

Human & Animal Power & Transmission Systems.

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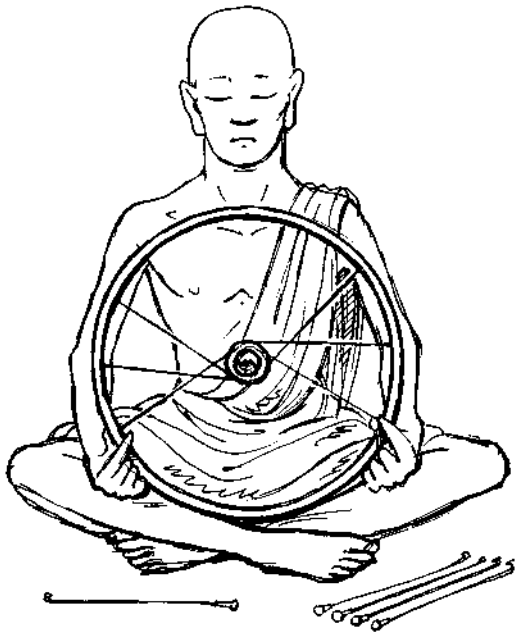
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How Much is a Human Power?

Power is measured in odd ways. Most of us understand it in terms of horsepower (hp), an fps unit of power based on the foot (12-inch kind), pound, and second as units of length, mass, and time. Thus, one horsepower equals 550 foot-pounds per second. However, most scientists and technicians use SI units, for which the derived power unit is the Watt (W), equivalent to 1 joule per second. A joule, heh, is the work done when the force of 1 newton is displaced through a distance of 1 metre. It takes 746 W to equal 1 hp.

One time at the York Cycle Rally, Bluebell rider Tim Gartside had a go on a bicycle ergometer run by the British National Team. He held a cracking pace for 5 or 10 minutes or whatever, and then did his thing, standing up out of the saddle and sprinting, registering a peak of 1.9 hp before the rig started to come apart. This kind of power output, even just for a few seconds, is very, very rare.

A common benchmark is the performance of world champion Eddy Merckx, who produced 455 W for 1 hour on an ergometer. A healthy, well-conditioned cyclist might be able to keep up this rate for perhaps a minute. A trained, healthy person can output about 700 W for a few seconds, and about 180 W for 1 hour. Over a longer period of a few hours, an average cyclist produces 50 to 75 W or about 0.1 hp.





An overhead
animal power gear

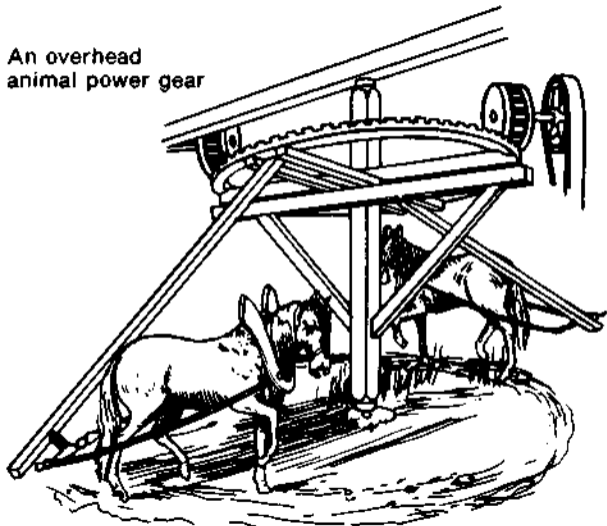
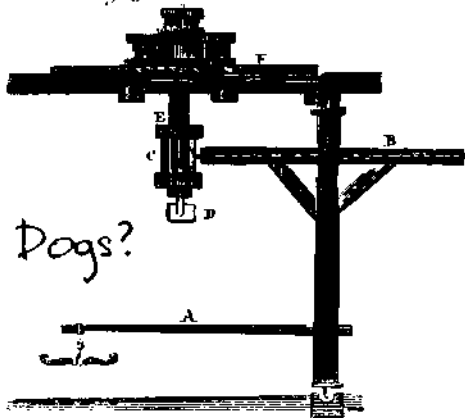
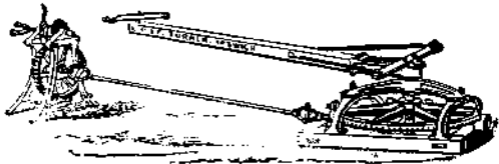


Fig. 3. A Horse-MILL.





IMPROVED HORSE AND CATTLE GEARS.

TECHNICAL PAPER #51
UNDERSTANDING PEDAL POWER

By
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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details.

People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Betsy Eisendrath as editor, Suzanne Brooks handling typesetting and layout, and Margaret Crouch as project manager.

The author of this paper, VITA Volunteer David Gordon Wilson, is a mechanical engineer at Massachusetts Institute of Technology. The reviewers are also VITA Volunteers. John Furber is a consultant in the fields of renewable energy, computers, and business development. His company, Starlight Energy Technology, is based in California. Lawrence M. Halls is a retired mechanical engineer who designed farm machinery for Sperry-New Holland for 23 years. Lauren Howard is a thinker, inventor, and bicycling advocate. She lives in Charlottesville, Virginia.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers.

UNDERSTANDING PEDAL POWER[\N]

by VITA Volunteer David Gordon Wilson

I. INTRODUCTION

Throughout history human, energy has generally been applied through the use of the arms, hands, and back. With minor exceptions, it was only with the invention of the sliding-seat rowing shell, and particularly of the bicycle, that legs also began to be considered as a "normal" means of developing power from human muscles.

A person can generate four times more power (1/4 horsepower(hp)) by pedalling than by hand-cranking. At the rate of 1/4 hp, continuous pedalling can be done for only short periods, about 10 minutes. However,, pedalling at half this power (1/8 hp) can be sustained for around 60 minutes. Pedal power enables a person to drive devices at the same rate as that achieved by hand-cranking, but with far less effort and fatigue. Pedal power also lets one drive devices at a faster rate than before (e.g. winnower), or operate devices that require too much power for hand-cranking (e.g. thresher).

Over the centuries, the treadle has been the most common method of using the legs to produce power. Treadles are still common in the low-power range, especially for sewing machines. Historically, two treadles were used for some tasks, but even then the maximum output would have been quite small, perhaps only 0-15 percent of what an individual using pedal operated cranks can produce under optimum conditions.

However, the combination of pedals and cranks, which today seems an obvious way to produce power, was not used for that purpose until quite recently. It was almost 50 years after Karl von Drais invented the steerable foot-propelled bicycle in 1817 that Pierre Michaud added pedals and cranks, and started the enormous wave of enthusiasm for bicycling that has lasted to the present.

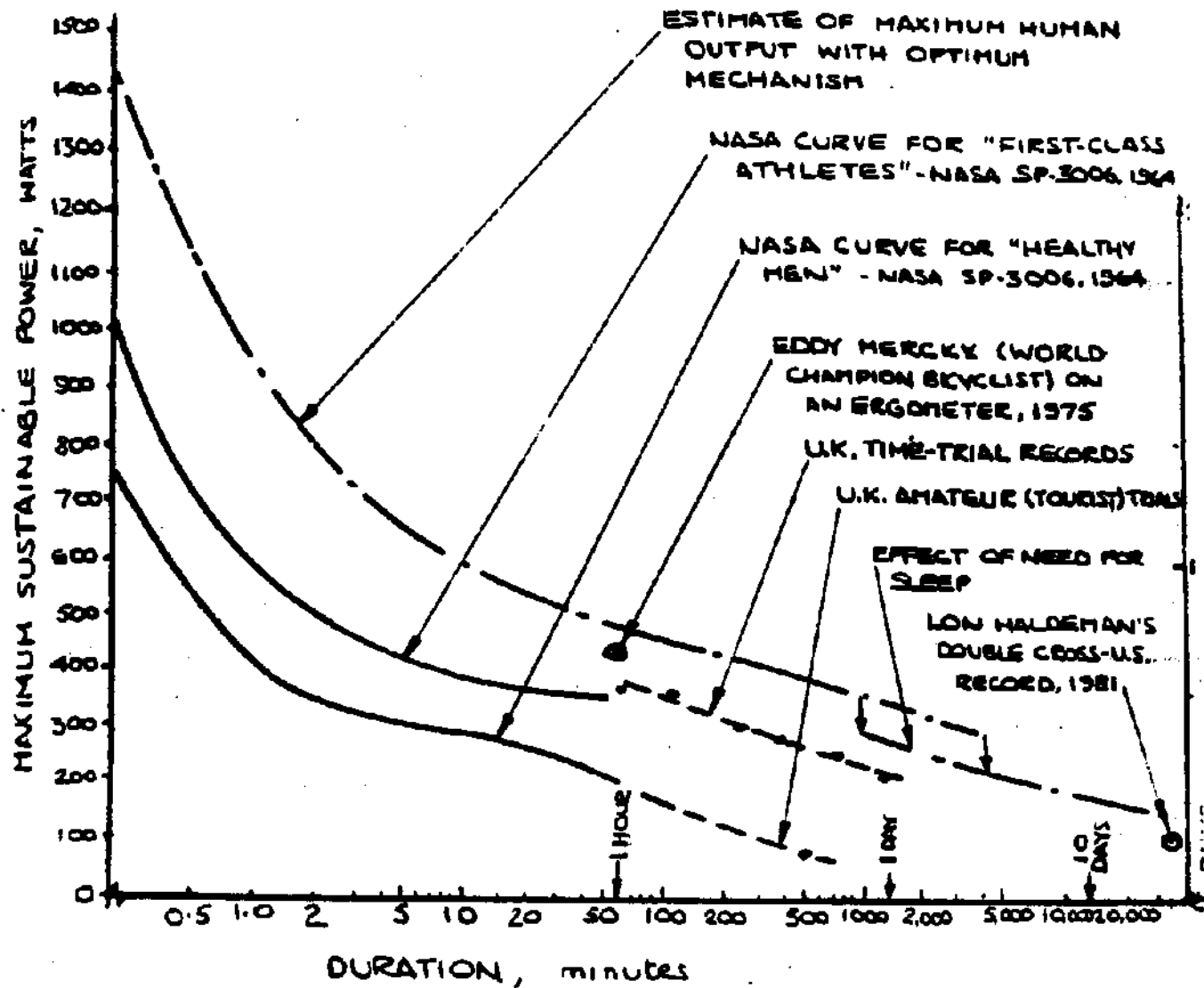
The main use of pedal power today is still for bicycling, at least in the high-power range (75 watts and above of mechanical power). In the lower-power range there are a number of uses of pedal power--for agriculture, construction, water pumping, and electrical generation--that seem to be potentially advantageous, at least when electrical or internal-combustion engine power is unavailable or very expensive.

II. OPERATING PRINCIPLES

POWER LEVELS

The power levels that a human being can produce through pedalling depend on how strong the pedaler is and on how long he or she needs to pedal. If the task to be powered will continue for hours at a time, 75 watts mechanical power is generally considered the limit for a larger, healthy non-athlete. A healthy athletic person of the same build might produce up to twice this amount. A person who is smaller and less well nourished, but not ill, would produce less; the estimate for such a person should Probably be 50 watts for the same kind of power production over an extended period. The graph in Figure 1 shows various record limits for pedalling under optimum conditions. The meaning of these curves is that any point on a curve indicates the maximum time that the appropriate class of person could maintain the given average power level.

Power levels are also directly related to the environment of the person doing the pedalling. To be able to continue pedalling over an extended period, a person must be able to keep cool-



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 (2ND EDITION) 1982
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 THE MIT PRESS

FIGURE 1: Human Power Output Pedaling

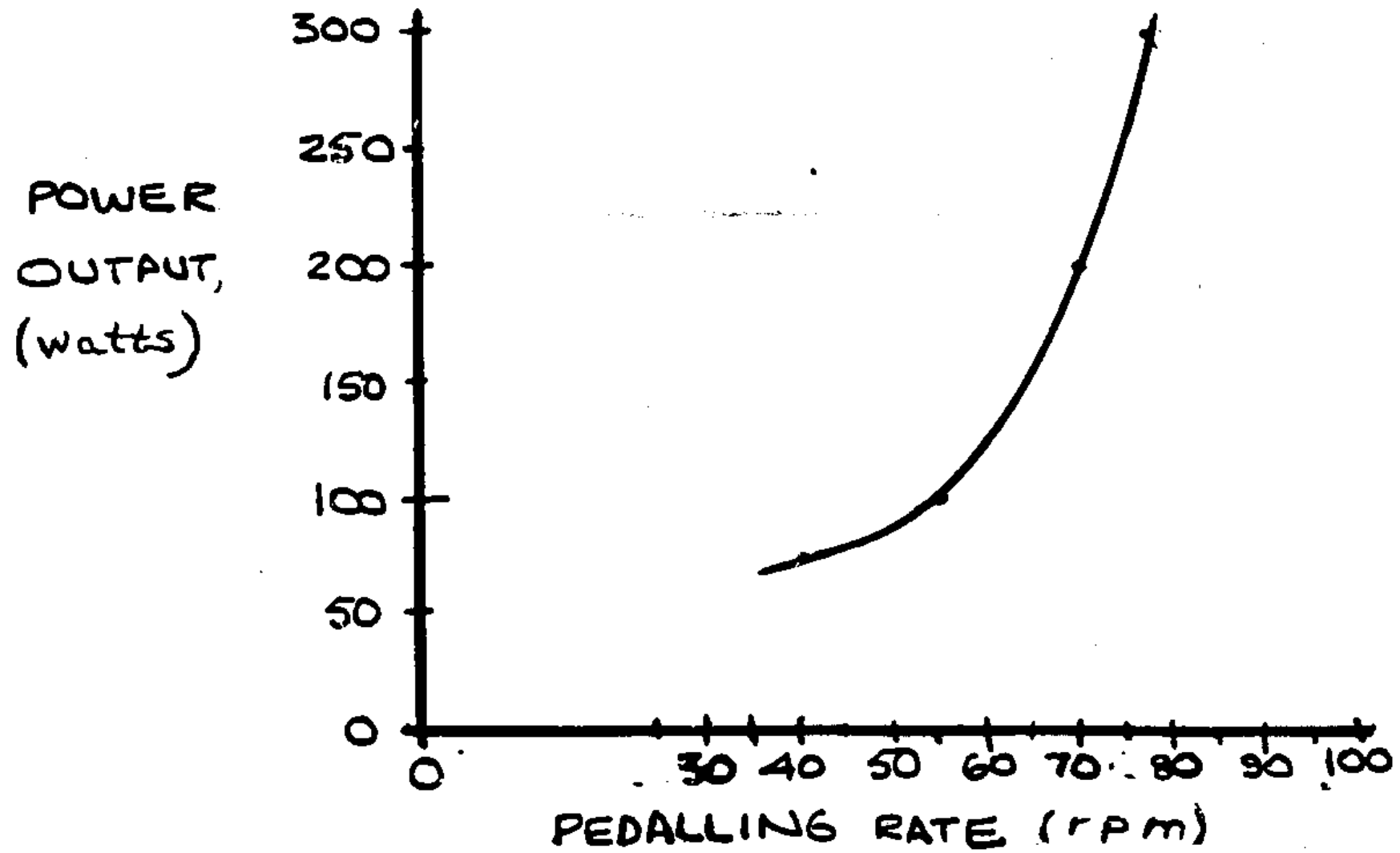


FIGURE 2: How Optimum Pedaling Rate Varies with Desired Power Output

-whether because the ambient temperature is low enough, or because there is adequate breeze.

There is a vital difference between pedalling a stationary device and pedalling a bicycle at the same power output. On a bicycle, much of the pedalling energy goes into overcoming wind resistance;

This wind resistance, however, provides an important benefit: cooling. Because of the wind, even in hot, humid climates, so long as the bicyclist drinks enough liquids, dehydration and heat stroke are unlikely to occur.

On the other hand, when pedalling a stationary device on a hot or humid day at more than about half the maximum possible power output, there is a considerable danger of the pedaler's collapsing because of an excessive rise in body temperature. Therefore, it is essential that an individual pedalling such a stationary device in hot or humid conditions be provided with shade from the sun, plenty of water, and preferably some sort of fan.

A portion of the power that the pedaler is producing can be used to drive this fan; this is an efficient use for the power, since it will help prevent damage to the pedaler's health.

PEDALING RATE

How fast should a person pedal? Human beings are very adaptable and can produce power over a wide range of pedalling speeds. However, people can produce more power--or the same amount of power for a longer time--if they pedal at a certain rate. This rate varies from person to person depending on their physical condition, but for each individual there is a pedalling speed somewhere between straining and flailing that is the most comfortable, and the most efficient in terms of power production.

(For centuries, this fact was apparently not recognized. The predominant method of human power production was to strain with maximum strength against a slowly yielding resistance. This is neither comfortable nor efficient. Neither is the opposite extreme of flailing at full speed against a very small resistance.

A simple rule is that most people engaged in delivering power continuously for an hour or more will be most efficient when pedalling in the range of 50 to 70 revolutions per minute (rpm). - See Figure 2. For simplicity's sake, we will use 60 rpm, or one revolution of the pedal cranks per second, as an easy reference value for estimates of the gear ratios required to drive a given load.

GEAR RATIOS

The relationship between the rotating speed of whatever is being driven and the pedalling rate (both expressed in revolutions per minute) is called the gear ratio. Most practical applications of pedal power will use bicycle-chain drives, which on bicycles range from 1:1 (the rear wheel turns at the same speed as the crank) - to 1:5 (the rear wheel turns at five times the speed of the cranks) for high gears.

Very-Low-Power Applications

There are some very-low-power applications of pedal power, in which the required power output is so far below that of which human beings are capable that maximum efficiency is not a concern. For example, sewing machines are generally limited to a less than optimum value to allow the sewing table to be

placed at a convenient height. The pedaler provides a range of sewing speeds without gear-change mechanisms. A large step-up ratio is usually given by a round belt made of leather. It cannot transmit large torques; this inability serves a purpose, because when the sewing needle jams, the belt slips, preventing the needle from breaking.

High-Power Applications

An example of an application at the higher-power end of the scale is a hypothetical maximum-power drive for an irrigation pump. Let us suppose that the pump has the speed-versus-power characteristics shown in Figure 3, and that the pedallers will be paid to produce as much power as they comfortably can for periods of two hours at a time.

Choosing a conservative value from Figure 1, we estimate that a mechanical output of 100 watts seems reasonable for this length of time. Furthermore, we estimate from Figure 2 that the optimum pedalling speed to give this power output is 55 rpm. We can then see from Figure 3 that when the pump absorbs 100 watts, its speed of revolution should be 95 rpm. We need, therefore, a step-up gear of 95:55. We have available a set of bicycle cranks and pedals with a chainwheel having 48 teeth. To achieve our ratio of 95:55, we then need

$$48 \times 55/95 = 27.8 \text{ teeth on the cog (the smaller sprocket attached to the pump shaft).}$$

Ideally then, we should use a sprocket of 28 teeth. However, sprockets of 27, 28, or 29 teeth would be acceptable.

No allowance has been made in this calculation for energy losses in the chain transmission. This is because a single chain going over two sprockets is very efficient--over 95 percent, even for unlubricated, worn, or dirty chains.

However, some applications require two stages of step-up transmission, and in these cases, power losses are greater. For instance, suppose that a ventilation fan must be driven for a long period at 900 rpm, and the optimum pedalling speed is estimated to be 60 rpm.

The step-up ratio is then $900:60 = 15:1$.

The smallest sprockets generally available for bicycles have 12 teeth. The chainwheel for a single step-up stage would need:

$$12 \times 15 = 180 \text{ teeth.}$$

Such a chainwheel is not available, but even if one were specially made, it would have a diameter far too large to pedal around. Moreover, using a very large-chainwheel with a very small cog produces a small angle of contact - (or wrap) around the cog; this causes high tooth wear on the cog.

Therefore, a step-up ratio of 15:1 is better produced by a two-stage step-up gear. For example, a standard high-gear arrangement from a bicycle could be used. It has a chainwheel of 48 teeth driving a cog of 13 teeth, fixed to a second shaft on its own bearings(*)

(for instance, another bicycle crankset with another chainwheel of 48 teeth on the countershaft, driving a cog of 12 teeth on the shaft to be driven.

PUMP
INPUT
POWER,
(Watts)

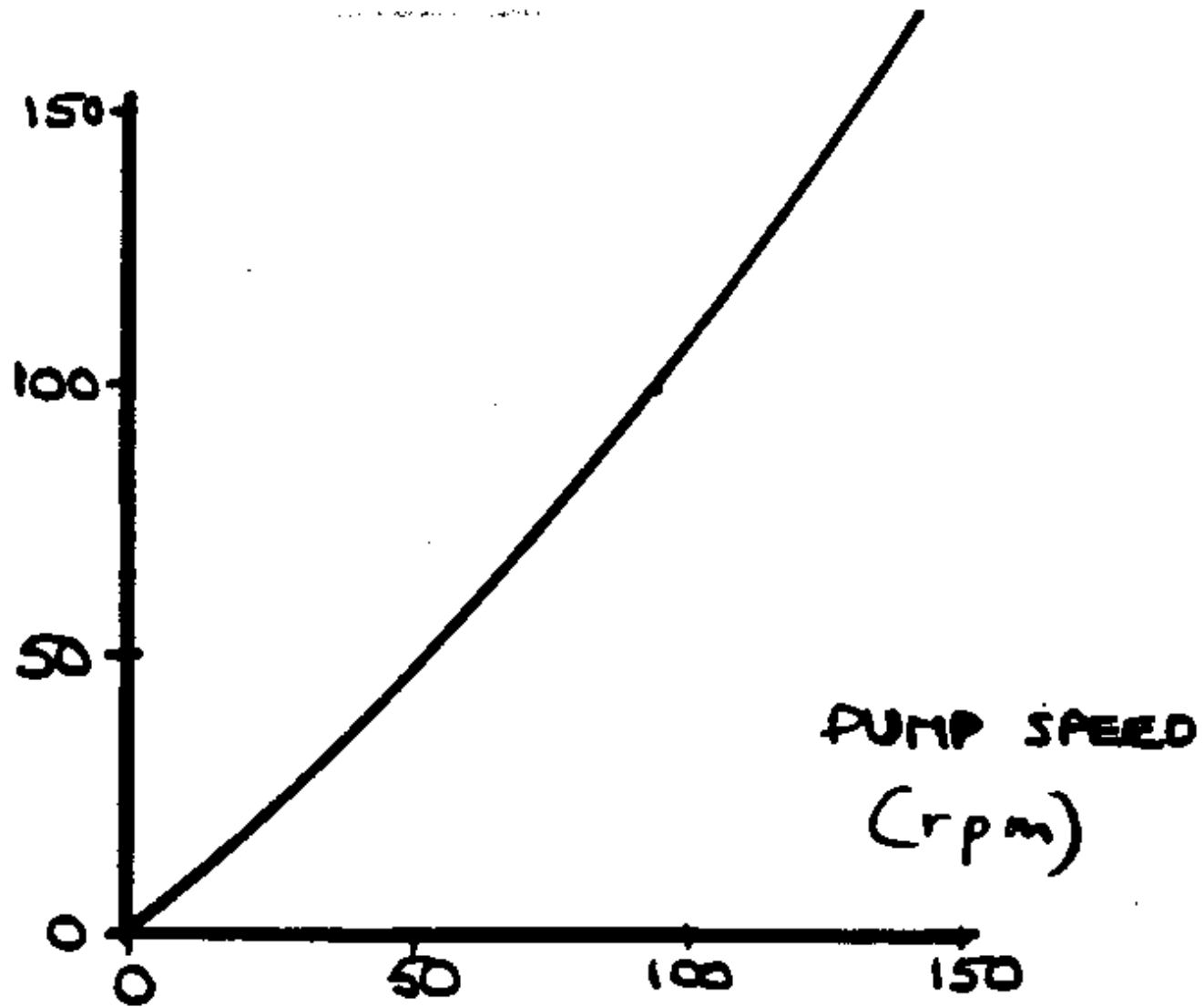


FIGURE 3: Hypothetical Pump Characteristics

The combination would then be

$$(48/13) \times (48/12) = 14.8.$$

this is close enough to 15:1 to be useful.

In this case, it would be best to assume that there would be a 10 percent loss of power. For example, if the pedaler can produce an output of 50 watts for the desired period, the driven device will receive 45 watts input.

III. DESIGN VARIATIONS

CRANK LENGTH

The crank length is the distance between the center of the pedal-spindle and the crank axis; that is, it is the radius of the circle defined by each pedal as it turns. The normal crank on an adult's bicycle is 165 to 170 millimeters (mm) long. However, people remain able to produce near maximum power output at any crank length from between 165 and 180 mm, so long as they have a period to practice pedalling at the new length.

SHAPE OF CHAINWHEEL

Evidence from tests suggests that elliptical chainwheels with a relatively small degree of elongation--that is, with a ratio of major to minor axis of the chainwheel ellipse of no more than 1.1:1--do allow most pedallers to produce a little more power. No subject tested showed a reduction in power. It is therefore recommended that, when elliptical chainwheels are available at a reasonable price, they be used. However, the gain in power output is small, and this must be considered when comparing costs and benefits.

PEDALLING POSITIONS

There are three common pedalling positions:

- o The first is the upright position used by the majority of cyclists around the world. In this position, the seat, or saddle, is located slightly behind where it would be if it were a seat, or vertically above the crank axis; the hand grips are placed so that the rider leans forward just slightly when pedalling. Tests have shown that subjects using this position are able to produce the most pedalling power when the top of the saddle is fixed at a distance 1.1 times the leg length to the pedal spindle at the pedal's lowest point.

- o The second position is the position used by riders of racing bicycles with dropped handlebars, when they are holding the upper parts of the bars. Their back is then at a forward lean of about 40 degrees from the vertical. Their saddle height requirements are similar to those of cyclists in the first position.

(The position of the racing bicyclist who is trying to achieve maximum speed is not suitable for power production on a stationary device. Even racing bicyclists sometimes experience great pain after a long time in this position, and the position is unnecessary on a stationary device because there is no wind resistance to overcome.

- o The third position is the position used in modern semi-recumbent bicycles. The placement of the center of the pedalling circle relative to the

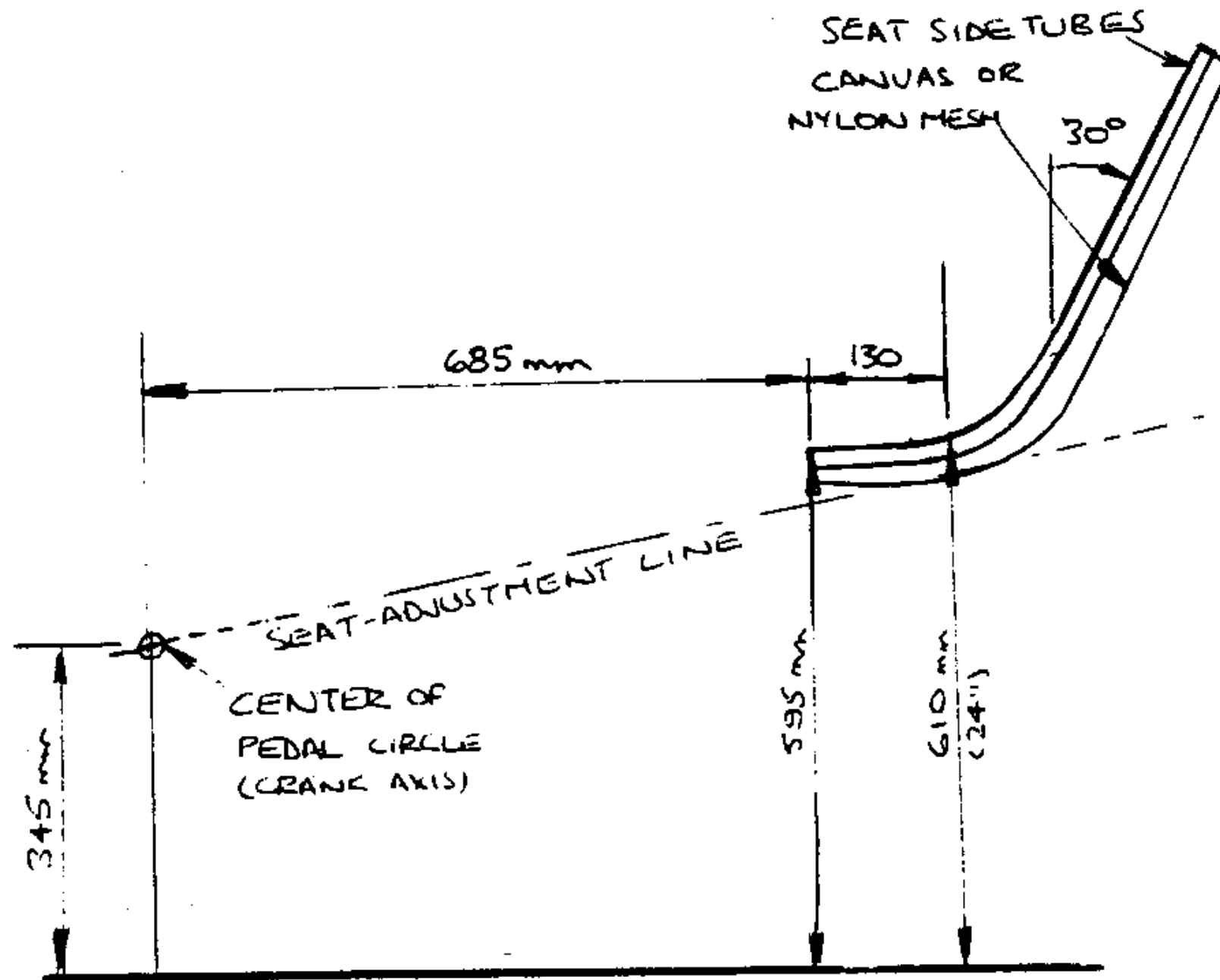


FIGURE 4: Semi-Recumbent Pedaling Position

seat is shown in Figure 4. In this seating position, the pedalling forces are countered by the lower back pushing into the seat (which is similar in construction to a lawn chair made of tubes and canvas). The arms and hands do not need to remain on the handlebars to perform this function, the way they usually do in the first two positions. They can remain relaxed, and free to guide the work that the pedaler is powering. The upper body too can remain relaxed, and the chest is in a position that makes breathing easier than when the pedaler bends forward. The major disadvantage of this position is that, since the pedaler's legs move forward from the body, it may be hard to position large, deep equipment like a lathe or saw so that it is in reach without being in the way. In almost all other respects, the semi-recumbent position is highly desirable, though not essential.

IV. APPLICATIONS OF PEDAL POWER

PEDAL POWER FOR TRANSPORTATION

The principal use of pedal power around the world is for the transportation of people and goods. A bicycle used by itself can carry a rider, plus 50 to 100 kilograms of goods in a front and/or rear carrier on the cross-bar, or on the rider's head. The carrying capacity of a bicycle can be greatly increased by attaching a trailer to it. One model of trailer has seats for two adults, and allows the bicycle to be easily converted into a rickshaw.

A rickshaw is usually made from the front or rear-portion of a standard bicycle, connected to a load-carrying platform over a two-wheel axle. Rickshaws can carry an extraordinary quantity of people and goods. In Bangladesh, they are responsible for transporting several times the total freight and passengers carried by all railroads, trucks, and buses combined.

However, the potential productivity of these rickshaws is greatly reduced by the fact that virtually every one of them has only a single-speed gear. Sometimes the gear mechanism is even deliberately converted to single speed. When the author lived in Nigeria, the most common bicycle was a Raleigh Roadster, which came equipped with a three-speed gear, but the retailers normally wired the gear-change lever in the low-gear position. A driver who has only one gear available must exert much more effort to pedal the rickshaw. The strain is severe and unnecessary, and productivity is greatly reduced.

OXFAM, an international development and relief organization, has done considerable work on a three-wheeled pedal operated vehicle capable of carrying payloads of over 150 kilograms. Called an "Oxtrike," the vehicle uses a three-speed gearbox in its transmission and a mild steel sheet frame. The frame can be manufactured on a small scale, using foot-powered cutters, hand operated folding machines, and welding or rivetting. It can be fitted with passenger seats or a cargo box.

It should be noted that an ordinary bicycle frame is not sturdy enough for payloads of this size. The weight also requires particularly good brakes. The Oxtrike's mild steel construction addresses the first problem. The braking system includes both the standard lever brakes on the front and a foot pedal on the rear. Each wheel has its own brake drum, with a balance bar to distribute the force equally.

OTHER USES OF PEDAL POWER

General Considerations

Broadly speaking, applications of pedal power are possible when the power level required is below a quarter of a horsepower (that is, below about 200 watts). Common applications of stationary pedal power include pumping water, grinding grains or metals, shredding, or threshing.

Pedal power can also be used to generate electricity for individual uses--to operate room lights, a television set, or a projector, for example. Surplus power could be diverted to a battery-charging circuit. The easiest way to do this is simply to drive either a DC generator or an AC alternator through a circuit feeding a battery in parallel with the load. The same circuit could be used for an alternator of higher power, chain-driven from the cranks, through an appropriate gear ratio.

Other pedal power applications include:

- o Cassava graters
- o Coffee pulpers
- o Coffee/grain hullers
- o Cracking of oil palm nuts
- o Fiber decorticaters--sisal, manila, hemp, etc.
- o Winches or hoists
- o Balers
- o Potter's wheels
- o Flexible shaft drive for portable grinders, saws, etc.
- o Tire pumps
- o Sewing machines

The use of pedal power for agricultural implements that have to move across soft or uneven ground is not recommended. A mower described and illustrated in *Bicycling Science* (see Bibliography) required so much energy to move the mower across the ground that a small proportion of the rider's total energy went into mowing. This loss of energy would occur for any use--like plowing, cultivating, or harrowing--in which the vehicle had to move across the ground. McCullagh's book - *Pedal Power* - describes some designs in which the pedalling unit is stationary at one edge of the plot, while the plow or other implement, guided by a second worker, is pulled by a rope or chain. This principle should be tried out further.

The Dynapod

Bicycles can sometimes be adapted to drive the devices mentioned above, but the result is often inefficient. It is frequently cheaper in initial and following maintenance costs to use a properly designed and constructed dynapod.

A dynapod is a portable pedalling device that consists of a stand, saddle, handlebar, pedals, and sprocket wheel. The name comes from the Greek words for "power" and "foot." Dynapod power varies according to the size and fitness of the operator and the length of time spent pedalling.

There are three kinds of dynapods:

- 1) A one-person dynapod that utilizes belt drive. It can be built either with or without chaindrive.
- 2) A two-person dynapod that can be pedalled either by one person at a time, or by two people together. It is also possible to fit a special adaptor so that a direct shaft drive leads off the unit and powers a flour mill or other machine. (When this is done, only one person can pedal at a time.)

3) A one-person dynapod that has belt drive, chain drive, and direct drive. It is very similar to the two-person dynapod.

The two-person dynapod illustrated below (Figure 5) has been attached to a grain mill, but the unit can be adapted to a wide variety of uses. The dynapod frame can be made of wood or welded steel, depending on cost and availability of materials. A heavily weighted flywheel provides extra power and smooths out the pedal stroke, reducing operator fatigue.

A similar device, designed to draw irrigation water from shallow wells in Bangladesh, consists of a welded steel frame with a drive wheel attached to the plunger of a handpump (Figure 6).

V. COMPARING THE ALTERNATIVES AND CHOOSING THE APPROPRIATE TECHNOLOGY

Whether or not pedal power is advantageous for an application depends absolutely on local conditions. In many countries, gasoline (petrol) is highly subsidized; one consequence is that pedal rickshaws, for example, are giving way to ones run by small internal combustion engines. However, in locations far from reliable fuel supplies and maintenance shops, internal combustion engines are not so attractive an alternative, and pedal-powered devices may be much more suitable.

Pedal power is often a comfortable choice because it is a familiar technology--even though it may be used in unfamiliar ways. Construction and maintenance skills are generally available among village artisans, as are spare parts from used bicycles.

Depending on the application, pedal power can be extremely versatile. A dynapod can operate a pump during the growing season, run a thresher at harvest time, and power a grain mill throughout the year. Its portability allows it to be moved from site to site to go where the work is.

Choice of pedal power--or any technology--must be made by carefully comparing the alternatives for the application desired and the availability of resources--construction and maintenance skills, financing, raw materials, labour.

Whether machines are made locally or purchased from nearby factories or even importers, they should be within the capability of local people to maintain and repair in order to avoid so far as possible lengthy periods when they are out of service.

At this level especially, pedal power often compares favourably with wind or water power. A windmill, for example, often requires considerably more resources in funds and construction time and skill than does a pedal-power unit based on a bicycle.

Windmills within the capability of a local village builder will generally be limited to a size giving an average output of 50 to 100 watts (though the maximum output may be 1 kilowatt). Windmills are more subject to the vagaries of the weather. While energy storage can help minimize the effect of variations in the wind, high winds and other kinds of severe weather often cause minor damage, and occasionally cause major damage.

Windmills in this range are probably best suited to charging batteries and to pumping water for irrigation, stock watering, or potable water supply. But even for these purposes, a pedalled pump might be preferable. It was found by the author's VITA group, for instance, that the output of a Savonius-rotor

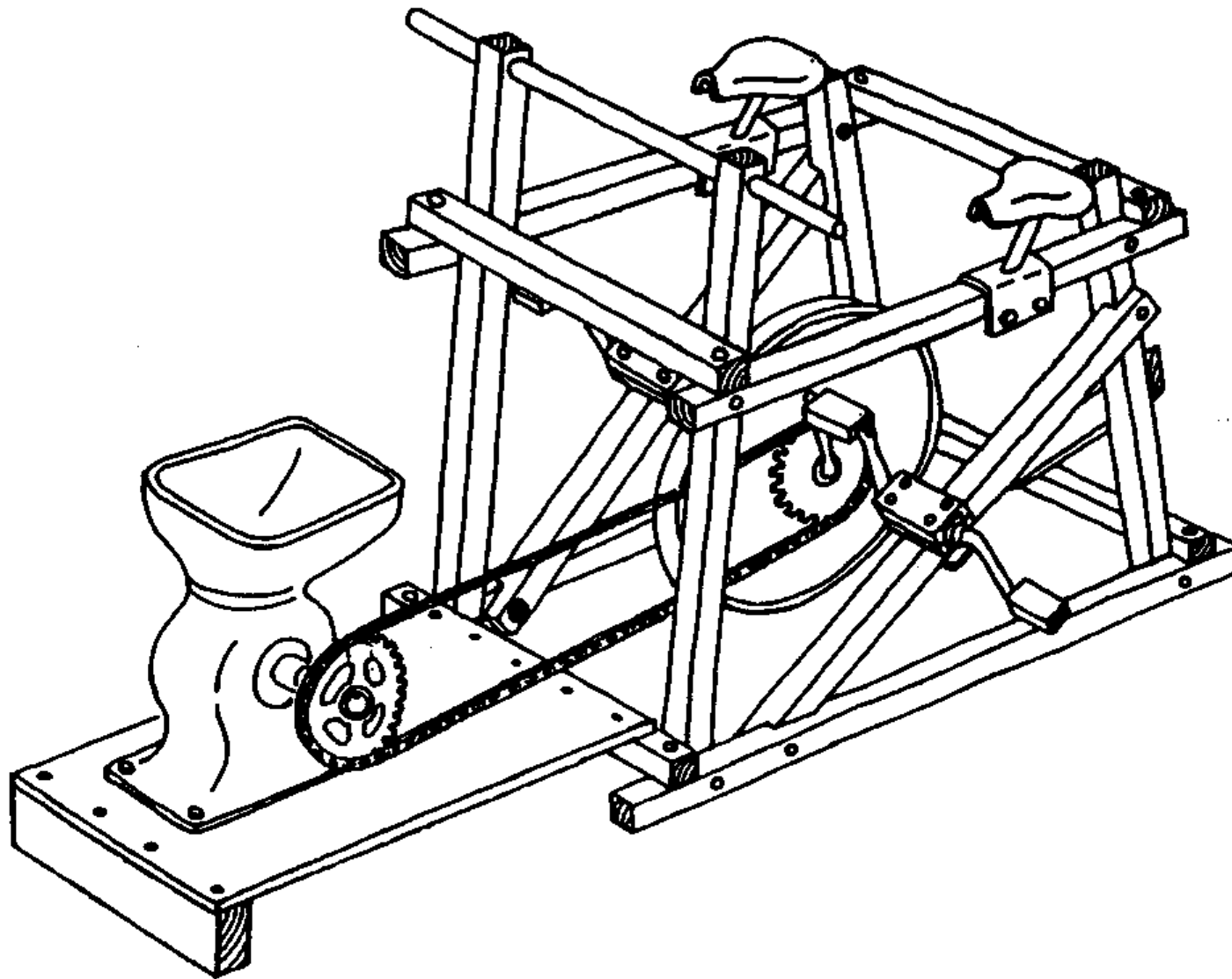


FIGURE 5: Two-person Dynapod with Chaindrive Operating a Grain Mill. Chainwheel is shown on left-hand side for illustration only.

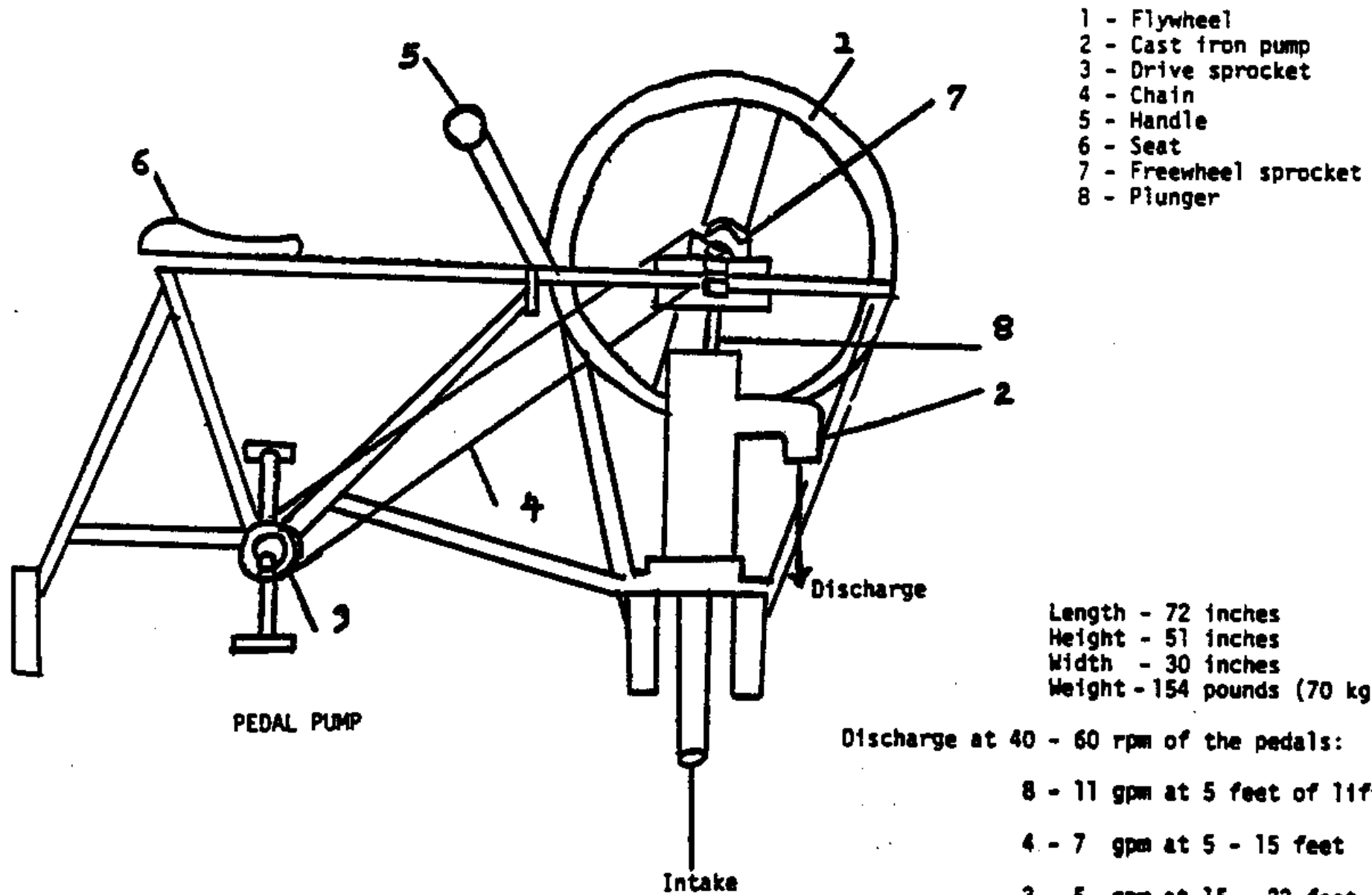


FIGURE 6: Pedal Powered Irrigation Pump

windmill in average Boston area winds was so small--even when the windmill was mounted on a headland overlooking the sea--that the windmill's output could be exceeded by a pedal-power unit operated for only two to four hours per week.

A pedalled pump may have several advantages if a farmer wishes to irrigate field crops: it is often less expensive to build; it can supply water at the most suitable times of the day and of the crop growth cycle; and it can be used at more than one location and possibly for more than one purpose.

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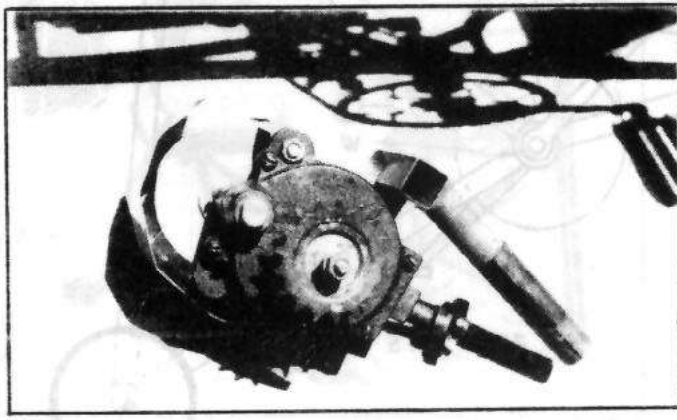
Pedal Power

The energy cycle is a relatively new application for an old technology; the pedal. It is designed to be a multi-purpose tool for use both in the kitchen and workshop. Most, if not all, of the parts may be salvaged from old bikes, tools, etc., and the machine itself can easily be built at home.

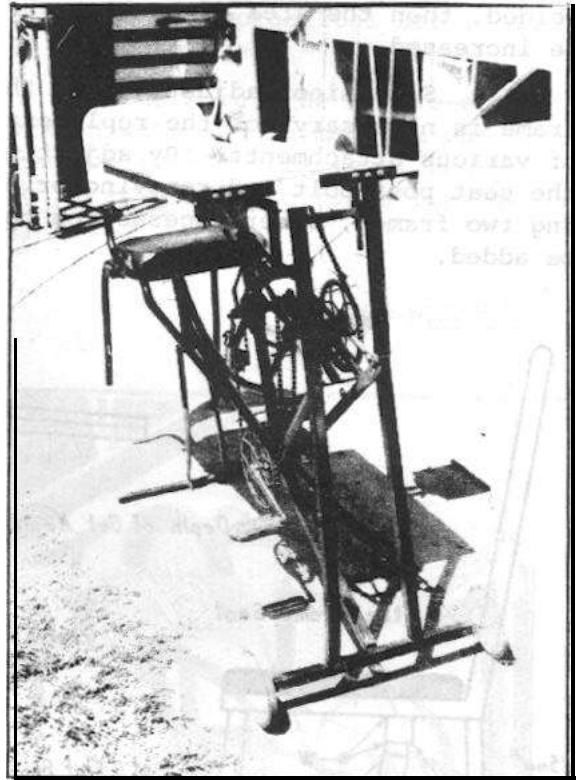
The uses of the energy cycle are many and varied, and probably any number appliances with wheels and cogs could be attached to it. Some of the uses outlined in the plans supplied by the designer included a saw, sander, drill and steel grinder. It can also be used to grind and mince food and mill grains.

The design also allows for the generation of electricity. The power produced in this way could be stored in 12 volt batteries and could be converted to standard voltage of household appliances by the use of an inverter.

Coupled with a wind generator system, the cycle could help provide power for isolated properties.



Close up of Steel Grinder



As an added advantage, the energy cycle requires a minimum of upkeep once constructed (apart from cleaning and lubrication of bearings and chains) and is easy to use. For some work, such as sawing long pieces of wood, a second person may be needed to hold the far end to provide the best results.

Construction

As has already been mentioned, recycled parts from old bikes can largely be used and modified in this design. The support for the work table would probably be of new material.

Pedal Power

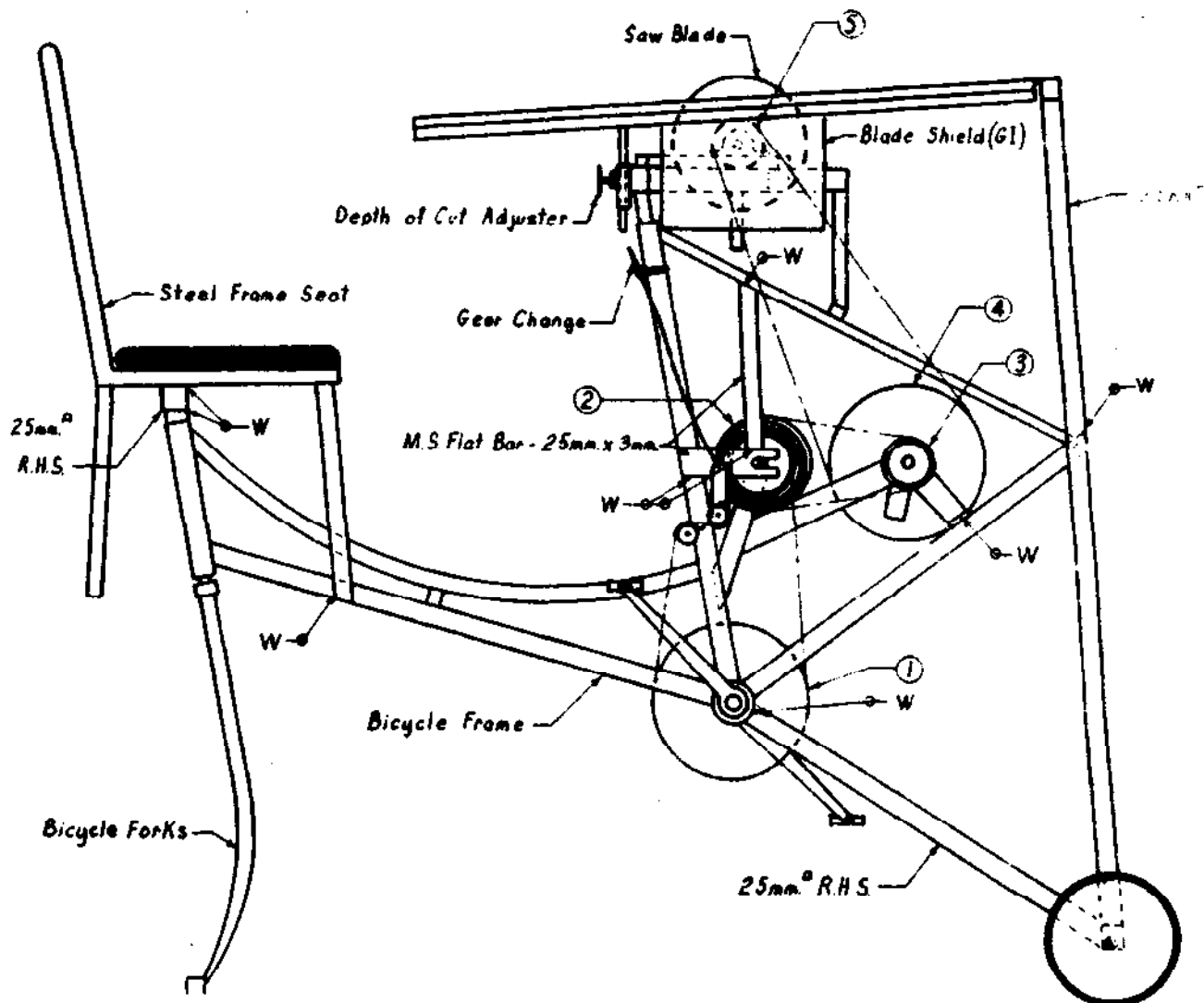
Normal wood and metal working tools are needed for cutting.. etc, as is welding gear of some sort. oxy-acetylene welders are recommended for all joints where stress is likely to occur. If they are braised instead of welded, then the area of contact should be increased.

Some minor adjustment of the frame is necessary for the replacement of various attachments. By adjusting the seat post bolt and removing or adding two frames, other accessories can be added.

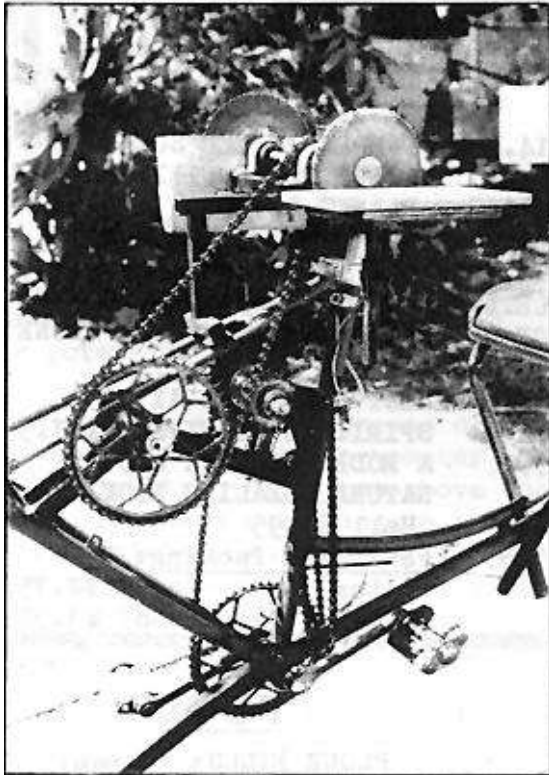
The dimensions given in the plans are only approximate. The main deciding factor in actual size is the type of bicycle frame being used, and will thus vary accordingly.

No flywheel weight has been added as the saw can be stopped more easily and quickly if an accident was to occur. However, the inclusion of such a weight could be advantageous in saw use.

Derailleur gears are used to vary speed. The gear change level is



Pedal Power



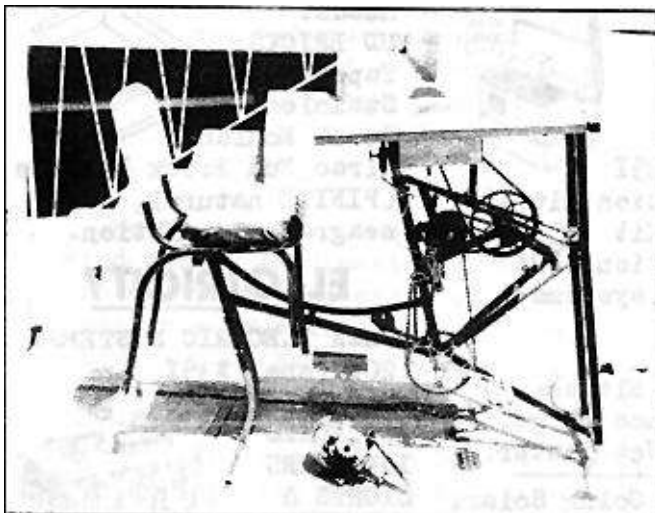
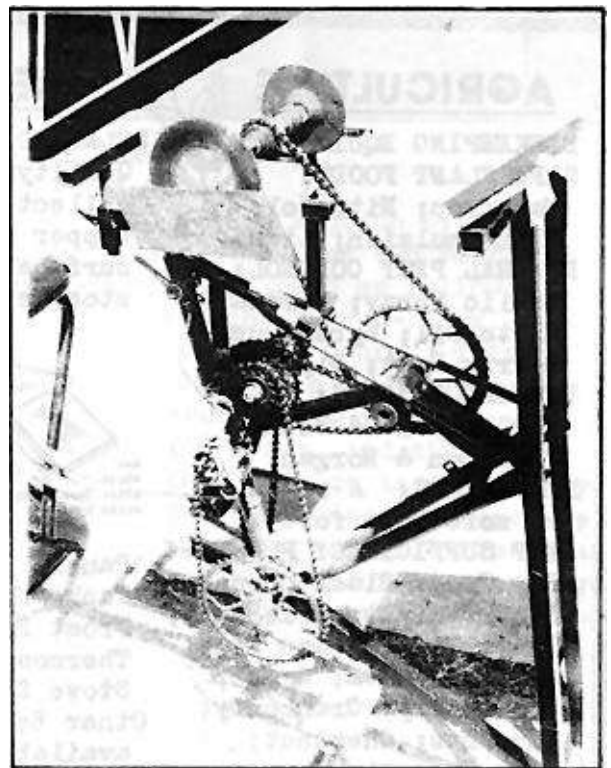
The energy cycle is a very practical machine. For those with the time and inclination to build it, it would undoubtedly be very useful, and the whole concept of pedal powered machines is obviously a part of appropriate technology in general, and research into and practical use of it should be encouraged.

Furthermore, the muscle-energy conversion with such a machine can be anything up to 95% efficient, thus making it even more suitable for low energy uses.

CAM WALKER

located below the saw platform, in the same position it would be on a bike.

The inclusion of the backrest on the seat is of considerable importance as it enables the user to achieve greater power than if only a normal bicycle seat were used.



Detailed plans for the design of the energy cycle can be obtained from Trevor Berrill, 37 Bangalla St., Torwood, Queensland. \$3.90.

Homemade Foot-Powered Generator

Materials

FRAME

Bicycle frame with:

- front^{52*} and rear⁴ forks
- pedals⁵³
- pedal crank⁵⁴
- chain²¹

The following lengths of 1" angle iron (approximate, measure as you go)

- 5 2' lengths^{1 2 3 5}
- 2 10" lengths^{7a}
- 2 12" lengths^{7b}
- 2 6" lengths⁹

DRIVE ASSEMBLY

- 4 1/2" bore self-centering pillow blocks^{10 11 18 23}
- 4 1/2" bore bushings^{13 19 22}
- 2 1/2" bore step sheaves (3 or 4 steps)^{16 25}
- 1 1/2" bore 10- or 12- tooth sprocket (bicycle sprocket)²⁰
- a 1/2" 20-thread Jacob's chuck¹⁵
- V-belt (appropriate length)²⁶
- a 12" length of 1/2" dia. steel stock (1/2"-20 right-hand thread on one end—1 1/2")¹²
- a 14" length of 1/2" dia. steel stock (1/2"-20 left-hand thread on one end—1 1/2")¹⁷
- 1 1/2"-20 right-hand thread nut¹⁴
- 1 1/2"-20 left-hand thread nut⁵¹
- 8 1/4" nuts, bolts, and washers for the pillow blocks⁵⁵
- extra chain links (if needed)
- flywheel—1/2" bore (optional)²⁴
- toe clips (optional)

IDLER

- One-piece grinder shaft assembly²⁷ complete with:
 - bronze bushings³⁰
 - 8" length steel stock same dia. of bushings²⁹
 - 2" dia. pulley to fit shaft³¹
- large gate hinge²⁸
- #62 spring³²

TABLE

- a 3' length of 3/4" steel stock³³
- a 16" x 11" x 3/4" hardwood board⁴⁰
- the following lengths of 3/4" ID steel tubing
 - 1 6" length³⁴
 - 2 3" lengths³⁸

*Numbers refer to parts labeled on photographs.

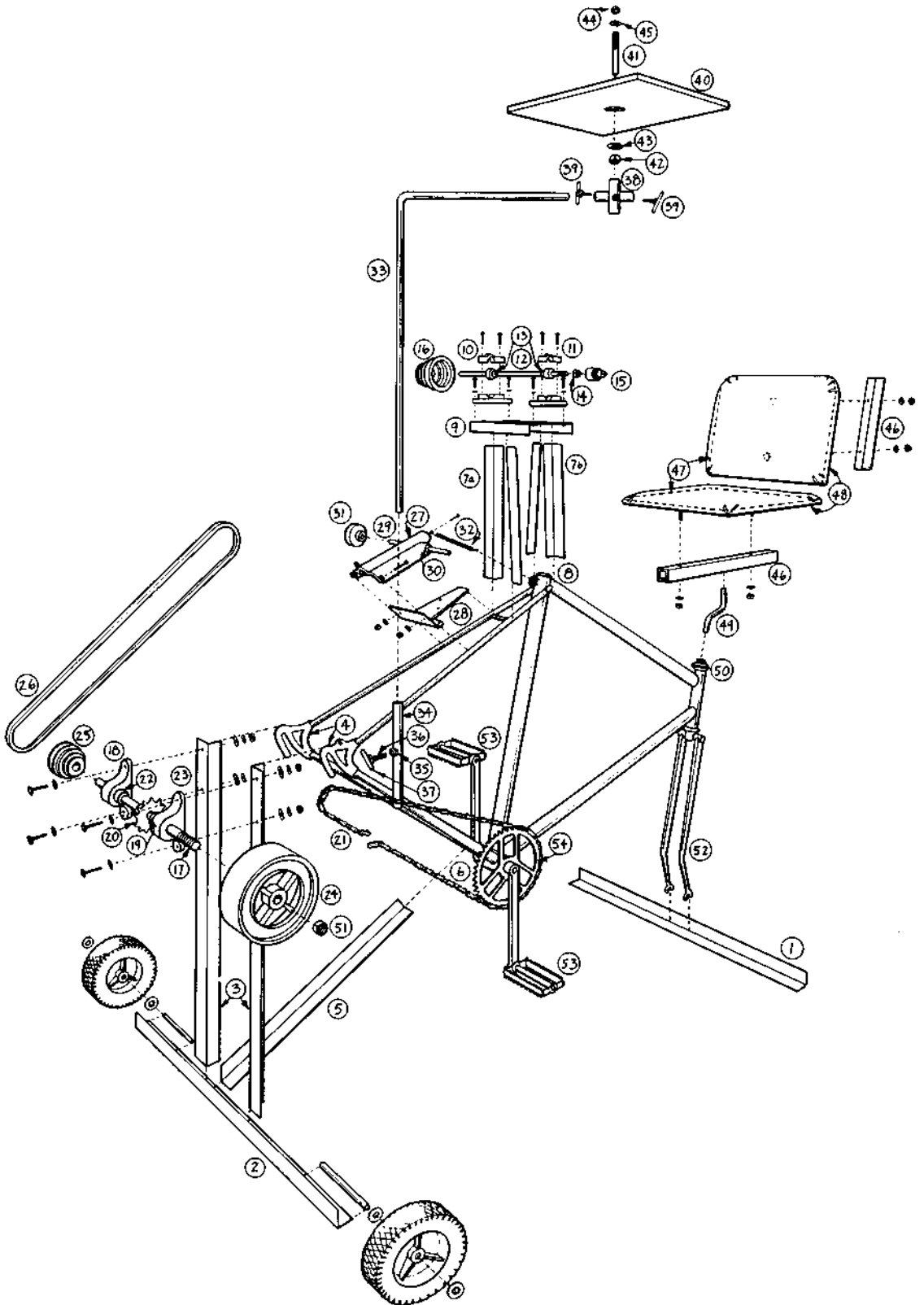


Figure 3-25 Exploded view of homemade Energy Cycle

- a 6" length of $\frac{3}{4}$ " steel stock threaded $1\frac{1}{2}$ " on one end⁴¹
- 3 $\frac{3}{8}$ " nuts³⁵
- 3 $\frac{3}{8}$ " bolts³⁶
- 3 $2\frac{1}{2}$ " lengths of $\frac{1}{4}$ " steel stock³⁷
- 2 $\frac{3}{4}$ " nuts^{44 42}
- 2 $\frac{3}{4}$ " washers^{43 45}

SEAT

- 2 12" lengths of $1\frac{1}{4}$ " square metal tubing⁴⁶
- 2 12" × 15" × $\frac{1}{4}$ " pieces of plywood⁴⁷
- 2 12" × 15" × $\frac{1}{4}$ " foam rubber⁴⁸
- 2 15" × 18" pieces of vinyl cloth
- 1 8" length of $\frac{7}{8}$ " dia. steel shaft⁴⁹

Building Instructions (Based generally on the present model of the Energy Cycle foot-powered generator)

Use these general guidelines of this model to adapt to the materials you have available. Read the instructions thoroughly, following the photographs before proceeding with construction. Be sure you understand the directions before starting and take time to improve the design to best suit your situation and materials.

Tools for building this unit should be found in many common workshops. To assemble the frame you will need to use either welding equipment or an acetylene outfit. That is the part of construction requiring some expertise. Other tools include a hacksaw, drill, wrenches, allen wrenches, clamps, file, and pliers.

The basic frame of the cycle should be easy to scrounge. Any old bike frame will do. You won't need wheels, tires, or handlebars but be sure to find a frame including the front and rear forks, pedals, crank, and chain. All new frame support pieces will be fashioned from 1-inch angle iron.

Cut a 2-foot length^{1*} of angle iron and tack weld it horizontally to the bottom of the front fork⁵² of the bicycle to form the back end of the Energy Cycle. (Do not be confused. In building the cycle, the bike frame is turned

around so that the back of the bicycle becomes the front of the unit.) Build a T-frame support for the front end from one 2-foot length² of angle iron (to rest on the floor) and two vertical pieces.³ Welded to the horizontal support and the back fork⁴ of the bicycle, the vertical pieces should be long enough to keep the pedals at least 4 inches off the floor. For extra support, weld a piece of angle iron⁵ between the front horizontal support and the crank section⁶ of the frame.

Next, you will build a power-head support where the seat used to be. Cut four lengths⁷ of angle iron to extend vertically from the front fork to a height 38 inches off the floor. Position one post on either side of the front fork, close to the former bicycle seat connection.⁸ A platform⁹ to support two pillow blocks will rest on top of the four vertical posts; therefore, the width of the pillow blocks will determine the position of the second set of posts (3 or 4 inches forward on the frame). Clamp, making sure all four posts are level, and weld.

Cut two 6-inch lengths⁹ of angle iron and weld one horizontally on top of each set of support posts⁷ to form the platform. Mark and drill holes and bolt two $\frac{1}{2}$ -inch self-centering pillow blocks^{10,11} in place. Next, insert the threaded end (right-handed thread $1\frac{1}{2}$ inches up shaft) of a $\frac{1}{2}$ -inch × 12-inch

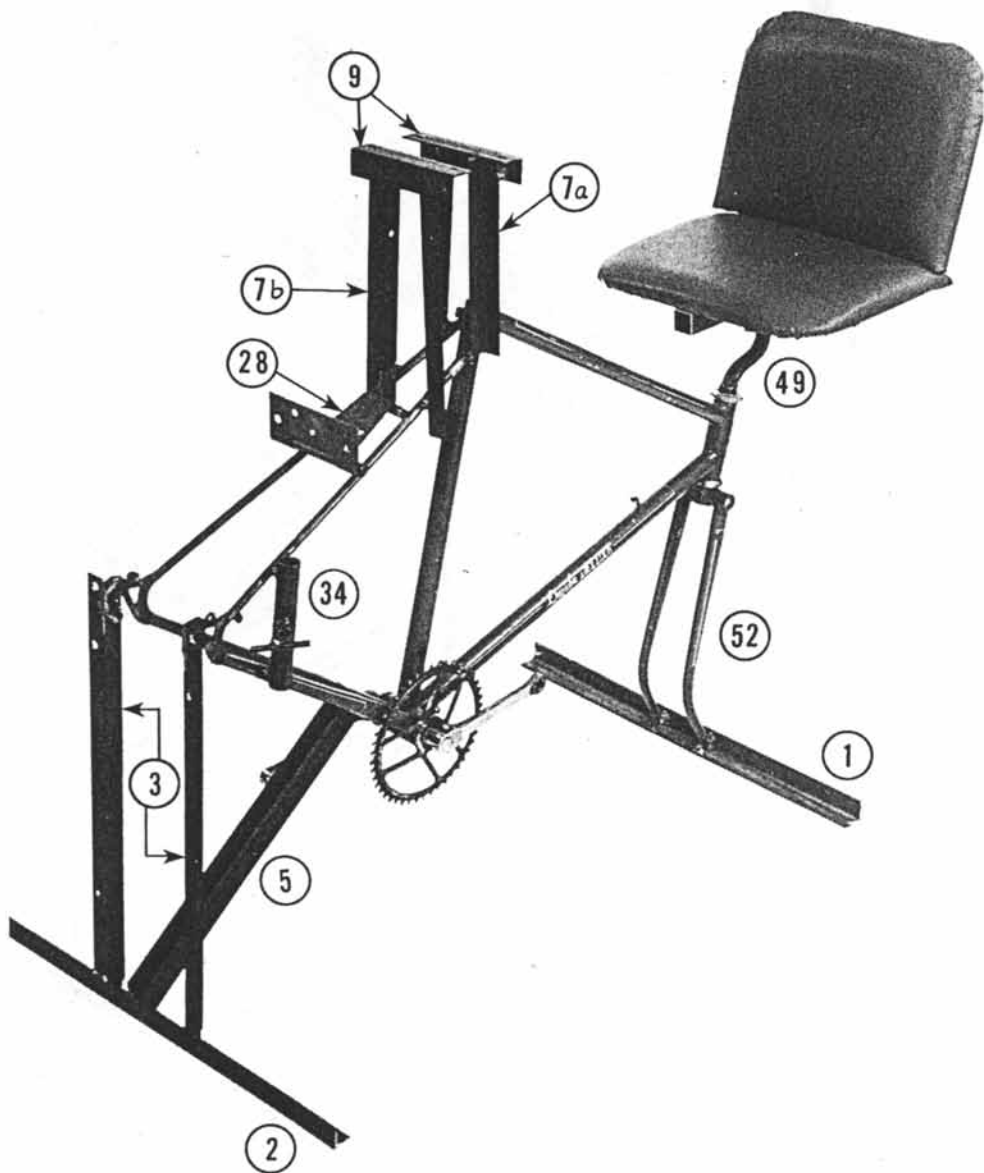


Figure 3-26 Basic frame with seat, power-head support, hinge for idler, table support tubing, and pedal crank

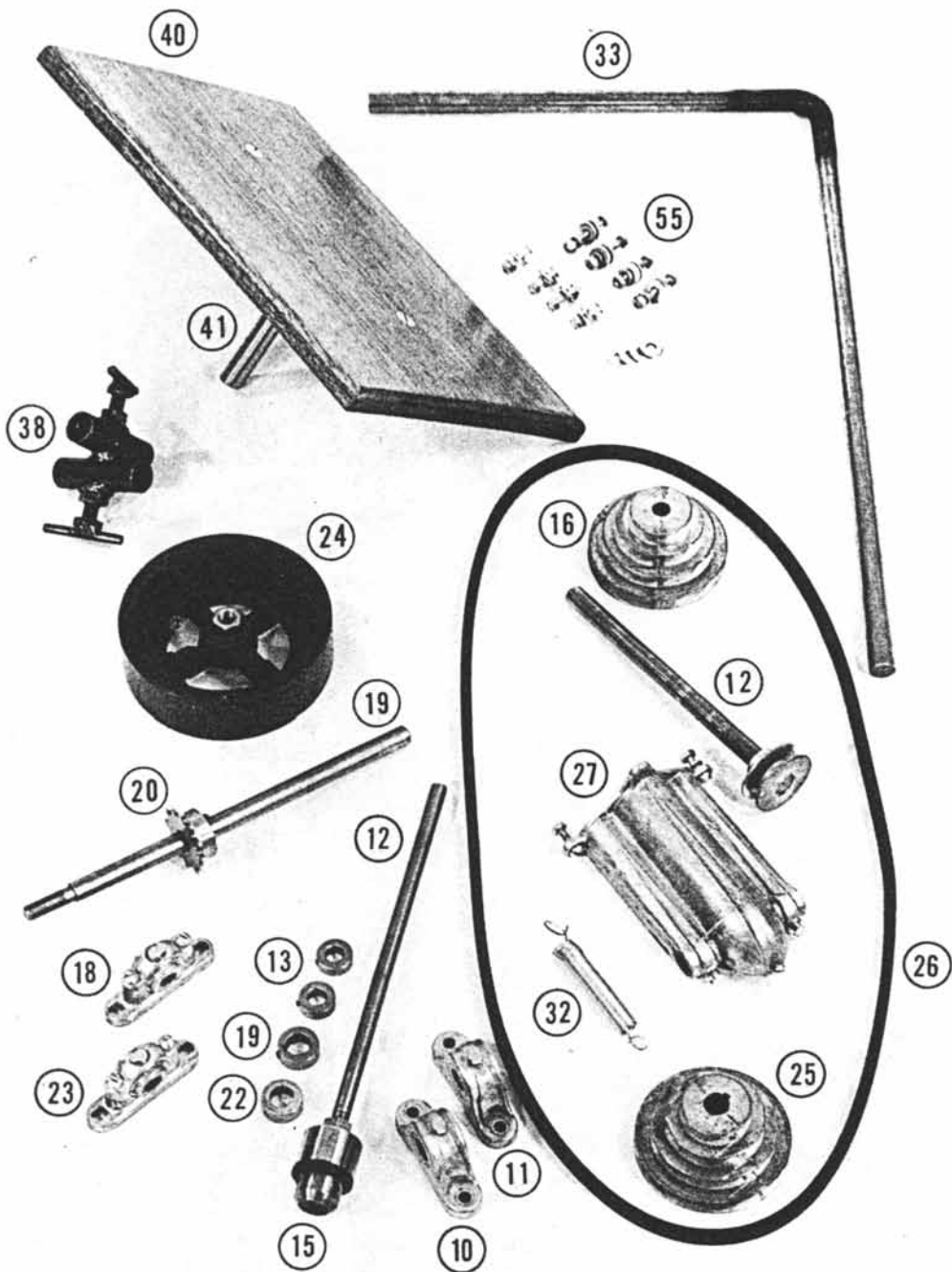


Figure 3-27 To help keep costs down, it should be easy to scrounge many of these parts.

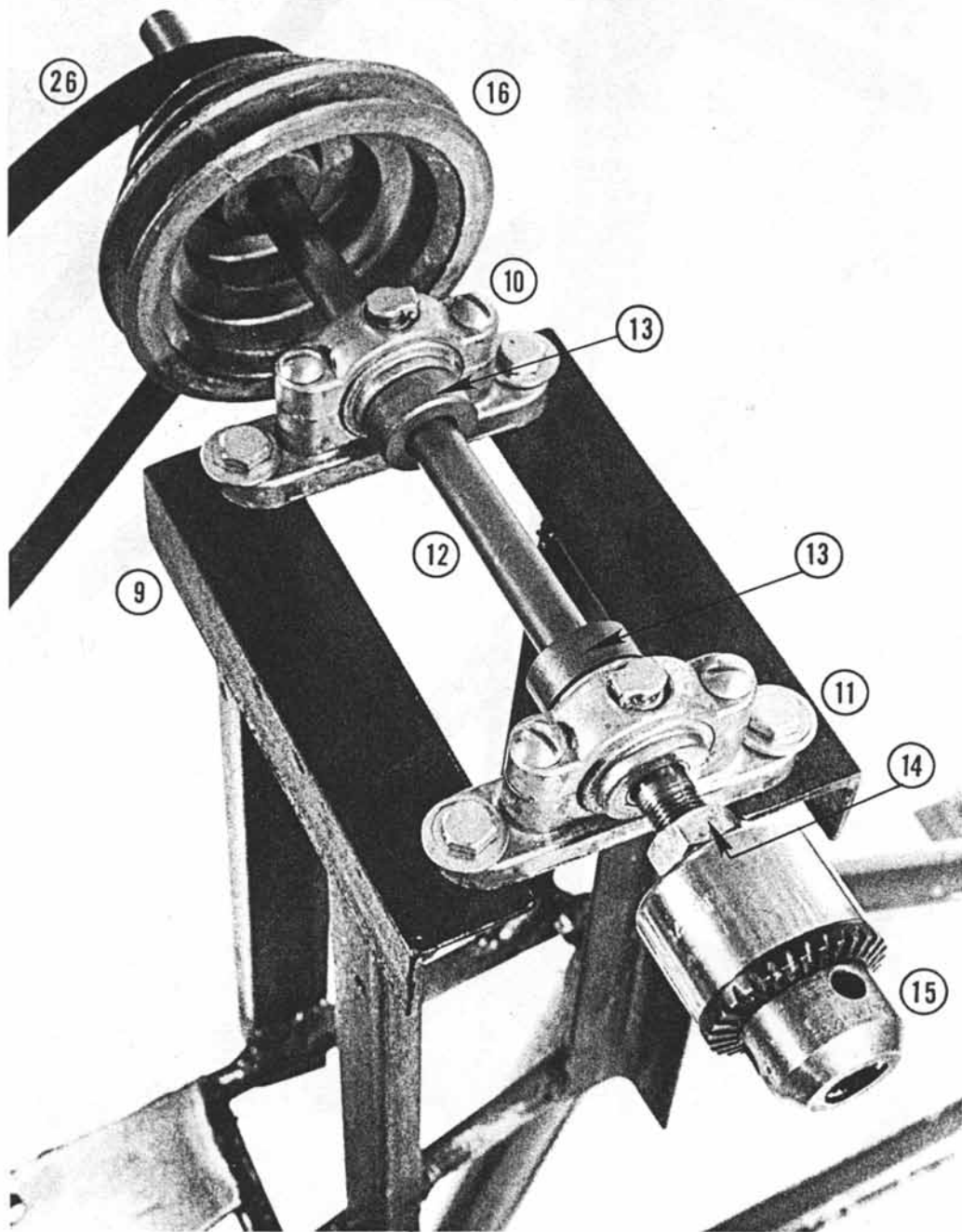


Figure 3-28 Power head: self-centering pillow blocks support an axle which transfers power from the V-belt to the chuck.

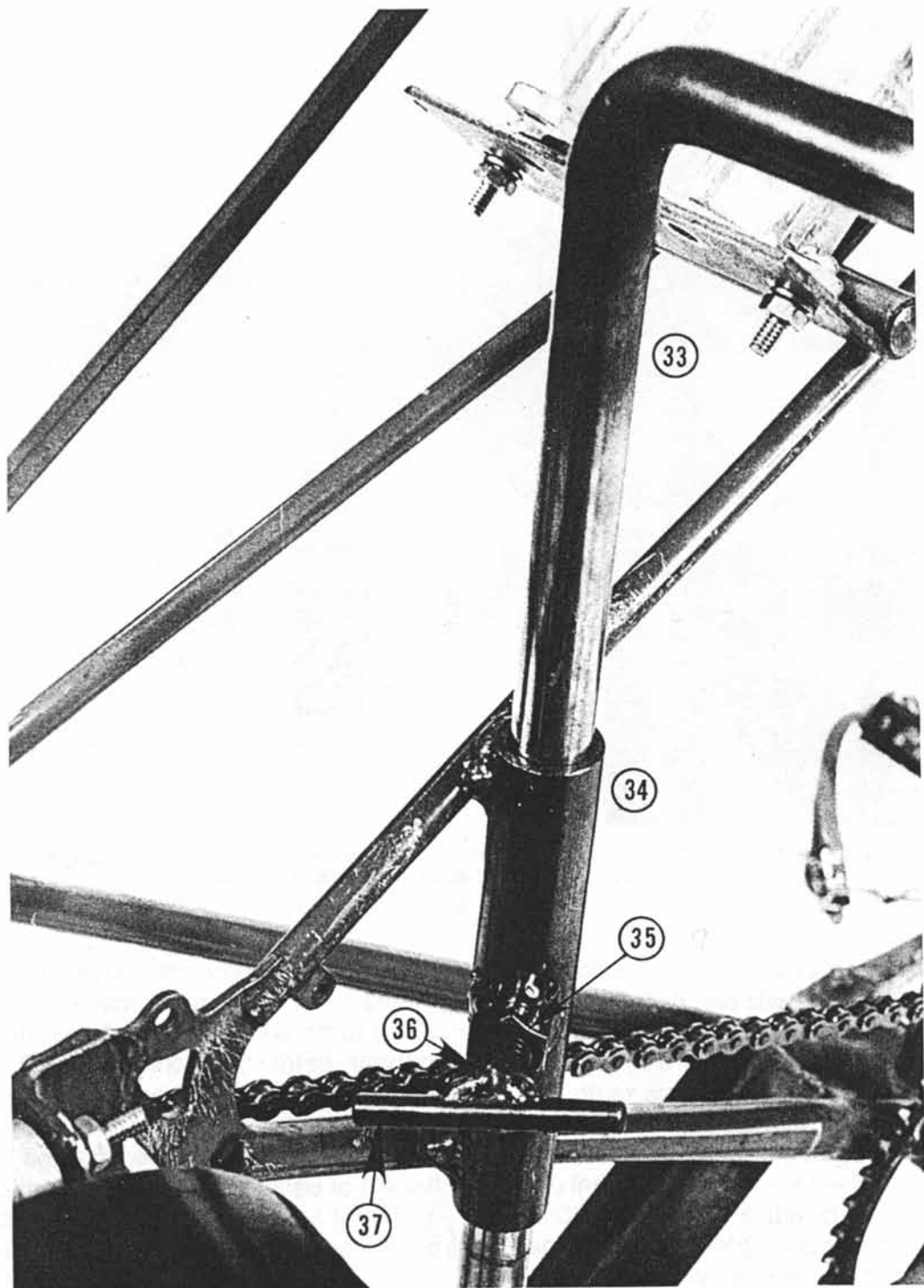


Figure 3-29 The table support bar is supported by a 6-inch length of tubing and locked in place by a hand-tightened "T-bolt."

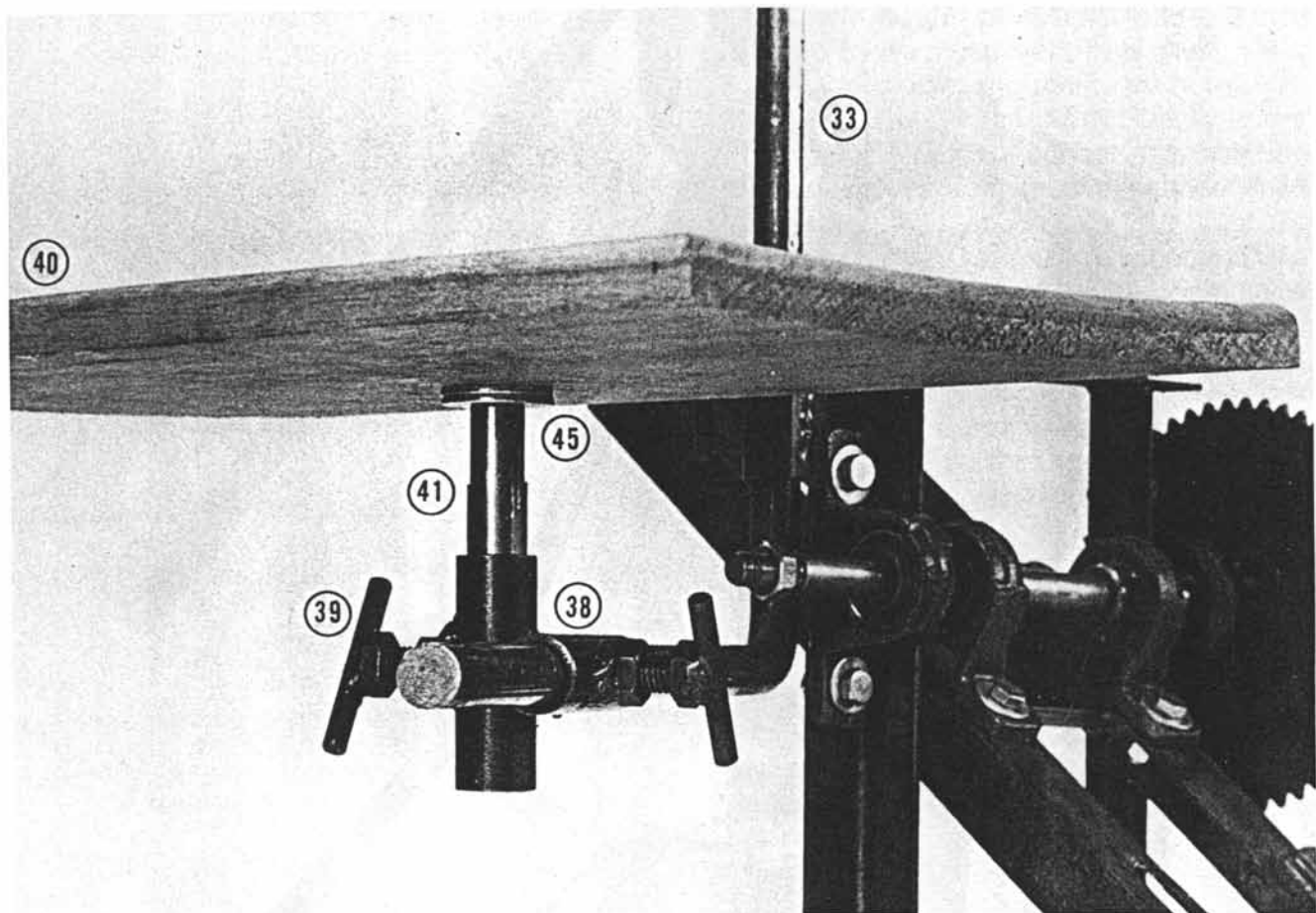


Figure 3-30 The table, which can be moved to most positions, offers a universal means of attaching various tools to the cycle.

steel shaft through the right pillow block.¹⁰ Place two 1/2-inch bushings on the shaft¹² and push the shaft through the other pillow block.¹¹ Screw a 1/2-inch nut¹⁴ three-quarters of the way onto the thread and screw the Jacob's chuck¹⁵ onto the shaft until firmly wedged against the nut. Slide the shaft to the right so that the chuck is as close to the left pillow block¹¹ as possible without touching. Place a step sheave¹⁶ on the right end of the shaft. Do not secure the fittings yet.

At the front of the cycle, at the top of the T-frame support, drill holes for and bolt the two pillow blocks in place. Insert the threaded end of a 14-inch shaft¹⁷ through the right pillow block.¹⁸ In order, place a bushing,¹⁹

sprocket,²⁰ chain,²¹ and another bushing²² onto the shaft and slide the shaft through the other pillow block.²³ The threaded end is for a removable flywheel²⁴ and the right end for the other step sheave.²⁵ If the top sheave¹⁶ has been mounted with the small pulley on the inside, be sure the large sheave²⁵ is on the inside on the bottom shaft.¹⁷

Check to see if the chain fits the new sprocket.²⁰ If it does not, remove the master link (slightly larger link) and either add or remove links until the chain is taut. With the chain in place, pedal forward a few revolutions so the front sprocket²⁰ can align itself. Then align all the bushings^{13, 19, 22} and sheaves^{16, 25} and file "flats" onto the shafts

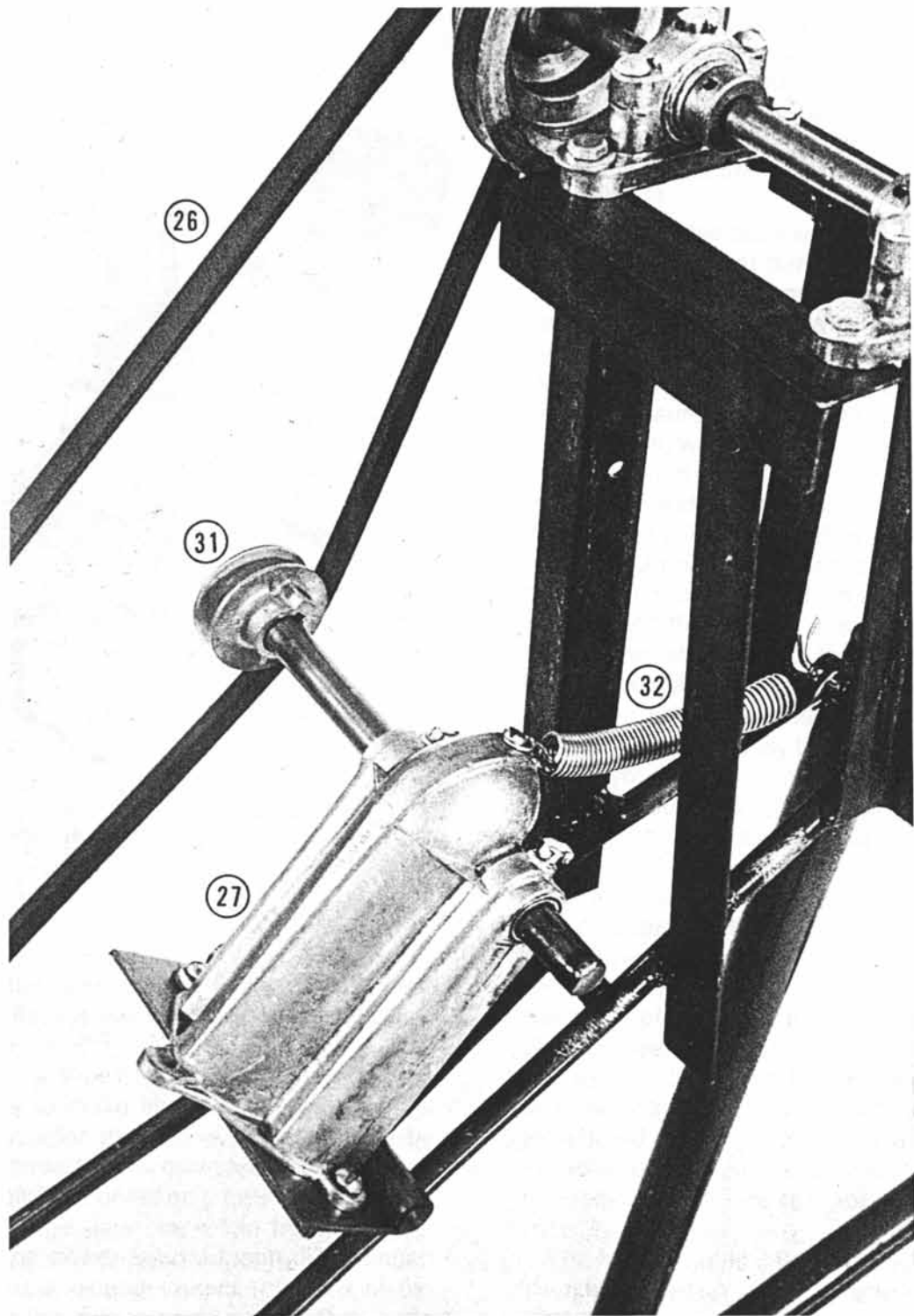


Figure 3-31 Research and Development personnel adapted a one-piece grinder shaft assembly to perform the task of an idler—a mechanism to remove slack from the V-belt.

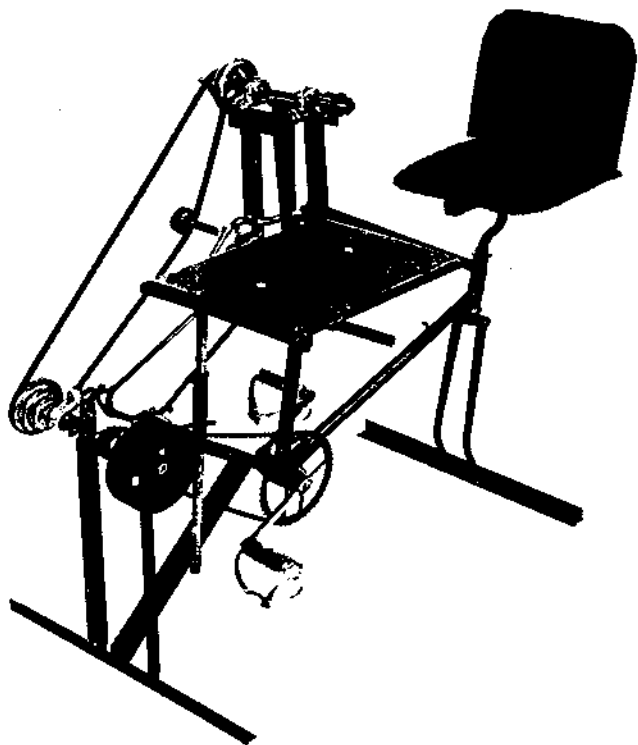


Figure 3-32 Homemade Energy Cycle built by Rodale R & D for less than \$60

where the allen screws line up so they will have a flat surface to tighten to. Oil all pillow blocks.^{10, 11, 18, 23}

Select a V-belt²⁶ to fit loosely on the step sheaves to make changing gears a simple task. An idler to remove the slack can be easily made from a one-piece grinder shaft assembly²⁷ mounted on a gate hinge.²⁸ First, weld a large gate hinge²⁸ to the frame just below the power-head support. The hinged end should extend toward the front of the bike and be able to open a full 180 degrees on a horizontal axis. Bolt the one end of the assembly to the flexible part of the hinge and insert an 8-inch shaft²⁹ through the bronze

bushings³⁰ at the other end. Add a 2-inch pulley³¹ to the right end of the shaft, file a "flat" on one side, and secure the pulley with the allen screw in the pulley. Finally, run a #62 spring³² from the former seat hole⁹ on the frame to the free end of the grinder shaft assembly.²⁷

The adjustable table will be supported by a 3/4-inch, 3-foot steel bar³³ with a right angle bend 14 inches from one end. To bend the bar, secure it in a vise and hold a torch 14 inches from one end. Let it get good and hot. When it turns a dull, red color, bend by exercising pressure on the other end by hand—remember to wear gloves!

Cut a 6-inch length of 3/4-inch steel tubing³⁴ to support and guide the table bar³³ you just bent. Weld a 3/8-inch nut³⁵ to the side of the tube³⁴ and drill and tap threads through the tubing, guided by the nut, so that a bolt³⁶ can be screwed through the side of the tubing to secure the table support bar in place. As an option you may want to weld a 2 1/2-inch piece of 1/4-inch shaft³⁷ across the bolt's head to form a "T-bolt" for easy tightening by hand.

Now you're ready to weld the tubing to the frame. Place it far enough forward on the frame to be out of the pedaler's way. The T-bolt should face away from the bicycle, to be readily accessible for quick adjustments. Use a square to align the tubing on a vertical axis. Any misalignment will be amplified by the long table extension. File all burrs from the inside of the tubing to allow the table support bar maximum mobility.

Construct two more bar supports from 3-inch lengths³⁸ of tubing and weld them together at a 90-degree skew. Slide one onto the table bar support. The other will support the table. Build T-bolts³⁹ for the bar supports.³⁸

We found that a 16 × 11-inch piece of 3/4-inch hardwood made a nice table top.⁴⁰ Thread a 6-inch length of 3/4-inch steel rod 1 1/2⁴¹ inches.

Screw a 3/4-inch nut⁴² onto the rod, add a washer,⁴³ and insert the shaft through a 3/4-

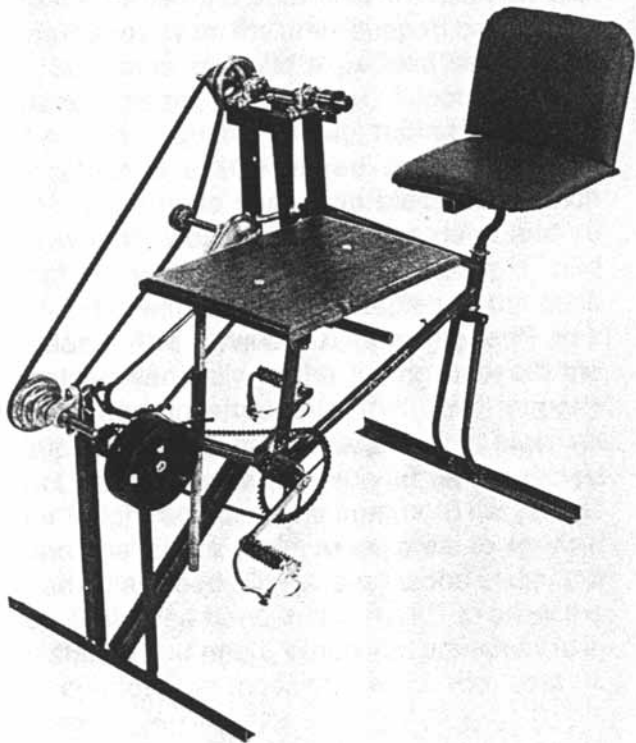


Figure 3-32 Homemade Energy Cycle built by Rodale R & D for less than \$60

inch hole in the table. Countersink a thin nut⁴⁴ and washer⁴⁵ when securing the shaft on the other side of the table. Now you are ready to slip the shaft into the support tubing³⁸ already on the table support bar.³³

Scrounge or build a padded seat with a back support. We used two 1-foot lengths of 1¼-inch square metal tubing⁴⁶ welded together at a 100-degree angle to support our homemade seat. Two pieces of ¼-inch plywood⁴⁷ were cut 12 inches deep and 15 inches wide, padded with foam,⁴⁸ and covered with vinyl cloth stapled to the back sides of the plywood. A 7/8-inch shaft⁴⁹ was welded vertically to the tubing beneath the seat and inserted into the hole formerly supporting the handlebars.⁵⁰ This seat will not be adjustable and should be measured for height and distance from both the pedals and the chuck-table work area to fit your particular needs. If the seat is too close, put an S-shaped bend in the shaft⁴⁹ to allow the distance you need. When you are sure it is in a comfortable position, weld the seat in place.

You may find it helpful on some jobs to have toe clips for the pedals. Pick these up at your local bike shop. The flywheel²⁴ is another option. A lawn mower graveyard is a good place to scrounge one of these. You may not find it helpful for every job, so we suggest bolting⁵¹ it on instead of welding to keep it removable.

Always think safety when using your cycle. The flexibility of the idler should help you avoid pinching your fingers when changing gears. We strongly suggest building guards for the pulleys so your fingers don't get caught in the V-belt.²⁶ Safe Pedaling!

Rear-wheel Bicycle Adapter

Materials

MAIN FRAME

The following lengths of angle iron:

- 2 40" lengths²⁴
- 1 5" length²⁵
- 2 4¾" lengths²⁶
- 2 7½" lengths²
- 2 18" lengths³
- 2 self-centering pillow blocks¹⁶

BICYCLE MOUNTS

The following lengths of angle iron:

- 2 14" lengths⁶
- 2 8" lengths⁷
- 2 7" lengths⁸
- 4 1½" lengths⁹
- 2 turnbuckles (one end loop, other hook)¹⁰

POWER ARM

The following lengths of angle iron:

- 2 18" lengths
- 1 5" length
- 1 4½" length
- 4 self-centering pillow blocks^{13 15}
- 1 10" length of steel stock¹²
- 1 11" length of steel stock¹²
- 1 6" dia. wheel²⁰
- 4 bushings (optional, if pillow blocks without lodging screws)
- 2 54-tooth sprockets, #35¹⁷
- 2 12-tooth sprockets, #35¹⁷
- length of #35 chain²²
- 1 heavy-duty spring²³

TABLE (see other set of plans)

- 1 3-foot length of ¾" steel stock³³
- 1 16" × 11" × ¾" hardwood board⁴⁰
- 3 3" lengths of ¾" ID steel tubing^{34 38}
- 1 6" length of ¾" steel stock threaded 1½" on one end nuts, bolts, washers⁴¹
- 3 2½" lengths of ¼" steel stock³⁷

Building Instructions

This design adapts any ordinary bicycle to a rear-wheel power takeoff to harness the power-of-the-pedal. For less than \$45.00, you should be able to build this simple

mounting frame to use your bicycle one minute for grinding grain and the next minute to ride to the store.

Except for a welding or an acetylene outfit, tools needed to build this unit are commonly found around most workshops—drill,

hacksaw, file, and allen and common wrenches. Refer to the materials list and photographs regularly for clarity but use this model merely as an example. Let your imagination improve on our design to best fit your specific needs and available materials.

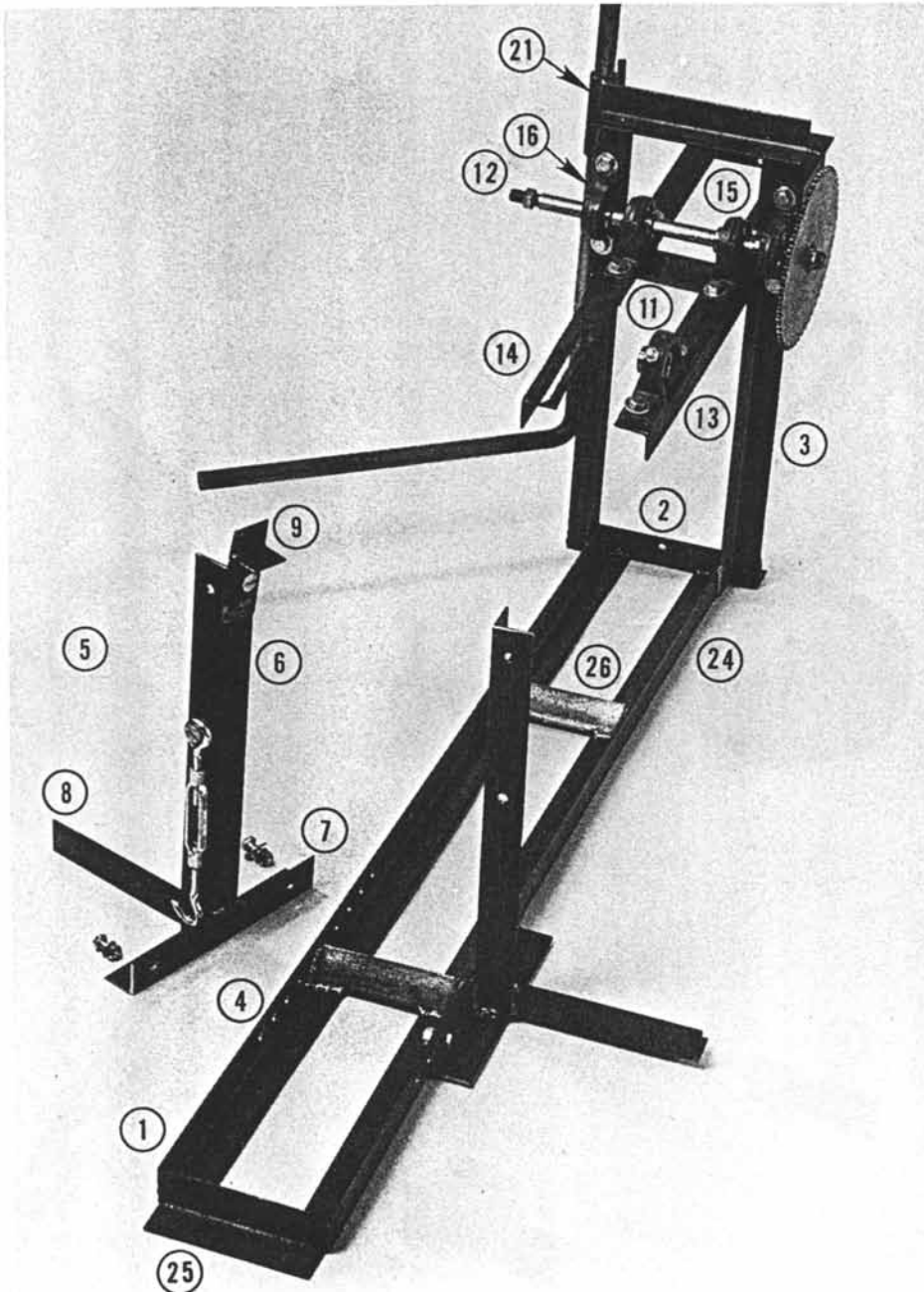


Figure 3-33 The rear-wheel adapter model consists of three components: floor frame and rear uprights, bicycle frame mounts, and spring-loaded power arm.

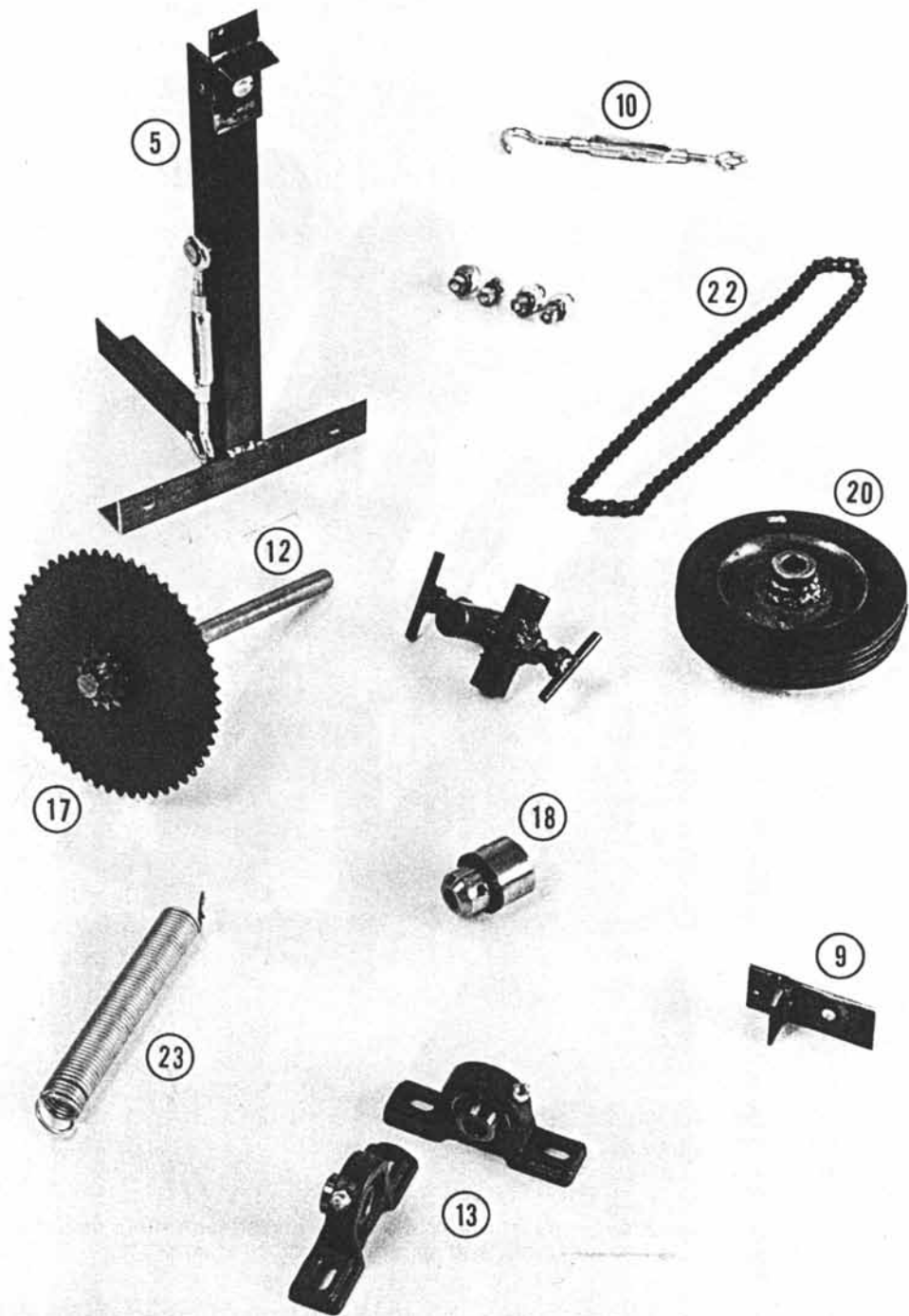


Figure 3-34 A few simple fabricated parts and some basic hardware make up the rear-wheel power adapter.

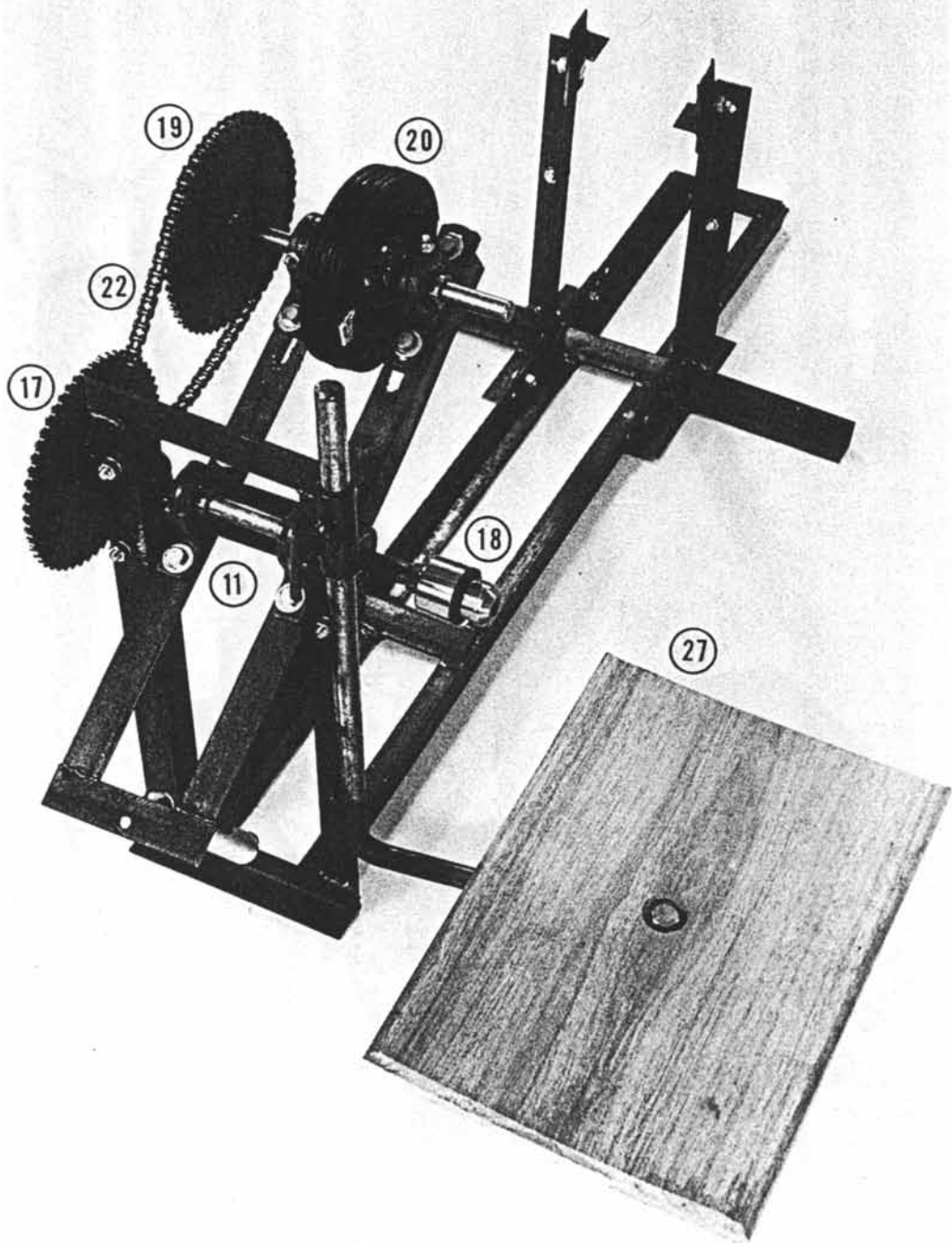


Figure 3-35 Attached to a five-speed bicycle, this prototype spun the chuck at a rate of over 5,000 rpm's.

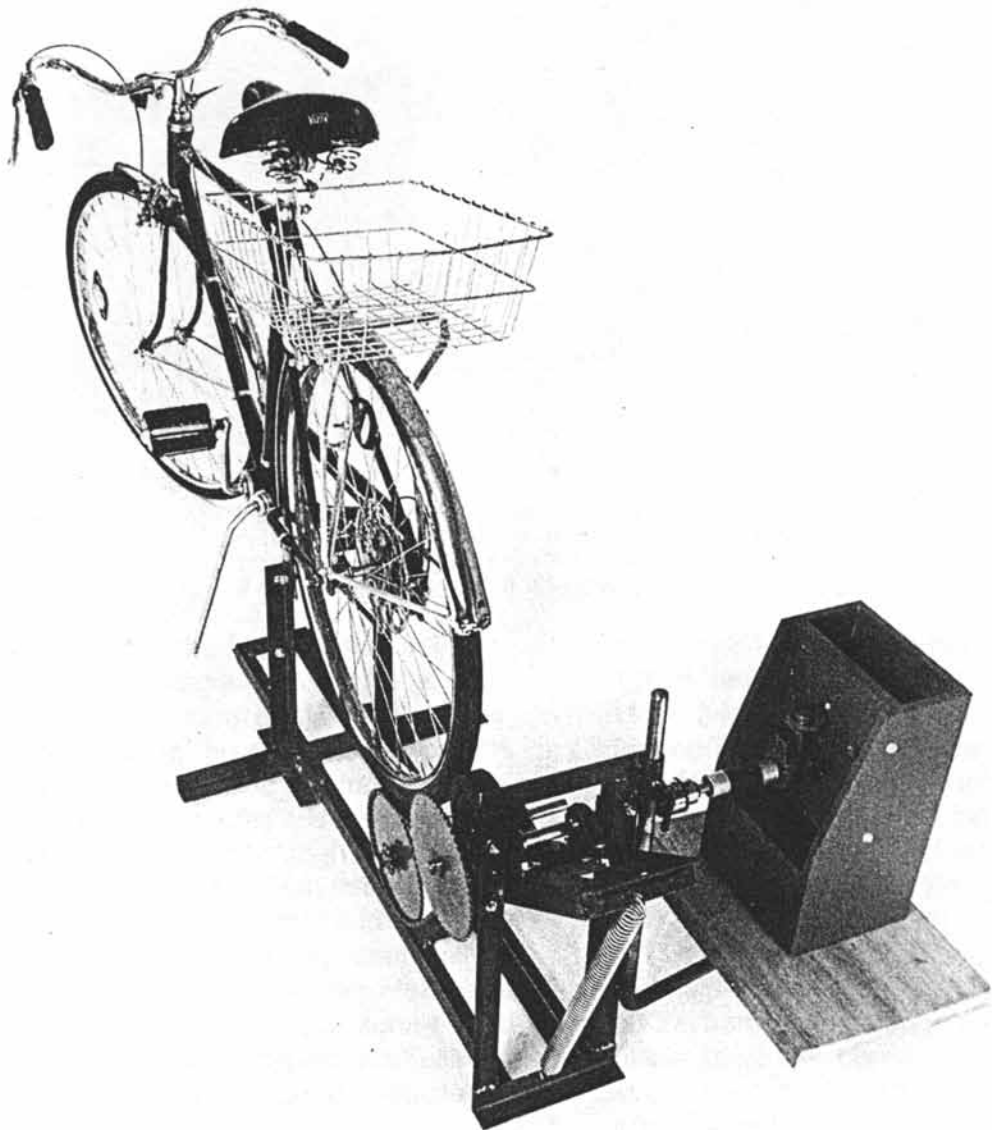


Figure 3-36 Bicycle rests on the two frame mounts and is secured in place with two turnbuckles. A converted electric grain mill sits on the adjustable table and its drive shaft is clamped inside the chuck.

Construction of the frame is the first step. Using 1¼-inch angle iron, build a floor frame¹ 40 inches long and 5 inches wide. The rear spacing brace² should be 7½ inches long to lap outside the frame to support two 18-inch uprights.³ Before welding, drill ten ¼-inch holes⁴ through the sides of the 40-inch²⁴ pieces at 1-inch intervals starting 7 inches from the front end. *Caution:* Everything must be aligned symmetrically in this model for parallel positioning. Make sure the holes are aligned directly across from their mates. The bike frame mounts⁵ will bolt through these holes and can be adjusted to fit different sizes of bicycles.

To build each bicycle frame mount⁵ you will need a 14-inch upright,⁶ an 8-inch securing bar⁷ with ¼-inch holes drilled 1 inch from either end for bolting the mount to the 40-inch floor frame, a 7-inch balancing extension,⁸ and a specially constructed frame-rest.⁹ Weld the three lengths of angle iron at right angles to each other according to the

photograph. The frame-rest⁹ is made from a 1-inch length of angle iron welded to a 1½ × 2-inch steel plate so that a ledge is formed for the bicycle frame to rest upon. A bolt fastens it to the upright. Another bolt fastens a 10-inch turnbuckle¹⁰ to the side of the upright. The turnbuckle¹⁰ should remain loose so you can swing it into place on the bike's frame before tightening.

The power arm¹¹ is an 18-inch-long, 5-inch-wide frame hinged slightly rear of center on the frame's rear uprights via an axle¹² and pillow blocks.¹³ Using 1¼-inch angle iron, space the two 18-inch lengths at the middle and rear with 5-inch lengths. Secure a set of sleeve-bearing pillow blocks¹³ at the front end of the power arm in slots¹⁴ rather than holes so the front pillow blocks¹³ are left adjustable. Center a second set¹⁵ slightly rear of center on the power arm and a third¹⁶ at the top of the frame's rear uprights.

Next you will need two axles¹² to fit the pillow blocks.^{13,15} Thread the end of one

with a right-handed thread¹² to fit the Jacob's chuck.¹⁸ Flush with the other end, weld a 12-tooth sprocket and a 54-tooth sprocket¹⁷ separated $\frac{3}{8}$ of an inch by washers. Place the axle¹² through the pillow blocks¹⁵ threaded end first and attach the chuck.¹⁸ The other axle¹⁹ should have the remaining sprockets welded in inverse order to those on the first axle. Placing a 6-inch wheel²⁰ between the pillow blocks,¹³ insert the axle¹⁹ through the pillow blocks,¹³ wheel,²⁰ and bushings to secure the wheel. If the pillow blocks ^{13,15,16} do not have lodging screws, you will need to secure the two axles¹² with one more bushing on the outside of each pillow block.^{13,15,16}

See the preceding set of plans for the instructions for building and supporting an adjustable, swiveling table.²⁷ The supporting tube²¹ for this model will be welded high on the frame's rear uprights.³

For the finishing touches, adjust a chain²²

to fit the sprockets. You can loosen the left pillow block¹³ and loosen the chain²² to change gears. Next, drill holes for and attach a heavy-duty spring²³ between the rear end of the floor frame. This will keep the wheel²⁰ on the power arm firmly wedged against the rear bicycle wheel.

To use your new power adapter, push the power arm¹¹ to the floor (expanding the spring²³) and back your bicycle onto the frame. Lift the bicycle so the rear wheel is off the ground and set the frame on the two frame-rests.⁵ Swing the turnbuckles¹⁰ around to secure the frame in place and tighten. Let the power arm up¹¹ and align it against the wheel.²⁰ Fix your tool in the chuck,¹⁸ secure it to the table²⁷ or wedge it against the floor. Most jobs will require two people for this setup—one to pedal, the other to operate and feed the implement being powered.

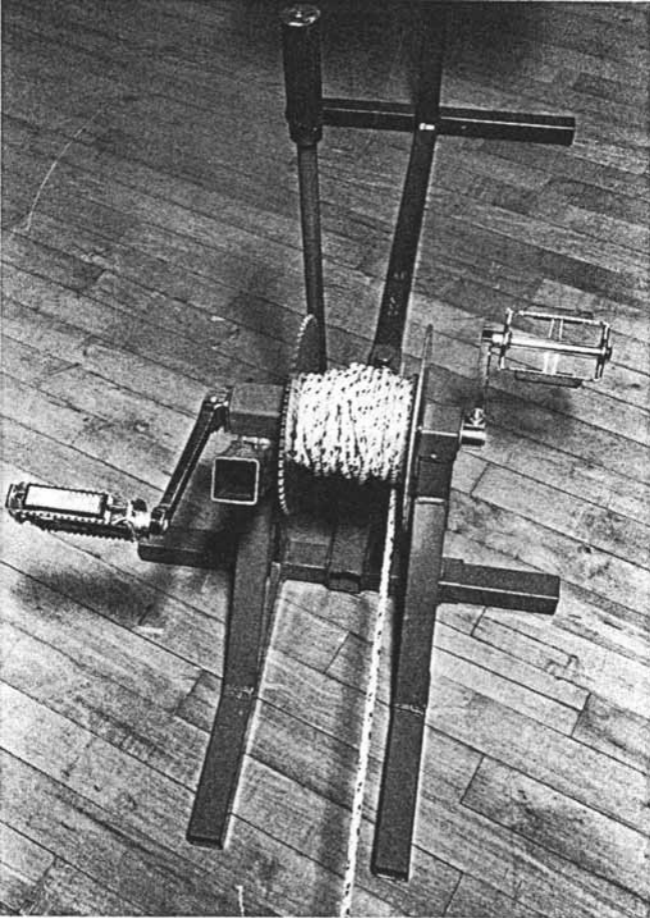


Figure 3-19 The winch assembly is built into a frame which also supports the seat.



Figure 3-22 A specially designed, multiuse frame with a cultivator attachment to harness the full potential of the winch

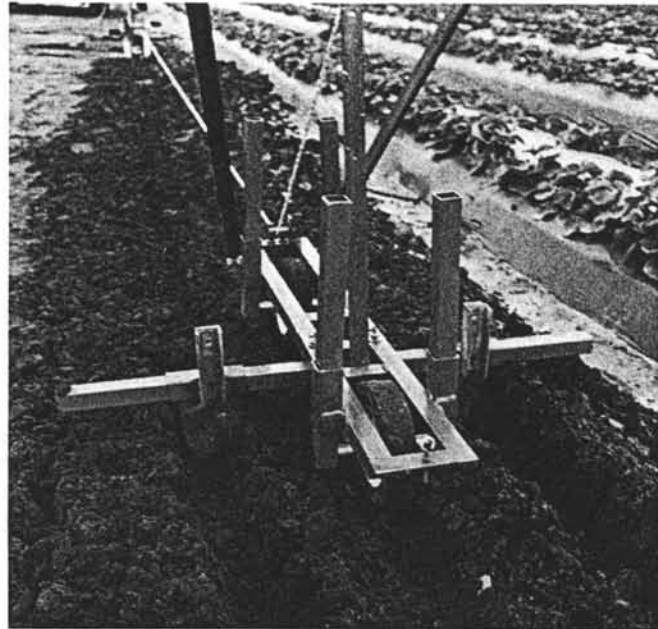
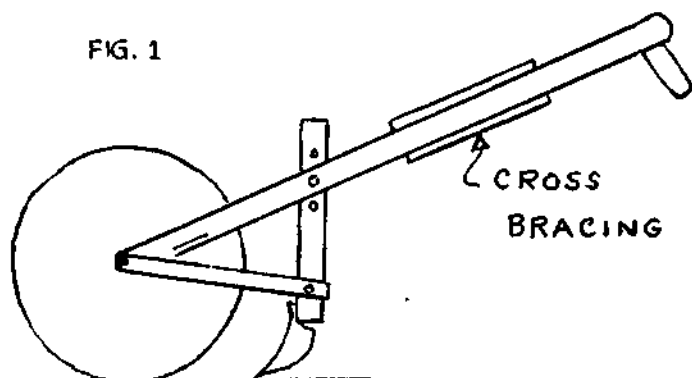


Figure 3-24 The winch performs gardening tasks on 12-inch centers rather than 24-inch, thereby increasing the productivity of the garden.

5. ONE-WHEEL PUSH PLOW

This plow is not to be used for breaking ground; it is a cultivating tool much like a hoe (Figure 1). Another term frequently used to describe this



garden tool is "wheeled hoe." Its use is justified in a large garden only, say 100×75 feet, unless you just want the fun of pushing it, which might be healthy.

The most useful attachments are the plow blade (Figure 2), the furrow opener (Figure 3), and the rake or cultivator (Figure 4).

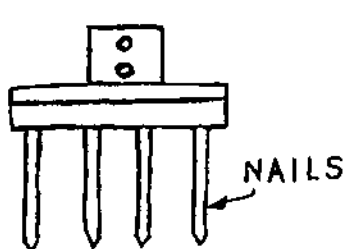


FIG. 4

There are two models, the high wheel (18-24 inches in diameter) and the low wheel (10-12 inches). The latter can also be a *two-wheel hoe* which can straddle a row of low plants.

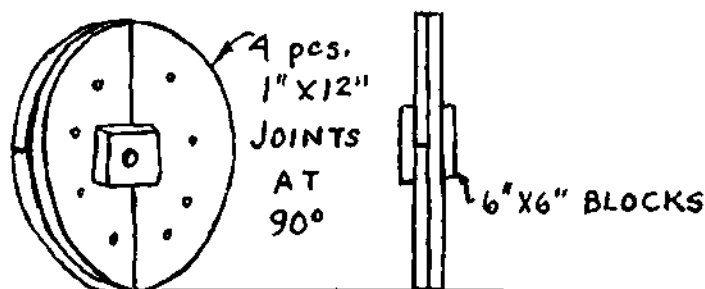


FIG. 5

The emphasis here is on the high wheeler, which is the form I have used since my youth.

The important things about the wheel are reasonable size and weight. An old bicycle wheel would probably be too light, yet the wheel should not be so heavy as to have the effect of rolling and packing the soil. A visit to your favorite junkyard should yield something suitable. If you want to make your own, cut a

FIG. 2



FIG. 3





FIG. 6

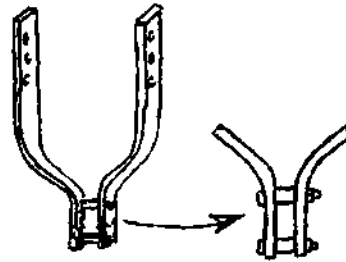


FIG. 7

wheel out of 1×12, with additional thickness for the hub, as shown in Figure 5.

Figures 6 and 7 illustrate alternative methods of supporting the attachments. Figure 7 is the better construction, but is more expensive if you must purchase new steel. If you are building this for your own use, probably only two adjustment holes will be required.

The plow blade and furrow opener (Figures 2 and 3) can be cut from steel no thinner than $\frac{3}{8}$ inch, and preferably $\frac{1}{2}$ inch, assuming the use of mild steel. A worn out shovel or spade may be available. Since such items are made of hardened steel, the top part would probably be sufficiently heavy for both the plow blade and the furrow opener.

The cultivator in Figure 4 is made from 50d (5½ inches long) or 60d (6 inches) nails. Hardwood such as oak should be used for the lower bar. The right angle steel for mounting is wider than the "tang" in Figures 2 and 3 because, in use, there is more sideways pull on the rake.

Expend time and effort on making the handle comfortable. Several methods of making the "pistol grip" might be used. Figure 8 shows one method.

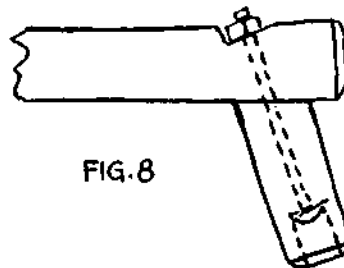


FIG. 8

Saplings of about 1¼ to 1½ inches can be found so you need not buy any lumber for the frame. Smaller saplings can be used for cross bracing. Small saplings could even be formed into a wheel, if you have the patience.

Exact dimensions have not been given here because everything depends on the diameter of the wheel you select. The handle is a good place to start. Four to five feet of length will probably work out about right. The person who is to use the plow should try out the handle for length. The operator must be far enough back to avoid stepping on the cultivating tool.

The wheel might have a $\frac{1}{2}$ inch shaft forced into it (assuming a homemade wheel), with the bearings in the handle, or the other way round, with the bearings in the wheel. In either case, be sure there is ample oil absorption by the wood in the bearing area.



As bicycles are needed as transportation devices in the Third World, this luggage carrier was designed to flip down and be used as a temporary power source when needed. Its construction is within the scope of the most modest village technology. Designed by Michael Crotty and Jim Rothrock, as students at Purdue University.

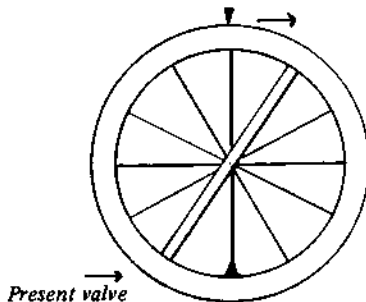




1) Construction: *Flywheel arrangement*: When one is engaged in a pleasant bicycle ride, the mass of the rider is the flywheel. His/her weight sustains the momentum of bicycle travel. During stationary pedal operations, this momentum is lost; thus, the incorporation of a flywheel to smooth out the jerkiness incurred when pedalling a bucket of wheat into flour.

Double chainwheel used: Inner (38T) sprocket aligned with forward mounted grinder & gear. The outer ring of chain wheel accepts a chain which runs back to the flywheel's sprocket. Rear sprocket (on flywheel) and hub *must* be welded or otherwise secured else the flywheel will freewheel, negating any useful work.

Flywheel is an old 24" balloon tire filled with water/anti-freeze solution designed to get the greatest amount of weight inexpensively to the outer circumference of the flywheel. To fill tire with water and anti-freeze solution, an additional valve and stem must be added. It is affixed opposite the present valve to vent air as tire fills with water. (See diagram)



Additional valve: made by removing tube, cutting and glueing new valve (remove inner seam). Check for leaks. Punch small hole at top of tire for valve insertion. Reassemble, fill water at original valve; air will vent out at top valve. Replace cap when filled.

Flywheel arrangement is suspended off ground by twin angle iron brackets mounted to a wood base.

2) Experience: Good. Had several days of bugs before everything settled down and "felt right." Once the flywheel is put in motion, the jerky grinding action smooths out. Better rider angle for longer and more efficient periods of work. Any inquiries: please include a self-addressed, stamped envelope.

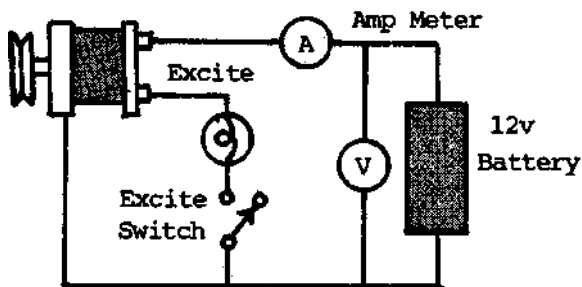
—Jim Burgel
331 E. Kinseley
Ann Arbor, MI 48104 ■

Peddalling for Power

With the acquisition of a number of free ex forklift batteries, and the sudden death of a home made battery charger, this pedal generator was built as a cheap way to keep the batteries charged. The batteries were used to provide power for a T.V., radio, and general lighting, about 2 amps x 4 hrs per night; a lot of pedalling.

Having a spare alternator and a spare bicycle around the place made it cheap to build. A stand was made which held the rear wheel off the ground and also mounted the alternator in line with wheel.

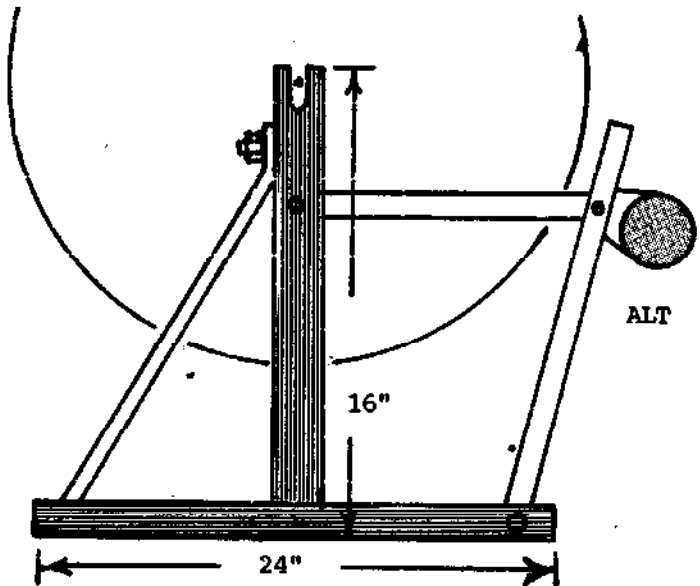
55 amp Bosch Alternator



The rear tyre was taken off the rim and the rim used as pulley. A belt running on the rim was used to drive the alternator, with 1 turn of crank there was 3 turns of the rear rim. With 1 turn of the rim the alternator turned 8 turns, pedalling at 100 rpm the alternator should be turning at about 2,400 rpm. The alternator used was a Bosch 55amp off a Ford. The alternator had a regulator built into it, so there was no problems worrying about how to wire the regulator,

The bicycle had a control panel mounted on the handle bars, this enabled you to start pedalling, then excite the alternator when you had a bit of speed up.

8 amps for 5 mins. was the highest I ever achieved; 2 amps for 50 mins longest time pedalled. Any longer time spent pedalling you had trouble trying to

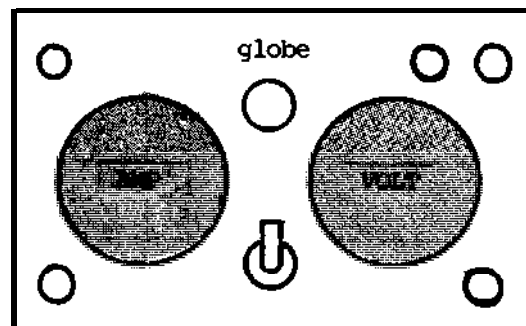


stand up afterwards. Unfortunately this was not enough to keep the batteries charged. To solve this problem I brought a new battery charger.

Presently I am trying a few different alternators and generators to try and achieve 8 amps, but for a longer period.

Kevin Earl

Excite Neg. Alt. Pos. Alt.



Neg battery Excite Switch Pos. battery

A Pedal/PV System

David Haaren & Kathy Abbott

We live in a small house on 14 acres of land in southern Vermont. The house is located a mile from utilities in a wooded, sloping area. Solar access is excellent. Three photovoltaic panels, which produce 65 watts in full sun, charge our two deep cycle batteries. An exercise bike and generator are also used to charge the batteries.

The batteries power a variety of appliances: a dozen incandescent bulbs, five fluorescent lights, a TV, video cassette player, stereo, water pump (our supply is gravity), fan, Makita cordless tools, vacuum cleaner, weed-wacker, typewriter and an inverter for a computer, printer and movie projector. We find that the pedaled generator is enough to provide the necessary boost to take our system through the winter. We prefer pedaling to a noisy and polluting gas generator. A gas refrigerator and stove and wood heat help provide for our other needs.

The system shown here has evolved over a dozen years. Earlier systems have been more portable or made use of a ten-speed bike, but none have performed as well. The power transmission is incredibly efficient, as evidenced by the length of time it takes for the flywheel to slow down once it's going. The permanent-magnet generator converts most of the pedal power into useful electricity.

With this system you can pedal-charge a 12 volt battery at up to 15 amps. The generator is rated to deliver 5 amps continuously and is more efficient at easier cruising rates, say 3 amps.

We don't generally measure amps but instead watch the voltage of the battery as indicated by LED voltmeters. The "V for Voltage" has been in the Sunnyside Solar catalog. These voltmeters are similar to the ones featured in HP #10 and The Mother Earth News, May/June '82.

The pedal system consists of a Schwinn DX 900 exercise bike and a Thermax generator, mounted with what we will call a Haaren aluminum bracket. Power transmission from Schwinn's large flywheel to the generator is accomplished using Berg sprockets and plastic chain. This steel reinforced plastic chain runs on precision sprocket gears and is efficient and quiet, quiet enough so that you can read or converse while pedaling. All parts are easily attached and aligned, though a drill and tap are needed to mount the sprocket onto the flywheel.

Our pedal system performs very well as a supplement to our PV home power system. We can offer a kit to retrofit the Schwinn DX 900 or we can assemble a complete machine.

For more information write
Pedal Systems
Box 6
Westminster Station, VT 05159

A Schwinn bike and a Thermax generator turn muscle power into electricity. Power transfer is handled by Berg sprockets and a plastic chain. Photo by Pedal Systems



Pedal Power

John W. Hill

You too can be a human power plant. A lot of folks have expressed interest in pedal power setups as backup or primary power sources. Here is a general perspective on the utility of this approach to greater independence.

Power Output

If you hook up a bicycle to a generator how much power can you generate? How practical is it as a home power resource?

The answer depends largely on your use and expectations. The first consideration is how much power can you generate. A fit olympic-class athlete may be able to generate as much as half of one horsepower for a brief time. At 746 watts per horsepower that translates into approximately 370 watts peak. A modestly fit person can expect to generate about one tenth horsepower (roughly 70 watts) for a brief period. For normal regular use a generator capable of producing 50 watts or more is quite adequate. If you are a cyclist interested in serious training, a generator capable of 100 watts or more is desirable. Permanent Magnet (PM) generators ranging in size from 60 watts to 200 watts are readily available and can be obtained with the bike generator options described below.

Compare this to the output from a 50 watt solar panel that runs 6 hours per day. If you could sustain a 50 watt rate for 6 hours, you could match the power generated by one solar panel, provided that you had nothing better to do with your days and nights. Clearly, a bicycle generator is not a competitor for solar panels, wind generators, or microhydro as a home power source.

For What?

Now look at it from another point of view. A high efficiency PL light will draw from 5 to 13 watts of power and a small DC television will draw from 15 to 60 watts of power depending on it's size and type. One hour of serious pedaling would provide enough power to supply a PL light for 3 to 10 hours depending on the size of the light. Or, it could power the TV set for 1 to 3 hours depending on it's size. So for such essentials as lighting, communications, or entertainment, a bicycle power system can provide adequate and useful power.



Above: exercise and battery charging all at the same time.

Photo by John W. Hill

Can Do

The next question is, "Can you pedal at a stiff clip for an hour?" The same question is, "Can you ride a bicycle for an hour?". If you ride a bicycle for transportation or regular recreation, the bicycle generator will prove to be a natural part of your lifestyle. If you can't ride a bicycle for an hour, perhaps you should add the bike generator to your lifestyle as a physical fitness and training aid.

How So?

"How do you use it?" To obtain the maximum efficiency, the generator needs to be a permanent magnet DC type. The PM generators produce voltage directly proportional to the shaft speed. Of the several generators available, output voltages can reach 40 to 100 volts or more if you set the bicycle into a high gear and pedal at a very fast clip. These voltages can burn up a 12 volt appliance in short order. There are two ways to handle the problem.

First, you can use a storage battery to regulate the voltage for the appliances. If you connect a generator spinning at a 40 volt rate to a 12 volt battery, the generator output voltage will drop to match the battery voltage. This occurs because the current from the generator has to flow through its internal resistance and produces a voltage drop that is equal to the difference between the open circuit generator voltage and the battery's terminal voltage. If you are charging batteries, you will need a few additional components. These include a voltmeter to monitor the state of battery charge, a blocking diode, and preferably a charge controller. You have to be a bit careful with charge controllers though. If you use a charge controller that was designed for solar panels, it may not tolerate the excessive voltages that the PM generators can produce. Some additional circuitry to protect the charge controller is desirable.

Batteries

A battery for use with a pedal power set up should not be too large. After all, you wouldn't want to have to pedal for two days solid just to charge the rascal back up, would you? Industrial pocket plate nickel cadmium batteries are ideal for this application because they have a relatively flat discharge curve and don't mind being deeply discharged and operated in a partial state of charge. This applies only to the pocket plate type of NiCad cell which has no memory characteristic. Unless several people are contributing regularly to the charging process, 20-40 ampere hours of capacity is very adequate. Larger capacities will work of course, or you can simply pipe the current generated into the larger battery bank of a complete home power system.

Voltage Regulator

The alternative to using a battery is to use a voltage regulator to buffer the variable output from the generator down to a constant 12.6 volts. With this arrangement, the lights and other appliances are on while you crank but go off when you quit. This offers a real education in the amount of power we drain from the system. Cranking a color TV and VCR is hard work while powering a reading light or two is so easy of a load that you hardly feel it. The advantage of having a regulator available is that you can get full use from the system even if your battery is flat dead. It also doesn't take up the space required by the batteries and it provides some discipline in the use of certain appliances. Some folks, for example, connect the TV set to their bike generator with a regulator and require the kids to carry their own weight when watching TV.

Bike Type

The next consideration is the type of bicycle setup to use. Most standard bicycle trainers can be fitted with an appropriate PM generator. Daniel Millton of The Power Company offers a relatively inexpensive conversion kit for converting your bicycle or exercise stand into a pedal power unit. He also makes a complete converted exercise stand, a recumbent pedal powered generator setup, and offers complete pedal powered systems with all electronics and system components.

The recumbent is a real pleasure to use. First, it is comfortable, and the recumbent design allows maximum use of leg strength. The seat is adjustable for any size person from 6 years old on up and it comes with a book holder for reading while pedaling. You can even sit in the padded seat and lean forward and turn the pedals with your arms. After tossing a log on the fire, and leisurely cranking away while the PL reading lights ignited and flickered to life, I realized that pedal power does indeed

have a rightful place in the lives of people who defy slavery to the 60 Hz. umbilicals and all the economic, environmental, and resource waste that they represent. This reminded me of an old Amish farmer's comment on electrical power and telephones. He said, "It isn't that we believe that these things are bad particularly, it is just that we don't want to have wires binding us to the Englishman's world."

Security

During the winter storms a few months back, when the power lines were down, the wind generator was iced up, the solar panels were covered with snow, and the main battery bank was gasping up its last amp, the pedal power unit made a very nice addition to the home.

In summary, pedal power is valuable as a reliable emergency power source, as an auxiliary power source for driving small tools or appliances, and as a fitness aid. If you are considering pedal power, be realistic and don't expect it to compete with solar panels and other alternative power sources. Happy pedaling!

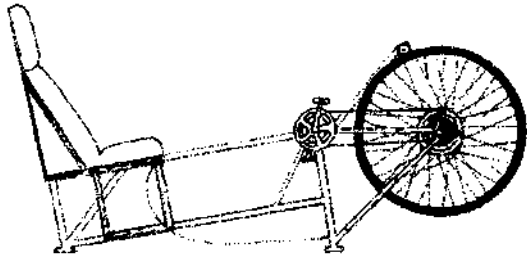
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Pushing Pedals

David Haaren

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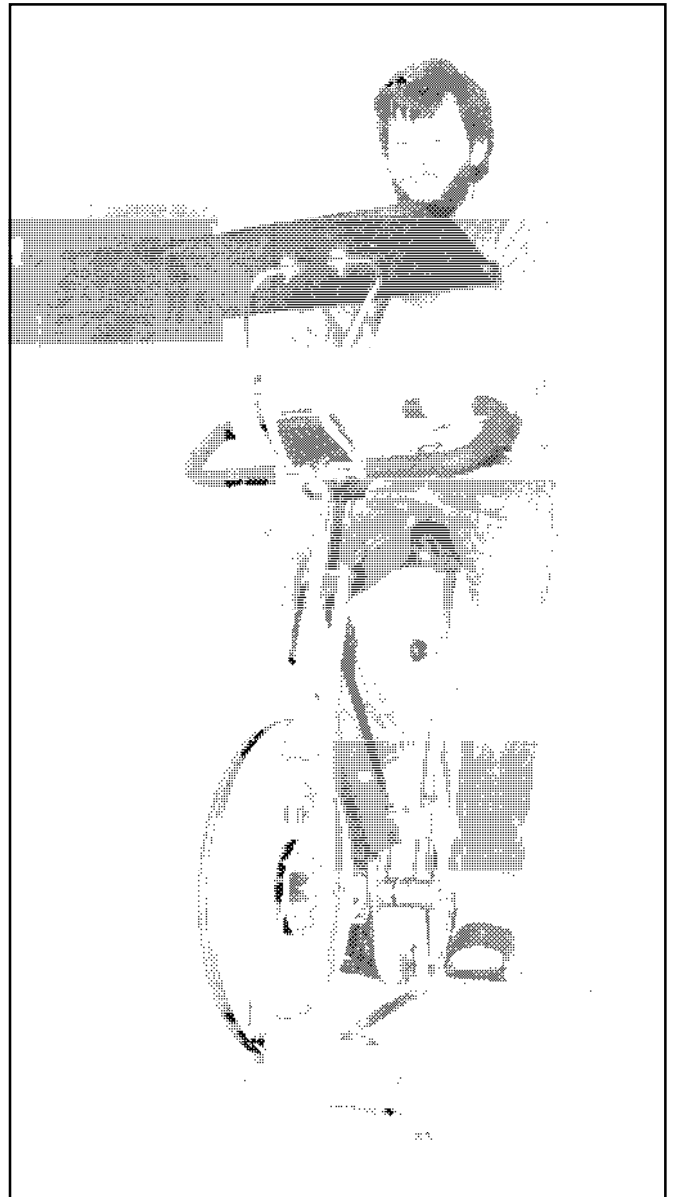
One simple way to make electricity is to push pedals. The pedals turn a dynamo that charges a battery. To some the idea might sound as practical as trying to catch their dinner with their bare hands. Others who have tried it are enjoying the benefits of indoor exercise and free electricity.

My wife, Kathy, and I have been riding the system shown here for several years to supplement photovoltaic power. We are making the system as a kit that specifically adapts the Schwinn DX 900 exercise bike. It uses a Thermax 5 Ampere DC permanent magnet generator. Power is transmitted from the flywheel to the motor using Berg sprockets and a self-lubricating, steel-reinforced plastic chain. We typically charge our two 12 Volt deep-cycle, lead-acid batteries in the 3 to 6 Ampere range, while reading, strumming the mandolin, or just pedaling. We find we only need to pedal in the winter. I get motivated when I see our battery voltage getting low. Our time on the bike varies, but we may average about 30 minutes a day between us when required. Thanks to all the work done with efficient appliances, even an extra 2 Amp-hours really can brighten our electrical outlook.

Where Do The Watts Come From?

Our bodies produce mechanical power in our muscle cells using food or stored fat as fuel. This conversion is about 20 to 30% efficient. Some of the losses are due to our creaking joints and when one muscle contracts against another. The rest of the energy manifests itself as body heat or is used to maintain vital functions. One food Calorie contains about 4000 Watt-seconds or about 1000 Watt-seconds of mechanical energy assuming 25% efficiency of the human engine. The 150 Calories in one large banana should be good for about 42 Watt-hours of energy and about 430 BTUs of body heat.

Our muscles can produce power over a wide range of forces and speeds. We can push with a force exceeding



Above: David Haaren makes electricity by pushing pedals on an exercise bike harnessed to a generator. Photo by Kathy Abbott

our body weight (if we pull down on handlebars or push against a recumbent seat) or we can push lightly. We can pedal slowly or spin very fast. The experts recommend a high number of revolutions per minute (70 to 90 rpm), when bicycling to reduce the forces and strain on the muscles and bones. Pedaling slower may be vastly more tolerable. What's the hurry? Everyone has their own preference. Here are some typical values for the human body's ability to produce Watts of mechanical power:

Human Mechanical Power

Watts	rpm	comment
14	50	a bare minimum of effort
51	60	easy to read etc., no sweat
136	80	breathing harder, but can maintain
283	100	going all out and not for long
33	100	geared too low, spinning too fast

These numbers agree with other literature. The average factory worker will work at a rate of 75 Watts. World-class bicyclists can maintain over 300 Watts for races that last for over an hour. Thus we can expect our pedal power to be in this range. Our muscles are easily trained and made stronger. The more we pedal the easier it is to pedal.

Gearing Up

Gearing determines what amount of force is required at what rpm. The simplest approach is to use a single gear. The gear must be carefully chosen for a suitable force and a suitable rpm. With a constant force applied to the pedals, the power produced is proportional to the square of the rpm. Increasing the crank length is a way to decrease the force required for a given power output at a given rpm. At the end of the day, our legs will tell us if we've found the right crank-length and gear to use.

Where Do the Watts Go?

We should anticipate a smaller electrical yield per banana than the mechanical Watts we produce because of the inevitable losses in converting mechanical power at the pedals into electricity. There are losses due to friction at every bearing, including the pivoting links of the bicycle chain. There is even resistance from the air. Fortunately if you use positive-drive transmission (chains or gears), these frictional losses can be kept very low. Rollers and smooth belts are generally very inefficient and should be avoided. A blocking diode introduces electrical losses because of the voltage drop across it (at half a Volt that's 4% of the power at 14 Volts). The major source of losses in the system, however, is dynamo heat.

Dynamo Heat

A dynamo is a type of generator that uses magnets and motion to induce voltage and current in a conductor. AC current is produced in a closed circuit conductor when the conductor is rotated in a magnetic field (or is stationary in a rotating magnetic field). The phenomena can be witnessed by moving a magnet near a TV and watching the stream of electrons deflect. The magnets can be electro- or permanent magnets. The latter are preferable because they do not require current to maintain their field. They are easily magnetized materials which

maintain a magnetic field for a long time. The conductor generally needs to be coiled in windings to build up a useful voltage. Any conductor has some resistance and that resistance is responsible for the unpleasant, but inevitable, dynamo heat. These winding losses can be calculated by multiplying the winding resistance in Ohms by the amperage squared. For instance, with a winding resistance of one Ohm there is one Watt of dynamo heat at one Ampere and 100 Watts of dynamo heat at 10 Amperes. Thus the losses to dynamo heat increase from 7% at one Ampere to 42% at 10 Amperes (assuming a 14 Volt charging voltage).

Here's how it's figured: if you're pedaling enough to put one Ampere of current into the battery, the battery is getting 14 Watts (1 Amp x 14 Volts), while 1 Watt ($[1 \text{ Amp}]^2 \times 1 \text{ Ohm}$) is wasted as heat. You produce 15 Watts, but only 14 Watts go to the battery, while 7% (1 Watt/15 Watts) is lost. Ten Amperes into the battery is 140 Watts, with 100 Watts ($[10 \text{ Amp}]^2 \times 1 \text{ Ohm}$) or 42% (100 Watts/240 Watts) wasted as heat. This decrease in efficiency will actually be even worse when the increase in the resistance of the wire windings with temperature is taken into account. One nice side effect of this decrease in efficiency is that it justifies not pedaling too hard. Multiply the dynamo efficiency by the mechanical Watts to calculate the electrical Watts into the battery.

Dynamo Dementia

Two curved, ceramic permanent magnets in a steel tube form the body of the dynamo. The tube completes and thus strengthens the magnetic field in which the rotor rotates. The windings on the rotor transfer current to the external circuit via carbon-copper brushes at the commutator. The commutator produces DC current by reversing the connections to the circuit at the same instant the direction of the induced current reverses in the loop. The brushes should last over ten years in this application as they last two or three years on a windmill. The brushes do not seem to add much mechanical friction. The winding resistance of the dynamo measures over one Ohm when at rest and varies with the rotor orientation. The actual working winding resistance when the machine is in motion is not known. I have briefly measured a maximum of 15 Amps at about 15 Volts going into our batteries. I can't maintain even 10 Amps for long, and the dynamo just heats up, so I don't bother. We think the system represents a good compromise between efficiency and cost for this application.

The Ultimate Hand-built Dynamo

I recently purchased an amazing book from New Zealand called *The Homebuilt Dynamo*, by Alfred T. Forbes.

Human Power

Words and hundreds of photos show how to build the ideal dynamo for pedal power from scratch! The author charges a 65 Ampere-hour, lead acid, 12 Volt battery for about an hour a day (two in winter) at 8 Amps to provide all the fluorescent lights needed for his home. The dynamo is large, the parts are not cheap, and the construction looks like a challenge. But the winding losses are low right on up to 10 Amps of charge. You can get the book for \$65, shipping included, from Todd-Forbes Publishing, P.O. Box 3919, Auckland, New Zealand.

It's Only Natural

Pushing pedals can make the difference for a battery-based alternative energy system. Typical residential transformers are always using about 28 watts of electricity. Pedaling into the utility grid seems futile. Alternative energy enthusiasts spend large amounts of money in efficient appliances, PV panels, and other hardware. A few weeks of cloudy weather doesn't have to spoil that investment. We want to keep our batteries charged so they will last a long time and be ready with power. When the sun is gone, we have reason to pedal. I strongly recommend this type of battery charger. Without any sun, it's often more pleasant indoors anyway, and pushing pedals can help to push both morale and battery voltage a little higher.

Access

Author: David Haaren, POB 6, Westminster Station, VT 05159 • 802-722-4122. Kits: Pedal Systems, same address

Reference

Bicycling Science by Frank Rowland Whitt and David Gordon Wilson. The MIT Press. Second Edition. 1982. This book is an interesting look at the physics of bicycling and body power.



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Bicycle Powered Generator



I skim a few Usenet newsgroups daily, among them [misc.survivalism](#) and [alt.energy.homepower](#). Frequently posters on these two groups will inquire about generating electricity using a stationary bike coupled to some sort of generator. Most replies are to the effect that while it's possible to do this, the amount of power output by such a rig when pedaled by the average person wouldn't be worth the effort. I wasn't convinced that this idea was a lost cause. I decided to build one and see how well it worked.

Because bikes are made in a range of sizes to match their rider's stature I wanted to build the generator as an accessory which could be driven by any ordinary bicycle. I used to work in a bicycle shop when I was 13 and remember seeing the owner, Mr. Hank, ride his track bike on a set of rollers. While I was looking through bike accessory catalogs for rollers that I could adapt to my purposes I came across another similar device called a training stand. While rollers require a lot of skill to ride because there is nothing but the gyroscopic force of the spinning wheels and the rider's balance to hold you upright, a training stand clamps on the rear axle of the bike and keeps you vertical.



To make a long story short I bought the most versatile training stand I could find and then did extensive modifications to the roller assembly. Originally the ball bearings were pressed into the bore of the roller at the outer ends. The roller assembly spun on a stationary axle fixed to the frame. The end of the roller, opposite the integral three pound flywheel, drove the hub of a centrifugal clutch. The shoes of the clutch engaged a stationary drum which provided resistance increasing with speed. I had to make a new axle which is locked to the roller and move

the bearings to machined aluminum plates outboard of the steel frame. The plates are made to a standard NEMA 42 size and provide the mounting surface for a permanent magnet DC motor that is driven as a generator through a flexible coupling. The other end of the axle exits from the bearing through an identical plate and is available for PTO use. You can see a black sprocket on that end of the axle in the pictures. I also had to weld in a brace to stiffen up the frame to allow carrying the extra weight of the generator. I'm pleased with the result. Even under heavy load it runs cool and relatively friction free. The part of the frame that clamps to the rear axle of the bike pivots with respect to the ground so that the rider's entire weight forces the tire into contact with the roller

reducing slippage to a minimum. The black object under the front wheel is a contoured plastic block that levels the bike to avoid the feeling of riding downhill.



I have done quite a few tests to see how much output power could be produced and what practical applications there were. See the tables below for a list of those tests and the results. In summary I think the most practical application of the bicycle powered generator would be battery charging. This application presents a constant load to the rider which allows them to select a single gear ratio which lets them pedal at their optimal cadence. Another practical application is running small appliances and tools which use universal series wound motors or permanent magnet DC motors. All of the motorized items in the table below have universal series wound motors and would run on DC even though their nameplates all said "120 Volts AC Only". Induction type motors such as those found in washing machines and shaded pole motors which are used in clocks really are AC only and won't work at all. I couldn't get my variable

speed drill to work, probably because the speed control electronics are incompatible with DC. Good candidates are appliances or tools that can perform their functions with 300 watts of input power or less and which present a narrow range of loads such as the mixer and electric drill. Although producing heat with electricity is usually a bad idea, I think that small soldering irons might also work well since they are almost all are under 100 watts and most are less than 50 watts. Since there is no voltage regulation at all, connecting the generator output directly to the power input jack of battery powered TVs, radios, and similar devices will probably destroy the sensitive electronics. Use the generator to charge the batteries, and power the electronics from the batteries. Since the generator is capable of outputting several amps it may be best to charge only batteries that can accept a charging rate in this range, and then building an efficient switchmode regulator to charge smaller cells and batteries off of the large battery. The final, and as yet unexplored, application is hitching mechanical loads such as a water pump or grain grinder to the PTO end of the axle using roller chain. I expect a lot more useful work out of this arrangement as it avoids the inefficient conversion of the rider's mechanical energy into electricity and then back to mechanical energy via electric motors. Using 27" tire diameter on the bike and a 10 MPH "road speed" the roller will turn at about 2600 RPM. The sprocket shown is the smallest I could find at 9 teeth for 1/2" pitch #41 chain, so you would need to figure from there what size sprocket you need on the load to give the desired load RPM. One suggestion that came up during testing was to drive a heavy flywheel to dampen out electrical load variations, but that was never tried.

Electrical Tests:

Load	Output	Comments
Open Circuit	230 Volts DC	Spinning it as fast as possible in the highest gear that the test bike had and measuring the output with a DMM.
Short Circuit	4 to 5 Amps DC	Generator output shorted by the DMM on the 20A DC scale. This measurement doesn't mean much because it took a lot of torque to turn the generator against a short circuit. It was hard to get consistent readings due to the speed fluctuations from the low rate of pedaling that could be achieved.
2 Ohm Wirewound Resistor	5.5 to 6 Volts DC (15 to 18 Watts)	This test had the same problem as the short circuit current test, the load impedance was too low to allow the rider to pedal effectively.
65 Ohm Wirewound Resistor	100 Volts DC (150 Watts) Continuous, 130 Volts DC (260 Watts) Peak	The continuous figure is what the rider felt he could keep up for 15 to 30 minutes. The peak value was a few second burst of speed.
100 Ohm Wirewound Resistor	100 Volts DC (100 Watts) Continuous, 150 Volts DC (225 Watts) Peak	The difference between this test and the previous one could be variability of effort on the part of the rider, perhaps as a result of fatigue. Another possibility is impedance mismatch between the source (generator) and load. The generator has a very low output impedance and the ideal load would be the lowest resistance that will still allow the rider to pedal at an effective rate.

Practical tests:

Load (Nameplate Data)	Results	Comments
Battery Charging	Great	Able to push a continuous 4 to 6 amps into a 12 Volt automobile battery. The best setup was to put a rectifier diode in series with the generator output. This stopped the battery current from driving the generator backwards and enabled the rider to start pedaling without any initial resistance. It was then possible to take up the charging current load gradually as the generator output exceeded the battery voltage plus the forward voltage drop across the diode.
Waring Multispeed Handmixer	Good	Moderate pedaling effort was required to run this appliance up to operating speed. I loaded the motor by trying to slow the rotation of the beaters by hand. There was plenty of available torque to use the mixer in its typical applications. I'm certain that similar appliances such as blenders and food processors would work just as well.
Black & Decker 3/8" Drill Model 7104 Type 1 (2.9 Amps 1200 RPM)	Fair	Lots of 1/4" holes were drilled through a 2" thick piece of framing lumber with a standard high speed twist drill and I'm sure that larger holes would be possible. The only special consideration was to ensure a steady feed rate while drilling to avoid load fluctuations.
Black & Decker 7-1/4" Circular Saw Model 7308 Type 5(1-1/2 HP 9 Amps 1200 RPM)	Poor	Considerable pedaling effort was required to get the saw up to operating speed and it bogged down to a standstill when a cut through a 2 x 4 was tried. We might have been able to cut 1/4" plywood or luan. I think the problem is that the motor in this tool is designed for maximum power output regardless of conversion efficiency. I'm sure a person has enough power to saw a board, after all, I can do it with a hand saw using only the muscles in one arm! I would like to try this test with a saw designed to run efficiently on DC such as the battery operated ones made by DeWalt.
McCulloch ElectraMac Chainsaw Model EM14ES (2 HP 11Amps)	Useless	This tool's motor has the same characteristics as the circular saw. It was impossible to get it up to full speed, and the blade merely bounced off the surface of the log and stalled when any meaningful cutting force was applied. The nameplate claimed 2 horsepower and the motor's size was perhaps 3" in diameter and 6" long.

Acknowledgements:

During my "what if" phase of research on the internet I was directed to David Butcher's [Pedal Generator](#) page which provided me with the proof of concept I needed to justify building my own

version of a bicycle powered generator. I think my results correlate well with his.

I would also like to thank my long time friend Mike who spent several hours with his Paramount mountain bike clamped in my contraption pedaling diligently while I measured and fiddled around. For reference he is in his mid 50's, in good physical health, a non-smoker and semi-regular recreational cyclist, so you can scale your own expectations accordingly.

THE HOMEBUILT DYNAMO

DYNAMO DESIGN AND CONSTRUCTION WITH CERAMIC MAGNETS

by Alfred T. Forbes

All Photographs, Drawings and Other Illustrations
by Alfred T. Forbes

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The Homebuild Dynamo

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the **Human Power Generator System** is small, portable, and dependable - perfect for emergencies, power failures, remote locations, and off-grid applications. It can be pedaled or cranked by hand to charge 12 volt batteries and run small appliances. Incorporate it into your existing 12 or 24 volt system or simply plug your 120 volt appliance into the Human Power Generator System outlet and start pedaling. It's as easy to operate as an ordinary bicycle.

The Human Power Generator System comes equipped with the Human Power Generator (pictured at left) and a stand-alone Portable Power System which includes: storage battery, 200 watt inverter (with 300 watt peak power), LED battery voltage readout, connection cables, and a 120 volt outlet to

turn your calories into useful power. All you need to do is plug into the Portable Power System outlet with your standard AC or DC lights or appliances. To keep your system charged, you just hook up the Generator to the Portable Power System, and pedal...it's the same way you would recharge an ordinary battery, except you provide all the power! The typical average continuous power that can be generated by pedaling the Human Power Generator is up to about 75 watts. The maximum amount of power that an average human can generate *sustainably* is about 125 watts. Up to 1,500 watts can be generated in short spurts. The maximum power obtainable through hand cranking typically is about 50 watts. The pedals and optional hand-cranks are interchangeable.

Though even the *Tour de France* winner could not run an entire household's electrical appliances with it, the Human Power Generator System can give you a boost when and where you need it most (charge your car or boat battery, recharge portable electric tool batteries, run emergency back-up lighting, run your PC at your remote cabin). You can maximize the use of your Human Power Generator System by retrofitting your home with compact fluorescent lighting and energy efficient appliances.

Easy to use and great exercise, the Human Power Generator System will give you a first hand idea of exactly how much energy it takes to run household lights and small appliances.

[Go to Technical Information](#)

Stock No. 454211, Stand-Alone Human Power Generator \$497 [Order Now](#)

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technical information**human power generator system**

The Human Power Generator System can be used for **charging batteries** or for running **lights and appliances**. To operate standard 120 volt ac lights and appliances plug directly into the outlet on the Portable Power System. If you choose to use the Human Power Generator without the Portable Power System, 12 volt dc lights and appliances can be connected directly to a small battery (for stabilization) in a circuit with the stand-alone Human Power Generator.

measurement of human power

The typical average continuous power that can be generated by pedaling is about 75-125 watts, or one-sixth horsepower, more or less, depending on the weight, strength, and endurance of the person pedaling. Higher power, up to as much as 1,500 watts, can be generated in short spurts. The maximum power obtainable through hand cranking is more a function of strength than of weight, and is typically about 50 watts.

The power in watts is equal to the generator output voltage multiplied by the output current in amperes. Pedal or hand cranking power can be measured by connecting a voltmeter and ammeter into the generator circuit, and by multiplying the readings together. For instance, if the voltmeter reads 12.5 and the ammeter reads 10 amperes, the power being generated is 125 watts. To convert watts into horsepower, divide the number of watts by 746. In this example, 125 watts would be equal to $125/746=0.17$ horsepower.








When the Human Power Generator is used to charge a battery, the approximate power can be read directly from the ammeter alone, by assuming the voltage to be that of the battery. In the case of a 12 volt battery, whose terminal voltage is typically 12.6, a 0-10 ammeter scale can be overlaid with a 0-125 watt scale, or even a horsepower scale.
more power to you!

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PEDAL POWER



Aaron Dahlen

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The author in his livingroom powering a 31 inch (79 cm) TV. Notice the volt meter on the floor. Voltage should be monitored to prevent damage to the inverter.

Getting into a regular exercise program isn't easy. My solution was to permanently connect my television to a pedal-driven generator. The machine born out of this idea turns out to be quite useful, providing over 100 watts of power (depending on your strength). I use the generator to power a TV, but it could have many other uses: lighting, charging batteries, and powering small appliances.

The Bicycle

Since the primary use of my machine was to power a TV, I wanted to be as comfortable as possible. I purchased a recumbent exercise bicycle, and it turned out to be a good choice. As a plus, it uses standard bicycle parts. I had no problem converting it from belt to chain drive.

Don't underestimate your strength when purchasing a bicycle. After about forty hours of use, the crank on my exercise bike fell off the frame. I made a quick trip to a welder, and was back to pedaling.

Generator #1

Selecting and installing a generator was the most challenging part of building the machine. I tried three different types of generators. The first generator I tested was a large 36 VDC motor. It develops 50 watts (at 12 VDC), with a shaft speed of about 100 rpm. Most permanent magnet DC motors make good generators.

The motor was salvaged out of a large battery-powered floor buffer machine. A standard 43 tooth bicycle sprocket on the recumbent bike coupled to a 20 tooth sprocket on the generator completed the transmission.

Generator #2

Generator #2 was actually a car alternator mounted in a professional-grade exercise bicycle. The results with this alternator were disappointing. It took all my physical strength to power the 31 inch (79 cm) television. My opinion—don't bother with car alternators!

Automotive alternators are not self-starting. A separate power source is required to "flash the field." In normal operation, the car battery provides field excitation. For this application, I temporarily connected a 12 VDC battery to the output of the alternator. The battery was disconnected once the alternator was functioning.

The power consumed by an alternator field winding is inversely proportional to the speed of the alternator. You

must keep the alternator rpm high, or the field winding will consume a significant portion of your pedaling power. This makes for a difficult machine to pedal. If you slow down, your pedaling is almost guaranteed to stop.

A battery connected to the output of the alternator would prevent the machine from stopping. However, you would have to remove the battery when done exercising, since the field winding would drain the battery. Also, when a battery is connected, voltage must be maintained religiously or battery damage will result.

Generator #3

Generator #3 was salvaged out of an electric wheelchair. This unit is a beautifully machined, 1/4 horsepower, 24 VDC motor. It is mated to a 10:1 gear reducer which contains two bevel-cut gears. The gear box is then connected to the main pedal crank via a 1:2.8 ratio (15 to 43 tooth sprockets) sprocket and chain set.

Of the three generators I have experimented with, this one works the best. Detailed side-by-side comparisons with the other generators are found in the table on page 73.

The Chain

The local machine shop was not able to provide bicycle sprockets or chain. However, they did have #41 chain and sprockets. Bicycle chain is about the same as #41, but bike chain is half the width. I purchased 10 feet (3 m) of #41 chain and the sprocket. It worked, but the chain twisted and moved around a lot on the crank sprocket.

I had two choices—machine the small sprocket to accept the smaller bicycle chain, or widen the larger crank sprocket. Surprisingly, it was easier to widen the crank sprocket. Since the #41 chain is twice as wide as bicycle chain, I simply added another 43 tooth sprocket. The sprockets are mounted side by side with no space between them.

To mount the sprockets, I first removed the crank from the frame, and then the bearing cone. I mounted the new sprocket flat next to the old one, and aligned the teeth. Only one sprocket needs to contact the pin on the pedal. I then reinstalled the sprockets. With the two sprockets side by side, chain twisting and movement was eliminated.

The pedal and crank set used in this project is often found in children's bicycles. The crank is a one piece design. You won't find these parts on a 10-speed bike.

DC to AC

Given the choice between an AC or DC load, I recommend AC. It's true that DC takes the 90 percent



Generator #3, capacitors, and inverter mounted and ready to install. A 1/2 inch (13 mm) thick aluminum plate serves as the base. The generator is bolted on while the capacitors and inverter are held on with Velcro.

efficiency of the DC to AC inverter out of the equation. But running pure DC removes the regulating function of the inverter. Without this regulation, a DC load can easily be damaged.

If DC devices are to be powered by the pedal generator, I recommend a 12 VDC lead-acid battery be installed instead of the capacitors. A battery will smooth out the voltage fluctuations. If your pedal effort is insufficient or if you pedal too fast, the battery will limit the minimum and maximum voltages.

In my project, a 300 watt Tripplite brand power inverter converts the 12 VDC to 120 VAC. I connected the inverter directly to the generator, but found the results unacceptable. Humans do not pedal at a constant

Close-up of the side-by-side sprockets. The white sprocket is behind the chrome sprocket.



torque. Maximum torque is delivered on the down-stroke, resulting in a voltage surge twice each revolution. There is also a period (twice each revolution) where no torque is produced.

This produced wild voltage fluctuation on the output of the generator. These voltage fluctuations are passed through the inverter to the load. I found the television picture width changing with each revolution—not good. It was annoying, and would probably result in a damaged TV.

A mechanical flywheel would have solved the problem, but it would have added weight and complexity. Instead, four 56,000 microFarad (μF) 15 VDC capacitors were installed in parallel with the motor and inverter. This eliminated most of the voltage fluctuations. The car audio folks also make a single capacitor that is perfect for this application. It is rated at 0.5 Farads at 15 VDC.

The voltage delivered to the inverter must be monitored. Ideally the voltage would be held at 13 VDC. In actual use, input voltages as low as 11 VDC or as high as 18 VDC will work. But the voltage must be maintained above 11 VDC. If it drops, the inverter will “flutter,” turning on and off rapidly. If this is allowed to continue, the inverter and TV could both be damaged. The maximum voltage should also be monitored. With a light load on the generator, the voltage will easily rise to over 20 VDC, damaging the inverter.

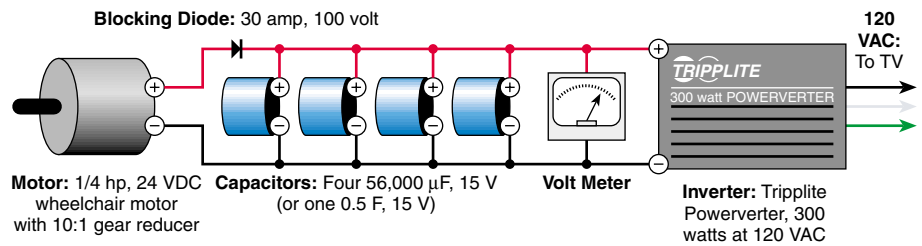
Remember, you are the regulator! You must monitor voltage and adjust your pedaling effort accordingly. Maintain as close to 13 VDC as possible. If you find yourself pedaling too fast or too slow, adjust the gear ratio by purchasing a larger or smaller sprocket. If you find that you can't maintain voltage, change to a smaller load.

Pedal-Powered Generator Costs

Item	Cost Range (US\$)	
	Low	High
Exercise bicycle	\$150.00	\$400.00
Generator	100.00	1,500.00
Inverter, 300 watt	75.00	150.00
Misc. electrical and hardware	50.00	50.00
Bass boost capacitor, 0.5 F*	49.95	49.95
Chain, #41, 10 feet	16.35	16.35
Sprocket, #41 (9 to 20 teeth)	7.64	16.17
Second sprocket for crank	Gleaned	
Total	\$448.94	\$2,182.47

* Used in high-power car audio applications.

Pedal-Powered Generator Wiring



Inverter Modifications

The inverter will have to be modified. I found this out the hard way. After two hours of operating at 16 VDC, the cooling fan died. It was rated at 12 VDC. Then the next week, the inverter's 16 VDC capacitors exploded!

The Triplite inverter had two electrolytic capacitors that required replacement. They were easily identified by their 16 VDC rating. I recommend replacing these capacitors with 25 VDC units available from Digi-Key. Using a micrometer, measure the installed capacitors. Purchase capacitors of the same physical size as found in the 25 VDC section of the catalog. The rated value (μF) will be smaller than the capacitor you removed, but that won't cause problems. These modifications will void the inverter warranty.

I've had no problems in over 150 hours of use since I replaced the capacitors. And I don't anticipate further problems, since the inverter is running at less than 50 percent capacity and displaying no signs of overheating, even with the cooling fan removed. Most inverters in this class are identical in circuit layout and function. If possible, find an inverter that does not have an internal fan.

The Television

I started pedaling using a 19 inch (48 cm) Sony Trinitron, model number 20S42. The picture was perfect; there were no interference problems from the inverter. After greatly improving my strength and stamina, I am now able to pedal a 31 inch (79 cm) RCA television, model number G3164CK.

All color TV sets are sensitive to magnetic fields. These fields cause color abnormalities and strange picture distortions. The purpose of the degaussing coil in a TV is to nullify the effects of these magnetic fields. You can hear it operate as a loud 60 Hz buzz for a moment when a TV is first turned on. The coil consumes a large amount of power—several times more than the TV set requires in normal operation.

There are a couple of options to getting around the difficult startup:

- A. Use a smaller TV. The degaussing coil is smaller and requires less power.

- B. The degaussing coil on most TVs will not activate again if the unit loses power for less than 30 seconds. To trick your TV, perform these steps:
1. Connect the TV to main 120 VAC power.
 2. Turn on the TV and let it warm up.
 3. Unplug the TV—Do not turn it off!
 4. Turn the pedal generator inverter off.
 5. Connect the TV to the pedal generator.
 6. Start pedalling, and get up to normal speed.
 7. Turn the pedal generator inverter on.
 8. Watch TV!
- C. Live with the hard startups. This could cause damage to the TV and or the inverter.
- D. Modify your TV by disconnecting the degaussing coil. *This is a dangerous operation and should be undertaken only by experienced personnel.* The accelerating power supply in a TV is usually over 20,000 VDC. This lethal voltage may be present, even with the TV unplugged! The high voltage power supply can also retain a charge for hours. It only takes one mistake and you'll never make another. Unfortunately, disconnecting the degaussing coil is not something you can have

done at a TV shop. The TV set cannot be moved after this modification is made, since the magnetic fields of the earth could magnetize the picture tube causing distortions.

Performance

Before you connect a TV or other sensitive load to your generator, you should know your limits. Purchase several 25 W, 120 VAC light bulbs. Start small; connect one 25 W bulb to the output of your inverter. Pedal for twenty minutes. If this is easy, add another bulb the next day.

Try to do this at least three times a week. When you know how much power you can develop and you are comfortable with your generator, then and only then connect up a TV. Make sure that the TV you select requires less power than you can develop.

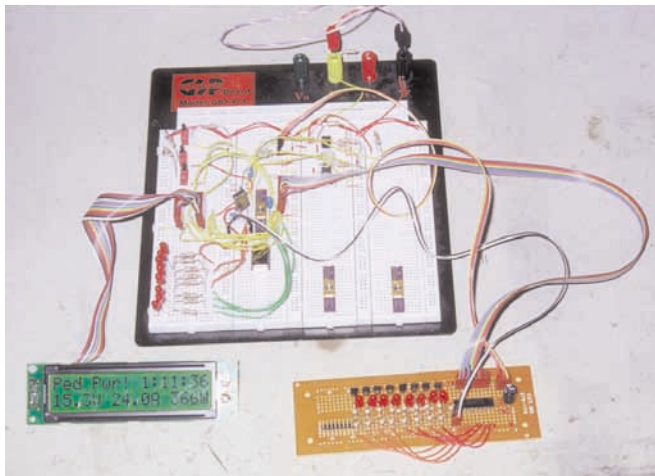
Newer TVs will require less power than older sets. The power requirements as found on the back of a TV are usually maximums. For example, my 31 inch (79 cm) TV is rated at 140 W; actual power consumed in operation is about 90 W.

Output power is dependent on your strength and stamina. I am 28 years old, 6 feet 2 inches (188 cm) tall, and in excellent health. The first night I had the pedal generator operating, I was able to power the

Pedal-Powered Generator Comparison

	<i>Generator #1</i>	<i>Generator #2</i>	<i>Generator #3</i>
Efficiency	Best	Poor	Good
Regulation	Fair (manual)	Best (electronic)	Good (manual)
Noise	Fair Brush noise.	Fair High speed alternator and transmission noise.	Good Dominated by chain.
Cost new*	\$500	\$100	\$1,500
Strength	Good Take care not to drop this heavy motor as the magnets will be easily damaged.	Best The alternator was made to operate in an inhospitable environment. Virtually bulletproof.	Good No problems encountered in 50+ hours of use. Don't drop the motor, or the magnets may be damaged.
Author's recommendations	Good Simple chain drive. If you can find the motor and put up with the weight, this is a good choice. Be careful not to pedal too fast; the voltage will rapidly rise to over 20 volts.	Not worth the effort! Complicated transmission and poor efficiency.	Best Simple chain drive, low noise, light weight, and good regulation make for a simple, functional machine. Avoid right angle gear heads. The worm gears used in these units will result in short life and poor efficiency.

* Cost is an approximation for newly manufactured units. The author spent less than \$50 at a recycling center for all the generators discussed in this article. If you build this project, you may have problems finding similar units. Look for the Windstream Power Systems Inc. advertisement found elsewhere in this magazine. They manufacture a small pedal generator system that can be used as is. Or the crank and generator could be remounted on a bicycle frame.



A work in progress. Microchip 16C73A controlled monitoring and control system, with LCD readout. The circuit in the lower right is the light-tree driver.

Sony TV for half an hour. The back of the TV indicates that it requires 90 watts. I measured 77 W at 16 V, with 4.8 A input to the inverter. Today I am able to power an entire two hour movie on the larger TV, and can do it again the next day!

The maximum power output of my machine is more than I can pedal. As of November 1, 2000, I am able to power a 100 watt light bulb for over an hour without any flickering. I can maintain 150 W for 2 minute intervals, and 210 W for about 15 seconds. These values are all observed by operation of light bulbs at the 120 VAC output of the pedal generator. At best, I estimate the machine efficiency to be 85 percent due to losses in the frame, transmission, generator, and inverter.

Although not required, an ammeter could be added. This will let you do power calculations. Multiply the voltage reading by the current reading to obtain power (volts x amps = watts).

I had always assumed the power consumed by the TV would be constant, but this is not so. Brightly-lit scenes or white backgrounds require substantially more pedaling effort. Remember, you are the regulator. Keep the voltage as close to 13 VDC as possible. If the voltage drops, the inverter or the TV will shut down.

Future Improvements

I want to purchase or build a better frame. The one I am using was never built to stand up to this abuse. The frame flexes with each push on the pedals. Thicker or stiffer metal or a better quality design would work. Also, it would be nice to sit about 10 inches (25 cm) higher relative to the pedals.

I'm also working on a "light-tree" to visually indicate voltage. Voltage, current, and wattage will be shown on an LCD display. Five lamps will provide the light-tree indicating voltage. I based this circuit on a microcomputer. The circuit is mostly complete, and the code has been written and tested.

But this aspect of the project has turned out to be academic. When the machine was first built, I monitored the voltage every minute. With practice, it was unnecessary to monitor voltage all the time. I can *feel* what the machine is doing, and how much power is required.

I'd also like to add an automatic battery assist to take over for quick breaks. If the voltage falls below 11.5 VDC, a PIC circuit will automatically connect a battery to the inverter via a relay. The peripheral interface controller (PIC—microcomputer) is a powerful device. If readers are interested, refer to the Microchip Web site (www.microchip.com).

Thanks

A big thanks to my wife Robin, who assisted in testing and building the machine. Thank you to the people at my local recycling center, where I found many parts at low cost. Without your service, this project would never have been completed.

I hope I've given *HP* readers some ideas about how to design and construct a pedal-powered generator. Please share your results with *Home Power*, and keep on pedaling!

Access

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Home & Heart



Kathleen Jarschke-Schultze

Mainstream America has come to expect and depend on electrical appliances in the home and the kitchen. If it makes housework faster or easier, I am all for it. But what is the trade off in power usage? Self cleaning ovens and frostfree refrigerators are not efficient fuel-wise. Is saving time, and not power, the most important consideration? Not in the RE lifestyle!

Bicycle Grinder

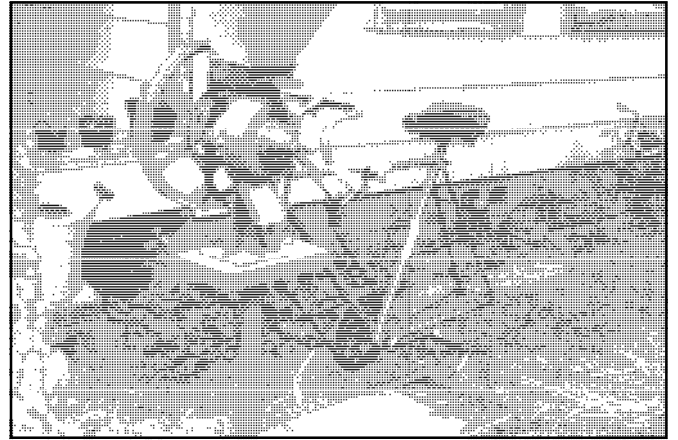
Bruce Johnson and Barbara Hagen of Spencer, OK have been using a bicycle powered grinder for 12 years. It sits on their front porch and gets frequent use. Bruce chose a C.S. Bell #60 mill because of its sturdy construction, with a 1 inch diameter shaft and bearings. He bolted some bicycle sprockets to a large iron wheel which is attached to the shaft. This acts as a fly wheel. The mill is attached to a pedestal on a platform.

He removed the fork from an old bicycle and then attached the front of the bicycle to the base of the mill, using a short piece of pipe and a flange. The rear wheel of the bike is replaced by a stand. A lengthened chain from a 10 speed bicycle couples the pedals to the mill. An old derailleur is used on the slack side of the chain as a tensioner. The chain can be moved by hand to different sprockets for different drive ratios. They use the mill mainly for grinding whole wheat flour. A ratio of one to one works best. If it was a mill with smaller burrs you would probably want to gear it up some.

Flour to Bread

After the wheat is ground to flour, Barbara and Bruce use a hand crank dough mixer. It looks like a two gallon bucket with a dough hook attached to the crank. A five dollar flea market special, the mixer is young enough to have a nylon bearing. All of the ingredients go directly into the bucket. They usually make two loaves at a time. It takes about 30 minutes from when the wheat first goes into the mill until the dough is ready to rise.

Martin Holladay, of Sheffield, Vermont wrote to tell me, "The best book that deals with your question is Pedal Power edited by James C. McCullagh, and published by Rodale Press in 1977." He also sent me excerpts of the book. It has a comprehensive set of instructions on



Above: a bike powered grinder.

building an Energy Cycle foot powered generator. Complete with parts lists and exploded views (I love those) and pictures, the Energy Cycle is designed to be adapted to a builder's recycled materials. When assembled the foot generator can be adapted to almost any machine with cogs or wheels.

Food Processor

Before HP #31 was even back from the printers, I received a hand crank food processor to test. Bob and Golda Maynard, of Energy Outfitters, saw a Kitchenmate™ manual rotary food processor at their local county fair. They were so impressed that they bought one. Now they sell them.

The Kitchenmate™ actually performs three functions. It is a rotary chopper, a rotary beater, and a salad spinner. The main bowl is only slightly smaller than my electric processor's. I have used the beater to make salad dressings and a garlic mayonnaise or aioli. There is a well in the lid to pour your oil into so that it dribbles into the mixture slowly, freeing your hands for cranking the beater. It works very well. For homemade salsa or chopping onions (or garlic, or shallots) it works great. You have to coarsely chop the veggies first, but I have to do that with my electric model too. The salad spinner option is really kind of small for a family sized salad, but is perfect for washing and spin drying fresh herbs.

The unit is made of sturdy impact resistant plastic. It washes up very easily and doesn't take up much space. Since the top locks on to the bowl, it is easy to handle without spilling or a lot of unnecessary movement. It has been worth the \$19.95 price to me.

Lehman's

Several readers have called or written to give me the access on a company called Lehman's Hardware.

Home and Heart

Apparently they have a whole catalog of non-electric appliances and tools, including a selection of mills and bread dough mixers. I am told they supply the Amish communities with products which fit into their simple lifestyle. I have sent for the catalog but have not received it yet. Again readers have assured me that Lehman's has always been a good company to deal with. I am eager to get their literature and see what they've got that I need (or want).

Access

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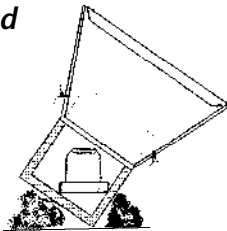
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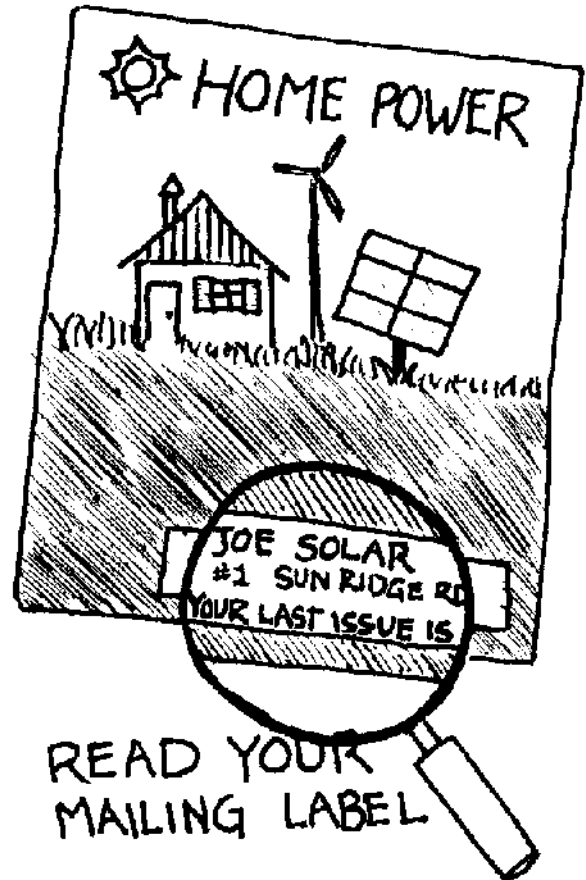
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RENEWAL NOTICES



Your mailing label has the number of the last issue of your subscription. We don't send out renewal notices, so keep an eye on your label to be sure you don't miss an issue — the HP Crew

Driving a Wringer-Type Washer • The non-automatic washer, which was common up till the middle or late 1950s, has possibilities as a pedal-power laundry machine. These wringer machines are available from Sears and other sources. The motor frequently drives a belt system. The pedal-power primemover can be substituted for the motor in this case too.

You must constantly bear in mind whenever you plan to use the primemover as a substitute for an electric motor that you must gear or belt up to a speed which matches the electric motor's normal speed. About 40–60 pedal rotations per minute is a comfortable rate on a bike. The washing machine of this type normally has a 1,800 rpm motor. The pedals' rpm must be geared up by $\frac{1800}{60} = 30:1$

Speed Changing • To figure out speed ratios, work like this:

Assume 60 rpm is your normal pedal speed. Most people will find that 50–60 rpm is comfortable. If you can find the machine's motor name plate, it will give you the horsepower rating and rpm. Don't attempt to power a machine which has more than a one-third horsepower motor. No one can produce that much power except in Olympic effort. Stick to jobs of one-fourth horsepower or less.

If the rpm of the motor is more than 1,800, the gear up ratios will be too great to operate. As the ratio increases, so do the losses and it can reach the point at which the losses in the belts, pulleys, and bearings are equal to one-half the power developed. Look over the mechanism which you intend to drive and see if you can get into the drive train someplace that gives you a direct ratio.

For example, I have a Polish-made grain grinder which is designed to operate at about 60 rpm. The motor I had was a 1,800 rpm so I had to step the motor down by 30:1 to go to 60 rpm. Now, to get 30:1 you basically need a 1-inch pulley. Generally speaking, this is out of the question because a 30-inch pulley is large and a 1-inch pulley is so small the belt has too small a radius to curve around and not enough friction area to effectively transmit power.

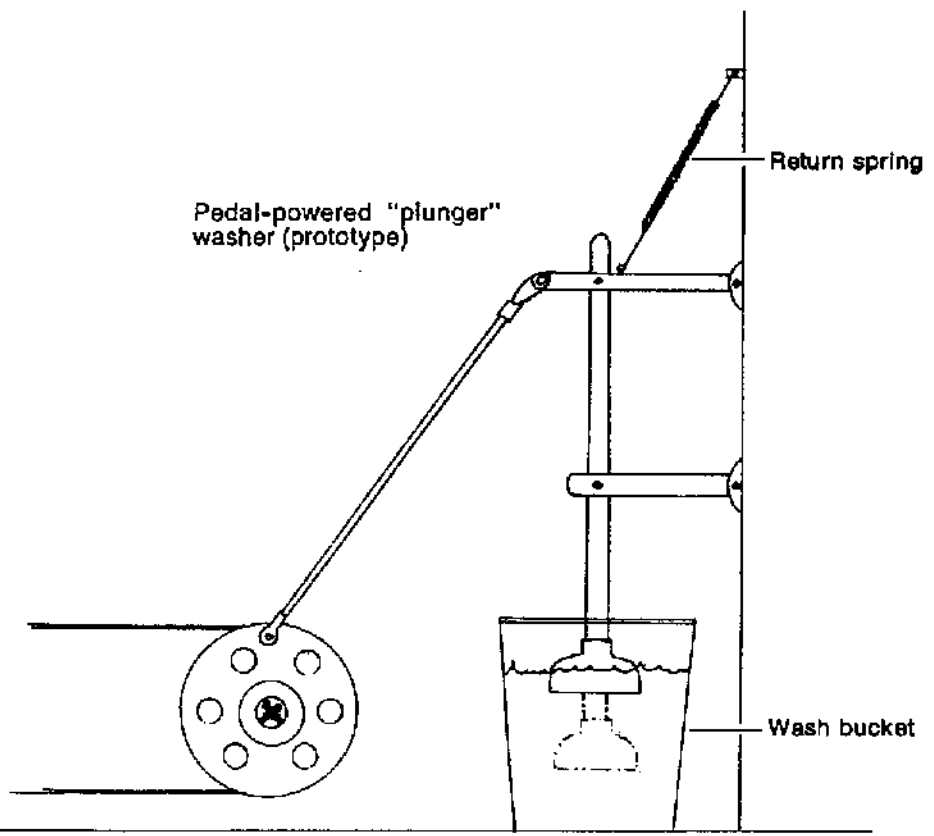
The answer is a two-step reduction, 1:6 and 1:5, which is easy to do. The losses here are greater than with a single reduction; however, the system is much more compact.

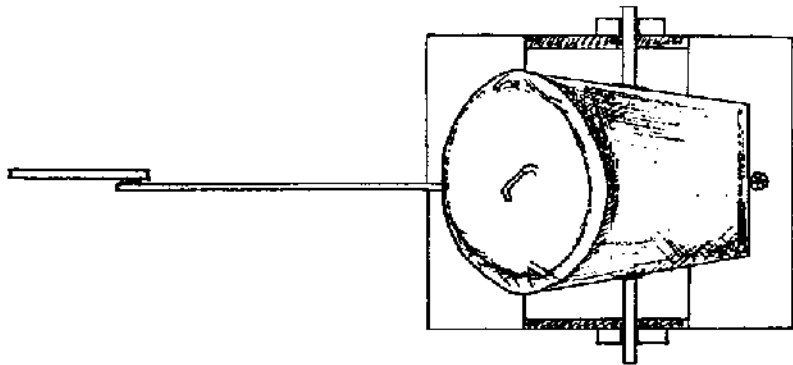
To replace the motor with a pedal system here would be ideal. A direct one-to-one drive will do nicely. It is not wise to go up to motor speed with a speed increase and then back down again by a like amount when you should have gone directly or nearly directly. Analyze your problem.

Pedal-powered "plunger" washer (prototype)

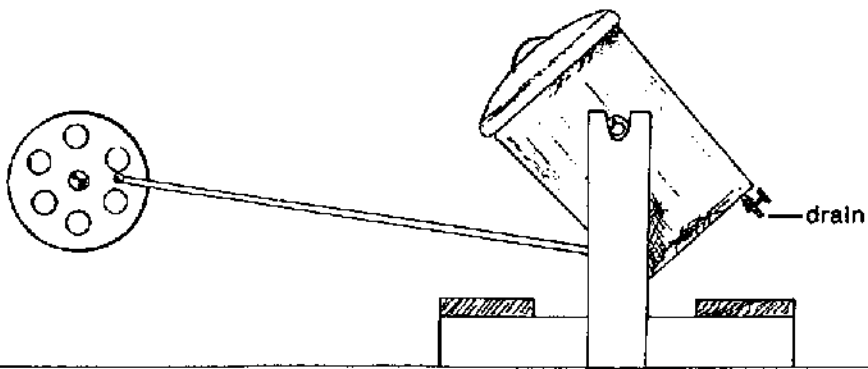
Return spring

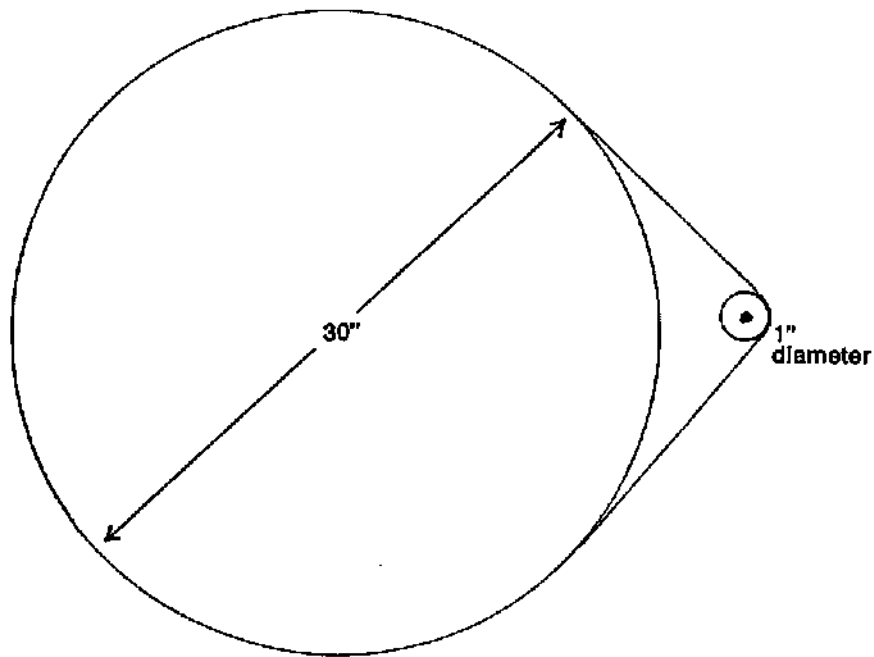
Wash bucket



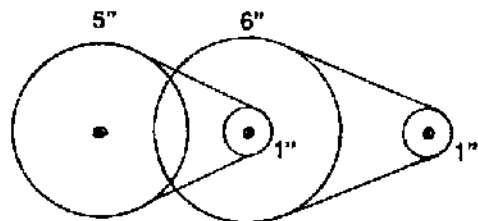


Trash can washing machine





30 to 1 not practical



30 to 1 in two steps

Pulley system

10. HAND-POWERED WASHING MACHINE

The hand-powered washing machine shown in Figure 1 is the drum type much like models used in public "washerterias." This revolving drum is more efficient than the agitator type, uses less water, and therefore less soap or detergent.

The drum fits into a square galvanized iron washtub obtainable at most hardware stores. Get a tub that measures about 20×20 inches if you can. Dimensions are not given for the drum, as these are determined by the size of the tub you choose. The drum which fits into the tub should clear the sides by about an inch. The drum is supported by short lengths of pipe, threaded at one end, and screwed into pipe flanges.

Two or three "baffles" of 1×4 lumber should run the length of the drum inside and be fastened to the slats. Space them uniformly around the interior. As the drum revolves, these baffles lift the clothes, and drop them back into the water thus providing the washing action.

The hardwood, oil-treated "bearing" can be secured to the tub by wood screws or stove bolts. If the tub has sloping sides, you should wedge shaped spacers between the bearing and the tub to make a neater job.

The slats around the drum should be fastened with wood screws, and the space between the slats should not be so large as to let small items like children's socks escape. When not in use the drum should be removed and allowed to dry. The wooden drum will probably tend to float, so a hole is drilled horizontally in each bearing just above the pipe support. Push a large nail through each of these holes to hold the drum in place.

Three suggested methods are shown for draining the tub (Figure 2). A will give the most complete drainage without tilting the tub, but a depression must be neatly beaten into the bottom of the tub. In all three methods pipe locknuts are used. Locknuts have a depression surrounding the threaded opening and packing can be put in this depression for a tight joint. Thick paint, putty, or caulking compound can be used as packing. In A and B water can be confined by placing a cork or plug in the end of the pipe or attaching a valve. The combination fitting allows connection to a garden hose. If the washer is used out-of-doors, a metal supporting frame may be used, and the water can be heated in the tub by means of the portable stove described earlier (page 31).

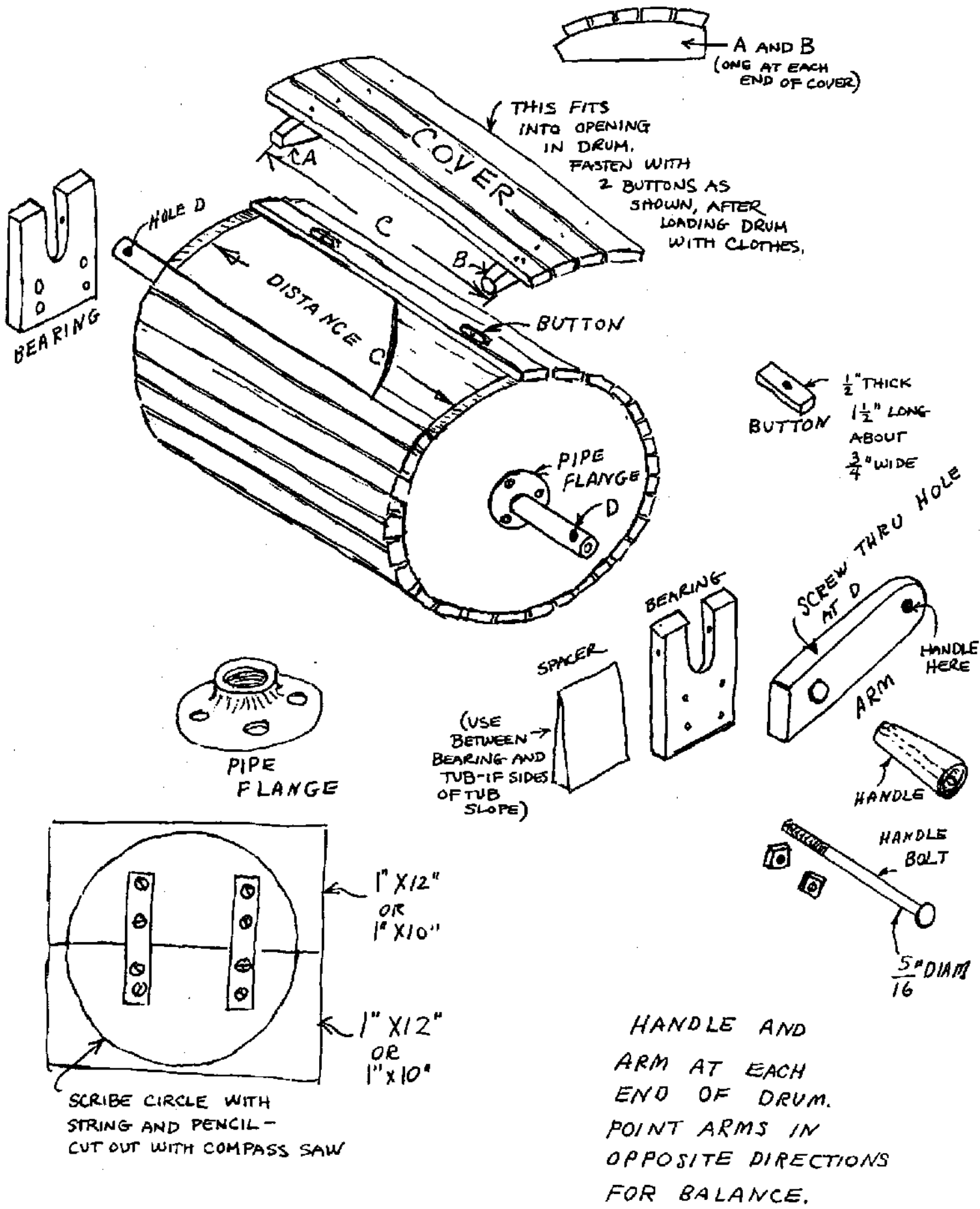
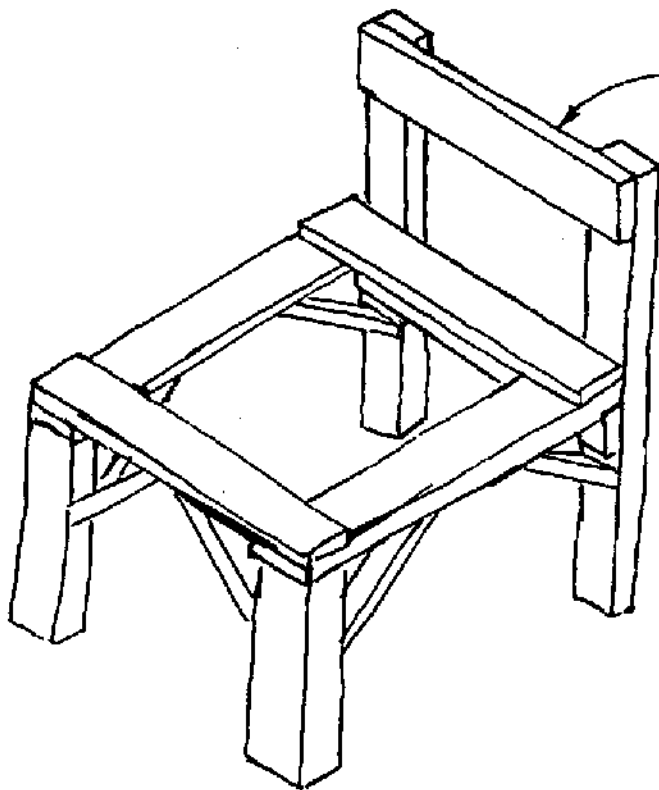
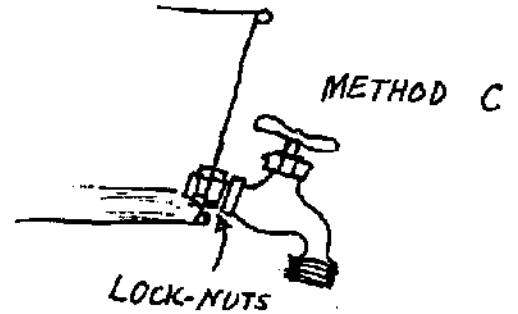
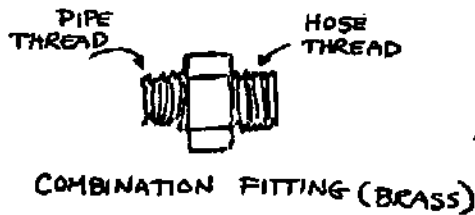
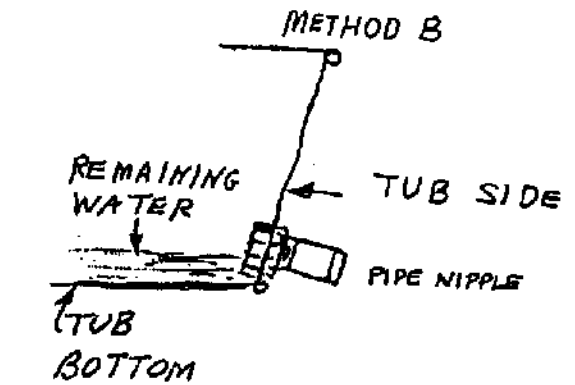
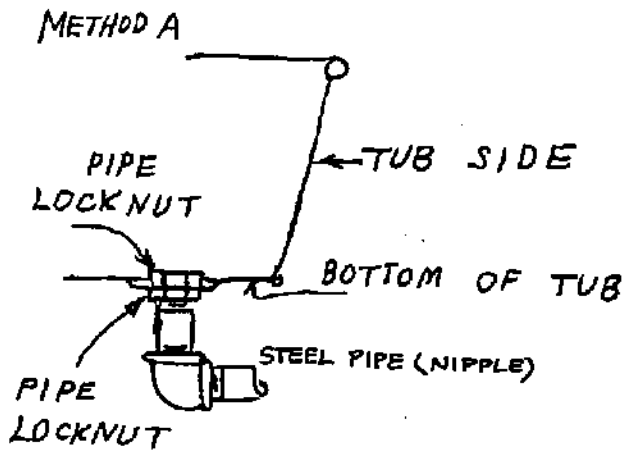


FIG. 1



SUPPORT FOR RUBBER
ROLL WRINGER
TUB SHOULD BE
PLACED AGAINST THIS
SUPPORT.

WATER FROM WRINGER
WILL THEN DRAIN
BACK INTO TUB.

TUB STAND AND WRINGER SUPPORT FOR HAND POWERED WASHER

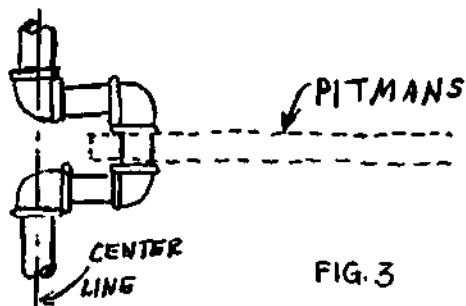


FIG. 3

Some people prefer the crank type where the foot is moving back and forth to keep the wheel in motion. A crank can be made up of pipe fittings as shown in Figure 3. Joints must be screwed up tight and care should be taken to see that the two parts of the shaft line are up along the same center line. There will be more friction in this type of construction.

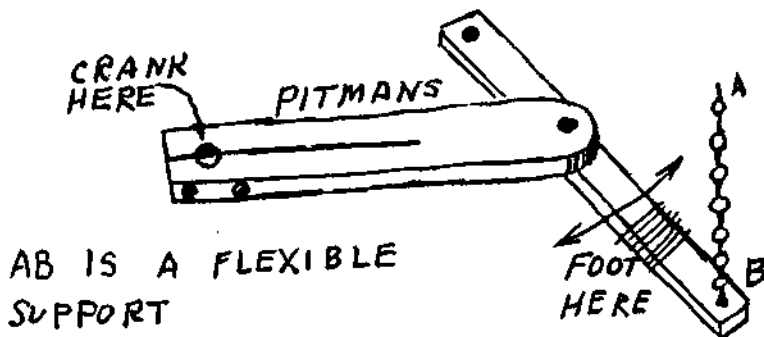


FIG. 4

The pitmans and kickbar shown in Figure 4 should be of oak. A slot in the pitmans allows it to be sprung over the crank. The pipe surface coming into contact with the pitmans should be well polished to reduce friction and wear.

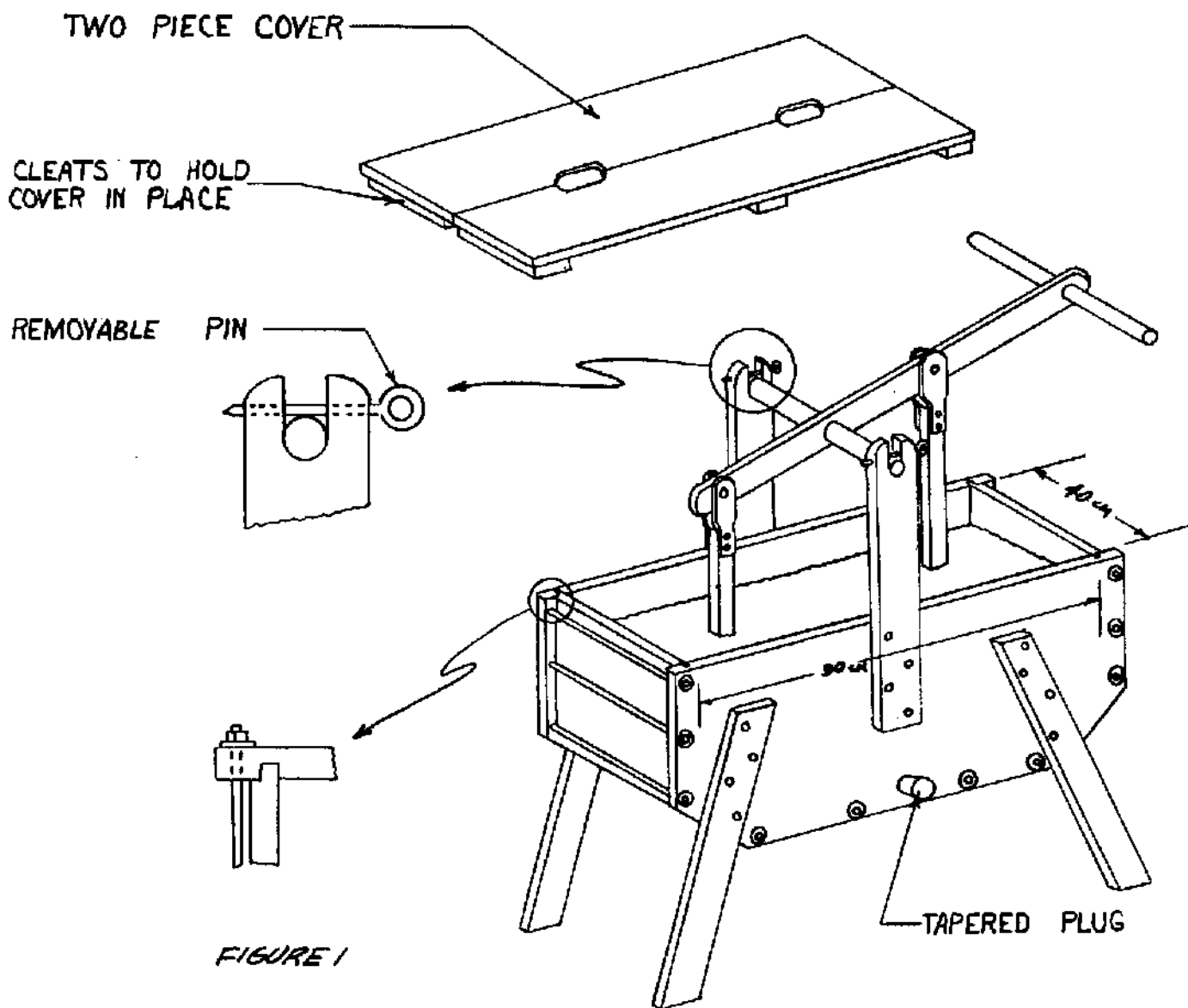
Keep in mind that the whole construction has to be sized for the user. You can experiment with various adjustments and also try out alternate means of thrust that may come to mind.

HAND-OPERATED WASHING MACHINE

This easily-operated washing machine can be built by a good carpenter from materials easily found in most countries. It is easy on clothes, effective and sanitary. The machine, which can take 3-kilogram (6-pound) load of clothes, can be shared by several families.

Clothes will last much longer if they are washed in this washing machine rather than beaten or scrubbed on rocks. Washing with the machine is also much less

work. A pilot model of the machine was made by the U.S. Department of Agriculture and tested in the U.S.D.A. Home Economics Laboratory, Beltsville, Maryland. Under test conditions, a comparison with standard electric commercial washers was very favorable. If the cost of the machine is too much for one family, it can be used by several. However, if there are too many users, competition for times of use will become keen and the machine will wear faster.



Tools and Materials

Tub Construction - Moderately firm soft-wood (such as cedro of Latin America) free from large heartwood growth.

Sides - 2 pieces - 2.5 x 45.7 x 96.5cm
1" x 18" x 38"

Ends - 2 pieces - 2.5 x 30.5 x 40.6cm
1" x 12" x 16"

Bottom - 2 pieces - 2.5 x 15.2 x 40.6cm
1" x 6" x 16"

Bottom - 1 piece - 2.5 x 40.6 x 66.0cm
1" x 16" x 26"

Legs - 4 pieces - 2.5 x 10.2 x 76.2cm
1" x 4" x 30"

Round Plungers -

2 pieces - 2.5 x 25.4cm diameter
1" x 10" diameter

2 pieces - 3.8 x 12.7cm diameter
1.5" x 5" diameter

Cover (may be omitted)

2 pieces - 2.5 x 20.3 x 91.4cm
1" x 8" x 36"

6 pieces - 2.5 x 7.6 x 20.3cm
1" x 3" x 8"

Operating parts - Moderately firm hardwood such as Caoba of South America.

Lever

1 piece - 2.5 x 7.6 x 122cm long
1" x 3" x 48"

Plunger stems

2 pieces - 2.9cm square 38.1cm long
1 1/8" square 15" long

Uprights

2 pieces - 2.9 x 7.6 x 61.0cm long
1 1/8" x 3" x 24" long

Pivot and Handle

2 pieces - 3.2cm diameter x 45.7cm long
1 1/4" diameter x 18" long

Metal Parts

Plunger connections -

4 pieces iron or brass plate -
.64 x 3.8 x 15.2cm long
1/4" x 1 1/2" x 6" long

10 rods - 3.6 or .79cm diameter
1.4" or 5/16" diameter

45.7cm (18") long with threads
and nuts on each end - iron or
brass.

20 washers about 2.5cm (1") diameter
with hole to fit rods.

1 rod - .64 x 15.2cm (1/4" x 6") with
loop end for retaining pivot.

6 bolts - .64 x 5.1cm long (1/4" x
2" long)

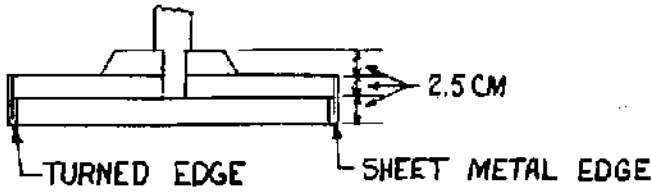
24 screws - 4.4cm x #10 - flat head
(1 3/4" x #10)

50 nails - 6.35cm (2 1/2")

Strip Sheet Metal with turned edge -
6.4cm wide, 152.4cm long (2 1/2" wide,
72" long)

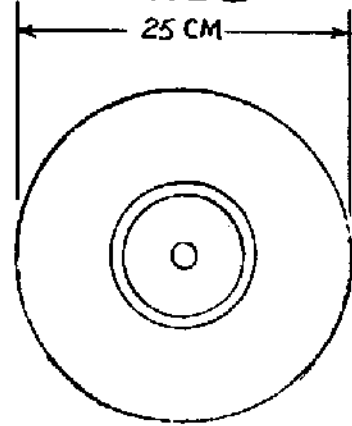
Small quantity of loose cotton or soft
vegetable fiber for caulking seams.

FIGURE 2



PLUNGER SECTION

FIGURE 3



TOP VIEW OF PLUNGER

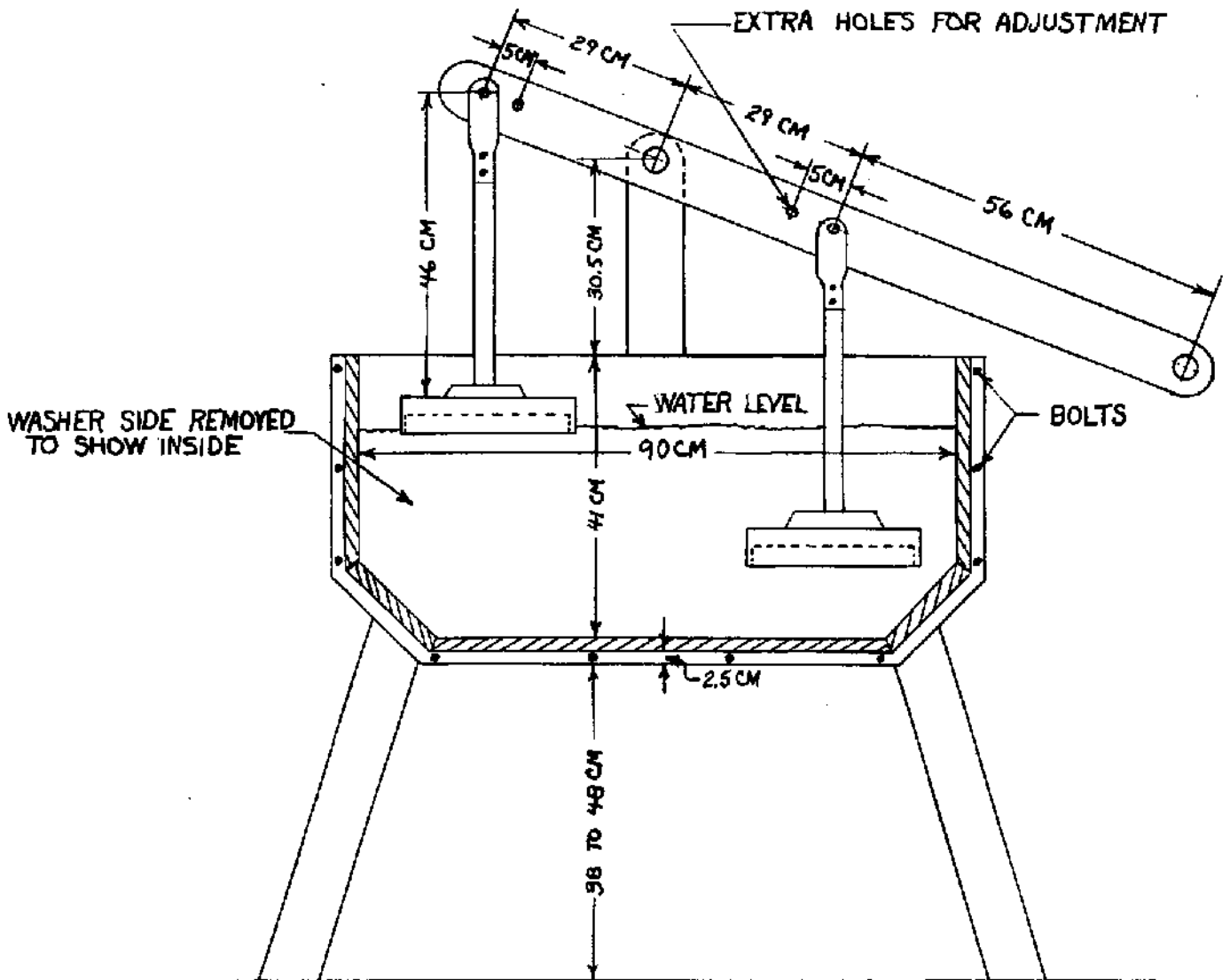


FIGURE 4

Minimum Tools Needed

Tape measure or ruler

Hammer

Saw

Wood chisel 1.3 or 1.9cm wide
1/2" or 3/4"

Screw Driver

Pliers

Adjustable Wrench

0.64cm (1/4") drill, gimlet or similar
tool

Draw knife or plane and coping saw

The machine reverses the principle used in the usual commercial washer, in which the clothes are swished through the water for various degrees of a circle until the water is moving, and then reversed. In this machine, the clothes stay more or less stationary while water is forced back and forth through the clothes by the piston action of the plungers. One plunger creates suction as it rises and the other plunger creates pressure as it moves downward. The slopes at the ends of the tub bottom help the churning action of the water caused by the plungers (see Figure 1).

A rectangular tub is best for this method of operation. This is fortunate since the rectangular box is easy to build. In general, any moderately strong wood that will not warp excessively (such as cedar in Latin America) will be satisfactory. The sides should be grooved for the ends and bottom of the tub as indicated in Figure 1 and bolted with threaded rods extending through both sides with washers to draw them tight. The bolting is necessary to prevent leaks.

The size described in the drawings is large enough for an average family in

the U.S. The same principle may be used for a larger or smaller machine provided the basic proportions are maintained. The tub should be slightly less than half as wide as it is long to get a proper surge of water. The pistons should be wide enough to move within a couple of inches of each side of the tub. The lever pivot should be high enough to permit the plungers to move up and down several inches without the edge of the lever hitting the edge of the tub. Likewise, the length of the rods on the plungers must be such that the plungers go well into the water and the clothes come completely out of the water at the highest position.

Mark and groove sides for end and bottom members (see Figures 1 and 4).

Drill holes for cross bolts.

Cut off corners and trim ends of side members to length.

Bevel ends and bottom pieces to fit into groove in side members.

Miter bottom and end members together.

Assemble and bolt.

Cut and install legs.

Caulk seams between ends and bottom members with loose cotton or other vegetable fiber to make seams water-tight. If joints to side members are carefully made, they may not need caulking.

Bore hole and make plug for draining tub. NOTE: This is shown on side in drawing but it is better in bottom of tub.

Make and install upright pivot members.

Make and install plunger lever. NOTE: the cross pivot member (round) should be shouldered or notched at each pivot to prevent side movement.

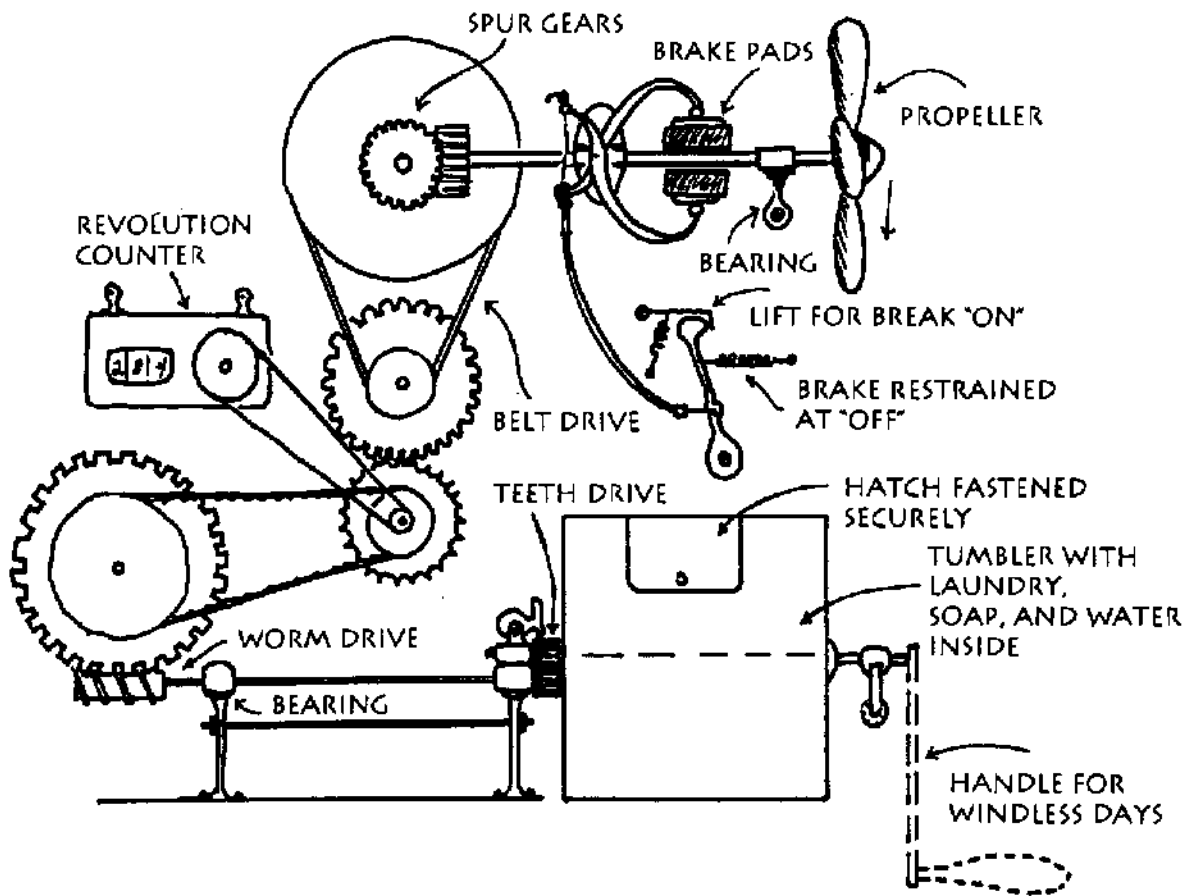
Make plungers and install (see Figures 2,3 and 4).

Here are several suggestions for using this washing machine: Fill the washer with fifteen gallons of warm or hot water depending on what is available. Remove stains. Rub soap into the areas of garments like cuffs and collars which come in close contact with the body. Soak very dirty clothes before putting them in the washer. Soap can be dissolved by shaving it into strips and then heating it in a small quantity of water before adding it to the wash water. A three kilo-

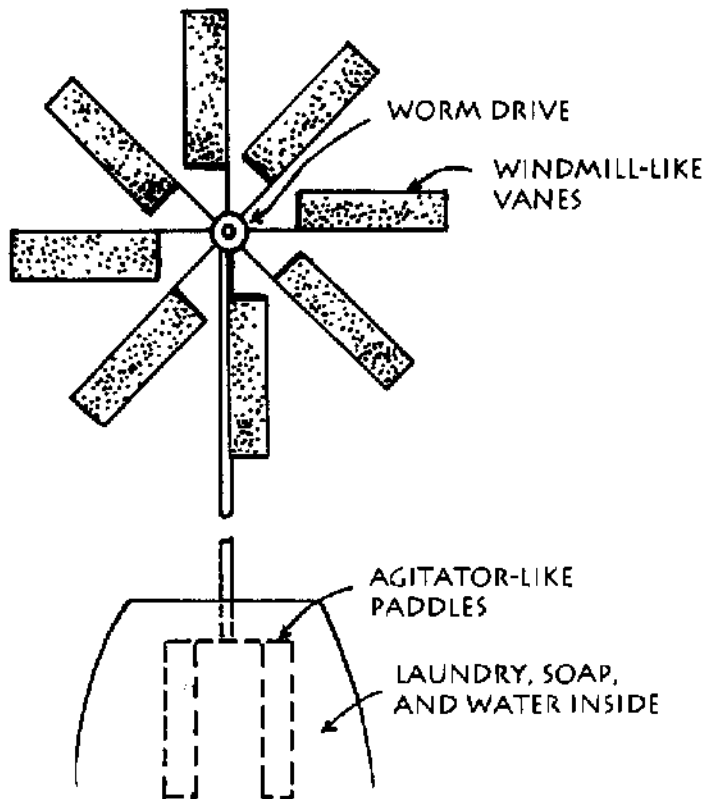
gram load of clothes is the right size load for best cleaning. Wash at a moderate speed, about fifty strokes a minute, for ten minutes -- longer if it seems necessary. After washing and rinsing the clothes, rinse the washer clean and then replace the stopper. To keep the wood from drying out and causing the tub to leak, put about 3cm of water in the washer when it is not in use.

Source:

"How to Make a Washing Machine,"
by V.C. Pettit and Dr. K. Holtzclaw, A.I.D.



WASHING MACHINES



considering foot-powered lathes and saws. The American Village Institute in Selah, Washington, has constructed a line of foot-powered machines with the craftsman in mind.

Pedal power holds great promise for application in useful work and transportation, but it also has significance in the home workshop for those who desire complete control over their craft.

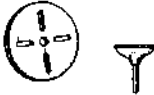
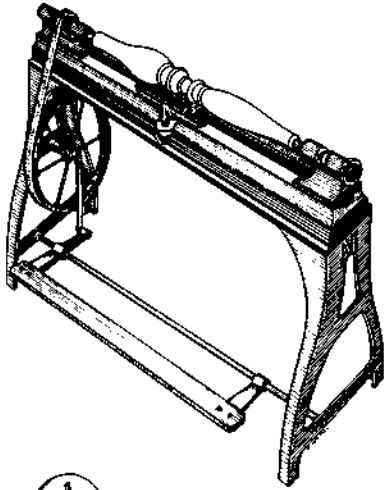


Figure 5-12 Wood lathe (American Village Institute)

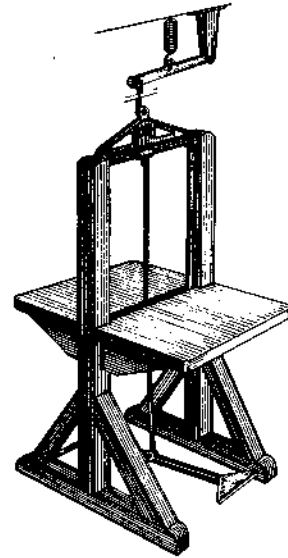


Figure 5-13 Sash saw (American Village Institute)

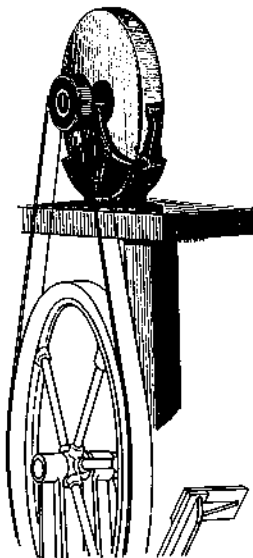


Figure 5-14 Grindstone (American Village Institute)

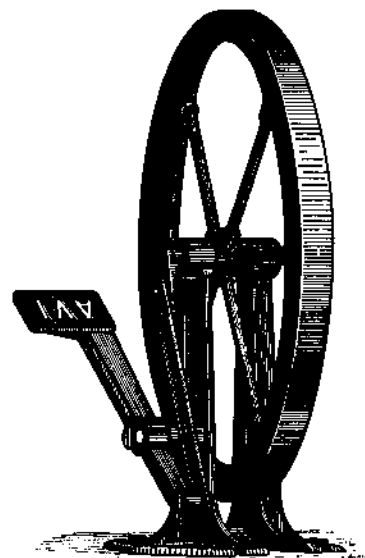


Figure 5-15 All-purpose foot treadle (American Village Institute)

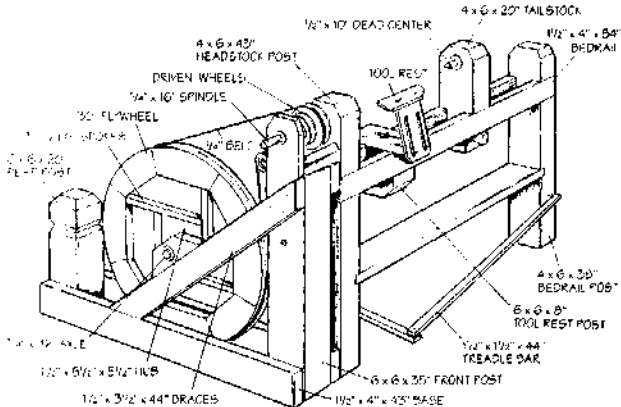
Treadle Flywheel Wood Lathe

The low-tech border between hand tools and power tools is inhabited by people-powered machinery. This clever wooden wood lathe is kin to a potter's kick wheel in principle, and is similarly capable of respectable work. It's how home-shop lathes used to be, but improved by adjustable speed and torque settings.

—J. Baldwin

Treadle Flywheel Wood Lathe

Plans and instructions
\$30 postpaid from Lake
City Lathe Co., PO Box
444, Lake City, CO
81235; 303/944-2245.

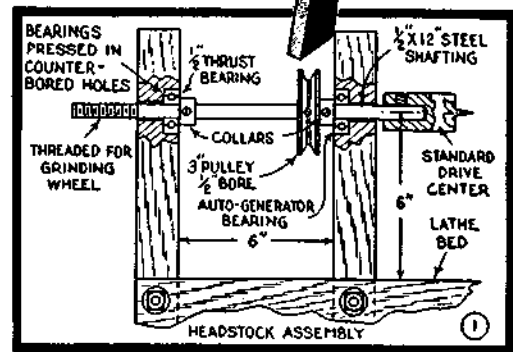
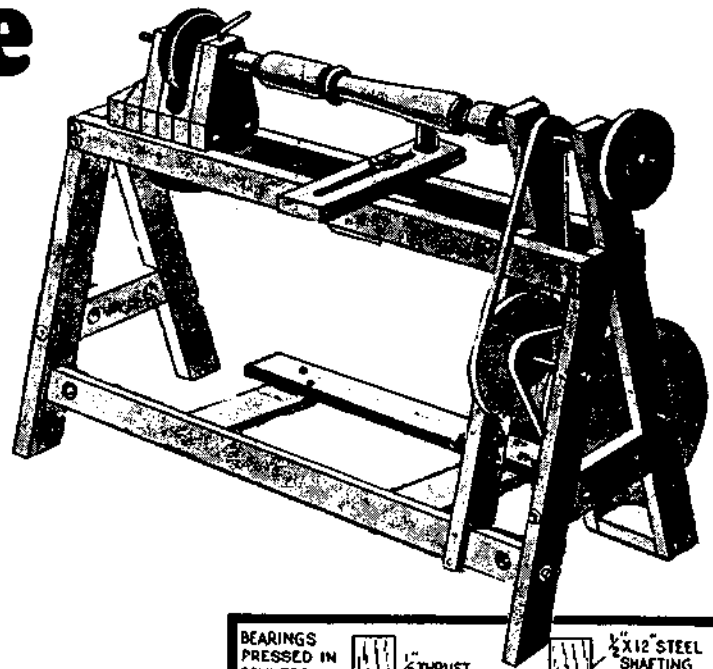


Besides allowing the right measure of control in my turning, [my foot-powered lathe's] motorless design permits me to take my work to crafts fairs, secluded spots, or anywhere else I might desire without worrying about extension cords.



A Treadle Driven Wood Turning Lathe

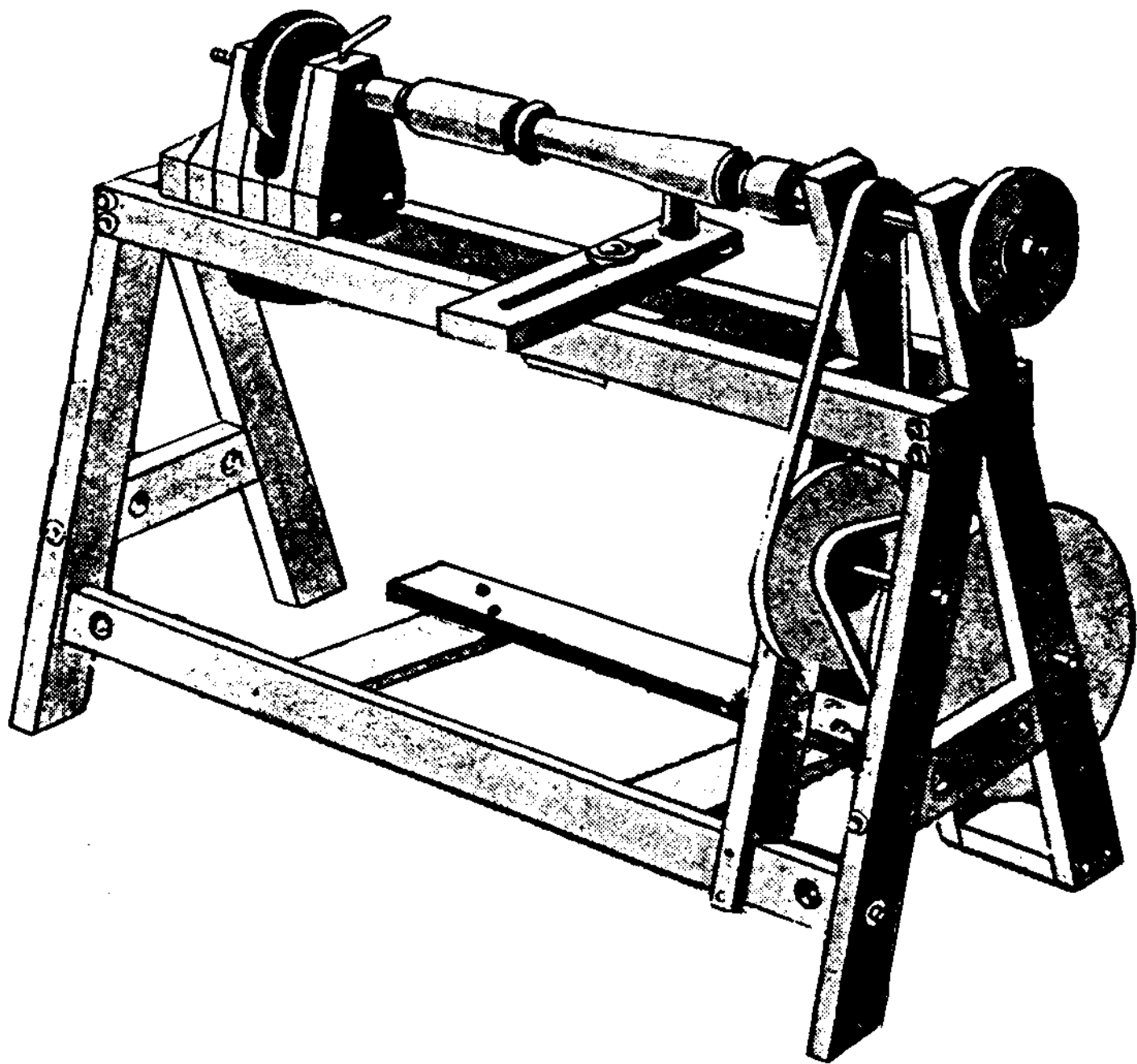
by w.c. lecky

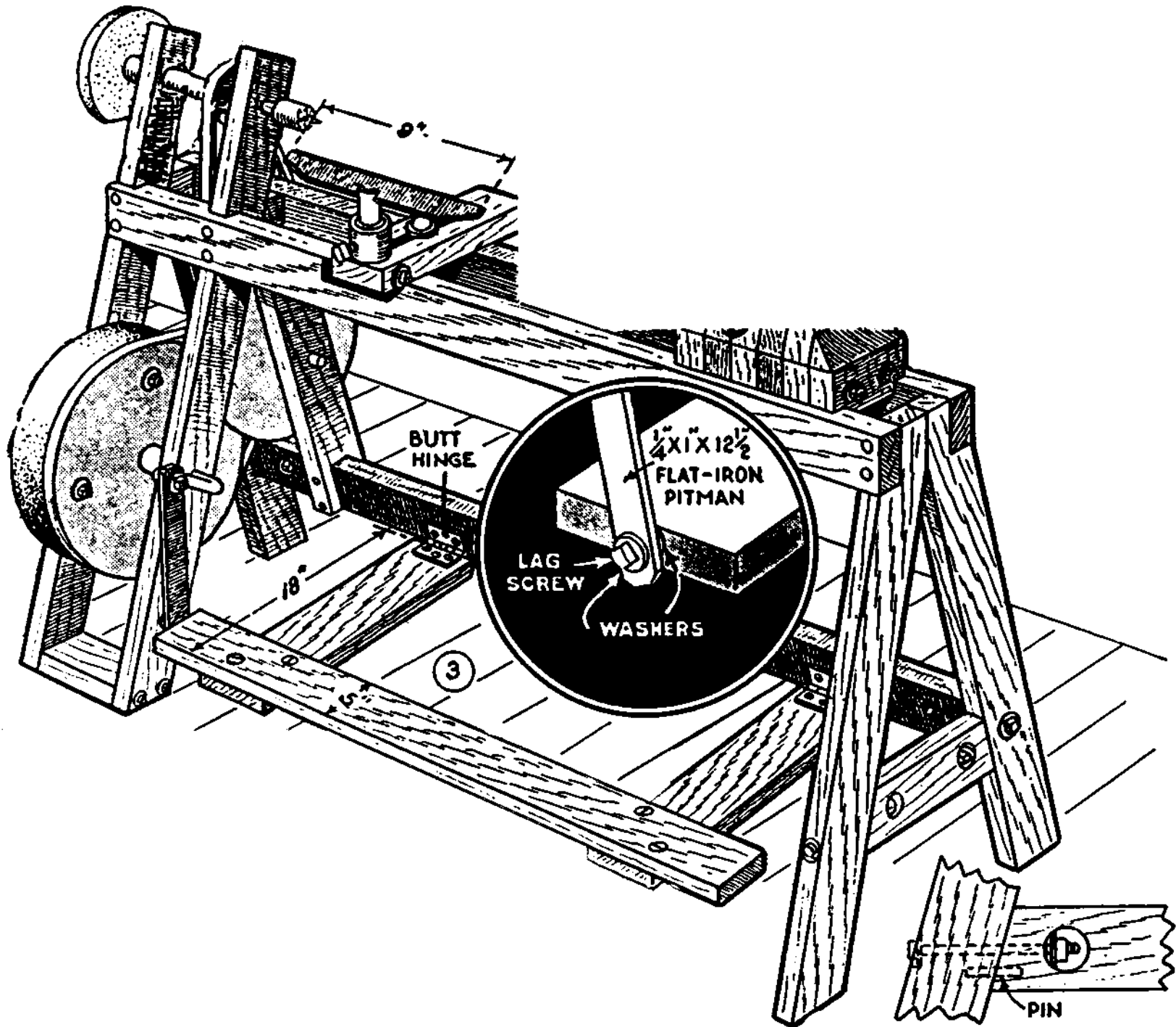


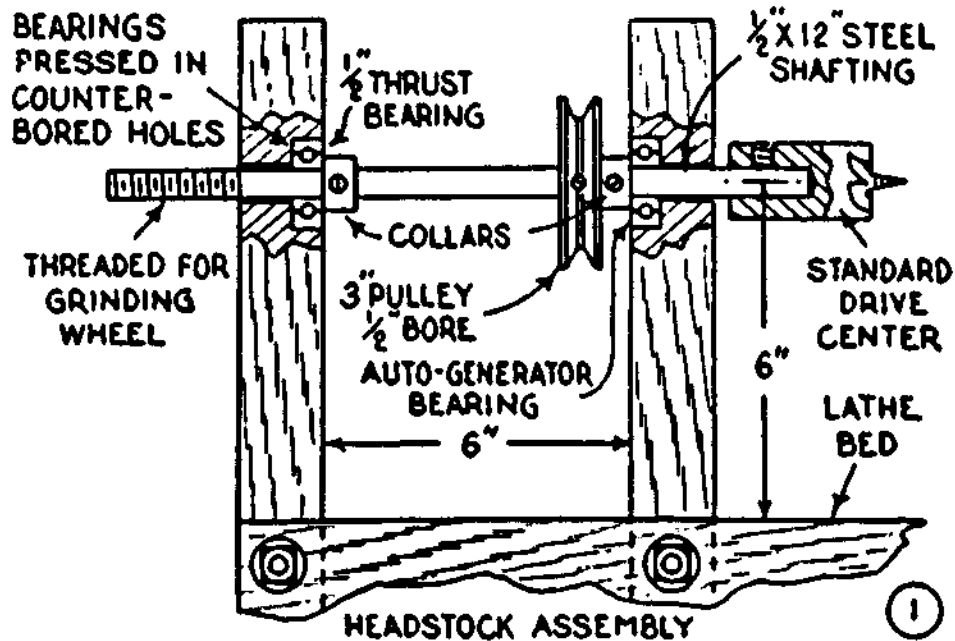
With the exception of turned wooden pulleys and the form to cast a flywheel, you can build this efficient treadle lathe with a few hand tools. Distance between centres can be increased to accommodate turnings more than 30 in. long, but in doing so, the treadle, which must be correspondingly lengthened, is apt to twist when pedaling is done at the tailstock end. Spindle height is such to enable one to pedal the lathe from either a standing or sitting position. Approximately 100 downward strokes of the treadle per minute will give a spindle speed recommended for turning. Common 2 by 4 in. fir stock is satisfactory for the stand. Side and front views in figure 8 give the correct length to cut each member. Note how the headstock is incorporated in the twin front legs. Except for fastening the bed pieces, the type of assembly shown to the right of figure 3 is used throughout, which permits tightening joints that may become loose. The small pin indicated is provided to keep the members in line when drawing up the bolts. Endless V-beltting or round leather beltting, joined, will do to rig the countershaft. As no tension adjustment is provided, it will be necessary, if an endless belt is used to

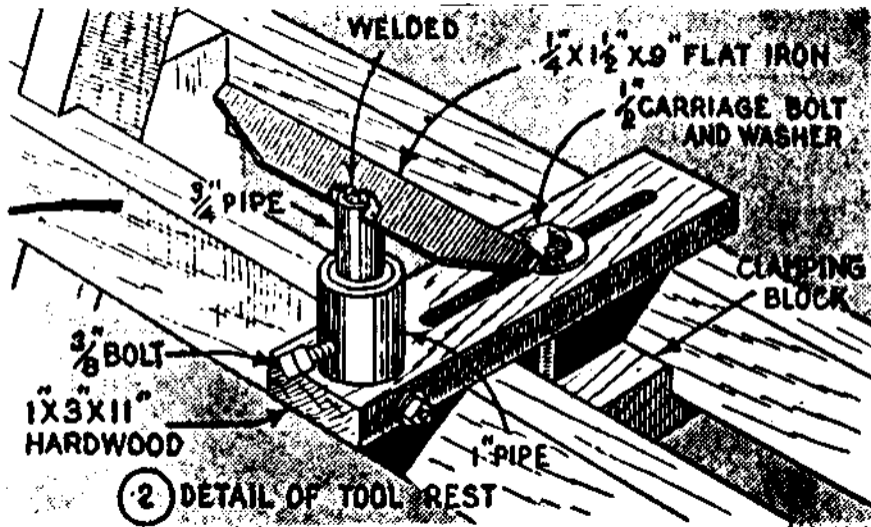
drive the headstock spindle, to vary the position of the rear countershaft pulley to be able to stretch the belt snugly over it. Belt dressing can be used if slipping develops.

Ball bearings in both the headstock and countershaft make the lathe exceptionally smooth running and are preferred to bronze bearings, although Ford model-T spindle body bushings can be used if you are unable to secure ball bearings. Figure 1 details the headstock. The holes for the bearings must be centered an equal distance above the bed and counterboard on facing sides to provide a press fit for the bearings. An auto-generator bearing will do for the inner bearing, but the outer one should be of the type to take end thrust when pressure is applied by the tailstock. The 3 in. pulley, besides the drive and tail centres, are standard and come fitted with setscrews for attaching them to a 1/2 in. shaft. A 6 or 8 in. grinding wheel fitted to the outer end of the spindle serves a double purpose in providing a means for sharpening your lathe tools and at the same time contributing to the momentum. Collars are used against each bearing to take up end play.









WELDED

$\frac{1}{4}$ " X $1\frac{1}{2}$ " X 9" FLAT IRON

$\frac{1}{2}$ " CARRIAGE BOLT AND WASHER

$\frac{3}{4}$ " PIPE

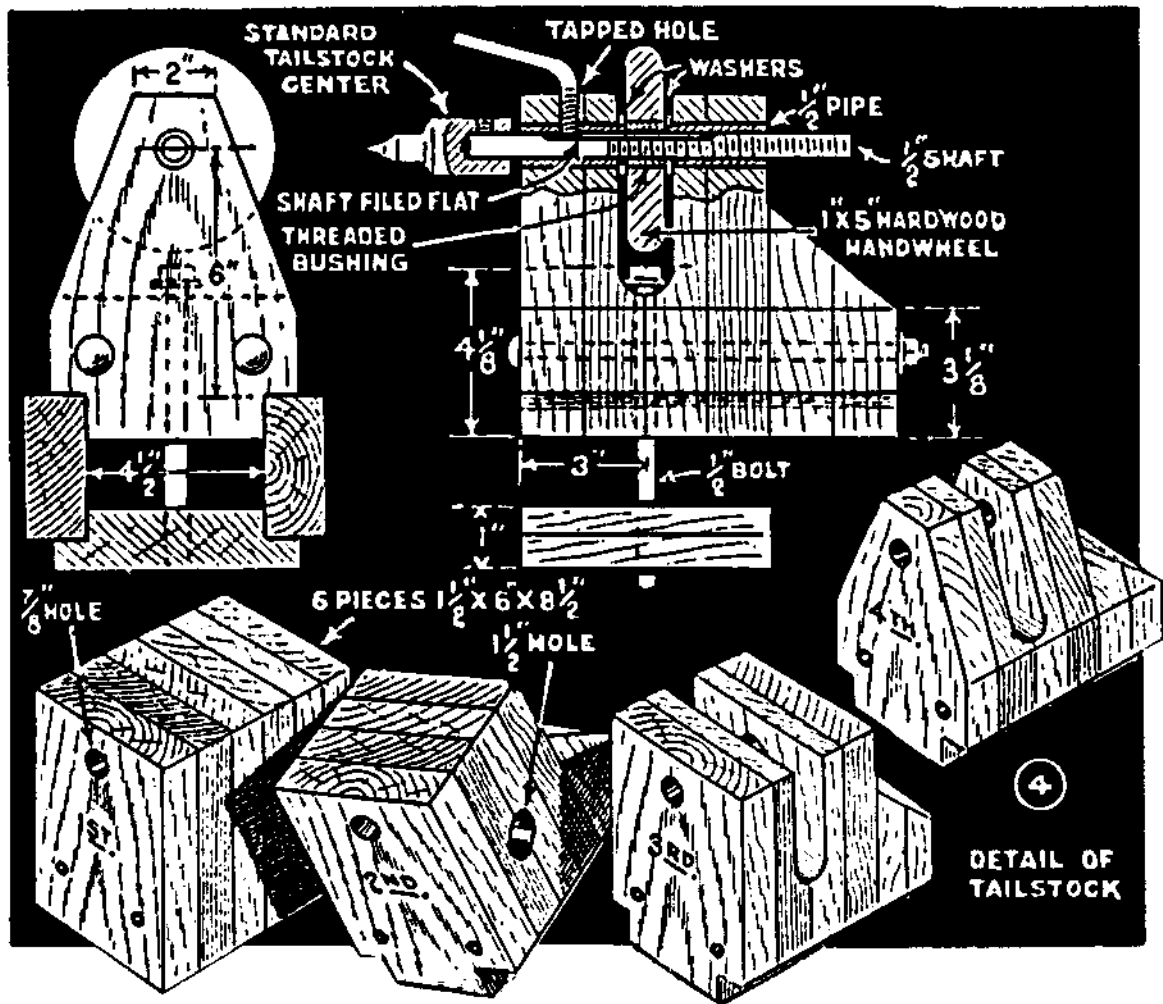
CLAMPING BLOCK

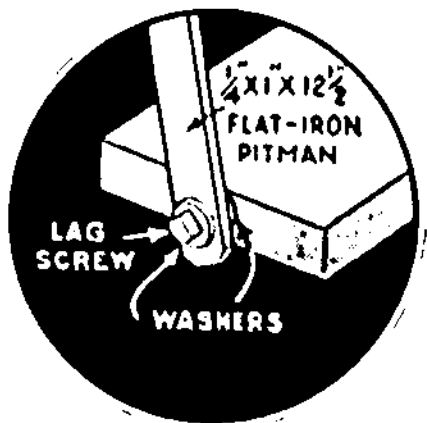
$\frac{3}{8}$ " BOLT

1" X 3" X 11" HARDWOOD

1" PIPE

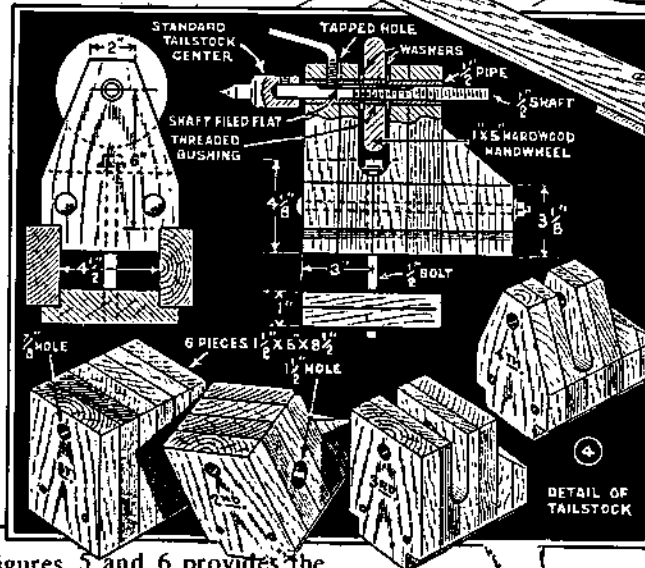
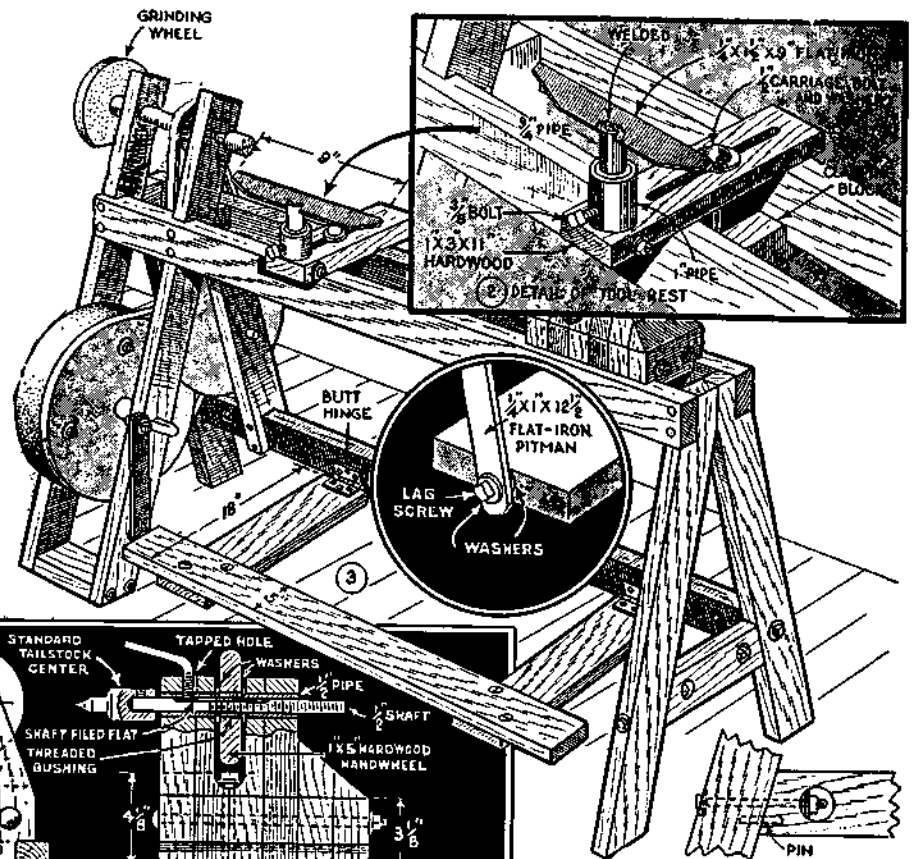
② DETAIL OF TOOL REST



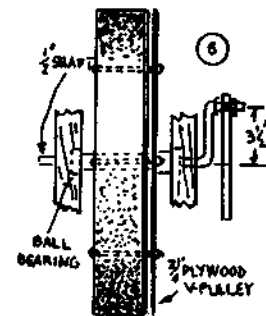
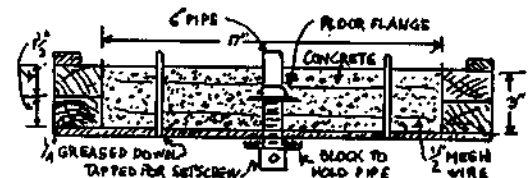
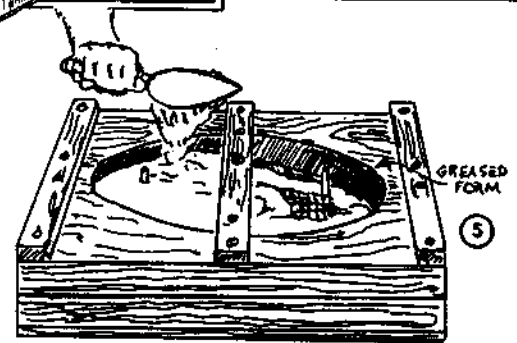


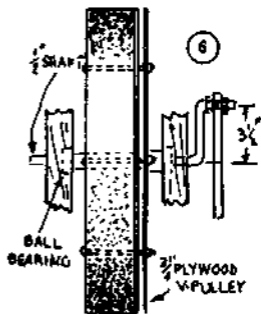
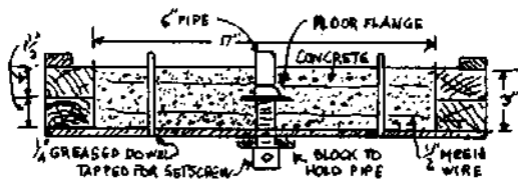
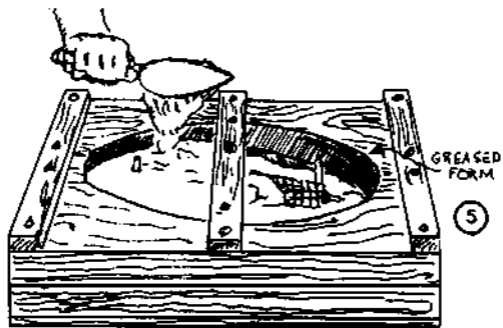
Inexpensive Sanding Disks Made From Plywood and Tin

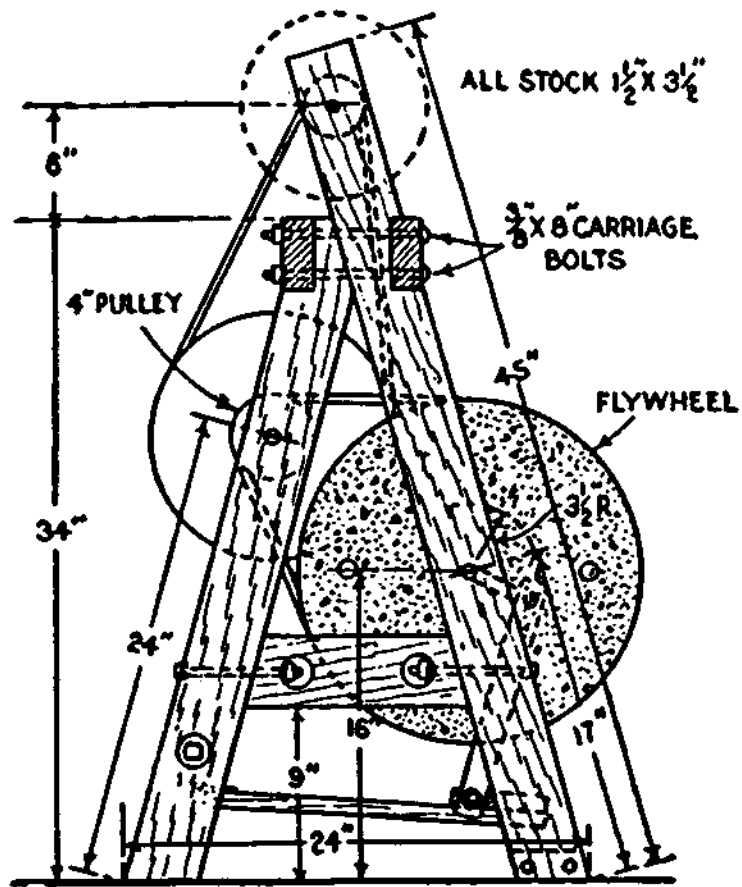
Small sanding disks for a lathe are made easily from plywood disks. After cutting to size, make a sheet-metal disk to match. Drill one wood disk and countersink the hole to take a nail. Then punch the metal disk for the nail and solder the two together. Drill screw holes through both metal and wood disks for attachment of second wood disk to which abrasive paper is glued.



The flywheel detailed in figures 5 and 6 provides the necessary momentum to keep the spindle turning at a uniform speed. Extra care must be used in centering the hub to have the flywheel run fairly true. About the easiest way to do this is to first mark a 17 in. circle on the plywood bottom of the form by which it can be centred when fastening it in place with screws. Then a hole is drilled in the exact centre to take the 1/2 in. pipe snugly. A cleat across the top of the form holds the upper end of the pipe in position, while at the bottom a small block and a coupling are used. The pipe should extend about 1/2 in. above the top of the form. As the drive pulley is fastened directly to the flywheel, greased dowels are placed in the form to provide bolt holes for this in the casting. Use a fairly rich aggregate consisting of cement, 1 part, sharp sand, 3 parts, and place pieces of wire mesh in the form as the pouring progresses to reinforce the work. Allow the concrete to set several days until fully cured. The flywheel is fastened to the pitman crank by a set screw tapped in the coupling. Note in figure 8 that the point of fastening the pitman to the treadle should be directly in line with the flywheel shaft. Bearings for the countershaft assembly are fitted the same as those in the headstock. Plywood is best for the countershaft pulleys, the two rear ones being turned and grooved separately, screwed together and pinned to their shaft. Here collars are used before to take up end play.







8

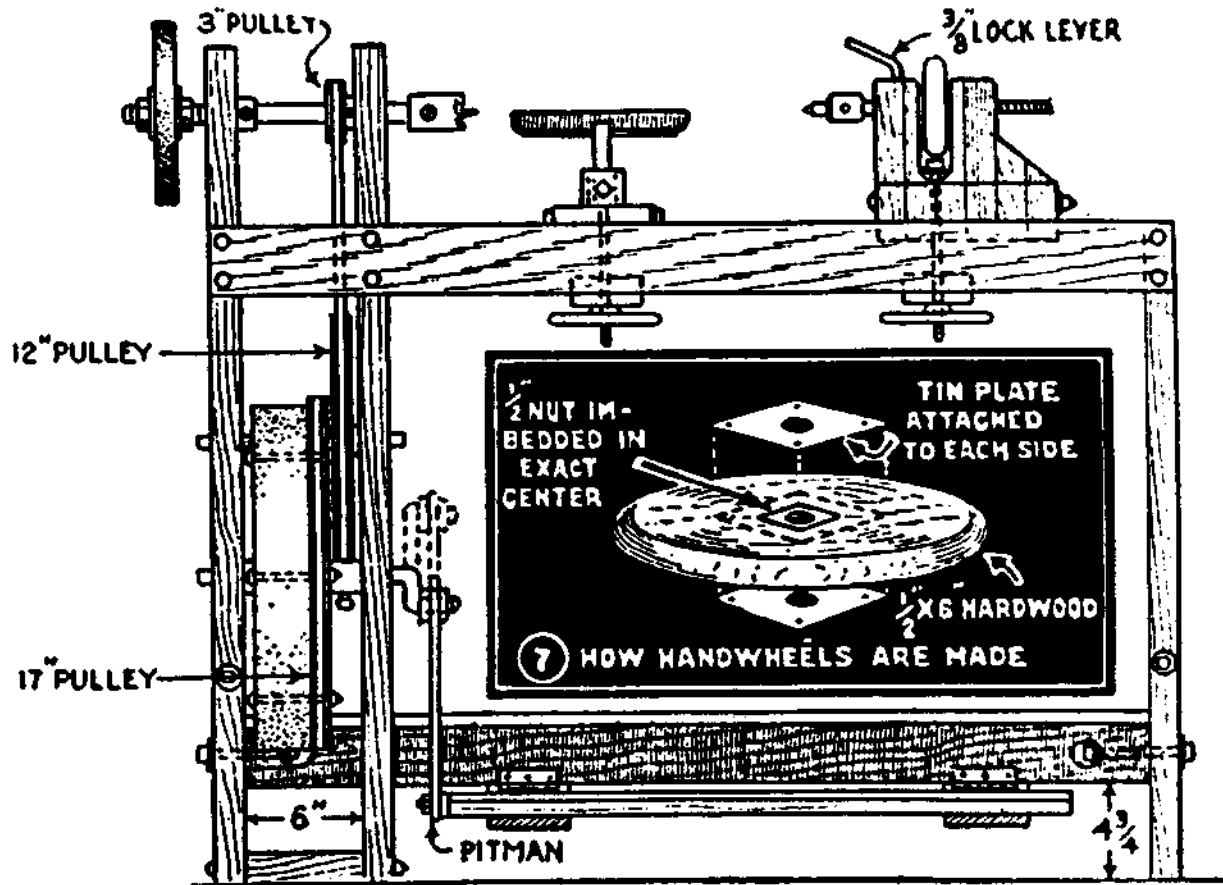
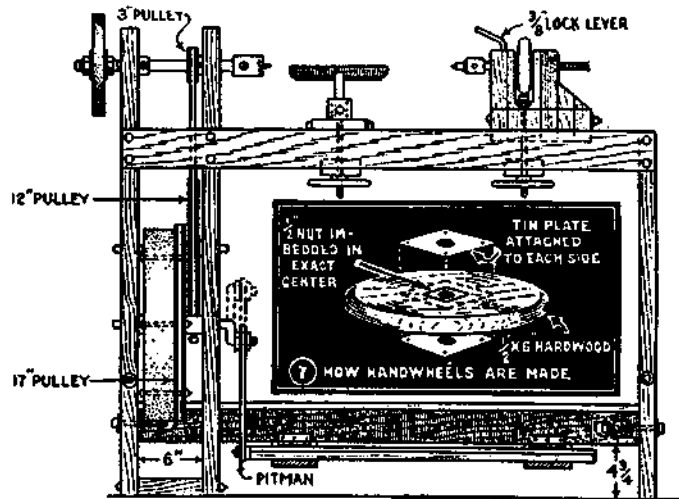
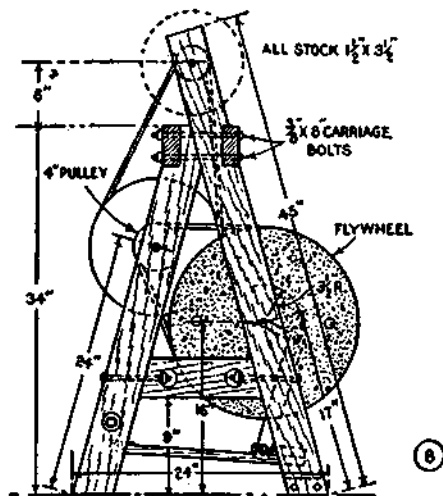
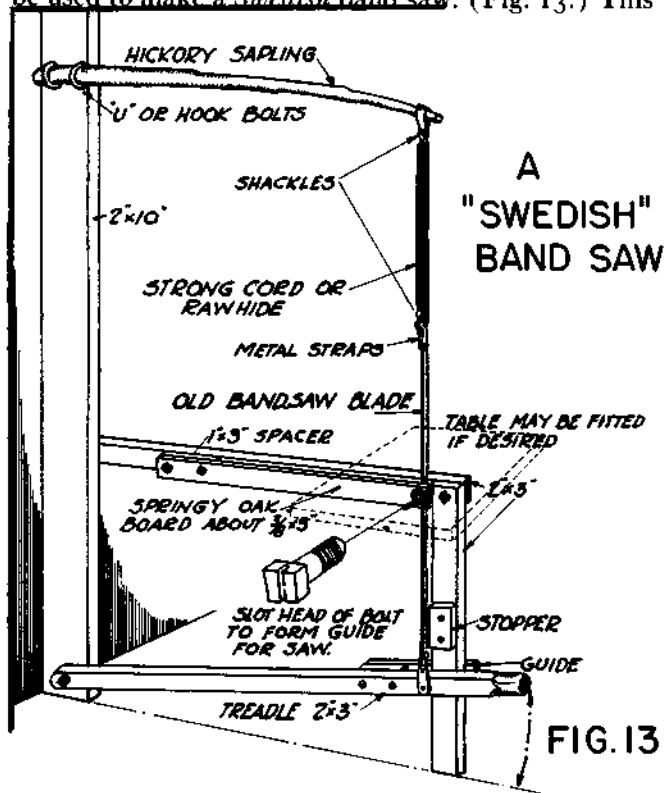


Figure 4 details the tailstock and shows the progressive steps to follow in shaping the glued-up block. The spindle hole, which is bored while the block is still square, is bushed on each side of the handwheel opening with a 1/2 in. pipe nipple to receive a 1/2 in. threaded shaft. Note that one side of the shaft is filed flat for the end of the lock lever which keeps the spindle from turning when being advanced or withdrawn by the handwheel. The latter is of wood and has a threaded bushing imbedded in its centre to

fit the spindle. Washers centre it in the opening. Both tailstock and tool rest clamp in place by handwheels fitted below the bed as shown in figures 7 and 8. The tool rest and holder are made according to figure 2. The post socket, which consists of a 1 in. pipe nipple inside a coupling, is anchored to the base by boring a hole in the latter to take the coupling snugly and then drilling crosswise through both for a 3 1/2 in. carriage bolt.



SWEDISH BAND SAW.--For ripping down planking and cutting the curves in heavy timbers too thick for a compass saw, an old discarded band-saw blade can be used to make a *Swedish* band saw. (Fig. 13.) This



saw is really the original jig saw, being worked with the foot (the operator actually did a jig when using it).