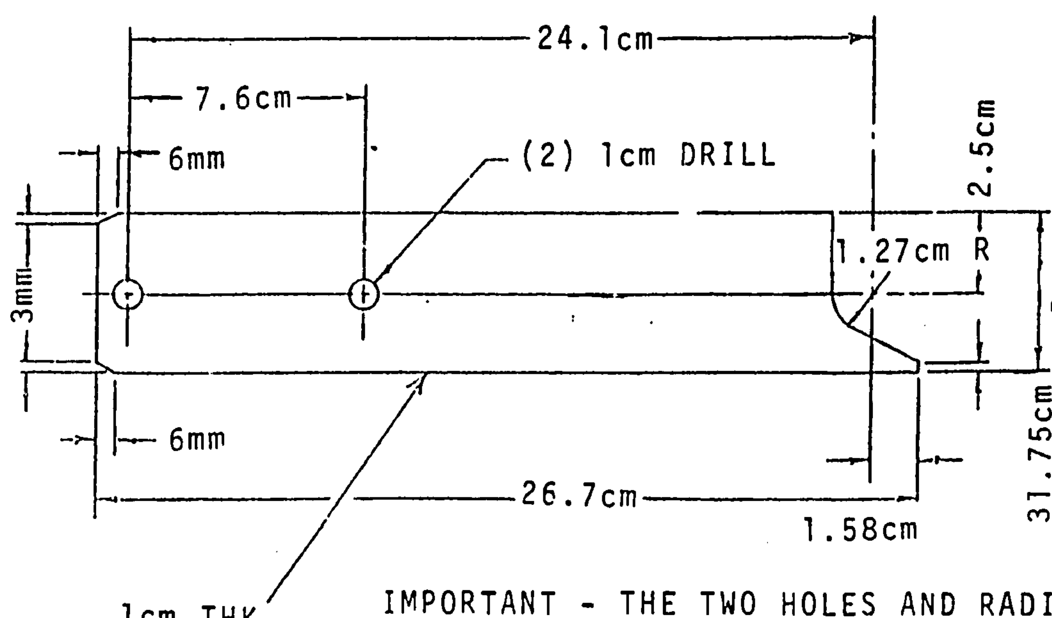


ALL ANGULAR DIMENSIONS = 0^{0} 5'

HUB SPROCKET PLATE

-- Take scrap steel plate, 10mm thick; cut 8 arms to the dimensions given in Figure 10. The two holes and radius center line measurements must be exact for each arm.

FIGURE 10



IMPORTANT - THE TWO HOLES AND RADIUS CENTER LINE AND DISTANCE MUST BE HELD.

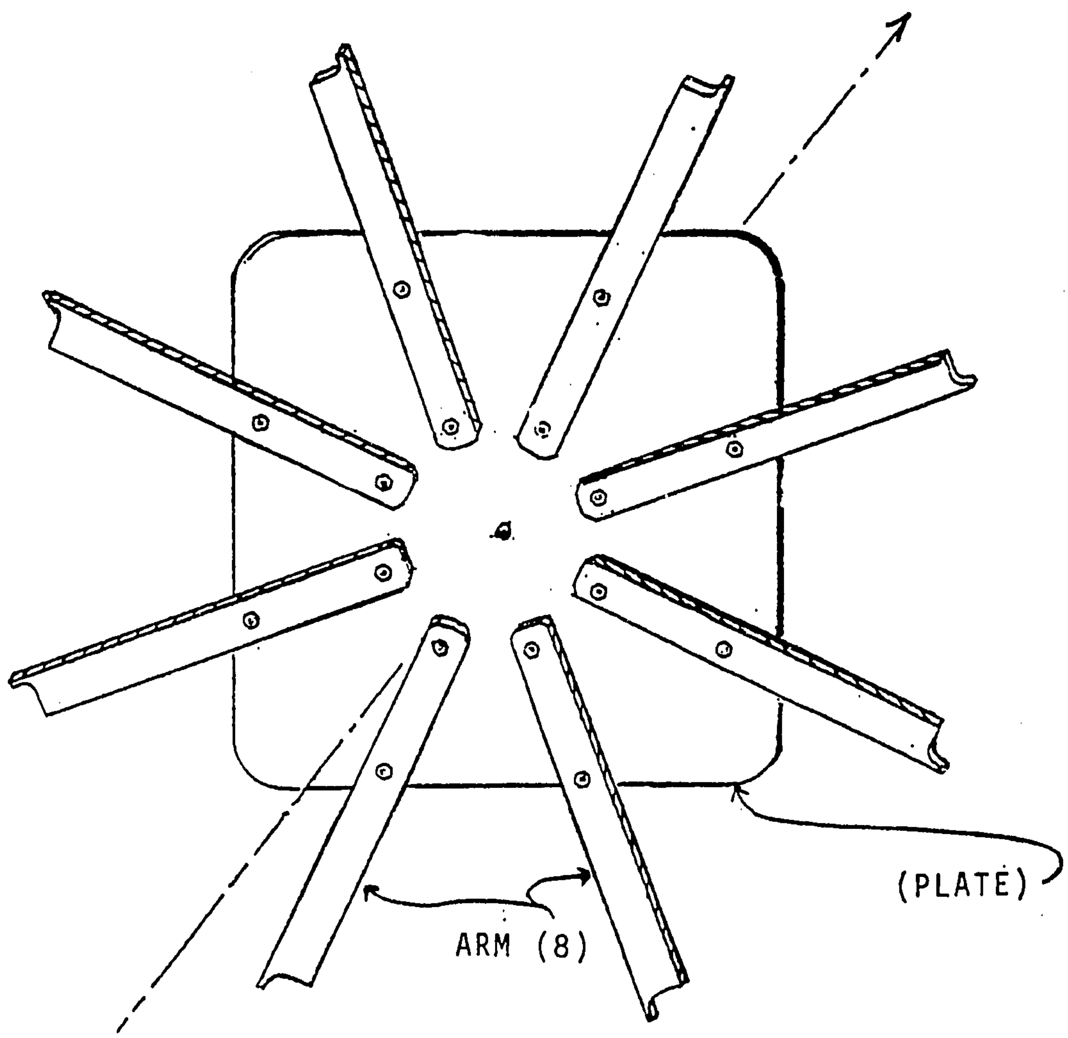
SPROCKET ARM

-- Attach the arms to the hub with 10mm x 2.5cm bolts and nuts. Be sure to insert the bolt from the back of the hub plate, through the arm section before fastening with the nuts.

FIGURE 11

SPROCKET/HUB ASSEMBLY

CONSISTS OF PARTS PLATE AND ARM



III. PREPARE THE FRAME

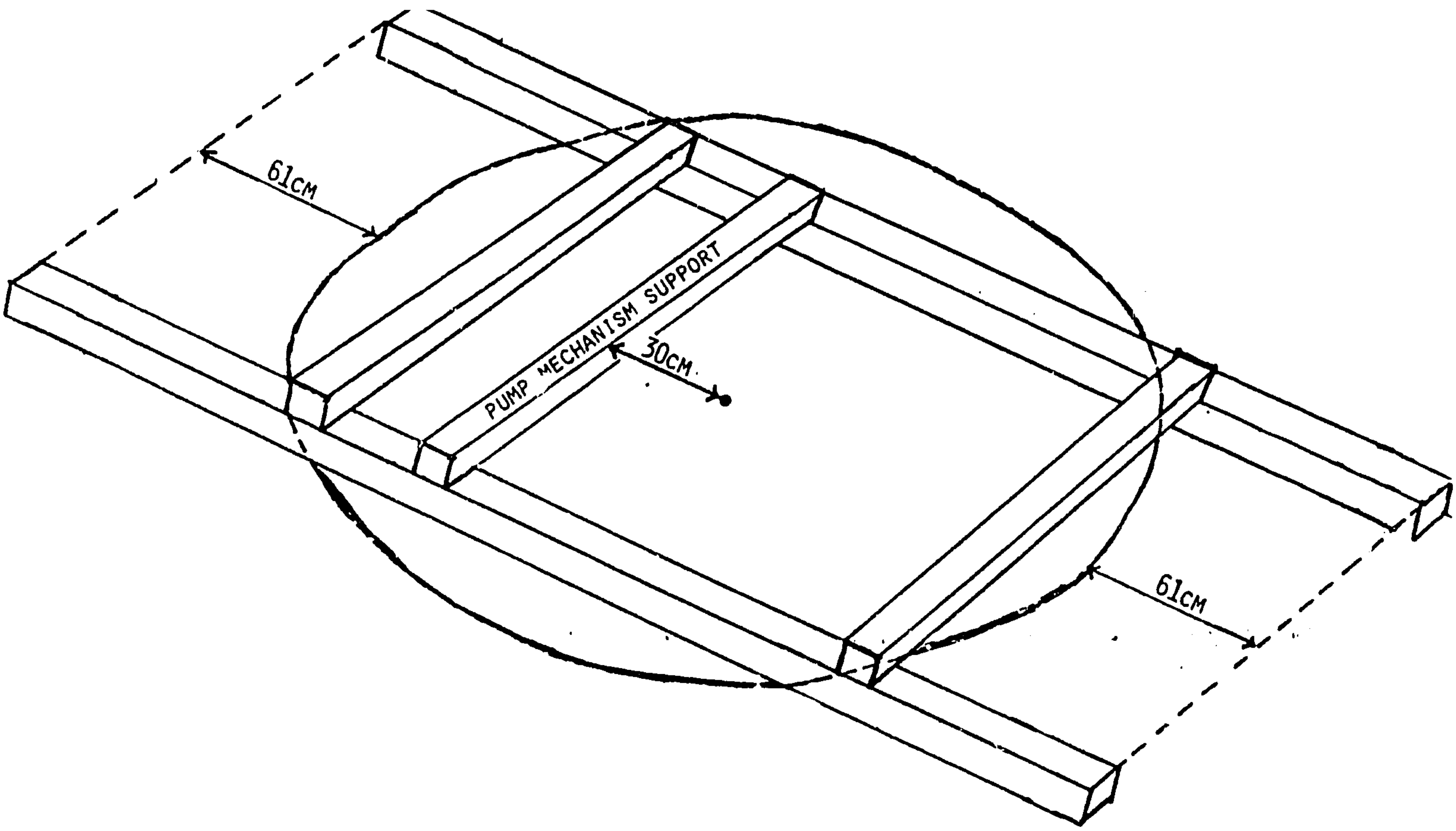
-- The frame is made from 3 wooden beams 10cm x 10cm x 1.6 meter long and 2 beams of 10cm x 10cm x (diameter of the well(s) + 122cm).

-- The wood beams should be laid out as shown below.

-- Make sure that the two bottom support beams extend at least 61cm on either side of the well's diameter. Mark board positions and remove from well.

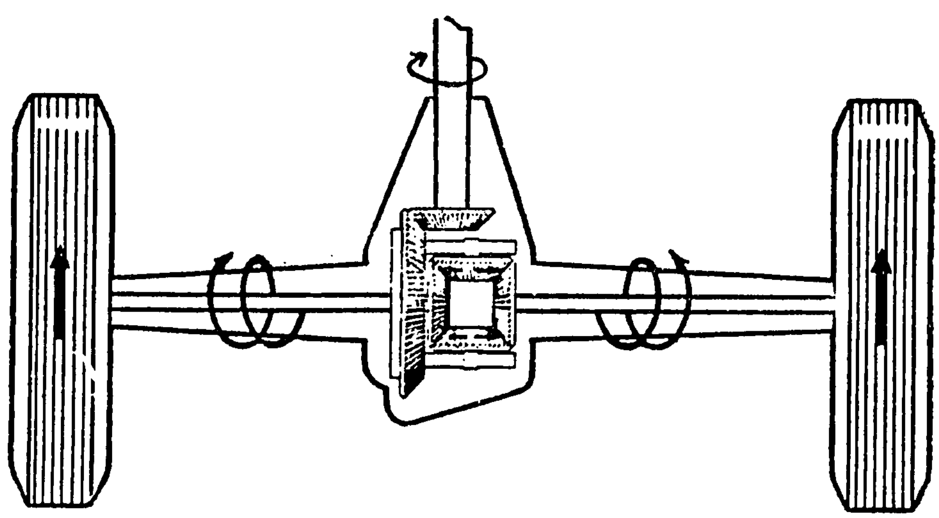
-- The wooden beam which supports the pumping mechanism should be bolted to the bottom support beam 30cm from the center point of the well.

-- Using a wood drill, bore out 10mm diameter holes and fasten frame together with 10mm x 22cm bolts and nuts.



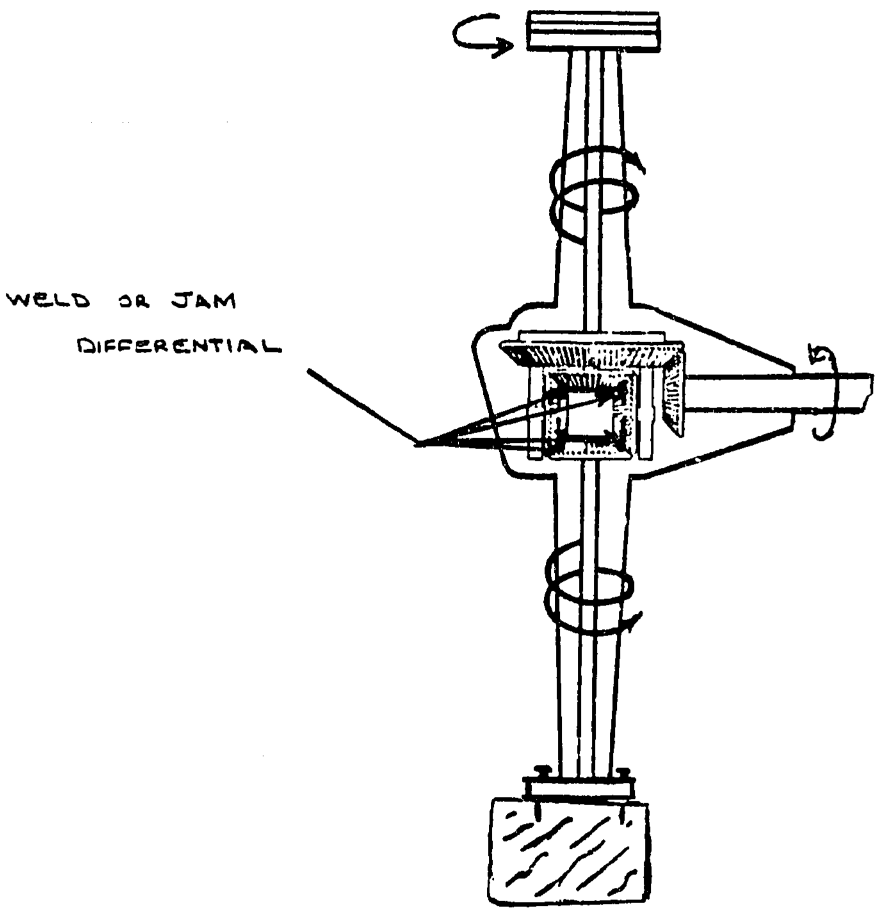
IV. PREPARE THE DIFFERENTIAL AND FRAME ASSEMBLY

- -- Find a scrapped four wheel drive vehicle differential. The two are similar and are designed for heavy-duty use. The differential must be placed in a vertical position.
- -- Remove one of the brake drums.
- -- Cut and bolt a rubber gasket and steel plate to cover and seal this end of the differential so that oil will not leak out.
- -- Jam the differential portion of the gearing by welding or inserting a piece of metal and securing it with bolts so that it cannot be moved. It may be necessary to provide a means for putting oil into the differential since it is normally used in the horizontal position. (The flow of power is reversed from that which was initially intended: instead of the drive shaft turning the axle, the axle turns the drive shaft.)



Normal Automobile Differential Operation

- -- Attach the sprocket hub to the flanged portion where the drive shaft normally fastens to the differential. The hub has a 10mm center hole; there will be a similar center hole in the drive shaft.



Automobile Differential - adapted for pumping

-- To center the sprocket hub on the drive shaft, place a pointed 10mm pin in the hole of the sprocket hub and the drive shaft center hole. Mark the hub plate so holes can be drilled for attaching the two. It may be possible to remove the inside arm bolts of the hub assembly and use those holes for attaching the hub to the drive shafts flanged portion. If this is not possible, drill new holes in the hub plate and flanged portion: in this case, use a minimum of four 13mm bolts.

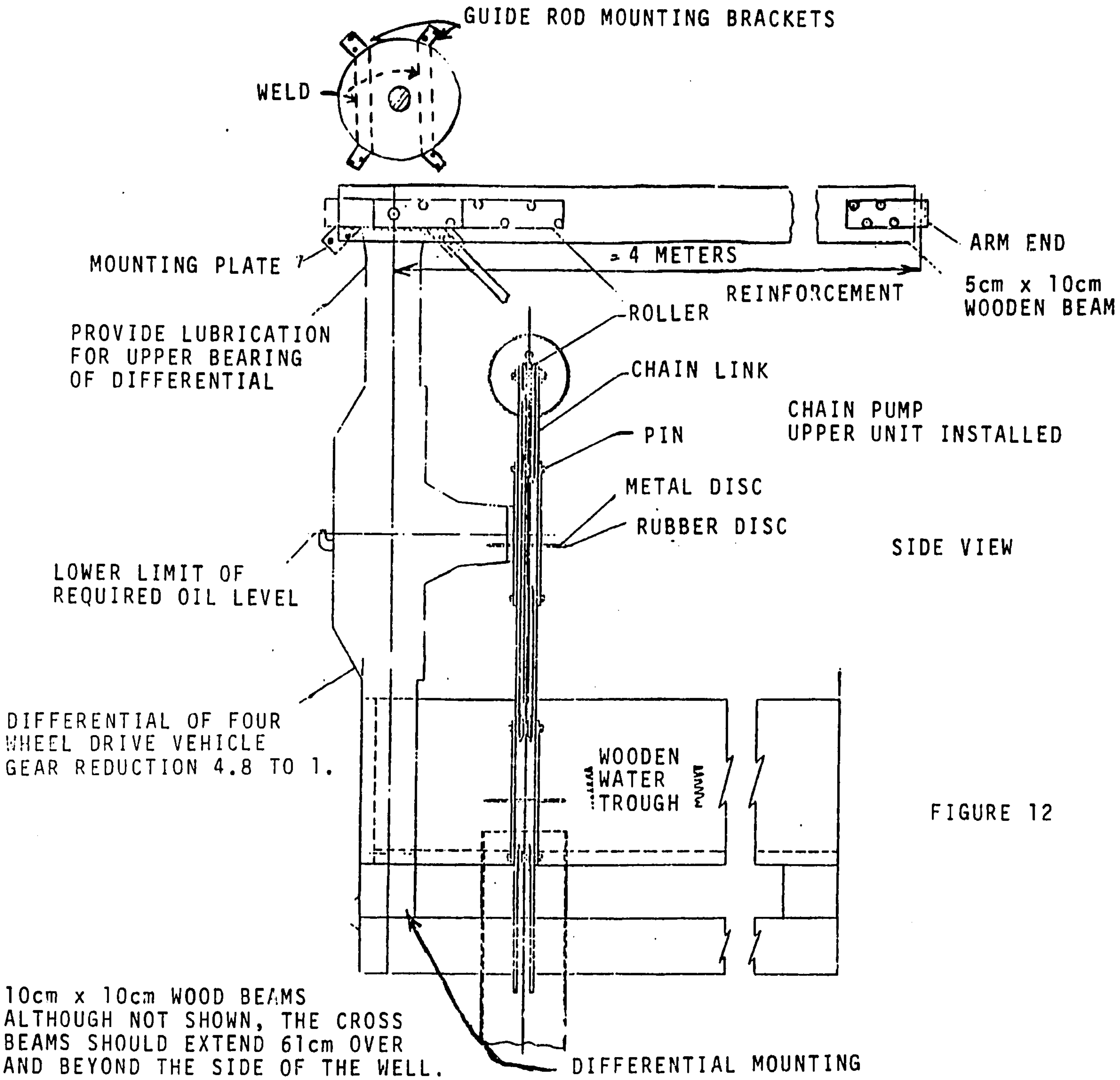
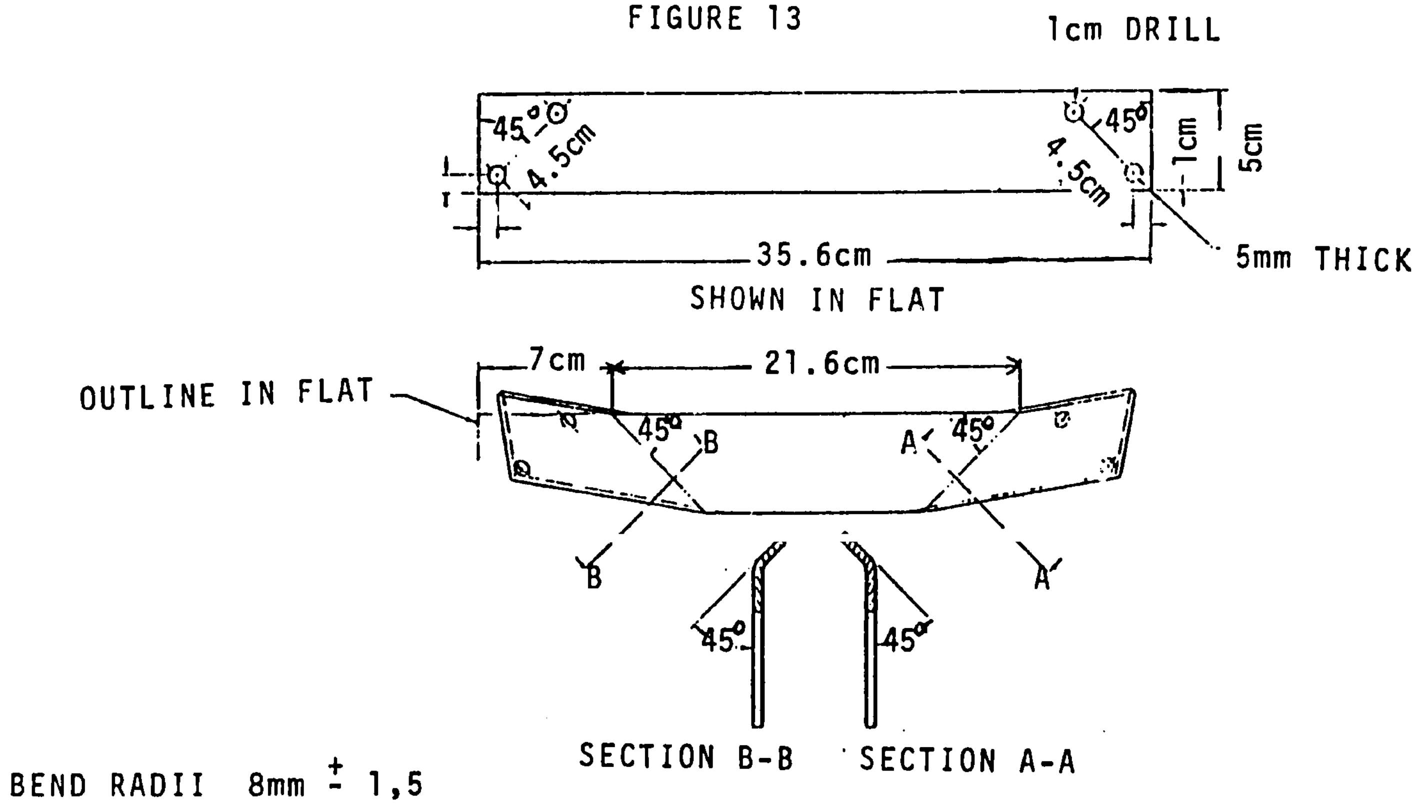


FIGURE 12

-- Make the guide rod mounting brackets: two brackets (2) have to be made and welded to the underside of the brake drum.

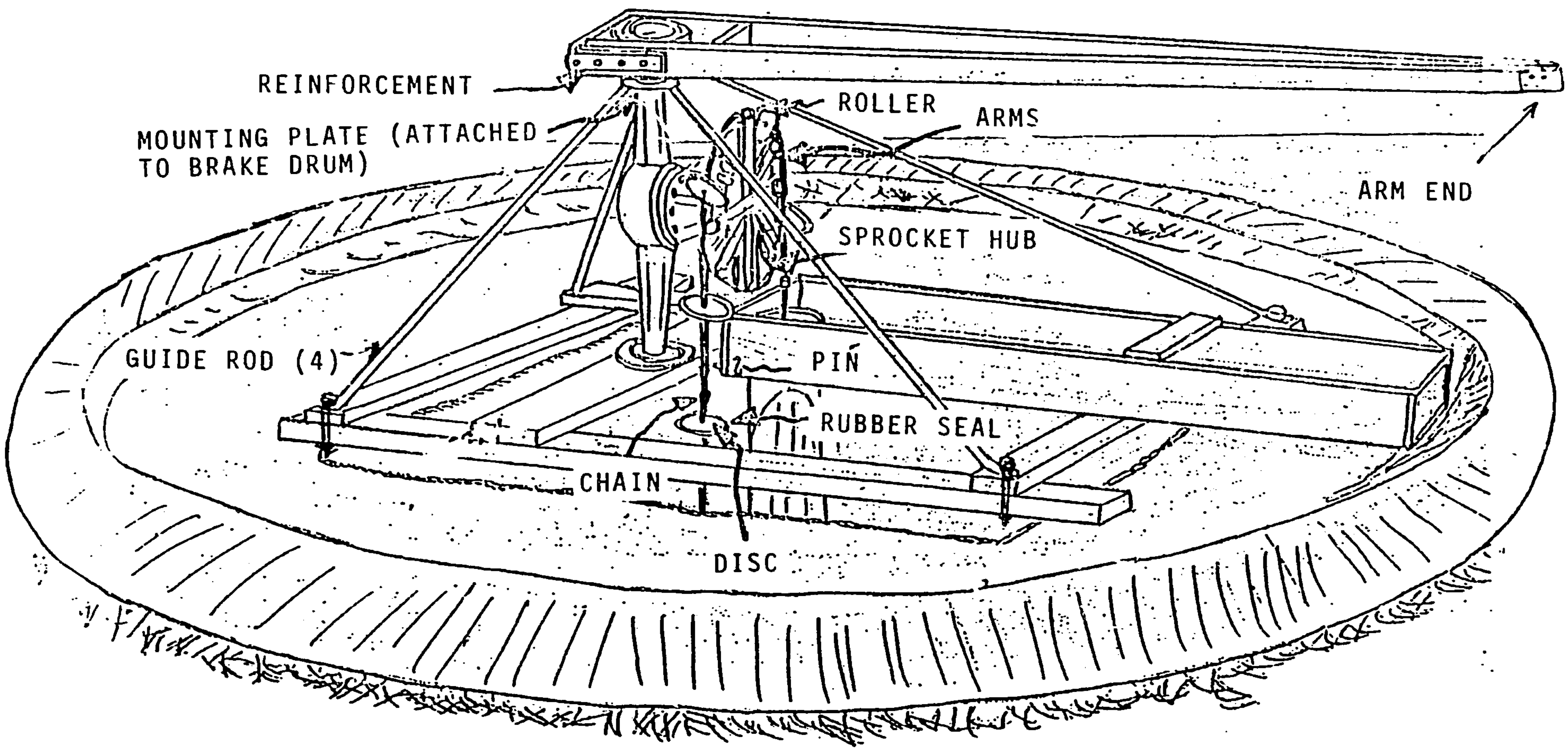
FIGURE 13



GUIDE ROD MOUNTING BRACKETS

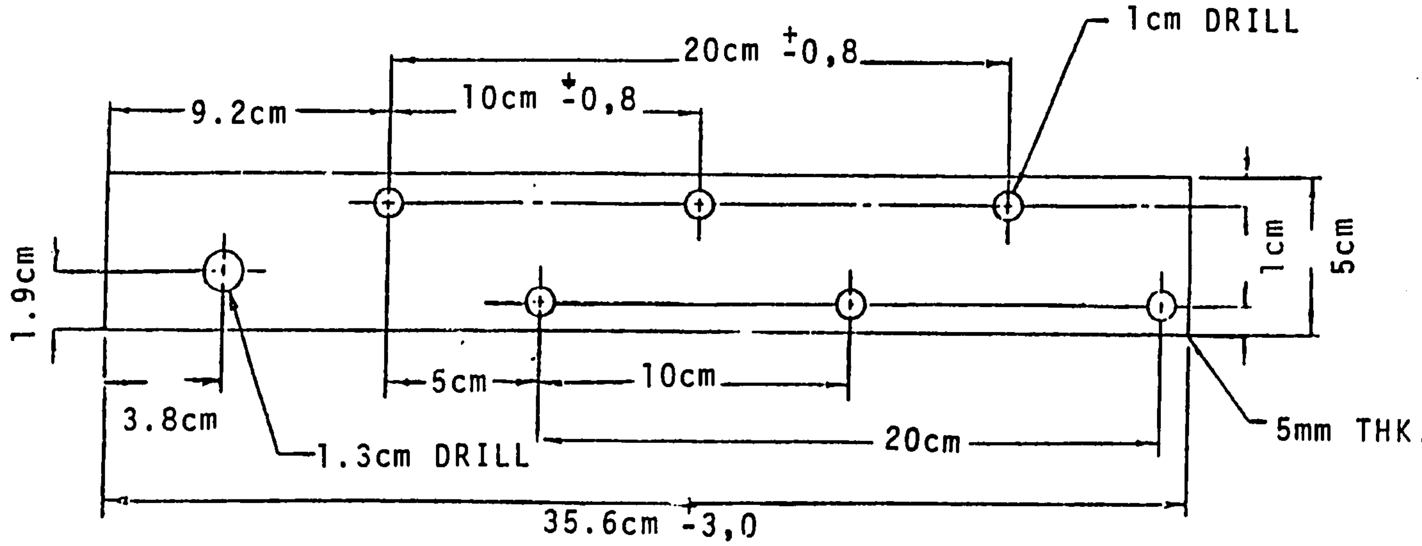
Figure 14 shows the guide rod arrangement. These metal rods support and stabilize the differential. The illustration shows the bottom of the guide rod connected to the wooden support members. This is done by removing from each corner of the frame one 10mm x 22cm bolt and nut. You should re-insert the bolts through the guide rods and then through the wooden members where they are then fastened.

FIGURE 14



ASSEMBLED CHAIN PUMP

FIGURE 15



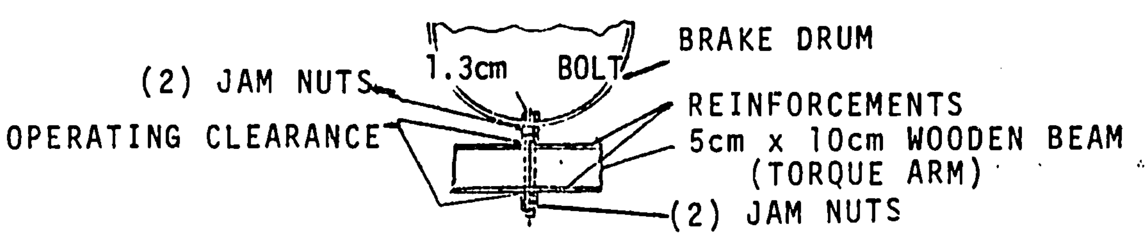
ATTACH ONE TO EACH SIDE OF BOTH TORQUE ARMS WHICH STRADDLE THE BRAKE DRUM. ATTACH WITH 2-1.3cm BOLTS TO THE DRUM. DRILL 2-1.2cm HOLES IN BRAKE DRUM.

TORQUE ARM REINFORCING PLATE

V. ASSEMBLE THE TORQUE ARM

-- Use scrap steel plate 5mm thick to make four reinforcing plates as shown in Figure 15. Attach one to each side of both torque arms (5cm x 10cm x 4.5m wood lumber) which straddle the brake drum. Each torque arm is attached to the brake drum with 13mm diameter bolts as shown in Figure 16.

FIGURE 16



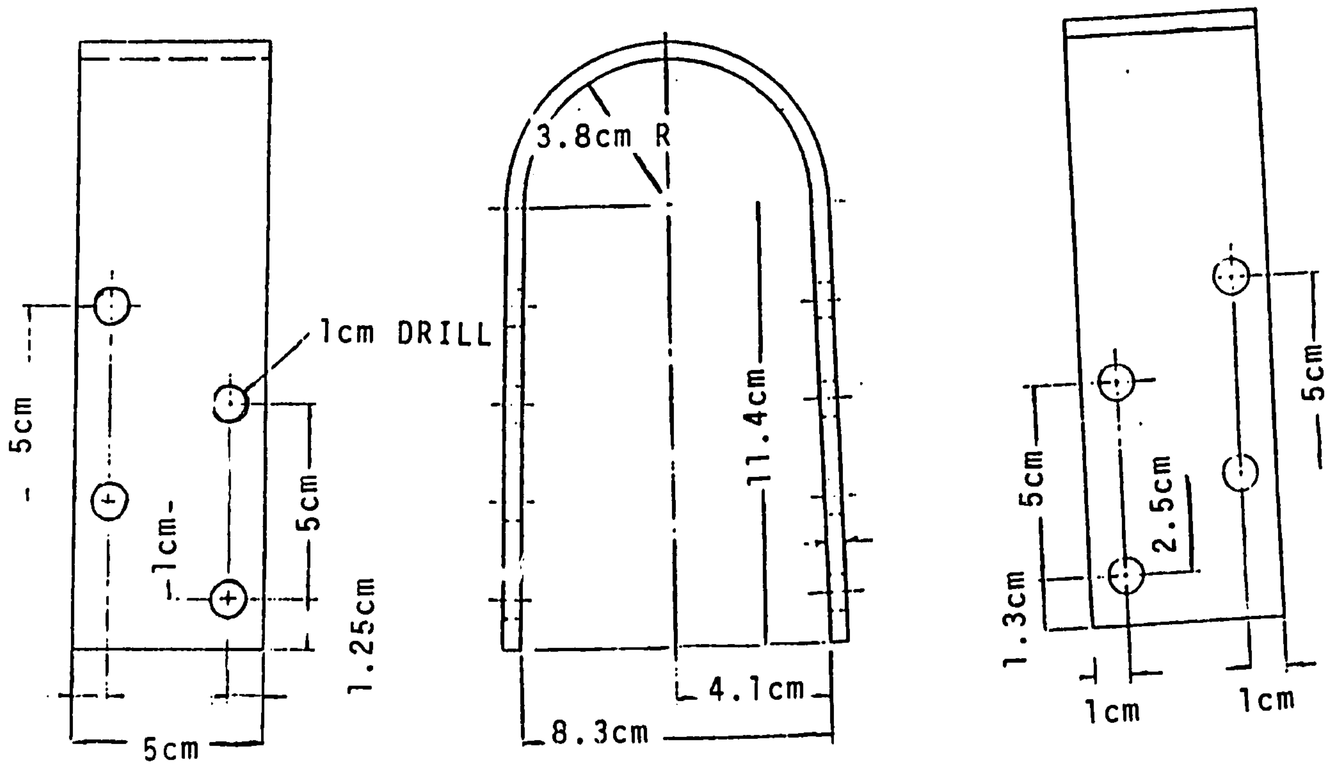
ONE HALF TOP VIEW OF ATTACHMENT OF TORQUE ARMS TO BRAKE DRUM

-- Drill two 1.3cm holes in the revolving part of the brake drum perpendicular to each other.

-- Use two 1.3cm nuts between the torque arm and the brake housing; these nuts serve to offset the stress of the torque arm on the brake housing.

-- Construct the torque arm end bracket as shown in Figure 17. This bracket serves to attach the two torque arms together and provides a means of hitching the animal. Be sure to drill through both (5cm x 10cm) wood members. Insert 1cm x 12cm bolts through one side of the metal bracket, through the wooden members and then through the corresponding side of metal bracket before fastening.

FIGURE 17



BLANK LENGTH 35.6cm

TORQUE ARM END BRACKET

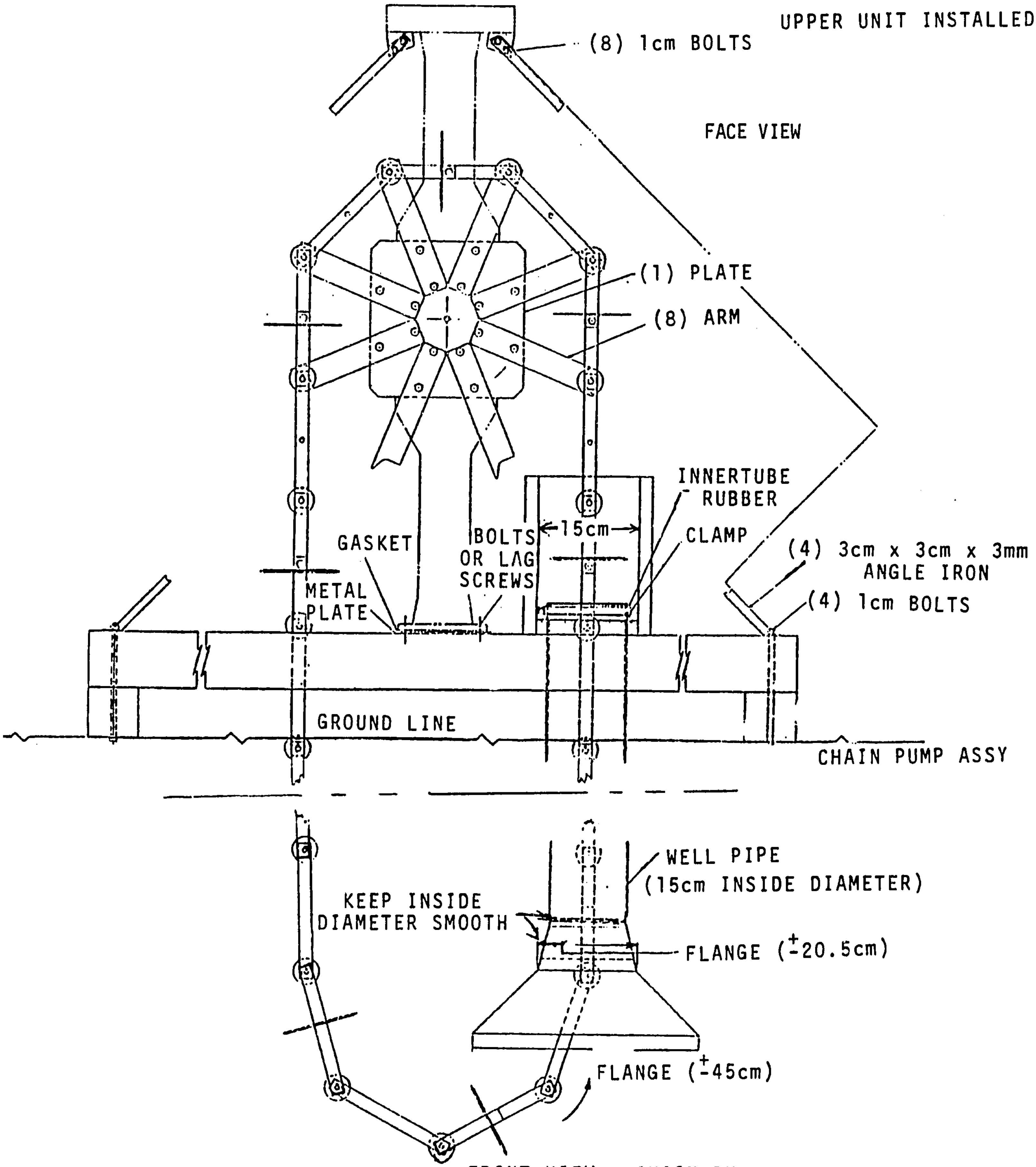
IV. ATTACH WATER TROUGH

-- Attach the water trough and 15cm diameter PVC pipe. Figure 18 shows the arrangement of the pipe and water trough. The bottom of the PVC pipe, which is at least 20cm below the water line, is flanged to facilitate the entrance of the discs as the water is pulled up the pipe. The bottom section of the flange should be 2-1/2 to 3 times the diameter of the PVC pipe. The flange sections can be made from 18 gauge (1.2mm) steel sheeting. The inside diameter of the 20.5cm flange should be as smooth as possible where it joins the 15cm pipe, otherwise the rubber discs will wear out quickly.

FIGURE 18

CHAIN PUMP

UPPER UNIT INSTALLED



FRONT VIEW - CHAIN PUMP

The top of the 15cm PVC pipe enters through the bottom of the wooden water trough, where it is clamped both under the trough and on top to keep the pipe from being pulled through the trough when the pump is operating. Inner tube rubber or scrap pieces of 15cm PVC pipe can be used as reinforcing material under the metal clamps.

Nail or bolt the water trough to the wooden frame supports, the differential, and also to the wood cross member located on the outer perimeter of the well (see Figure 14). A metal water trough can be substituted for the wooden one if you prefer. The extra expense will assure a longer life and less chance of leakage problems.

IV. OPERATION AND MAINTENANCE

Before installing the pump in the well it is necessary to connect the disc/chain link assembly. Run the chain through the 15cm PVC pipe before fastening the remaining roller and chain link. The following procedures should be carried out in order to keep maintenance at a minimum:

1. Make sure there is enough oil in the differential at start up.

2. Check oil level monthly.

3. Drive Shaft/Sprocket Hub should be checked every day for oiling needs. Dust accumulation tends to dry up the oil quickly.

4. When the pump sits for a time without being used, the rollers tend to freeze up and need to be oiled and tapped loose.

5. The rubber discs should be checked and replaced if needed after about 250 hours of use.

It is best that the animal pull the torque arms instead of pushing them as the weight of the water forces the pump to run in reverse when the animal stops walking and could cause injury to the animal. An animal can be expected to run the pump an average of 4 to 6 hours per day without undue fatigue.

<u>Characteristics of Well in Relation to Pump Performance</u>

In one complete revolution, the pump can lift an average of 232 liters of water from a well with a depth of 2 meters and a water table of 78cm. Over a period of an hour an animal (bullock) can average 141 revolutions or 32,712 liters of water/hour.

When the pump is operating, the water level in the well is decreased by 4cm on an average.

CONVERSION TABLES

Units of Length

1 Mile	= 1760 Yards	= 5280 Feet
1 Kilometer	= 1000 Meters	= 0.6214 Mile
1 Mile	= 1.607 Kilometers	
1 Foot	= 0.3048 Meter	
1 Meter	= 3.2808 Feet	= 39.37 Inches
1 Inch	= 2.54 Centimeters	
1 Centimeter	= 0.3937	

Units of Area

1 Square Mile	= 640 Acres	= 2.5899 Square Kilometers
1 Square Kilometer	= 1,000,000 Sq. Meters	= 0.3861 Square Mile
1 Acre	= 43,560 Square Feet	
1 Square Foot	= 144 Square Inches	= 0.0929 Square Meter
1 Square Inch	= 6.452 Square Centimeters	
1 Square Meter	= 10.764 Square Feet	
1 Square Centimeter	= 0.155 Square Inch	

Units of Volume

1.0 Cubic Foot	= 1728 Cubic Inches	= 7.48 U.S. Gallons
1.0 British Imperial Gallon	= 1.2 U.S. Gallons	
1.0 Cubic Meter	= 35.314 Cubic Feet	= 264.2 U.S. Gallons
1.0 Liter	= 1000 Cubic Centimeters	= 0.2642 U.S. Gallons

Units of Weight

1.0 Metric Ton	= 1000 Kilograms	= 2204.6 Pounds
1.0 Kilogram	= 1000 Grams	= 2.2046 Pounds
1.0 Short Ton	= 2000 Pounds	

CONVERSION TABLES

Units of Pressure

1.0 Pound per square inch	= 144 Pound per square foot
1.0 Pound per square inch	= 27.7 Inches of Water*
1.0 Pound per square inch	= 2.31 Feet of Water*
1.0 Pound per square inch	= 2.042 Inches of Mercury*
1.0 Atmosphere	= 14.7 Pounds per square inch (PSI)
1.0 Atmosphere	= 33.95 Feet of Water*
1.0 Foot of Water = 0.433 PSI	= 62.355 Pounds per square foot
1.0 Kilogram per square centimeter	= 14.223 Pounds per square inch
1.0 Pound per square inch	= 0.0703 kilogram per square centimeter

* at 62 degrees Fahrenheit (16.6 degrees Celsius)

Units of Power

1.0 Horsepower (English)	= 746 Watt = 0.746 Kilowatt (KW)
1.0 Horsepower (English)	= 550 Foot pounds per second
1.0 Horsepower (English)	= 33,000 Foot pounds per minute
1.0 Kilowatt (KW) = 1000 Watt	= 1.34 Horsepower (HP) English
1.0 Horsepower (English)	= 1.0139 Metric Horsepower (cheval-vapeur)
1.0 Metric Horsepower	= 75 Meter X Kilogram/Second
1.0 Metric Horsepower	= 0.736 Kilowatt = 736 Watt

BIBLIOGRAPHY

1. Chain Pump for Irrigation (Hand Powered), Village Technology Handbook, pp. 92-96 (Drawings and instructions). Available from VITA, 3706 Rhode Island Avenue, Mt. Rainier, Maryland 20822. $9.00.

   Basic concepts from which the animal powered chain pump was designed. Very useful as it includes step-by-step construction procedures.

2. "Chad Chain Pump" by Tom Corcoran, Peace Corps, taken from Peace Corps Tech Notes (August 1969), pp 8-9. Available from ACTION/Peace Corps, M-703, 806 Connecticut Avenue, N.W. Washington, D. C. 20525.

   Gives drawings and explanation on initial Peace Corps work on modifying the VITA Chain Pump to animal power. Good background material but does not include good working drawings.

A LISTING OF RECOMMENDED RESOURCE MATERIALS

--ANIMAL-DRIVEN POWER GEAR, United Nations Div. of Narcotic Drugs, Publication GE .75-1437 (Feb. 1975) 30 pp. Available from the UN Div. of Narcotic Drugs, Palais du Nations, Geneva, Switzerland. The animal-driven power gear described in this publication works on the same principle as a bicycle. The device is basically an arrangement of levers and gears that transform slow leg movement into the speedy rotation of a wheel. The output gearing provides up to 135 revolutions per minute--enough for operating a variety of individual processing machines. No technical drawings but there are photographs of the power device which may be useful.

--MAK GONATSOTLNE - MOCHUDI TOOL BAR, Agricultural Information Service, Ministry of Agriculture, Private Bag 003, Gaborone, Rep. of Botswana (Aug. 1975) 50 pp. Available from Mochudi Farmers Brigade, Box 208, Mochudi, Rep. of Botswana, US $5.00. The tool-bar presented is a multi-purpose, animal driven machine capable of a variety of agricultural applications through the addition or subtraction of several components. This tool-bar can also be used for carting or transporting drums of water. By removing some of the components from the device, a walking model can be made which will allow inter-row cultivation when crops are taller. This is a complete construction manual with clearly presented drawings and working dimensions for all of the tool-bar components.

--LOW COST RURAL EQUIPMENT SUITABLE FOR MANUFACTURE IN EAST AFRICA, East African Agriculture & Forestry Rsch Organization, East African Community (June 1975) 82 pp. Available from the Inst. for Development Studies, PO Box 30197, Univ of Nairobi, Kenya (Africa). Complete description of a variety of low-cost agricultural implements, many of which are animal drawn. Many of the implements discussed have working dimensions and construction procedures. A very useful book full of designs that have been used and tested in Kenya. Animal-drawn agricultural implements included in the book: ploughs, cultivators, seeders/planters, ox carts and water carts.

--FARM IMPLEMENTS FOR ARID AND TROPICAL REGIONS, Food and Agriculture Org. of the United Nations, FAO Agr. Dev. Paper #91, Rome, 1969.

--ANIMAL-DRAWN AGRICULTURAL IMPLEMENTS, HAND-OPERATED MACHINES AND SIMPLE POWER EQUIPMENT IN THE LEASE DEVELOPED AND OTHER DEVELOPING COUNTRIES--REPORT OF A MANUFACTURING DEVELOPMENT CLINIC, New Delhi, India, 21-30 October 1974, United National Industrial Development Organization, Geneva, Switzerland, Report ID/148 (ID/WG. 193/3) Jan. 1975.

--Michael Arayathinal, SIMPLE BULLOCK-DRAWN IMPLEMENTS FOR EFFICIENT IRRIGATION; Univ of Udaipur, College of Agr., Jobner (Ext. Bulletin #1) June 1964, 15 pp.

--EFFECTIVE USE OF ANIMAL POWER ON FARMS CAN LEAD TO LESS WORK AND MORE HARVEST, World Neighbors, Vol. 11, #1E, 8 pp. Available from World Neighbors Int'l Headquarters, 5116 N Portland AVE, Oklahoma City, OK 73112, USA. Very good section on training animals for farm use.

--LIST OF AGRICULTURAL EQUIPMENT AND TOOLS FOR FARMERS DESIGNED FOR LOCAL CONSTRUCTION, Intermediate Technology Parnell House, 25 Wilton RD, London, England. Essentially a publications list of agricultural equipment plans available from ITDG.

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