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Design for a Pedal Driven Power Unit for Transport and Machine Uses in Developing Countries

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Design for a pedal driven power unit for transport and machine uses in Developing Countries

Report for ITDG Transport Panel

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January 1976

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Coventry

This report describes a proposal for a pedal operated Drive Unit for use in rural areas in developing countries. The Unit can be used to drive simple machinery and can be coupled to a 2-wheel chassis to form a load carrying tricycle.

This project is sponsored by the Intermediate Technology Development Group.

Contents.

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1. Problem analysis - power sources for developing countries.

1.1 Context

The developing countries of the world with the poorest overall prospects of economic development are those without substantial deposits of valuable natural resources, particularly oil. Whether these countries have large (India, Bangla Desh, Pakistan) or small populations (Niger, Chad, Yemen, Mali), the problems are similar and manyfold. Part of the solution to these problems lies in the evolution of an Intermediate Technology* i.e. low capital, labour-intensive, locally based. This concept of a technology more appropriate to the needs of developing countries can be applied equally well to agricultural mechanisation and transport facilities.

The problems of underdevelopment are particularly acute in the rural areas of these countries, where the poorest people live and where agricultural underproduction and migration has most effect.

1.2 Power sources in rural areas

In rural areas power sources are needed for simple agricultural machinery such as winnowers, pumps, mills, graters etc. The use of such machinery, simple and locally manufactured, can result in appreciable advances in agricultural productivity. Power can also be used for local transport and small-scale industrial applications.

1.3 Available power sources

The possible types of power source are human, animal, oil-based fuel engines, electric motors, water turbines, windmills and solar energy collectors.

1.4 The suitability of a particular type of power source is determined by the following;

1.4.1 Simplicity of operation, maintenance and repair

1.4.2 Cost, both initial and running

1.4.3 For some field applications; portability

1.4.4 Capability for indigenous manufacture or with minimal foreign exchange component.

1.5 Suitability of available sources

The suitability of water turbines, windmills and solar energy collectors will be determined both by local geography or climate and by usage. Apart from static applications, such as for water pumping etc., these types depend on an energy storage medium to satisfy 1.4.3. The storage media currently used are electrical (accumulators), mass movement (e.g. water) and kinetic energy (flywheels). With current interest in these methods, the problems of system efficiency should be solved but at present the other methods have the advantage of greater versatility.

Electric motors operated from mains supply are probably the best conventional answer for static machines but the availability of mains supply in rural areas limits their use. The suitability of oil based IC engines is obviously determined by the availability and cost of fuel. In the countries under consideration, this cost is high and likely to remain so. Also IC engines and electric motors are relatively advanced technologies and so may not satisfy criteria 1.4.1, 2 and 3.

The use of human beings and animals as power sources is widespread but the methods used are commonly not efficient. The power available in this case results from the conversion of food calories by muscular action and so can be increased by greater food intake. The effective utilisation of this power can also be increased by the efficient design of machinery. Animal power is widely used and efficiency could no doubt be increased but application will be restricted to those requiring high torque at low speeds (winches, large mills etc.) In those areas under consideration, the efficient use of the muscle power of human beings affords the most flexible and useful solution as this can satisfy all the criteria in 1.4.

1.6 Power available from human muscle action

The maximum power output from a human being occurs in a rowing action because most muscle groups in the body are used. However, these outputs are closely approached by those obtained from the legs applied to moving pedals. Little advantage appears to be gained from pedal motions other than simple rotating cranks as on a bicycle* and the use of cranks gives a fairly smooth rotary motion at speeds of 60-80rpm. Hand cranking is frequently used but as the arm muscles are smaller than the thighs, power output is reduced. The power output to be expected from normal pedallers are around 0.1HP. This output can be maintained for 60 mins or more. Higher outputs can be produced for shorter periods (see 1.13.1). Due to poor nutrition levels in developing countries, this output is likely to be rather high and a lower figure of 0.08hp would be more reasonable for continuous pedalling.

* Whitt & Wilson 'Bicycling Science'. MIT Press

In static applications, the outputs available tend to be lower than those measured from the performance of cyclists because of the effect of wind in reducing body temperature*. It may prove advantageous to provide fans for pedallers in static situations to improve output.

1.7 Pedal Power ergonomics

The evolution of the bicycle over the last 100 years has resulted in the determination of the optimum position for continuous pedalling over a long period. This is the position adopted on the standard 'safety' bicycle - the other positions used by racing cyclists are adopted primarily to reduce wind resistance. Some increase in output can be obtained for short periods by a more horizontal relationship between pedals and saddle; leg muscles can push against a back rest and so exert more force. Maintaining the legs in this horizontal position results in the onset of fatigue after a short period, making the normal upright position the best compromise for most uses.

1.8 Particular suitability of Pedal Power in this context.

Because the 'fuel' involved in the use of Pedal Power is food, no irreplaceable fossil fuels are consumed with obvious benefits. The technology involved is that of the bicycle hence the criteria of 1.4 can be more easily satisfied. Although bicycle ownership in the countries of the developing world is not universal, it is equivalent to the level of car ownership in Europe, hence spares and maintenance facilities are commonly available. The capability for indigenous manufacture (1.4.4) can be developed from this basis (as in India, Nigeria, China etc.). If this is taken into account at the design stage, then material or process substitution can result in simpler methods of construction than with current bicycle practice.

1.9 Use of pedal power to drive machinery

As would be expected, a number of manufacturers already produce machines fitted with pedal drive. Designs have been produced by individuals notably Stuart Wilson (Oxford University) and Alex Weir (University of Dar-es-Salaam) both of whom have worked for several years in this area. A survey of existing machinery that utilises pedal drive and existing machinery suitable for adaptation to pedal drive is given in 1.13.2.

1.10 Methods of using Pedal Power

There are three methods of using pedal drive for machinery - first, by building pedal drive onto the machine; second, by using a converted bicycle; third, by using a free-standing pedal drive unit which can be connected to a number of machines in turn. The manner in which a machine, or machines, is used and by whom will determine which method is most appropriate. This question is discussed fully in 1.13.3, The concept of a free standing pedal drive unit appears to have particular merit when a variety of machines can be used by a farmer, small manufacturer, machine hire company or a village commune/cooperative. As this type of usage is most

* Whitt and Wilson. op cit.

appropriate to the long term development aims of developing countries the object of this project is to pursue this concept. The author can claim no credit for the original idea - a design was published by Stuart Wilson in 1968 and the device was called a Dynapod. Since that time both Stuart Wilson and Alex Weir have developed dynapods of various types to demonstrate the validity of the idea.

1.11 Pedal Power in transport applications.

As stated in 1.2, the other area of need for power sources in rural areas is for transport of goods and passengers. This movement is local, as an intermediate stage between porterage and major transport systems (trucks, railways etc.) In areas where pedal driven vehicles exist (primarily in Asia), their suitability has been demonstrated. Bicycles are, of course, the most common type and customarily are used to capacities far beyond their original role as personal transport. Loads of up to 100kg are not uncommon but problems are imposed by wheel strength, stability and safety.

Apart from the bicycle the other configuration most commonly used is the tricycle, either with two wheels at the front (as in the ice -cream cart used until recently in this country) or at the back (as in the Indian cycle rickshaw). These types have load capacities up to approx.150kg. Many other types of pedal driven vehicle have been designed and built since the 1890's. Only the tricycle has been continuously successful as a load carrier due to the combination of stability and capacity with minimum structure and light weight.

1.12 Rationale for Pedal Power Unit designed for both machine and transport applications.

The study of the application of Pedal Power to machinery also indicated there was likely to be a related transport function in many situations. In agriculture, for example, this relationship would be the farmer using crop processing machinery and then transporting produce to market. As pedal power could be used in both applications, the design of a single unit capable of both functions emerged as a feasible proposition. The use of a Dynapod as a transport device extends its utility and enables the cost to be amortised more quickly. This concept is exactly analogous to the use in this country of tractors for transport and for driving machinery via the power take-off.

Examples of typical use patterns would be,

1) agriculture - cable ploughing, winnowing, milling, waterpumping, grain elevation, haulage of produce, fertiliser and seed.

2) industrial - winching, sawing, drilling, turning, spray painting, haulage of manufactured items and raw materials.

3) construction - winching, cement mixing, electricity generation, sawing, haulage of raw materials.

1.13.1 Chart showing methods of using pedal power

Type	Option	Appropriate uses
1. Bicycle	1.1 Roller drive from back wheel	1. Several machines operated by one man. 2. One machine operated in various locations. 3. Machines operated sporadically. 4. Machines hired for short periods.
	1.2 Drive taken forward from pedal sprocket	1. Machines hired for fairly long periods. 2. Machines operated periodically (for fairly long times) 3. Machines requiring efficient drive for their operation.
	1.3 Pulley on rear wheel	1. Several machines operated by one man. 2. Machines operated daily as a job. 3. Machines operated sporadically (for fairly long periods) 4. Machines operated in various locations (assuming machine fitted to bicycle)
2. Pedal drive on machine		1. Machines operated continuously. 2. Machines used by many people. 3. Machines hired for fairly long periods. 4. Machines requiring very efficient drive. 5. Machines requiring more than one pedaller. 6. Machines operated as workplaces.
3. Dynapod		1. Several machines operated in close proximity. 2. Machines requiring efficient drive. 3. Machines operated seasonally. 4. Machines requiring more than one pedaller for efficient operation.

Comments	Hardware
High RPM takeoff (depending on roller size) System losses greater than direct drive Use of bicycle means capital costs could be lower Drive is taken backwards, so machines requiring loading continuously by the pedaller are not really suitable.	Roller and stand or modified kickstand needs to be fitted to bicycle or machine could be fitted to rear carrier of bicycle
Drive is taken forward so machine could be loaded by pedaller. Efficient drive system front forks can act as fixing to machine Setting up procedure is more elaborate than 1.1 so more suitable for longer use times	Machine needs to be fitted with clamping frame for bicycle
Drive is taken backward to machines requiring continuous loading by the pedaller are not suitable; bike needs to be lifted off the groubd abd clamped. The back wheel must be removed for belt fitting, unless removable belt linkage is used An efficient drive system results with some flywheel effect from the wheel	Machine needs to be fitted with frame to locate bicycle and raise rear wheel or machine could be fitted to rear carriage of bicycle
Drive can be arranged to be suitable for power requirements and also to allow control or loading of the machine. More suitable the longer the use time, the larger the number of people using the mcahine or the more efficient the drive required	Machine needs to be fitted with pedal cranks, simple saddle and handlebars with some measure of adjustment
More suitable if a number of machines are operated by the Dynapod. The optimum case is continuous use of the Dynapod, with variety of machines. As each machine may have differing drive requirements (RPM torque etc.), the Dynapod should be of minimal design.	Dynapod comprises a frame comprising pedal cranks, saddle, handlebars and power take-off to be clamped to machine. (see designs by S. Wilson and A. Weir)

1.13.2 Machines suitable for pedal drive

1. Agriculture and food preparation uses

Machine type	Known machinery with Pedal drive	Known machinery which could be adapted
Winnower	NCAE Winnower (AW)	Hunts No.8 (57) Cossul fan (63)
Grain Mill	Atlas Mini-mill (SW)	Atlas Mill (72) Others (73,74,76)
Thresher	Aplos (55) Doring (63) VITA design, Malayan design (RM)	Midget (56) Cossul (62)
Cassava Grater	IDG design (WE)	
Maize Sheller	Hunts Cobmaster	Huntsman 1 & 4 (54)
Banana Fibre Pulper		
Groundnut decorticator		Kirloskar (59)
Riddler		
Palm nut cracker		Voms (65) Rapid (66)
Crop sprayer		
Shearer		
Winch Plough		
Coffee Pulper		Mtoto (68)Irima DG(69) No.10 (70) Congo (71)
Rice Huller		Java (73)
Grain Elevator		
Water Pump	Traditional Chinese Dragon-tooth pump Autometric pump (SW)	Golwin (41) Biscoma(43) Cossul (44)African & Africa (45)

2. Small-scale industrial uses

Dynamo	Converted car alternator(SW)
Winch	Design (SW)
Forge Blower	Zambian example (ITDG)
Air compressor	
Bandsaw	
Fretsaw	
Drill	
Grindstone	
Lathe	
Potters Wheel	
Electrical Generator	

Numbers in the list refer to pages in ITDG 'Guide to hand-operated equipment'. Initials refer to designers or sources of information.

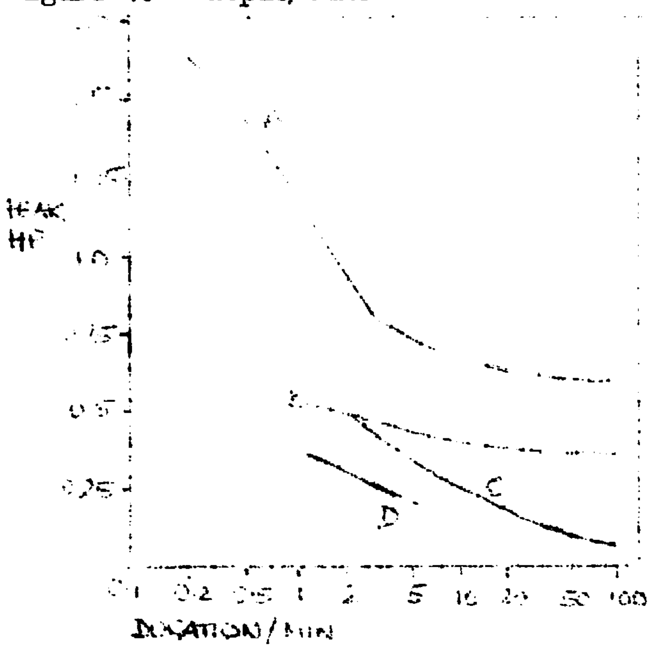
SW Stuart Wilson, Department of Engineering Sciemce, Oxford University
AW Alex Weir, University of Dar es Saleem
RM Robert Mann, NCAE, Silsoe

1.13.3 Human power outputs

The data in this section is drawn largely from the book 'Bicycling Science' by Frank Whitt and David Wilson (MIT Press). This book is the definitive analysis of the ergonomics and mechanics of bicycles and constitutes an invaluable reference for work in this area.

Muscle power output arises from the conversion of food calories by oxygen so is limited by nutrition levels and oxygen intake. General fitness or training results in a higher efficiency of oxygen conversion and hence greater power outputs. As would be expected, outputs vary with the muscle groups employed and with duration, higher outputs being obtained over shorter periods. Figure 1 (1) shows this relationship and also provides a comparison between different muscle groups.

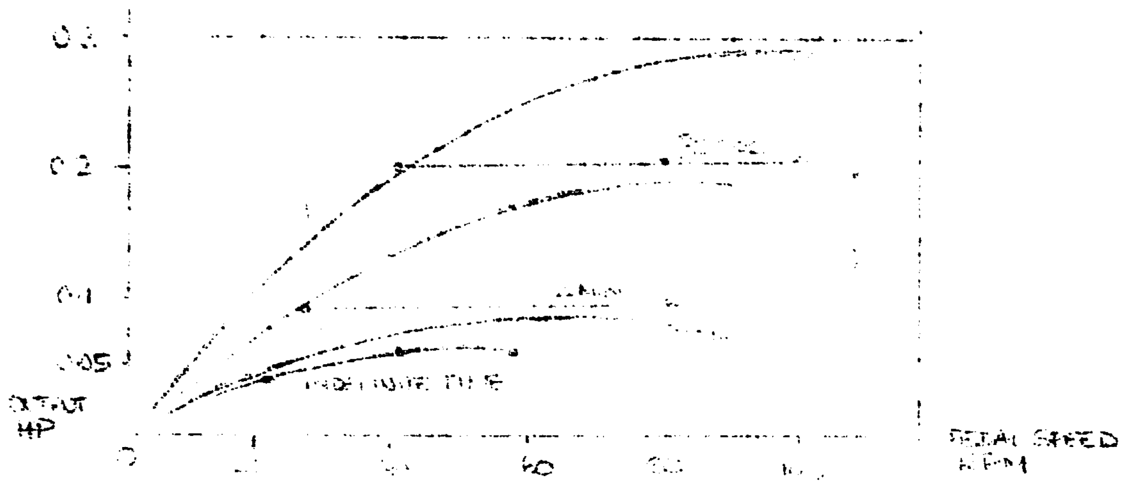
Figure 1. Output/time



A Racing cyclist
B Pedal Ergometer
C Winch
D Hand Ergometer

It can be seen from this that the outputs obtainable from hand cranking are approximately 30% or less than that measured from cyclists and on average 50% less than measured on pedal driven ergometers. The difference between ergometer measurements and cyclists performance occurs because of the effect on windflow in reducing the rise in body temperature resulting from muscular activity. This indicates that for static application of pedal power provision of cooling fans may be advantageous. These figures, however, were measured from athletes performances and should not be taken as average. It has long been assumed that an average bicyclist produces 0.1 HP (75 watts) which would give a road speed of 9-13 mph (4-5.8 m/sec) and this accords with accurate measurement and observation. Figure 2 shows the variation of output with time for american college students (2) and indicates for general purposes over long times (20 mins or so) that this output can reasonably be expected. This output is obtained using about 50% of maximum breathing capacity.

Figure 2. Power output/time/pedal speed



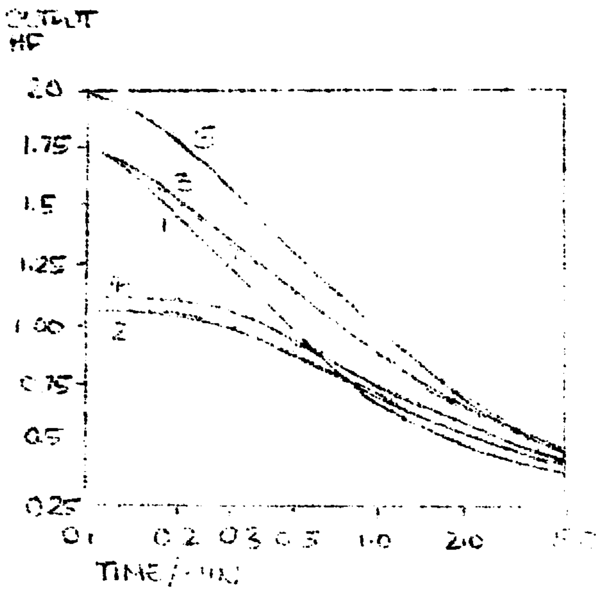
This figure shows how output varies with pedal speed and that for low outputs a variation of pedal speeds between 30-60 rpm have little effect. For racing cyclists producing higher outputs, the effect of pedal crank speed is more critical and crank speeds up to 150-180 rpm are used. For high outputs the optimum has been suggested by the Japanese Bicycle Research Association (3) to be 70 rpm using much higher gears than usual for racing cyclists. The optimum crank length was determined to be 6¾" (170mm) which accords with practise.

Tests on ergometers (4) have shown that pedalling in a near horizontal position is only about 80% as effective, in terms of muscle usage, than the normal upright position. Over long periods, pedaller complained of 'knee strain' when pedalling sitting down. In spite of this, records have been made, particularly in the 1930's, on recumbent bicycles, but only for short distances. This is probably due to slightly higher outputs being obtained by the seat back counteracting pedal thrusts rather than the arm and trunk muscles, and also due to lower wind resistance.

Comparisons of walking up gradients (6), stepping up and down and pedalling, indicate that the usage of oxygen for a given power output is similar. This means that there is no gain in efficiency from lever systems which use leg motions other than pedalling. There may well be increased losses with 'stepping' actions due to mechanical inefficiency of the transduring system. Indeed for most applications, the pedal and crank system which gives a smooth rotary motion initially is likely to be most useful.

Rowing actions have been tested by Harrison (5) and in these studies it was found that higher outputs than those obtained by pedaller could be produced, particularly if the rowing action was connected to a mechanism which defined the end of the stroke (forced action). Outputs against time are shown in figure 3 and this indicates that the rowing action becomes less advantageous with times over 5 minutes.

F Figure 3. Rowing versus pedalling actions (5)



1 Cycling
2&3 free and forced rowing, feet fixed
4&5 free and forced rowing, seat fixed

The general conclusion of these comparisons is that for applications both in vehicles and for driving machines, the normal pedal and crank action is best suited for general use over periods greater than 5 minutes or so. For shorter times, where higher outputs are necessary, it may be better to use a recumbent pedalling position or a rowing action. Outputs of 0.1 HP (75 watts) are produced by normal cyclists for reasonable times, but lower outputs are obviously more easily maintained. It is difficult to predict how these outputs would be modified by lower nutrition levels prevalent in developing countries but figures of 0.05-0.08 HP (37.3-59.7 watts) could be relied on.

References

(1) Whitt & Wilson, 'Bicycling Science' MIT Press p.13.

(2) 'Report on the Energy Storage Bicycle', Thayer School of Engineering, Dartmouth College, New Hampshire 1962.

(3) 'Report of the Bicycle Production & Technical Institute' Japan 1968.

(4) P.O. Astrand & B. Saltin 'Maximal Oxygen Uptake and Heart Rate in Muscular Activity'. Journal of Applied Physiology, vol. 16 1961 00. 977-981.

(5) J.Y. Harrison et al 'Maximising Human Power Output by Suitable Selection of Motion Cycle and Loan'. Human Factors vol. 12 No. 3, 1970 pp. 315-329.

(6) Whitt & Wilson op cit p.30.

2. Performance Specification for Pedal Power Unit

2.1 Machine applications

2.1.1 Unit should be suitable for driving existing machinery with minimum adaptation.

2.1.2 Unit should form basis of range of improved machine types.

2.1.3 Unit should be capable of connecting to other units for applications requiring more power.

2.1.4 Drive from Unit should be taken forward to allow operator, where appropriate, to load, unload or use machine himself.

2.1.5 Drive train efficiency should be high to maximise power output.

2.1.6 Unit should have a range of gearing for various applications.

2.1.7 Conventional upright pedalling position should be used being most suitable.

2.1.8 Unit should be stable in use.

2.2 Transport applications

2.2.1 Unit should constitute major mechanical and structural component in a loadcarrying tricycle.

2.2.2 The vehicle chassis section should be usable independently of the unit as a hand-cart.

2.2.3 Resulting tricycle should have a load capacity of up to 150kg. (either goods or 2 passengers).

2.2.4 Tricycle should be capable of accepting a variety of bodies for different applications.

2.2.5 Unit should be usable for machine operation whilst fixed to the vehicle chassis.

2.2.6 Design should allow flexibility on the construction of vehicle chassis to suit local availability of parts and materials.

2.2.7 Connection between unit and vehicle chassis should be simple and fool-proof and not require special tools.

2.2.8 Total cost of tricycle should be equivalent to competitive pedal driven vehicles.

2.3 Unit construction

2.3.1 Unit should be capable of local manufacture assuming simple metal working and fabrication facilities (e.g. welding, brazing, folding, drilling).

2.3.2 Unit should use standard bicycle components where possible.

2.3.3 Unit should be simple to operate and maintain.

2.3.4 Unit should use a minimum of imported components.

3. Pedal power unit design proposal.

3.1 Basic concept

The pedal power unit comprises a frame with a wheel mounted in forks. The wheel is driven by pedal cranks and a chain fitted to the forks and a saddle is fitted to the frame. For transport applications, the unit is connected to a two wheel chassis and so forms the driven front wheel of the tricycle. The two wheel chassis is usable independently as a handcart. A sub-frame fitted to the forks carries a secondary chain and layshaft driven from the wheel, for use as a power takeoff. This subframe pivots on the wheel axle and acts as a stand to raise the wheel off the ground, enabling the power takeoff to be used whether or not the unit is fixed to the rear chassis.

3.2 Drive train

The primary drive train consists of a 46 tooth pedal sprocket with a ⅛" chain driving a 24 tooth wheel sprocket. This gives a lower gearing than a standard bicycle, to be suitable for load carrying. The wheel consists of a Raleigh Chopper (20"x 20") type rim spoked onto either a 3 speed Sturmey Archer hub or a dual threaded hub, with freewheel thread on one side and fixed sprocket lockring thread on the other. The Sturmey Archer hub is modified to allow the fixing of a fixed sprocket and lockring in the same manner. The fixed 24 tooth sprocket drives a similar sprocket on the layshaft via the secondary chain. The layshaft is a standard bracket axle with provision at each end for power takeoff. The chains are tensioned by jockey pulley or moving the PTO axle housing in slotted hole.

3.3 Power take off

With the gearing arrangement described in 3.2, the power take off speed will be 150rpm at normal pedalling rates. By substitution of different sprocket sizes in the secondary chain this can be varied. If the Sturmey Archer hub is fitted, this will give speeds of 112/150/200rpm and gives a convenient means of altering rations. Because the road wheel drives the secondary chain system, it is used as a flywheel for power smoothing and enables the road brake to be used as a machine brake.

At one end of the layshaft is fitted a threaded block to attach the secondary chain sprocket with an extension collar into which a take off shaft can be fitted. This shaft can be used to connect two pedal power units together or to drive machinery. On the opposite end of the layshaft is a similar block with provision for attaching either a pulley shaft or chain sprocket to provide drive for machinery. The shaft used for interconnection would be semi flexible (e.g. bamboo or GRP tube) to overcome alignment problems.

To improve the effect of the rear wheel as a machine flywheel, a circumferential weight collar can be fitted to the wheel. This would comprise a sand filled canvas tube or short metal strip sections threaded onto a rope.

Fitting would be by deflating the tyre, tying on the collar and then inflating the tyre to secure it. Clearance around pedal axle and brakes would need to be provided.

3.4 Variability and stabilisation in use

Because the secondary drive frame is pivoted, this allows the position of the final drive to be varied to suit different machines. The lower part of this frame forms the stand to raise the wheel. The unit is stabilised by connecting the base bar to the rear feet with guy ropes. These guys also stop movement of the forks. The unit can be pegged into the ground through holes in the feet and base bar. These holes can also be used with prepared floor fixings.

To allow for anthropometric variations, handlebars and saddle stem slide in tubes on the frame, position being fixed by normal methods.

3.5 Multiple unit connection

As stated in 3.3, flexible shafts are used to interconnect units for multiple applications. Because alignment is therefore less critical, the units need only be loosely lashed or pegged together. This arrangement allows effective use on rough terrain. The drive train configuration allows a pedaller to relax occasionally. The multiple flywheels and the probability that pedal cranks will be out of phase contributesto the smoothing of torque fluctuations.

3.6 Unit construction

It is envisaged that the unit will use standard bicycle parts for bearings, pedals etc. with a fabricated metal frame. A motorcycle type steering head is used for ease of construction but it may be possible to substitute a carrier bicycle fork. Standard frame pressings can be used for bracket axles if available. The main frame is designed to be fabricated from m/s steel sheet folded into rectangular section tubes. A number of other construction procedures can be used, including fabrication from stock tubes etc. The most suitable method will be determined by local conditions. The methods described above are all 'bicycle' level technologies but it would be possible to design for simpler techniques by using timber frames and possible hardwood oil-impregnated block bearings. Timber and bamboo bicycles have been built in the past but have tended to be superseded by steel tube frames because of their greater stiffness, strength, lightness and resistance to deterioration.

The units would be constructed in small scale workshops and the vehicle chassis could be built by local craftsmen.

3.7 Vehicle configuration

For transport use, the unit is connected to a two wheel chassis to form a front wheel drive tricycle. The chassis is designed to be usable independently as a handcart. Connection between the two sections is made at three points. These are the two rear feet of the unit and the top of the handle member on the chassis. The feet locate in lugs on the chassis and a clamp would connect the chassis handle to a bracket on the unit frame just behind the saddle.

3.8 Vehicle characteristics

The steering configuration of the vehicle is obviously unique but is similar to the Crypto Bantam bicycle (1890) - the difference being that a chain system is used for gearing rather than an epicyclic gearbox in the wheel hub. In the evolution of the design, several steering and drive arrangements were tested on a rolling rig prototype.

It was discovered that the configuration used gave rise to less front wheel instability than other arrangements with improved load distribution as the pedaller is well behind the steering axis. Some instability is inevitable as pressure on the pedals with the inclined steering axis tends to turn the wheel. This tendency is minimised by the proposed design as the arc of greatest pedal forces is close to the steering axis and any tendency to turn can be corrected hy the handlebars and by the other foot. The use of a wide tyre also improves matters. Although the riding technique involves some learning, the same process has been found necessary with conventional tricycles, especially for people used to riding bicycles.

The angle of maximum turn whilst pedalling was discovered in practice to be 45^{o} from centre line. As load distribution necessitates a shorter, wider vehicle than conventional tricycles, the turning circle is comparable. Driven wheel traction on gradients is improved by the pedallers normal reaction to hard going in standing up out of the saddle.

3.9 Rear chassis types

In comparison with rear wheel drive tricycles, this arrangement allows the load platform and hence centre of gravity to be situated as low as is consistent with the requirements of ground clearance. This gives improved cornering stability.

As long as the dimensional constraints of the attachment points, vehicle geometry and the requirements of structural strength and stiffness are satisfied, a great variety of chassis designs are possible. These range from wooden structures with fabricated wheels developed from local cart practice to metal frame chassis using available readymade wheels. As mentioned in section 2, the designed payload is 150kg (3 cwt). Two chassis designs are illustrated in the model photographs. One uses Raleigh Chopper wheels in a light tubular space frame - the frame supporting the wheel axles at each side as normal. The other is designed to be fabricated from steel sheet and uses light motor car or motorcycle sidecar wheels on stub axles.

The vehicle has a wheelbase of 1300mm and a track of 1200mm with ground clearance below chassis of 200mm. The ground clearance can be easily varied in the chassis design to suit operating conditions.

3.10 Chassis bodies

A number of body types can be fitted to the chassis for different uses. The standard body would comprise a platform and two angled sides forming wheel mudguards. This gives a platform size of 1050 x 750mm for loads up to 150kg. A seat can be fitted on the sides to carry 2 passengers with space for luggage underneath the seat. The seat would dismantle to form the front and tailgate of a box trailer for goods carriage. A folding canvas hood can be fitted for weather protection in both applications. For tipping, the front of the vehicle can be lifted, pivoting above the back wheels. Alternatively a removable skip can be fitted for bulk transport. For particular applications other bodies can be used e.g. tanks for water carriage (up to 35 gallons).

3.11 Vehicle braking

The front wheel can be fitted with calliper brakes operated by handlebar lever, coaster brake operated by pedal cranks or motorcycle type disc brakes. Depending on the rear chassis design, a variety of rear wheel braking systems can be used. In the case of the chopper wheel chassis, calliper or hub brakes can be used. Hub brakes are more efficient and less prone to fade in wet conditions. The rear brakes would be operated by cables from a handlebar lever with detachable connection at the chassis attachment point. For the stub axle chassis using light motor car wheels, drum brakes in the hubs would be used.

A simple alternative for front wheel braking is to use a fixed wheel sprocket in the primary chain system. This involves more skill in use but gives a reverse gear as well.

3.12 Suspension

Although a refinement, the design allows provision of suspension of the rear wheels. The simplest method is to use 'Indespension' rubber sprung trailing arm units produced for trailers. These are obtainable with stub axles and drum brakes to suit a range of wheel types.

By modifying the steering head, the front fork can be mounted on a rubber block, which would work in shear to give suspension. An alternative is to use a leading link frame to carry the wheel, pivoted at the pedal axle, suspension being achieved by hydraulic units (as on BMW motorcycles) or by a rubber bush at the pivot. Although improving the ride, such arrangements obviously increase cost and complexity.

3.13 Motor assistance

Motor assistance by means of a small two stroke engine can also be employed. Although a further refinement, this demonstrates the flexibility of the design. The engine would be fitted to the front fork, driving the wheel through the secondary chain system. This gives a moped arrangement, using the pedals to start the engine. 2-3hp engines would give speeds of 20mph (30km/hr) for the fully laden vehicle on level ground. Greater speeds would require a stronger chassis and much improved brakes so are not advisable.

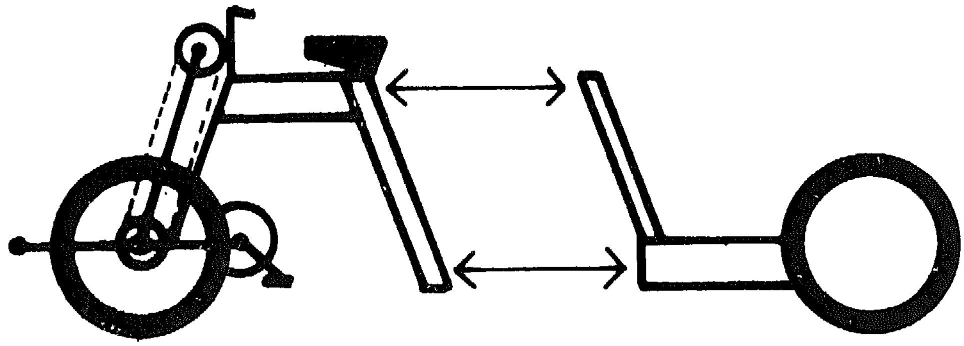
Such an arrangement would be an intermediate stage between pedal driven and conventional motorised vehicles.

3.14 Illustrations

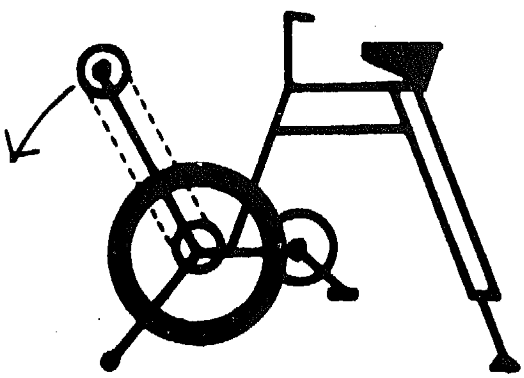
COMPONENTS OF SYSTEM

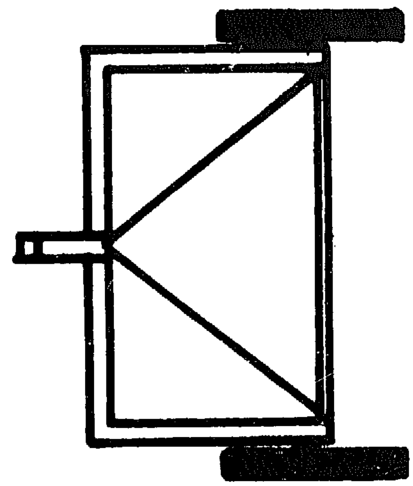
REAR CHASSIS BUILT FROM BOX-SECTIONS WITH "INDESPENSION" UNITS WITH STUB AXLES

DRIVE UNIT CONNECTS TO REAR CHASSIS AT POINTS INDICATED



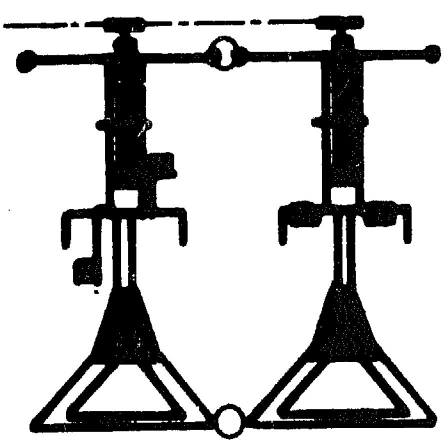
POWER TAKE-OFF CAN BE POSITIONED TO SUIT MACHINE, SECURED BY GUYLINES FROM FRONT BAR TO REAR LEGS

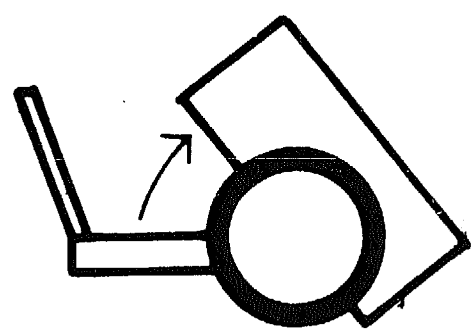




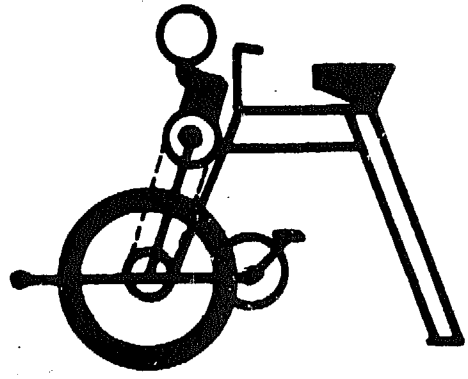
POWER TAKE-OFF

UNITS LINKED FOR MULTIPLE POWER USES



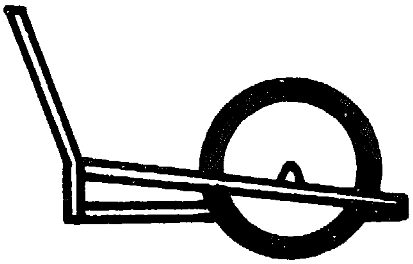


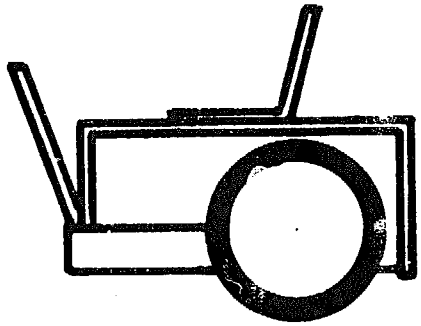
TWO-STROKE ENGINE FITTED TO SECONDARY CHAIN



TIPPING BODY FITTED TO CHASSIS

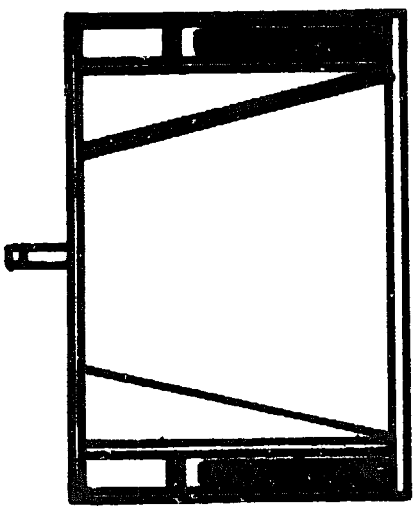
REAR CHASSIS BUILT
FROM STOCK TUBES
WITH STANDARD
BICYCLE WHEELS
AND BRAKES

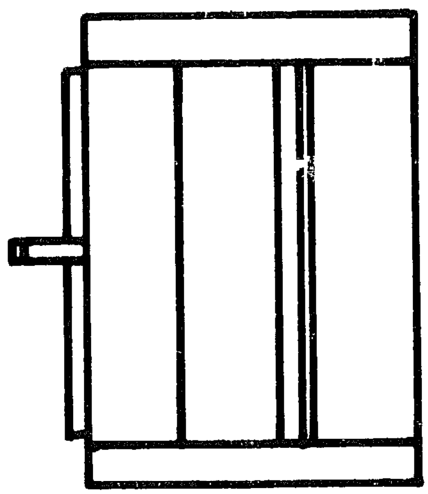




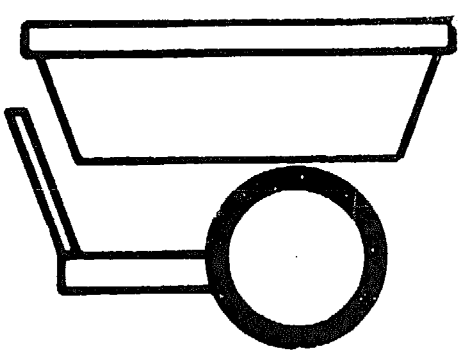
WOODEN BODY WITH
REMOVABLE SEAT

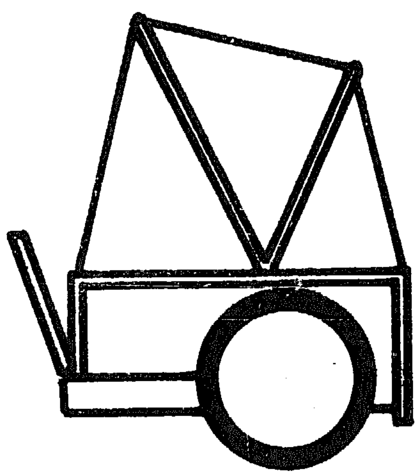
SEAT SECTIONS
FORM FRONT AND
TAILGATE FOR
GOODS TRANSPORT





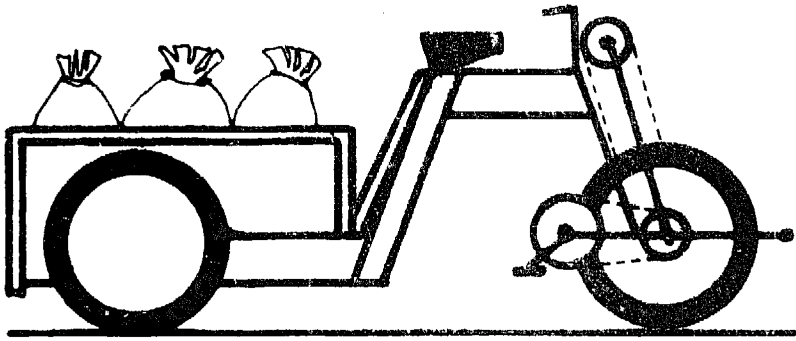
FOLDING CANVAS
COVER FITTED TO
PROTECT PASSENGERS
OR GOODS



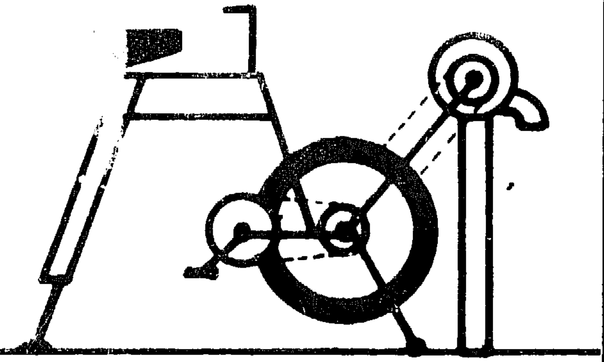


CHASSIS WITH
REMOVABLE SKIP

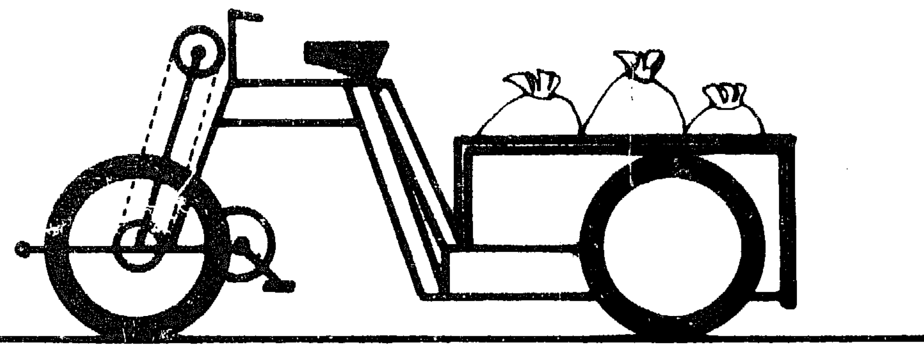
TYPICAL PATTERNS OF USE



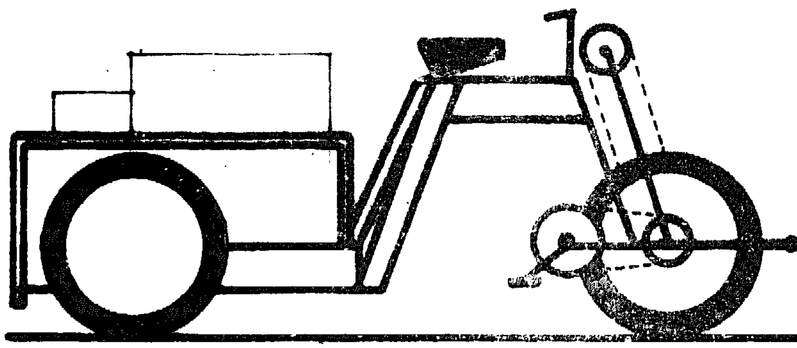
AGRICULTURE • TRANSPORT OF SEED



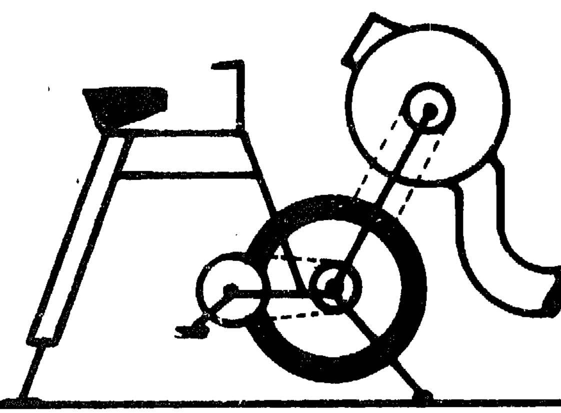
WATER PUMPING



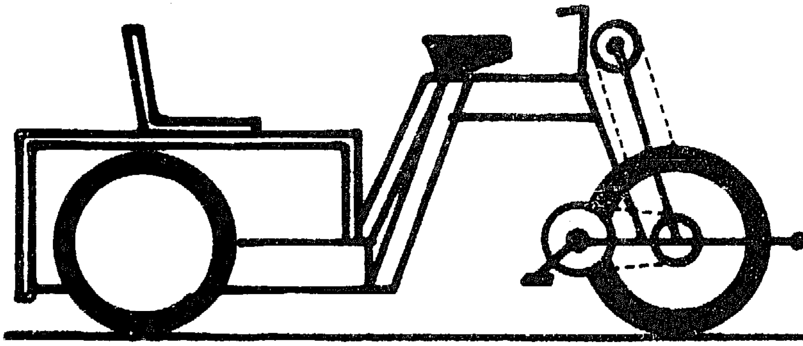
TRANSPORT OF PRODUCE TO MARKET



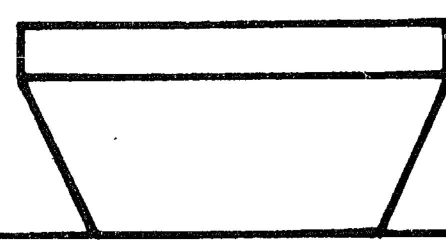
SMALL-SCALE INDUSTRY • HAULAGE OF MATERIALS



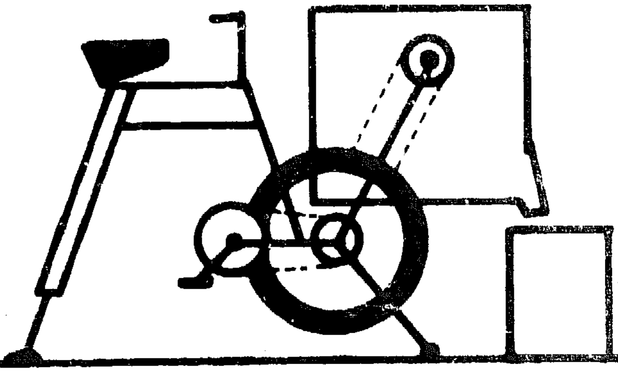
FORGE BLOWING



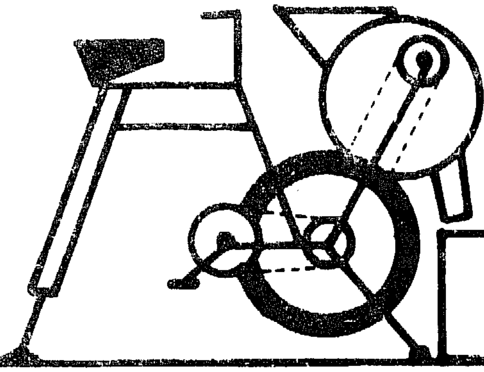
CONTRACT USE • TAXI HIRE



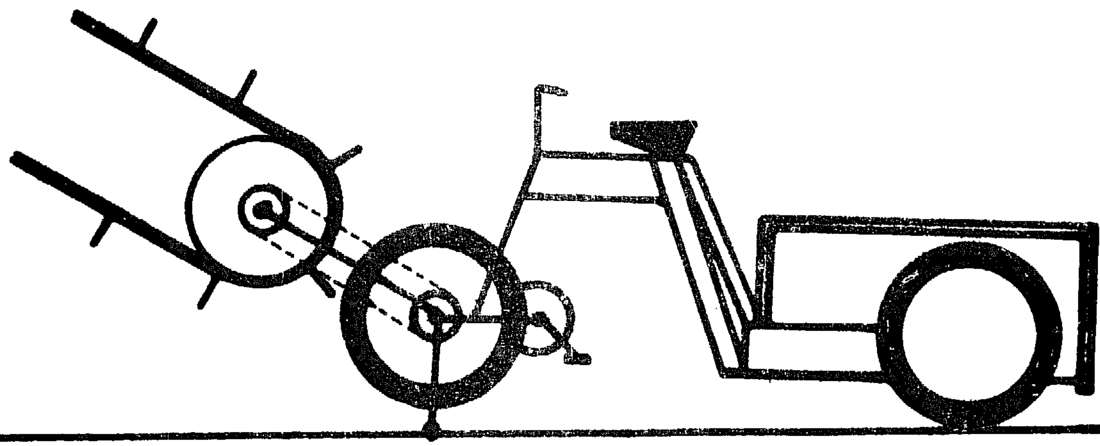
SKIP DELIVERY



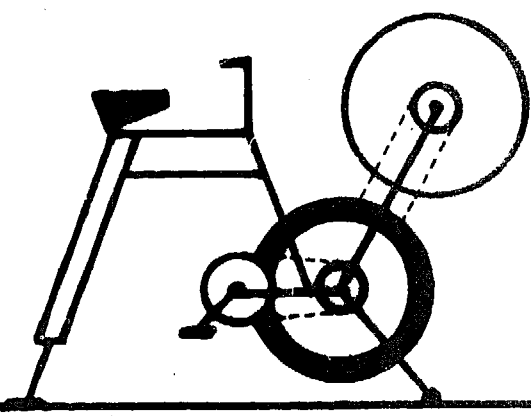
GRAIN WINNOWING



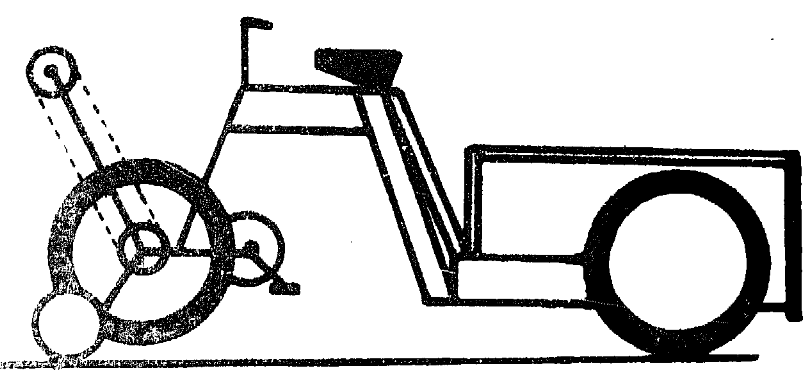
GRAIN MILLING



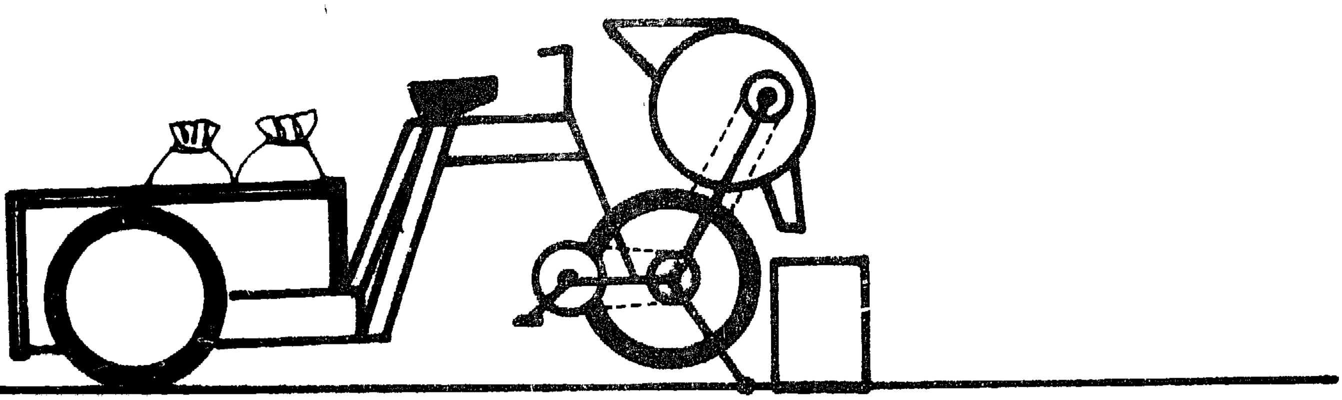
GRAIN ELEVATION



TOOL GRINDING



BATTERY CHARGING



HAULAGE OF GRAIN TO COMMUNAL MILL