

Design and development of a pedal driven rice thresher

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DESIGN AND DEVELOPMENT OF A PEDAL DRIVEN RICE THRESHER.

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WLV. LANDBOUW EN TRANSPORT MECH-

S U M M A R Y

The aim of this work was to develop a simple, human driven, low cost portable rice thresher. This objective is in line with the general policy of the Indonesian government, which allows limited form of agricultural mechanization in Java due to enormous population pressure. In this work the average and optimal power produced by a human being was measured using a bicycle-ergometer. Besides that the power requirement of the thresher, which consists of a wire loop threshing drum with concave screen and a winnower, was also determined. The data showed that the thresher can be driven by a man within a reasonable period of time. In addition, the threshing efficiency and the cleanness of the rice grain were observed during field tests. The capacity of the unit was about 100 kg/hour and it should be operated by 3 man.

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1. INTRODUCTION

As in most tropical countries rice is the staple food for Indonesia. The area harvested under paddy is about 8.3 million ha/year and the milled rice production about 17 million tons/year (Central Bureau of Statistics, 1977). There is a tendency now that in the relatively flat and irrigated rice growing plains in Indonesia, where high yielding IRRI varieties are grown intensively, the traditional ani-ani harvesting knife is replaced by the sickle harvesting method.

Harvesting with the ani-ani knife of IRRI varieties is very time consuming and more difficult as compared to the harvesting of local varieties with this knife; more difficult and tiring because of the shorter straw and very time consuming because of the large quantity of small panicles that are often still surrounded by green leaves at the time of harvesting. Local varieties on the contrary present much less panicles for the same yield level and their panicles are heavier and at a more convenient cutting height for the harvester. Moreover, with the relatively easy-shattering IRRI varieties, this traditional harvesting method with its subsequent handling and transport results in heavy shattering losses, especially in case of delayed harvest. Harvesting by sickle is therefore becoming more and more important in these areas.

Because of the transport limitations, in case of sickle harvesting the thresher operation has to be carried out inside or close to the fields. Traditionally the following types of threshing take place :

- a. *by foot trampling* in case the crop is cut by sickle *just below the panicles* (straw length of 10 to 15 cm). The short cut crop is directly put in bags after cutting and transported for threshing to the border of the field or to the farmyard. For each ton of rice (gabah) about 500 kg of straw has to be transported. Transport in bags minimizes the transport and handling losses.
 - b. *by handbeating of bundles of paddy* on wooden frames (placed flat on the ground under a slope or placed as a table in case the crop is cut by sickle just above the ground; straw length 50 to 70 cm). This long cut crop is placed on heaps inside or at the border of the field for threshing by handbeating. For each ton of rice about 2 tons of straw has to be handled. Especially with the easy-shattering IRRI varieties, losses during handling and transport in field are important.
- I In both cases threshing should be executed as soon as possible as the relatively wet crop cannot be stored in bags or on heaps for too long. Losses can be prevented by putting large plastic sheets on the ground and screens around the threshing area. Since this types of threshing require hard work, it should be possible to improve them by using mechanical means.

Actually several types of small *engine-driven* portable thresher for rice are already manufactured in Indonesia. Due to low income of Indonesian farmers and cheap labors, especially in Java, these thresher are less suitable for use.

Beside that the one foot driven pedal thresher (Minoru type) has never been popular in Indonesia. The one-foot treading movement is very tiring, the power efficiency is low (compared with two legs cycling as on a bike) and the capacity is low compared with foot trampling. Furthermore local production of this type of thresher meets problems because of the application of gears in the transmission. Thus, the objective of this work is to optimize the efficiency of the power delivered by a man and to design, develop and test a portable thresher which can be driven by one man.

2. HUMAN ENERGY.

The muscles of man are sources from where biological energy can be delivered. The power depends on the following factors; the person who delivers the energy, his condition and the time period over which the power has to be delivered continuously.

Figure 1 gives, according to Wilkie (1960) the maximum power generated by a man in relation to the length of time in which this power can be delivered. This graph shows that the maximum power decreases very fast if this power has to be delivered for more than a couple of minutes. *Trained* people are able to generate about 0,38 kW for along period of time. Wilkie's data, however, are rather optimistic as it can be seen later.

2.1. Measurement of power expenditure during work.

With the symplified formula of Wier, power expenditure of a human body during work can determined. The formula is as follows :

$$\dot{M} = 1,05 - 5,015 \times \frac{FO_2}{100} \times \dot{V} \text{ in kcal/minute}$$

in which: \dot{M} = power expenditure in kcal/minute

\dot{V} = volume of expired air in litres/minute,
measured with a respirometer.

FO_2 = oxigen content of the expired air (%), measured
with a paramagnetic oxigen analyser.

VAN LOON (1963) found that power expenditures of workers during actual working time were as follows :

- tree cutting	8,5 kcal/min (0,62 KW)
- plowing with handtractor without steering clutches in wet paddy fields	8,9 kcal/min (0,60 KW)
- rotary tilling with powertiller with steering clutches in wet paddy fields	6,2 kcal/min (0,43 KW)
- preparing soil with handtools	5 - 11 kcal/min (0,35 - 0,77 KW)

The following table provides a rough classification of workloads, according to Christensen.

TABLE. 1. The relation of type of work, power expenditure and heart rate.

Type of work	Power expenditure (KW)	Heart rate (beats/min)
Very light work	less than 0,17	less than 75
Light work	0,17 - 0,33	75 - 100
Moderately heavy work	0,33 - 0,55	100- 125
Heavy work	0,55 - 0,67	125 - 150
Very heavy work	0,67 - 0,84	150 - 175
Extremely heavy work	more than 0,84	more than 175

The endurance level of 6 kcal/min corresponds with about 0,4 kW power expenditure. Because the largest part of this power is converted into heat, only 10 - 25% of this power is really available for the productive work. The last mentioned percentage depends on the physical condition of the worker, the working methods and tool used.

2.2. Measurements on a bicycle ergometer.

A cycling man, who has to supply a certain amount of power to a machinery, for instance a blower, thresher, winnower etc, should be able to drive it comfortably. If the number of revolutions of this driven machine is more or less fixed (optimal working condition), the transmission ratio between the cycling man and the driven machine determines the number of revolutions which have to be performed by cycling man while delivering the power the driven machine requires.

Therefore, the optimal number of revolutions for a cycling man at different power levels should be investigated, in order that the transmission ratio could be determined.

A bicycle ergometer (LODE) with a hyperbolic characteristic was used for the measurement. The power level (watt) was chosen, so that the *product* of torque and the number of revolutions was always constant. In this comparative study, the heart rate of the testee was recorded **continuesly** by means of a recorder connected with an electrode on the testee arm. The experiments were carried out in a laboratory at a temperature of about 22°C and a relative humidity of about 40%.

All measurement have been repeated with several people. Every run on the ergometer took 13 minutes. **F**irst for warming up, the power was set at 50 Watt for 5 minutes, then for every 2 minutes it was set at 75, 100, 125 and 150 Watt respectively.

Figure 2 shows a typical recorder output of a 50, 60, 70 and a 80 rpm run. Test runs have been done with three different people with ages of 25, 28 and 30 years. From figure 2, it can be concluded that until about 100 Watts the 60 rpm speed is the most convenient for the testee. Above 100 Watts the heart rate between 50 and 60 rpm speeds are almost the same. The average of all test runs is given in Figure 3.

From this graph, it can be seen that the optimal rpm at power output of about 50 to 75 Watt is around 60 rpm. At higher power outputs (100 and 150 Watt) the comfortable speed is between 50 and 60 rpm.

Using Christensen classification, the efficiency of the power expenditure of a cycling man can be calculated. For example, a power of 100 Watt at 60 rpm with an heart rate of 140 beats/minutes corresponds with a power expenditure of 662 Watts and an efficiency of 16%.

Figure 4 gives the efficiency as function of the delivered power at 60 rpm and the heat production losses in the human body during cycling. The energy converted during normal cycling is relatively high and up to 20% of the power expenditure is converted to energy at the pedals.

In additional tests, it was clearly demonstrated that the power-output of a cycling man over a longer period of time, for instance half an hour, heavily depends on his physical condition, level of training, climatic conditions on the test place, the existence of a cooling air-stream (as on a bike) and last but not least the willingness of the testee. The results range from 150 Watt to even more than 200 Watt for a very experienced and trained Indonesian beca driver (Indonesian bicycle trishaw). At a power level of 150 Watt this beca drivers preferred to pedal with about 50 rpm as already found in figure 4. They cycled for a duration of forty five minutes without any problem.

3. DESIGN OF THE THRESHER.

With the obtained human power data, a thresher has been designed with the requirement that it should be driven by human power and in such a way that this limited amount of power is used as optimal as possible.

As the first step a portable thresher without cleaning device has been designed, consisting of a threshing drum with tip to tip diameter of 450 mm rolled from steelplate and fitted with wire-loop threshing teeth. Under the drum an adjustable concave screen of easy available netting was placed. A pedal mechanism was built out of bicycle parts and pipe to complete the first version of the thresher.

Figure 5 shows the set up of the power measurements in the laboratory and the results of the idle running tests at different drum speeds are plotted in figure 6. The graph indicates that at a drum speed of 400 rpm (drum tip speed of 10m/second), which is the optimal speed for threshing, the power input was about 25 Watt. During threshing (hold-on feeding) the total power increased to approximately 80 Watt, depending on the variety and the moistness of the long cut paddy.

Since the power requirement for the first version of the thresher is only 80 Watt and the available power is between 100 - 150 Watt, a fan for winnowing the threshed grain was added. The choice was an axial fan (diameter 25 cm, speed 650 rpm) right across the thresher with a velocity at the outlet of 6m/second and consuming about 35 Watt. The results of the idle running tests of the second version of the thresher is shown in figure 7. The power input at 400 rpm is 60 Watt, bringing to total power consumption of the thresher at less than 125 Watt, thus within range of a healthy man. Figure 9 gives a picture of the threshing unit without the cover.

4. THRESHER FIELDTESTS.

With assistance from the Provincial Agricultural Extension Service of West Java limited fieldtests using one variety of paddy (IRRI-26) have been carried out in the paddy field. Moisture contents were measured with a portable moisture tester. Losses and impurities of the threshed grain were determined by selecting and weighing.

There was no problem in the threshing process, even at 25% moisture contents. The thresher was operated by 3 man, including the driver/cyclist and a capacity of about 100 kg of threshed grain per hour was reached (33 kg/man-hour). Furthermore, no difficulties were encountered regarding the power demand during threshing even with different drivers/cyclists. The determination of threshing losses and impurities met some problems because of an improper position of the grain outlet which caused mixing of threshed and unthreshed material outside the thresher. Also the connection between the driving mechanism and the thresher created some problems due to unevenness of the field.

Recently, these problems have been removed by modification of the design. The grain outlet has been moved underneath the thresher and a flexible coupling was fitted between the driving unit and the thresher to eliminate unevenness of the threshing place. In the near future, the thresher will be included in a research/testing program executed together with the Department of Agricultural Engineering of the Bogor Agricultural University where the thresher will be tested, compared and evaluated with at least 4 engine driven threshers.

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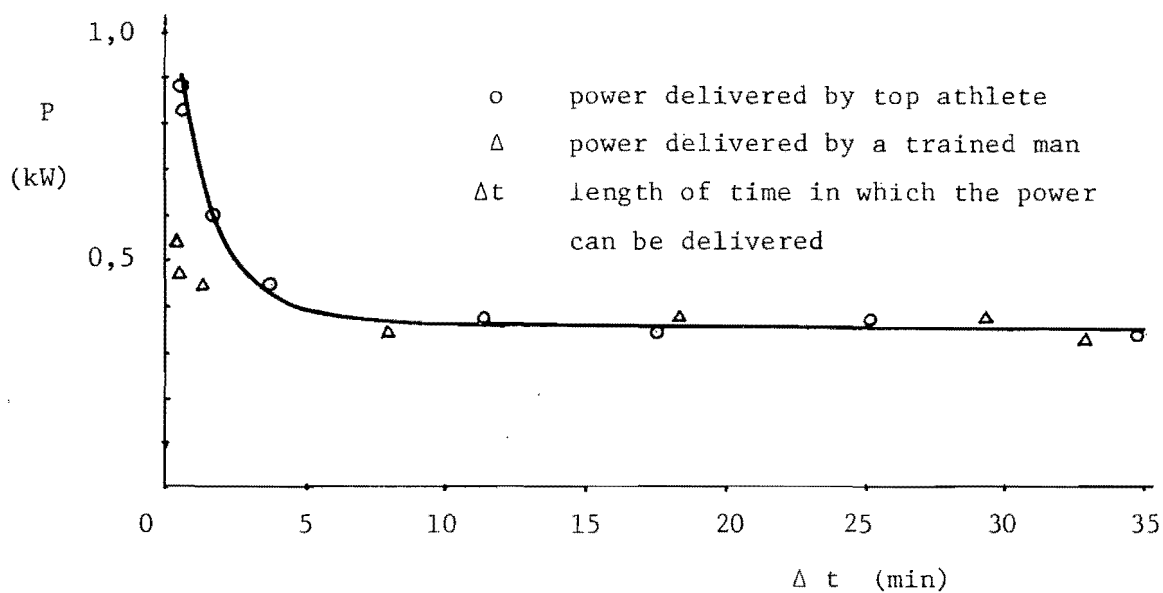


FIGURE 1. Power output versus duration of time according to Wilkie.

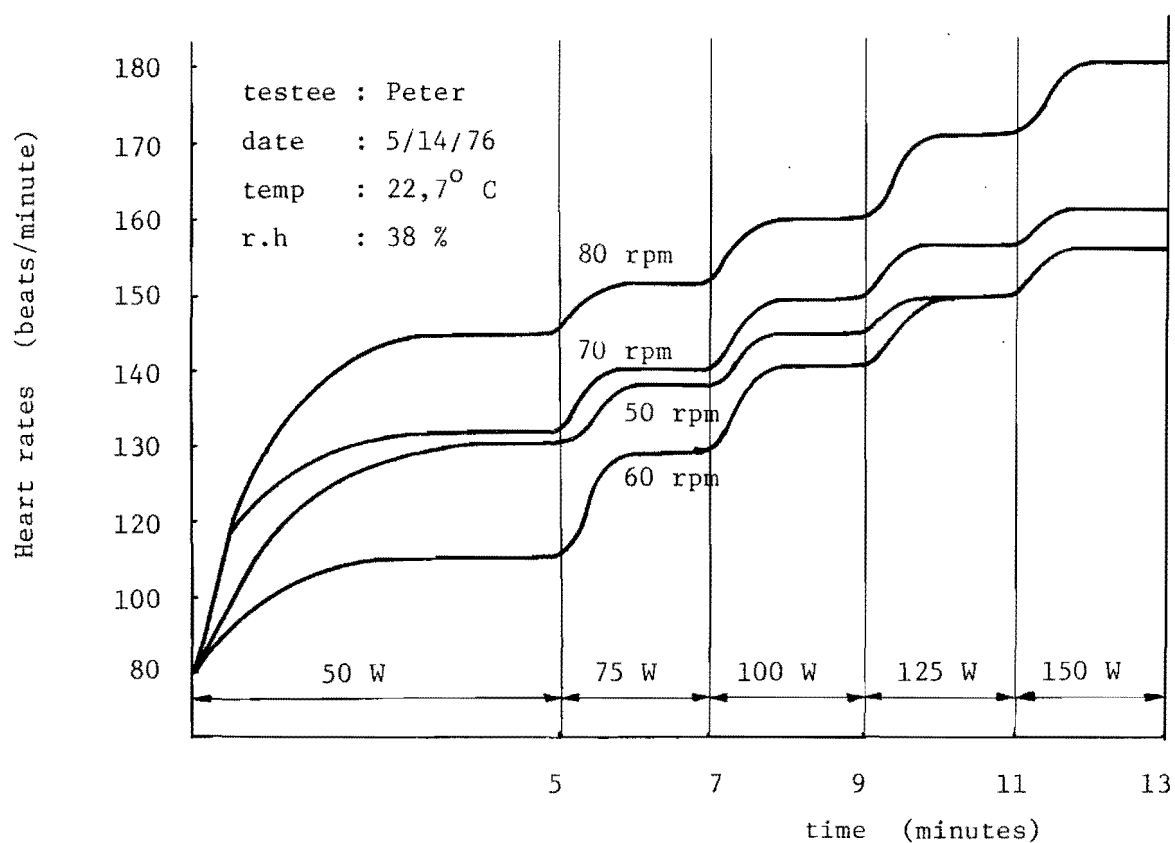


FIGURE 2. Typical recorder output at 50, 60, 70, and 80 rpm.

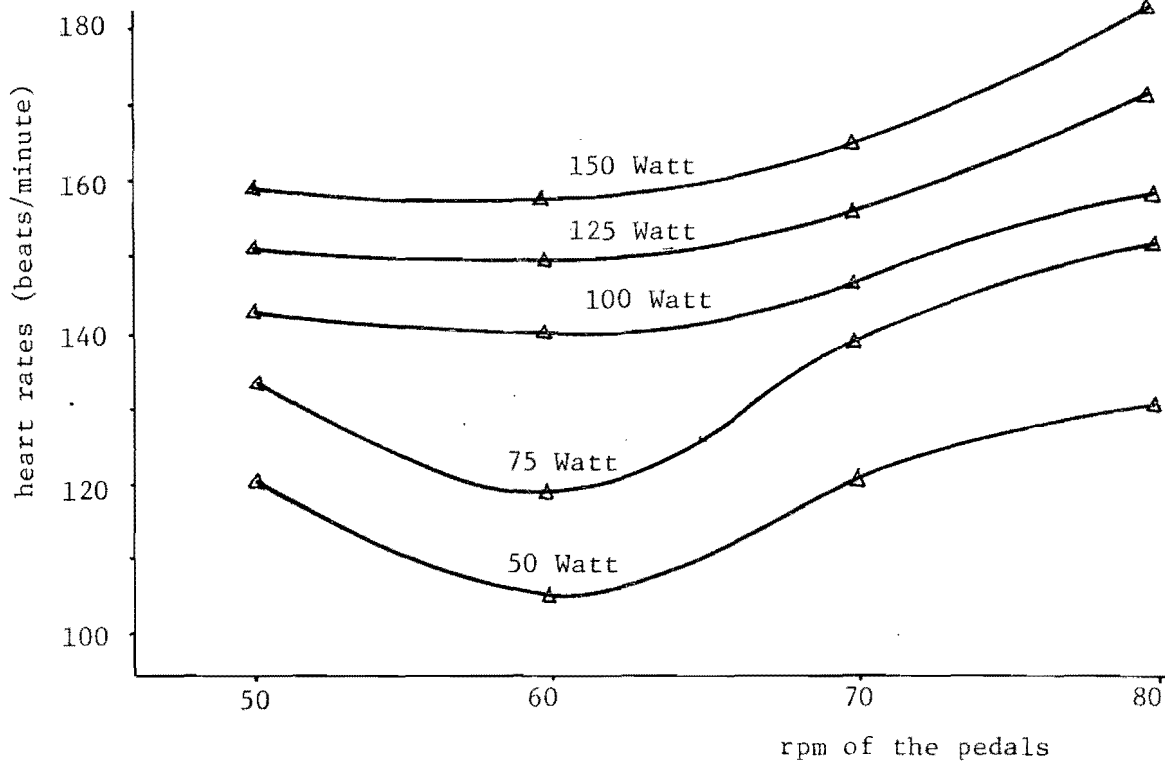


FIGURE 3. Average heart rate versus rpm for various power levels.

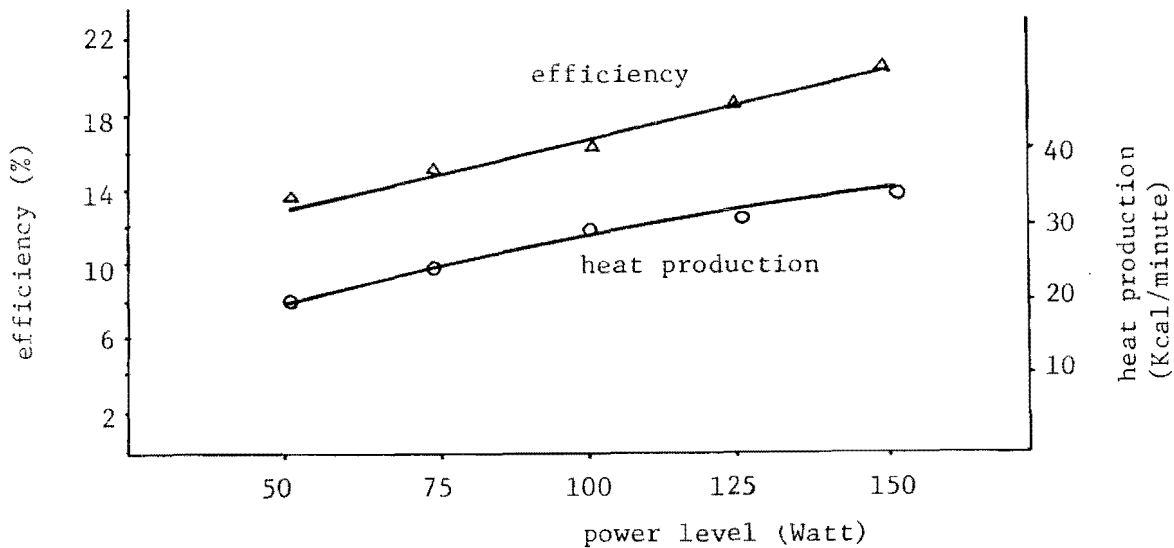


FIGURE 4. Efficiency and heat production versus power level.

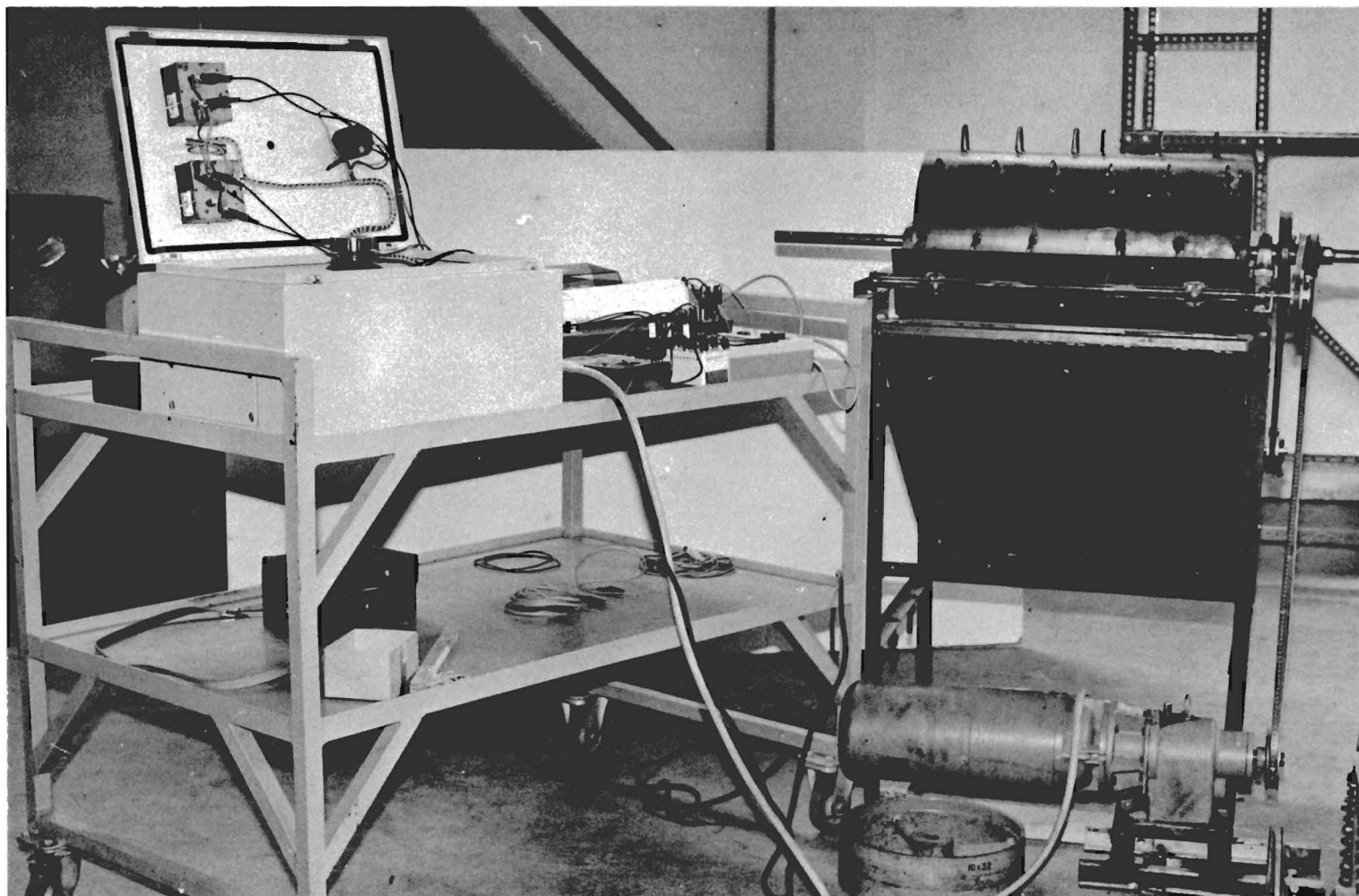


FIGURE 5. Set up of power measurements in the laboratory.

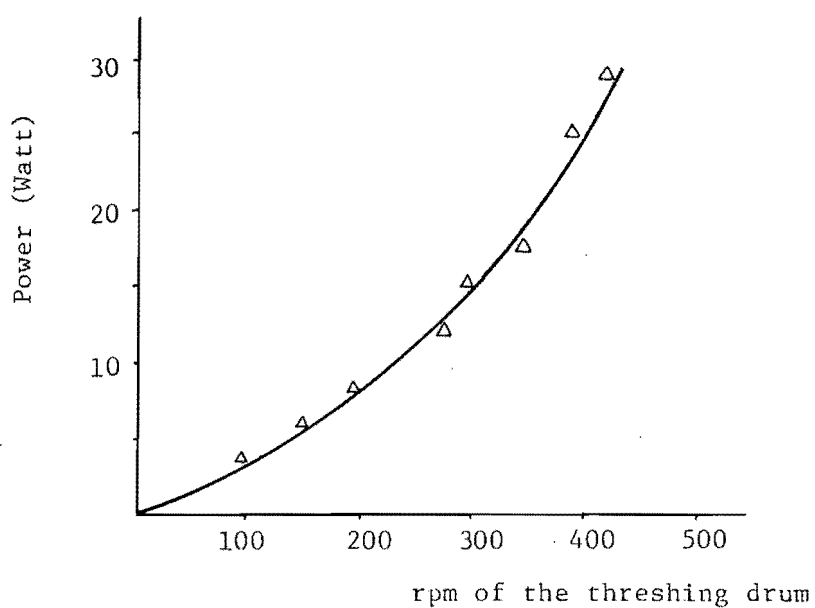


FIGURE 6. Power requirement of idle running of the threshing drum.

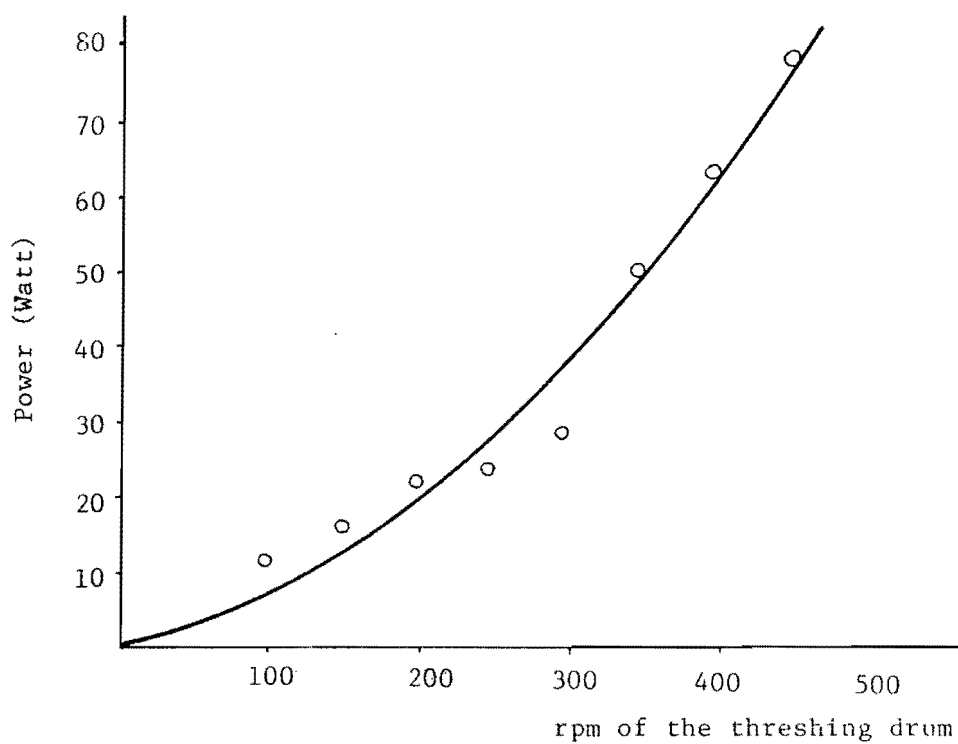


FIGURE 7. Power requirement of idle running of the thresher, including the winnower.

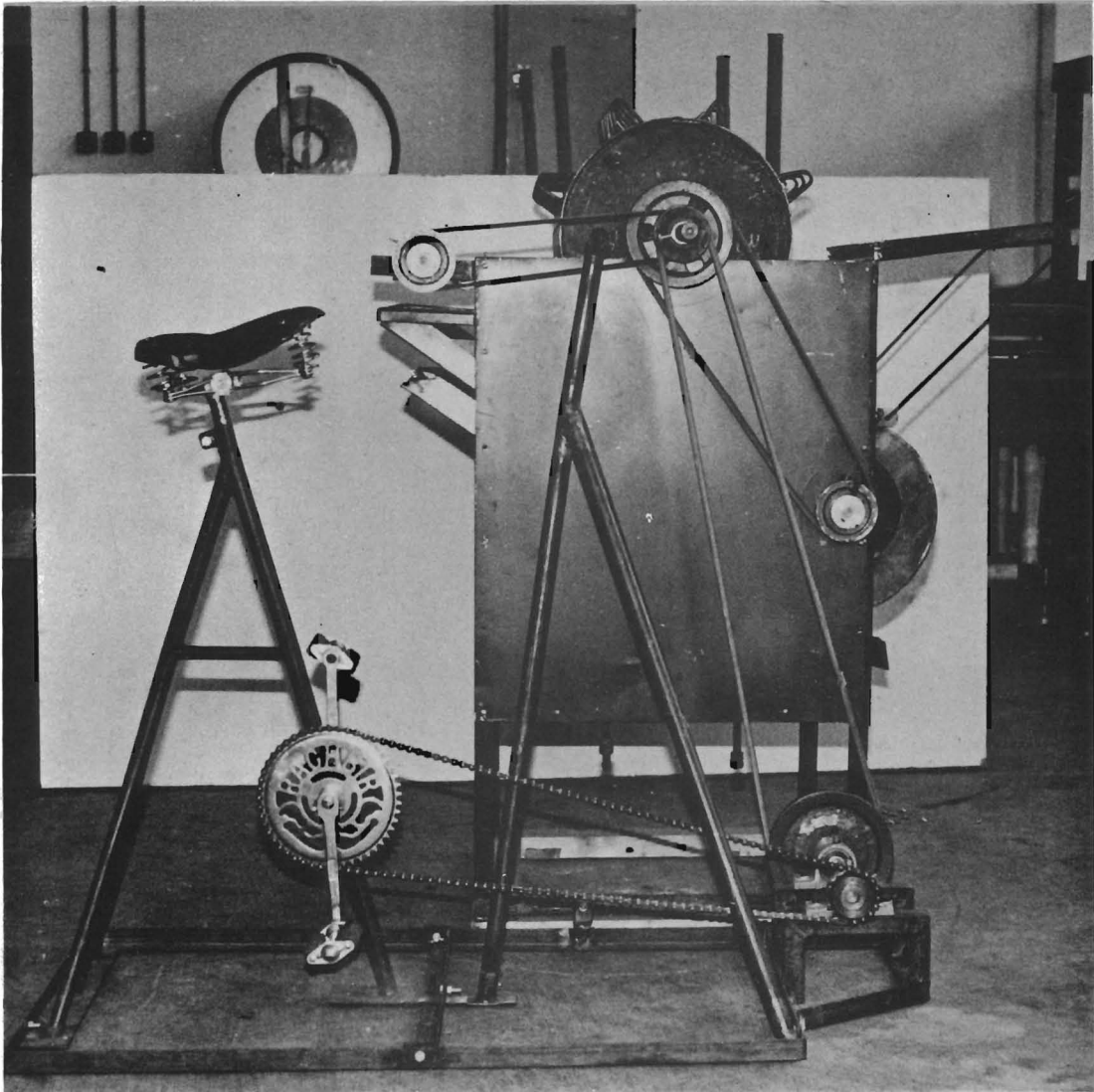


FIGURE 8. Side view of the thresher without top cover.