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<u>Low Cost Windmill for Developing Nations</u>

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VITA

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U S A

LOW COST WINDMILL FOR DEVELOPING NATIONS

LOW COST WINDMILL FOR DEVELOPING NATIONS

by

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ABSTRACT

Construction details for a low cost windmill are presented.
The windmill produces one horsepower in a wind of 6.4 m/sec
(14.3 mph), or two horsepower in a wind of 8.1 m/sec (18.0mph).
The windmill uses the rear axle and differential of a small car.
Other parts are made from sheetmetal, pipe, steel ribbon, rod,
angle iron, or channel, welded or bolted together, and wood.
No precision work or machining is required, and the design can
be adapted to fit different materials or construction skills.
The rotor blades feather automatically in high winds to prevent
damage. A fullscale prototype has been built and tested success-
fully.

INTRODUCTION

The VITA windmill (Fig. I1) is a complete aerodynamic and structural redesign of an earlier prototype designed, built and tested by W. Delameter and P. Miller under the supervision of H. Bossel of the Mechanical Engineering Department. The fullscale prototype proved the soundness of the rotor design, overloading control (blade feathering), and directional control (vane).

The VITA windmill consists of five major components: the transmission, the rotor with overloading control (feathering), the vane for directional control, the turntable (supporting rotor, transmission, and vane), and the platform and tower structure.

The rotor is constructed from steel rod, support wires, and sheet metal blades hinged to the spokes. A simple spring-loaded mechanism allows the blades to feather in high winds or when overloaded. The mechanism is explained in Fig. I2. The rotor center plate is bolted to the brake drum of the rear axle of a small car. The wheelbrake stops the rotor when it is not is use. The other wheel is permanently locked, resulting in a transmission ratio of about 1:4 from the horizontal to the vertical. The rear axle is free to swivel about the vertical on a turntable. A vane, which is set at a small angle to counteract the torque transmitted vertically, keeps the rotor pointing into the wind. The whole assembly is mounted on a small platform on a single-beam tower.

Detailed blueprints are not presented in this report, since the design will differ with the materials, parts, and skills the builder finds at his disposal. He should understand that most dimensions and details (except those stated explicitly) are not critical, and can be adapted to suit the needs. There are a few exceptions in particular. First, number, shape, and angles of the blades should remain unchanged to obtain the specified performance. Second, the control spring should come close to the stated specifications in order to adequately protect the rotor from possible destruction. Third, vane area, vane arm from the vertical axis, and vane angle should remain as given in the report for the same rotor and transmission ratio. More generally, the product (vane area) x (vane arm) x (vane angle) should remain constant, where the vane angle should always be less than about ten degrees. This product must remain proportional to the torque transmitted; i.e., it should be doubled if a transmission ratio of 1:2 instead of 1:4 is used for the same rotor.

A few possible modifications of the basic design might be of interest.

Automobile rear axles offer a rather wide choice of transmission ratios depending on how they are mounted, and whether one wheel drum or the slip gears are locked or removed. This range is from approximately 1:4 from rotor to vertical shaft if the rotor is mounted on the wheel drum, to 4:1 if the rotor is mounted on the drive shaft side. In the first case, a second

rear axle and/or an automobile gear box could be used to further
increase the rotational speed and drive a centrifugal pump,
circular saw, electric generator, feed mill and the like. In
the second case, the slow rotation would permit driving directly
a reciprocating pump, or other machninery requiring slow rotation.
In that case, the torque in the vertical shaft cannot be counter-
acted by the aerodynamic torque of a vane of reasonable size
and the rotor must either be mounted rigidly in the direction
of prevailing winds, or turned manually and locked, or turned by
a nonreversible control mechanism (which would greatly increase
the complexity). Manual turning should also be considered for
the case of lower torque and higher shaft speed of rotation.
It would eliminate the vane and simplify the central bearing
problem, since less precision and some friction would be permitted.
Specifications for a smaller 2 meter windmill, and suggestions for
electric power generation are provided in the Appendix.

PERFORMANCE DATA

Performance at sea level

Windspeed

m/sec	4	6	8	10
km/h	14.4	21.6	28.8	36.0
mph	9.0	13.4	17.9	22.4

Rotor speed

revolutions per minute (rpm)	21.0	31.5	42.0	52.5

Rotor torque

mkg$_f$	8.8	19.8	35.2	55.0
ft lb	63.6	143.2	255.0	398.0

Starting torque

mkg$_f$	15.3	34.5	61.4	96.0
ft lb	111.0	250.0	445.0	695.0

Power

mkg$_f$/sec	18.1	61.1	145.0	283.0
kw	0.177	0.60	1.42	2.77
hp	0.24	0.81	1.91	3.73

Altitude effects

Altitude

m	0	1000	2000	3000	4000
ft	0	3280	6560	9840	13,100

percentage reduction
of power and torque

%	0	9	18	26	33

(rotor rpm unaffected)

Feathering Information

For control spring of spring constant $1.5 kg_f/cm$ precompressed to $13.5\ kg_f$:

Rotor braked: Blades begin to feather at a wind speed V of 6 m/sec. Blades fully feathered at $V = 10$ m/sec.

Rotor running under load: Blades begin to feather at $V = 8$ m/sec. Blades fully feathered (and rotor stopped) at $V = 12.5$ m/sec.

Rotor running free: Little or no feathering. Rotor speed will increase with wind speed, and damage is likely. **Always brake rotor when not running under load.**
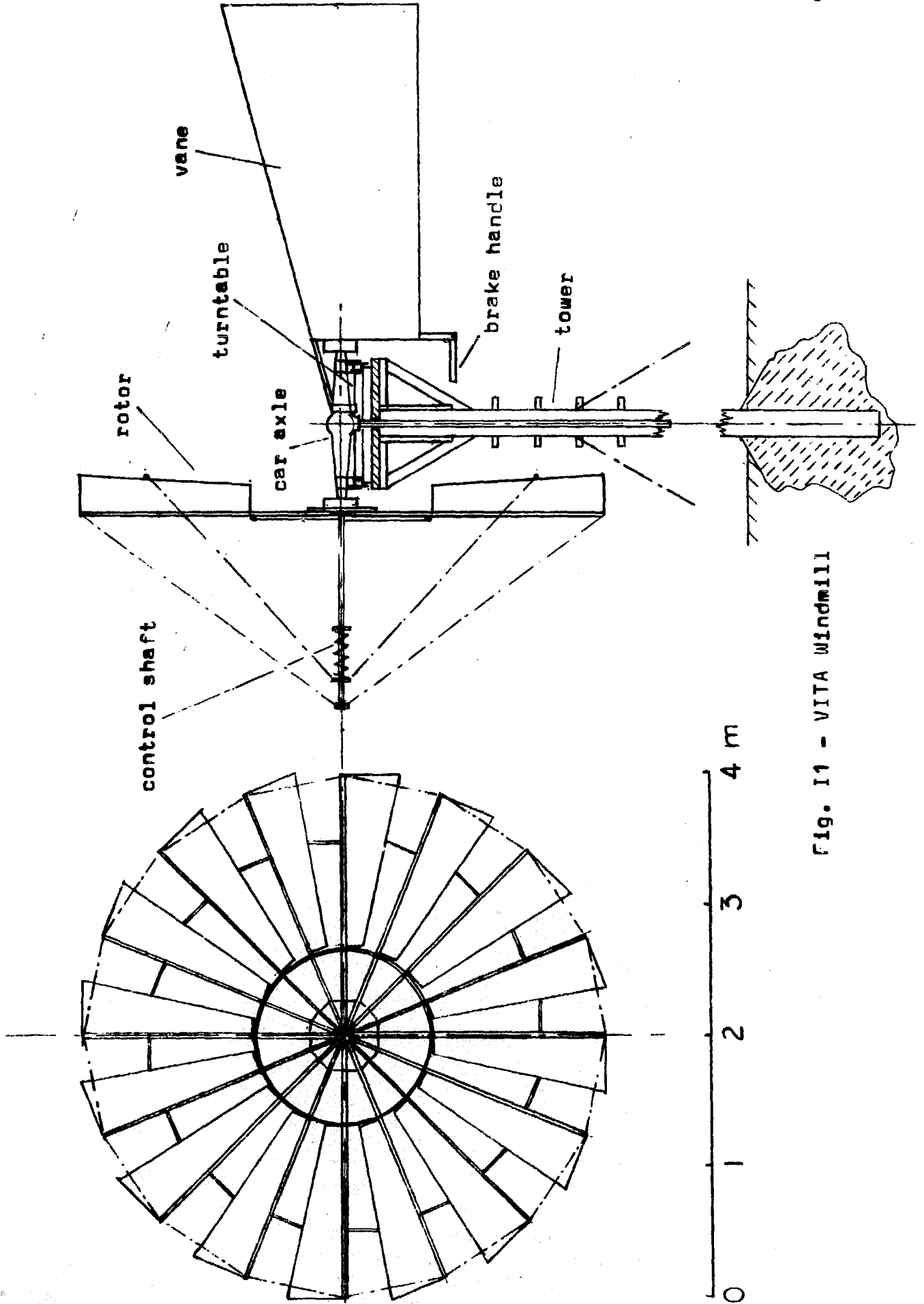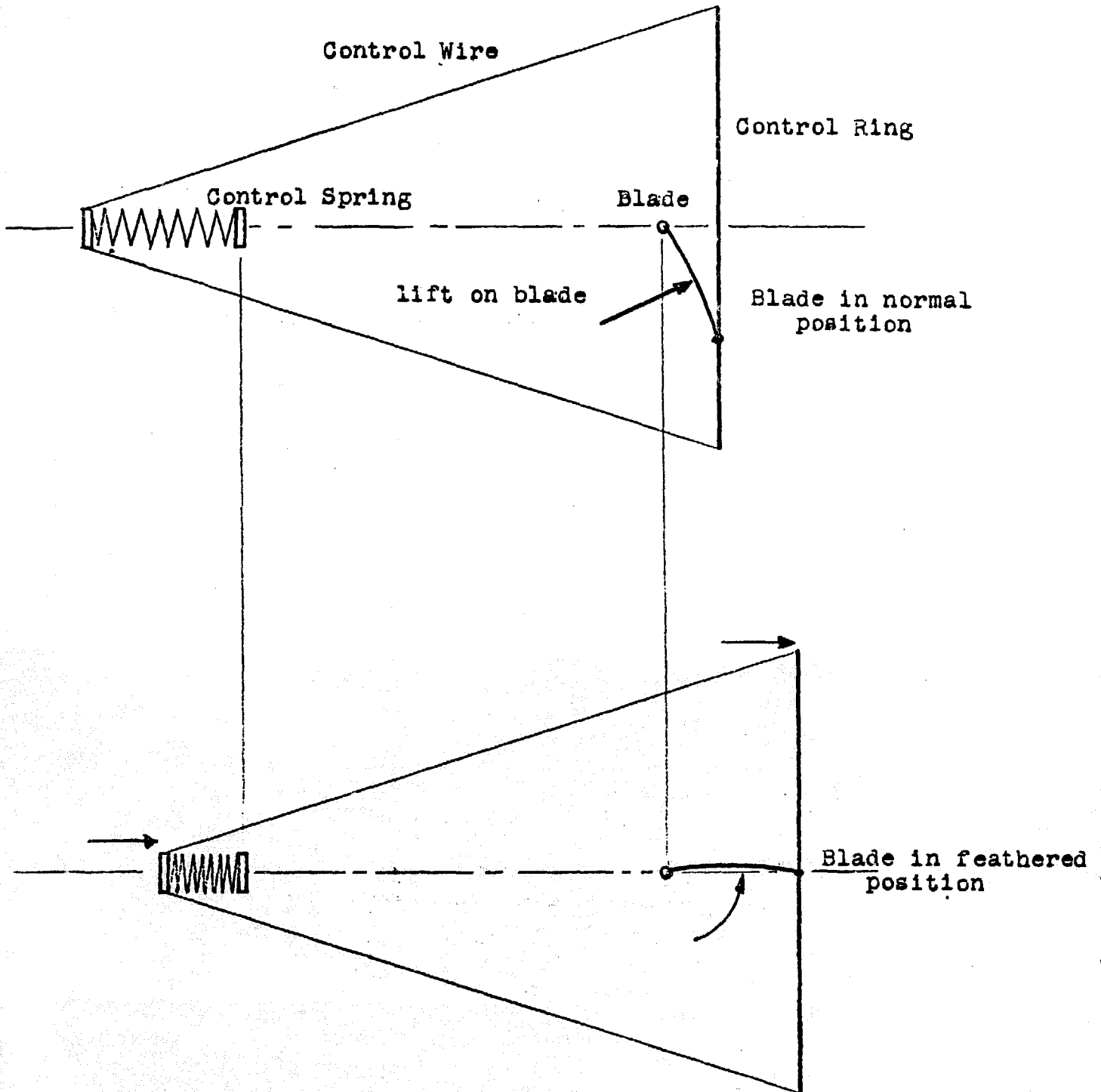
vane

turntable

brake handle

tower

rotor

car axle

control shaft

Fig. I1 - VITA Windmill

0 1 2 3 4 m

Sketch of Blade Feathering Mechanism

Control Wire

Control Ring

Control Spring   Blade

lift on blade

Blade in normal
position

Blade in feathered
position

When lift on blades becomes excessive,
control spring compresses and blades
feather so that blade angle is steeper,
thus slowing the rotor. When windmill
is stopped, blades feather parallel to
wind. Control ring forces all blades
to feather evenly.

Fig. I2

TOOLS

Protractor (to measure angles)
Hack saw
Welder (gas or electric)
Sheet metal shears
Steel drills (approximately 3 to 30 mm)
Hammer
Pliers
Adjustable wrenches, or set of wrenches

General Notes:

All sheet metal, nuts, bolts, wires, nails should be galvanized, if available.

All nuts must be secured by using spring washers, lock washers, or a second nut tightened against the first.

CONVERSIONS

1 m = 100 cm = 1000 mm = 3.28 ft = 39.4 in
1 in = 25.4 mm
1 kg_f = 2.2 lb_f

1 m/sec = 3.6 km/h = 2.24 mph
1 kw = 1.34 hp

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W. Delameter, R. Sprankle, Park H. Miller III,
        Windmill and Waterpump for Developing Nations.
        Mechanical Engineering Dept., University of California,
        Santa Barbara, Calif., June 1969.

TRANSMISSION

The present design uses a rigid rear axle and differential (from a small car) with mechanical brakes. Other car axles can be used with corresponding modifications. If the wheels have hydraulic brakes, use the master brake cylinder and other components from the car brake system to build a rotor brake system.

Lock permanently the wheel drum on which the vane is to be mounted, by either locking the brake completely and permanently, or by blocking the slip gear. In most cars the rotational speed of the drive shaft will then be approximately four times higher than that of the rotor mounted on the wheel drum.

The drive shaft and the two universal joints are used to transmit the rotor power to the driven machinery (see Fig. A1). The drive shaft can be lengthened by using pipe of approximately 20 to 40 mm outer diameter. Note: Permit some axial motion of the drive shaft to allow for thermal expansion and use shear pin to prevent damage (see Fig. A2).

Various possibilities of transmissions using a second automobile rear axle and/or automobile transmission are shown in Fig. A1.
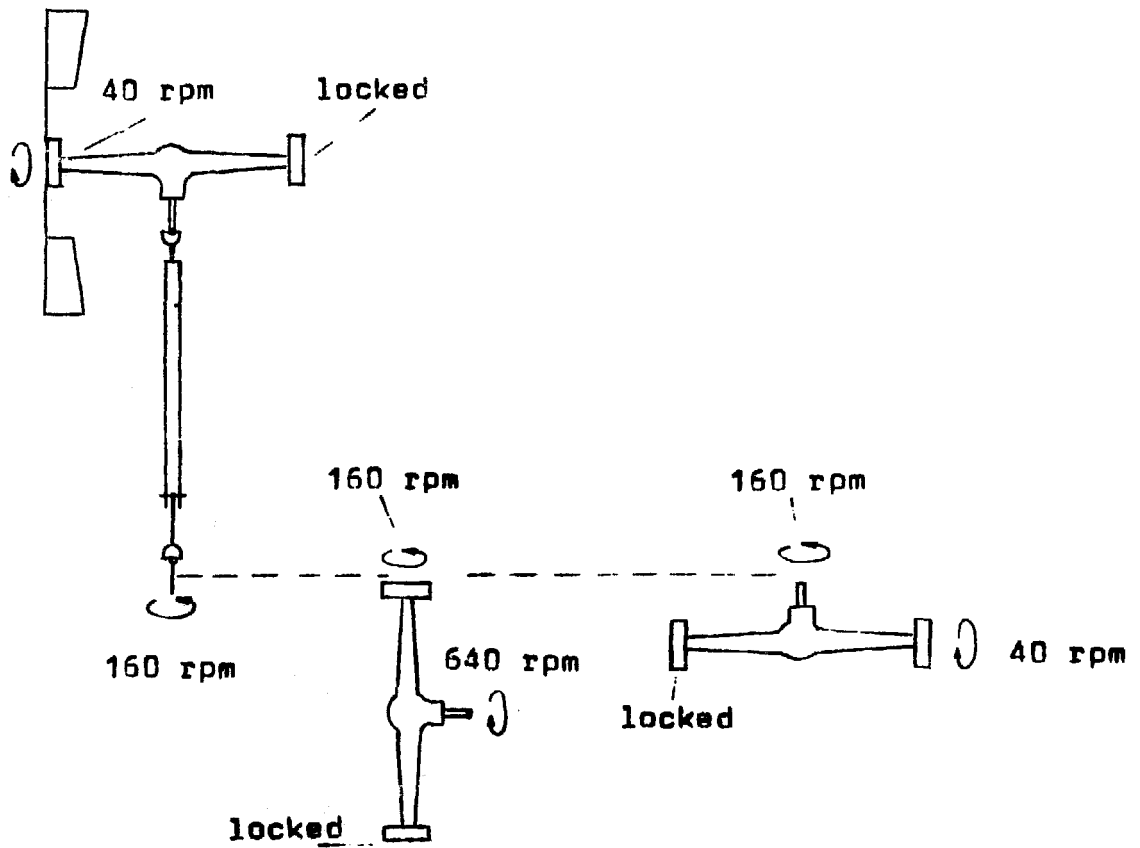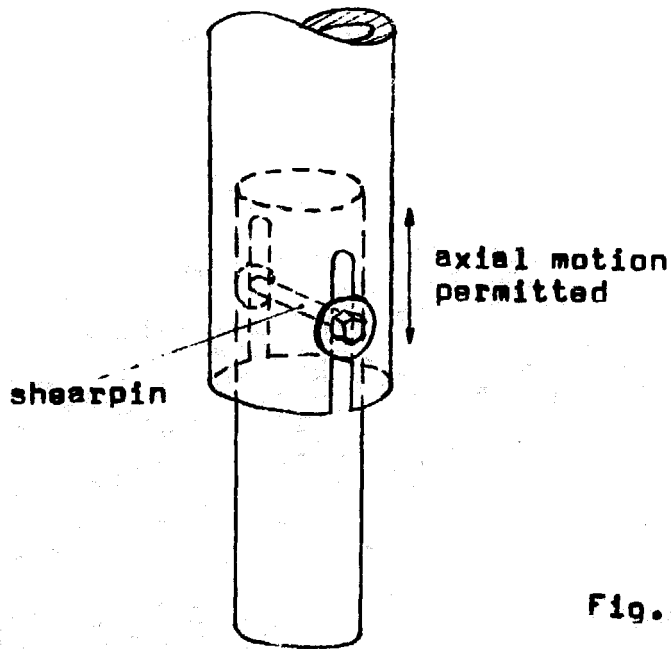
40 rpm   locked

160 rpm

160 rpm

160 rpm

640 rpm

locked

40 rpm

locked

locked

Fig. A1

axial motion
permitted

shearpin

Fig. A2

ROTOR

Part number	Quantity	Remarks (see Figs. R1 - R7)
R1	1	Steel plate 0.5m x 0.5m, approximately 5 mm thick. For mounting on axle, drill same drill pattern as required for rear wheels (Fig. R1).
R2	1	Steel rod (same as for spokes), 4.35m long, approximately 6 to 8 mm diameter. Bend into circle of 1.39m outer diameter, weld ends together (Fig. R2)
R3	16	Round steel rods for spokes 1.87m long, approximately 6 to 8 mm diameter (Fig. R1).
R4	48	Washers to fit loosely on spokes, approximately 2mm thick, 30mm outer diameter. Note: washers can be square and home-made from sheet metal.
R5	16	Sheet metal strips approximately 50mm x 70mm 2-3mm thick. Drill one centerhole to fit on spokes (R3) and three holes for wire (R10) and rigging wire (R13) (Fig. R1, Fig. R4).
R6	16	Galvanized sheet metal blades, made from 8 pieces 1.3m x 0.75m, approximately 0.5mm thick (Fig. R2).
R7	48	Sheet metal strips, approximately 50mm x 70mm; 1.5 - 2mm thick. Bend to shape shown (Fig. R2).
R8	16	Sheet metal strips, approximately 50mm x 50mm; same material as vanes (Fig. R2).
R9	16	Rubber strips, approximately 50mm x 100mm, made from side walls of used car tire (Fig. R2).
R10	1	Steel wire or cable, 26m long, 2 - 3 mm diameter.
R11	1	Steel wire or cable, 6 m long, 2 - 3 mm diameter.
R12	8	Steel wire or cable, 2.5m long, 2 - 3 mm diameter.
R13	16	Steel wire or cable, 3 m long, 2 - 3 mm diameter.
		Rivets or small nuts and bolts to fasten hinges and rubber strips on vane.

CONSTRUCTION OF ROTOR

Prepare parts (R1) - (R10).

Make the blade bending rig (Fig. R3). Bend blades (R6) into correct shape (see Fig. R3). Hint: Use rollers, or bend by hand over piece of pipe. Take care that hinge line remains straight.

Rivet or bolt hinges (R7) to vanes (Fig. R2). Very important: make sure hinges line up exactly.

Rivet or bolt rubber strips (R9) between blade (R6) and washer plate (R8) (Fig. R2, Fig. R6).

Weld spokes (R3) to centerplate (R1) (Fig. R1).

Weld ring (R2) to spokes at correct (22.5°) intervals (Fig. R1).

Weld 16 washers (R4) to intersections of ring (R2) and spokes (R3) (Fig. R1, Fig. R5).
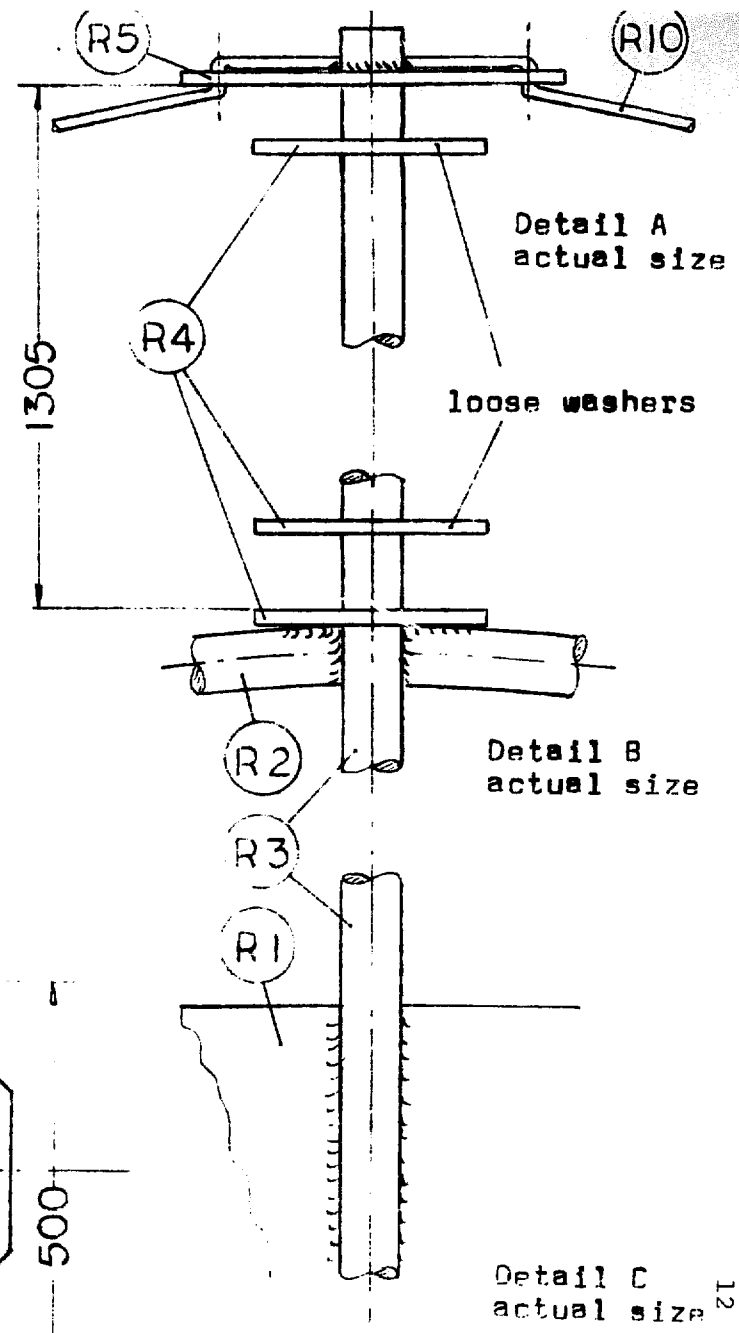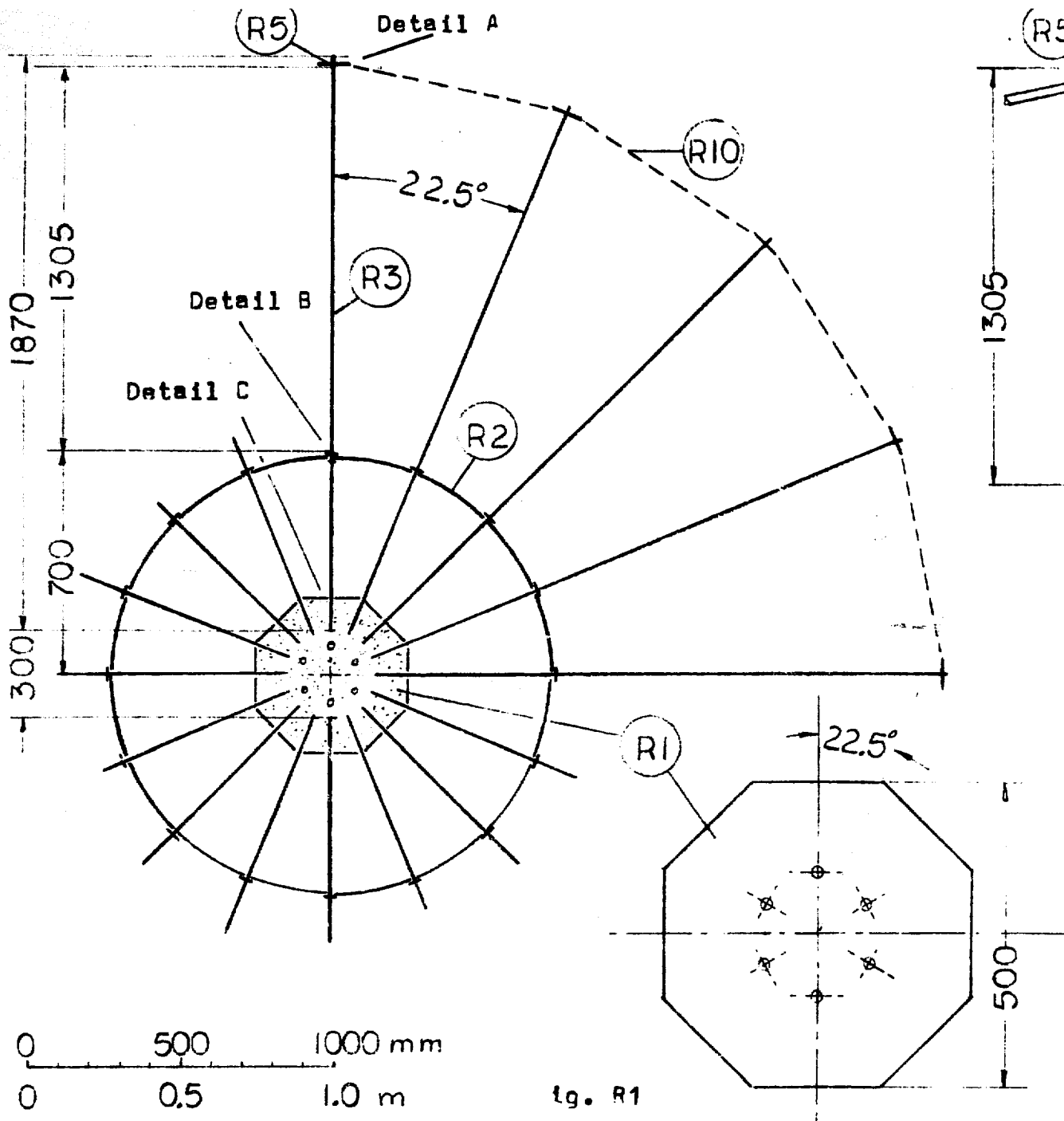
Slide one washer (R4) on each spoke.

Grease spokes at hinge locations.

Slide blades on spokes with the wider blade tip facing outward. Veryiimportant: All blades must rotate freely. If this is not the case, adjust blade shape, spokes, or hinge locations.

Slide one washer (R4) on each spoke.

Weld parts (R5) unto tips of spokes, giving about 1 mm play (blade movement in the direction of the spoke) (Fig. R1, Fig. R4).

Thread wire or cable (R10) through holes of parts (R5) and align spokes at 22.5° intervals (Fig. R4). After completing circle, stretch taut and connect both ends.
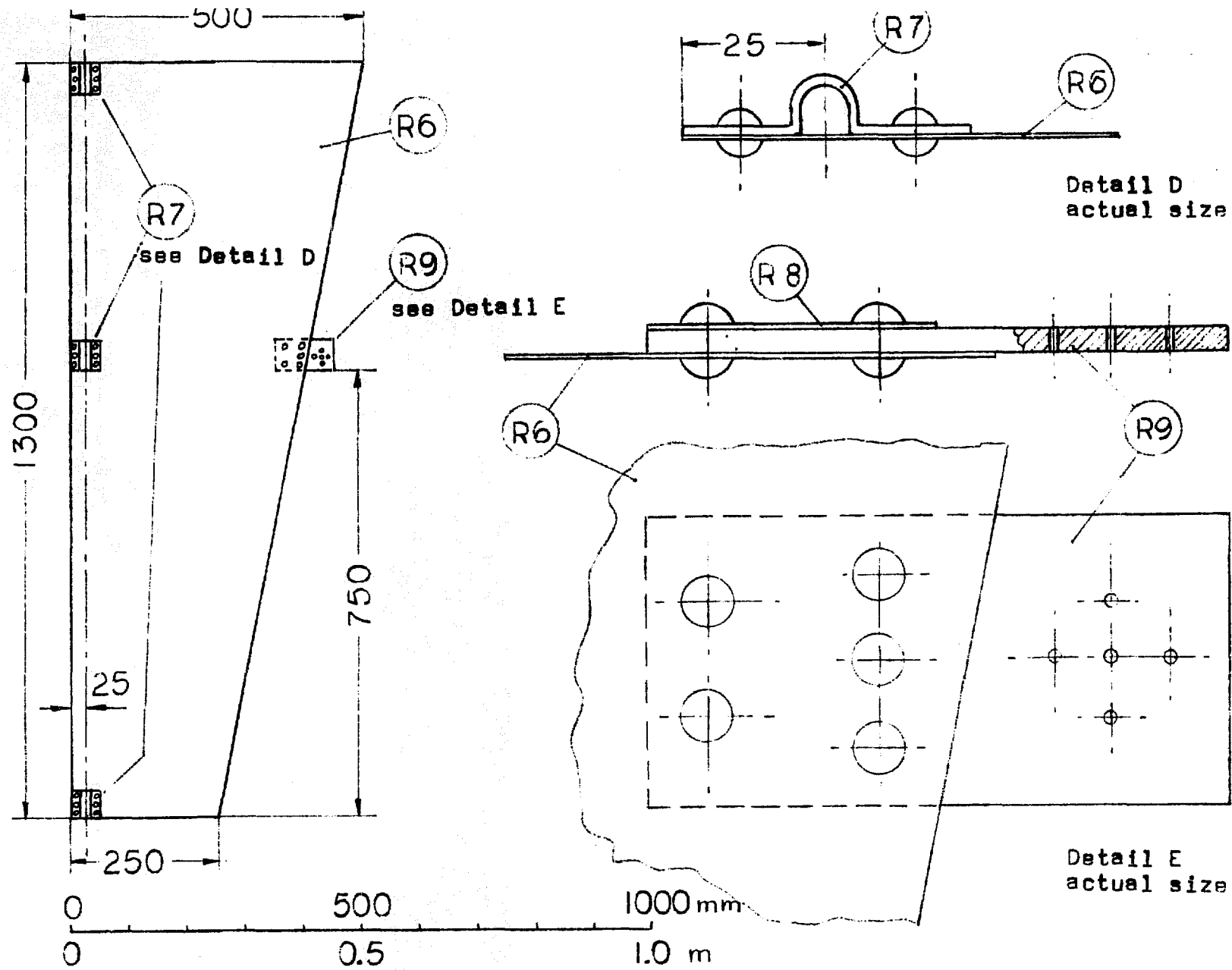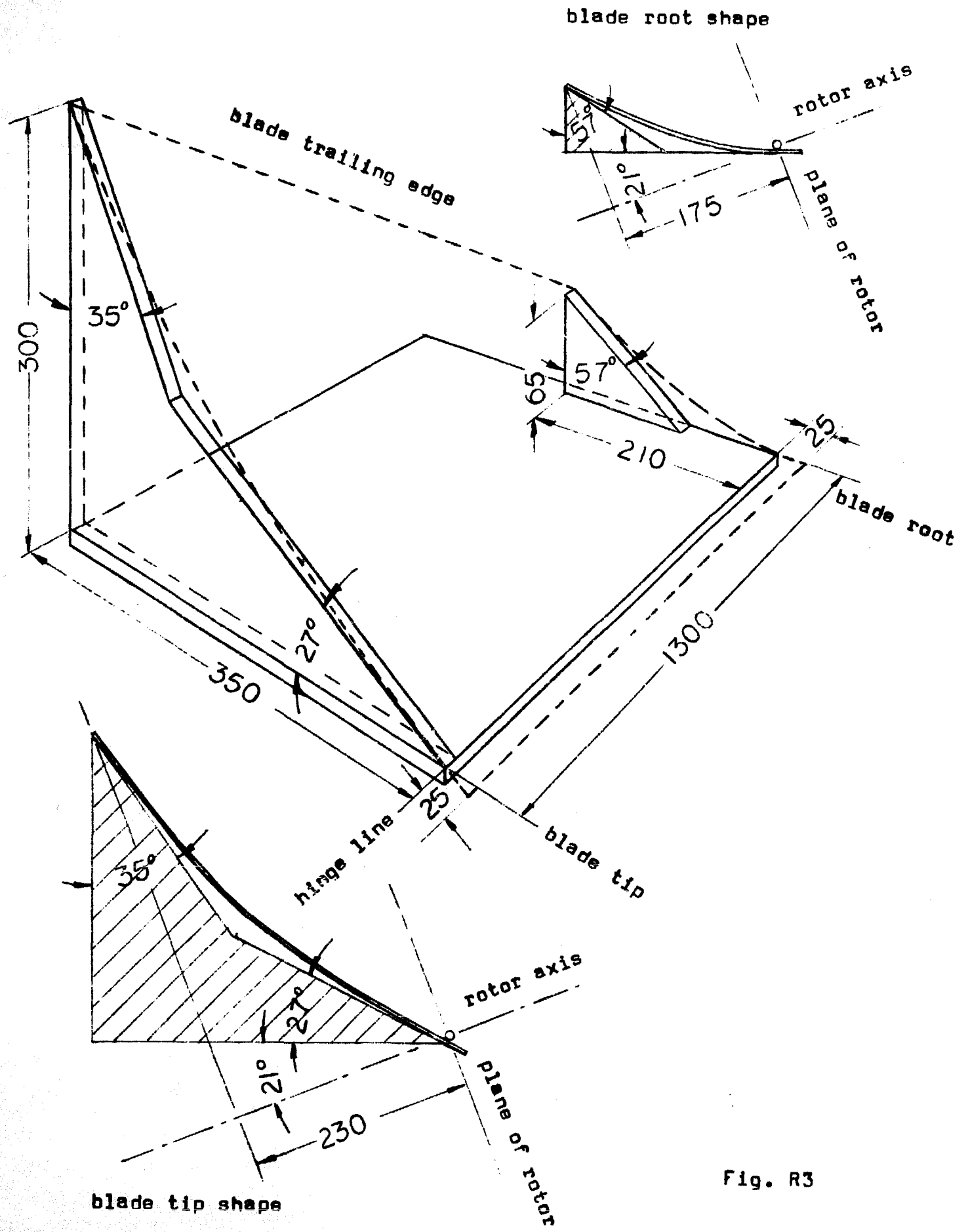
Detail A

R5

Detail A
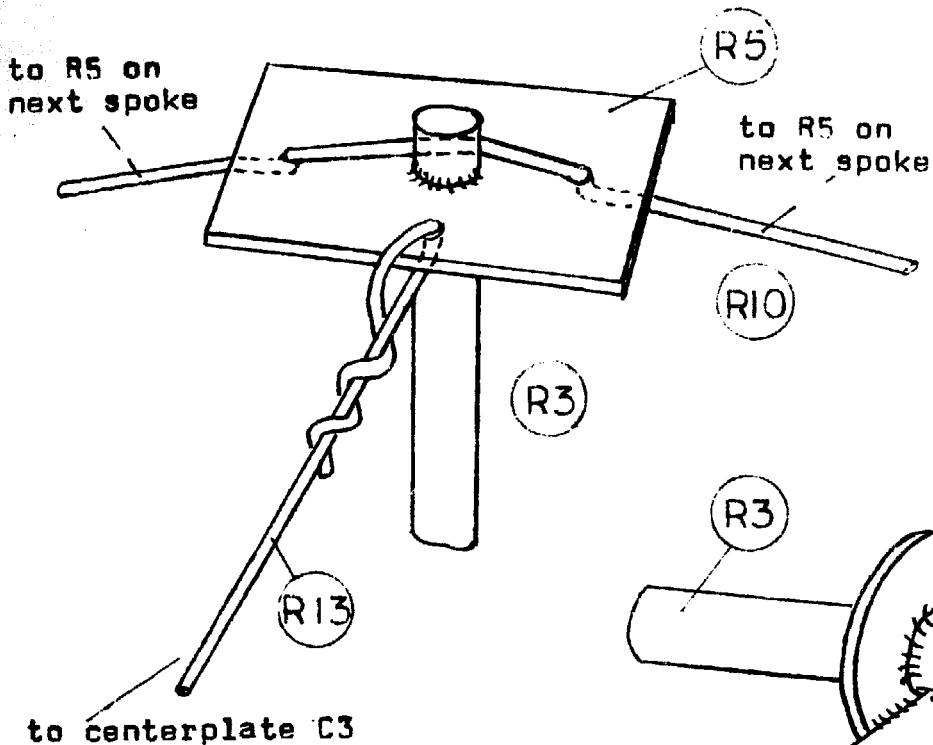actual size

22.5°

R10

1870

1305

Detail B

R3

1305

R4

loose washers

Detail C

700

R2

300

Detail B
actual size

R2

R1

R3

22.5°

R1

500

0   500   1000 mm

0   0.5   1.0 m

fg. R1

Detail C
actual size

12

Detail D
actual size

Detail E
actual size

see Detail D

see Detail E

Fig. R2

blade root shape

blade trailing edge

rotor axis

plane of rotor

57°

21°

175

35°

300

57°

65

210

25

blade root

27°

350

1300

hinge line

25

blade tip

35°

27°

21°

rotor axis

plane of rotor

230

blade tip shape

Fig. R3

to R5 on
next spoke

to R5 on
next spoke

Fig. R4

(R5)

(R10)

(R3)

(R13)

to centerplate C3

(R3)

(R4)

(R2)

Fig. R5

(R6)

to R9 on
next blade

(R9)

(R11)

to R9 on
next blade

(R12)

to controlplate C4

Fig. R6

42°

230

Fig. R7

blade tip alignment

CONTROL SHAFT

Part number	Quantity	Remarks (See Figs. C1 - C3)
C1	1	Steel pipe, 25 to 30 mm outer diameter, 1.5m long.
C2	1	Inner diameter same as outer diameter of part (C1). Use piece of pipe (also for C3, C4, C5). Drill end plate for wheel bolts (same drill pattern as part (R1)).
C3	1	Inner diameter same as part (C2). Plate has 16 evenly spaced holes for 16 support wires, and 2 holes for restraining rods (C8).
C4	1	Similar to part (C3), except plate has central hole and part slides freely on part (C1). 8 evenly spaced holes for 8 control wires, and 2 holes for restraining rods (C8).
C5	1	Part must slide on part (C1).
C6	1	Compression spring, approximately 330 mm long. Spring constant must be approximately 1.5 kg_f/cm (i.e. a compression of 1 cm for a weight of 1.5 kg).
		Note: Make spring from 4 mm steel wire according to Fig. C2, if suitable spring cannot be found. A softer spring can be used, but it must also be precompressed to 13.5 kg_f. Springs harder than 2 kg_f/cm should not be used.
C7	2	Washers (if spring diameter is larger than the outer diameter of parts (C4) and (C5)). Size depends on spring diameter. Make out of sheet metal approximately 2 mm thick.
C8	2	Wire, approximately 3 to 4 mm diamter, 400 mm long. Bend during installation (Fig. C3).
	4	Cotter pins, bolts, or wire to secure parts (C3), (C4), (C5) on shaft (C1).
	4	small washers

CONSTRUCTION OF CONTROL SHAFT

Make parts (C1) - (C7).

Lubricate shaft with heavy grease at the location of parts (C4) - (C3).

Mount all parts on shaft (C1) as shown.

Secure parts (C3) and (C4) by cotter pins, bolts, or wire.

Compress spring to a force of 13.5 kg$_f$ and secure part (C5) by cotter pin, bolt, or wire at this location.

Install wires (C8) with washers as shown (Fig. C3). Bend each end to a loop. Wires must stick out 130 mm when pulled. (These wires prevent blades from going over dead center.)
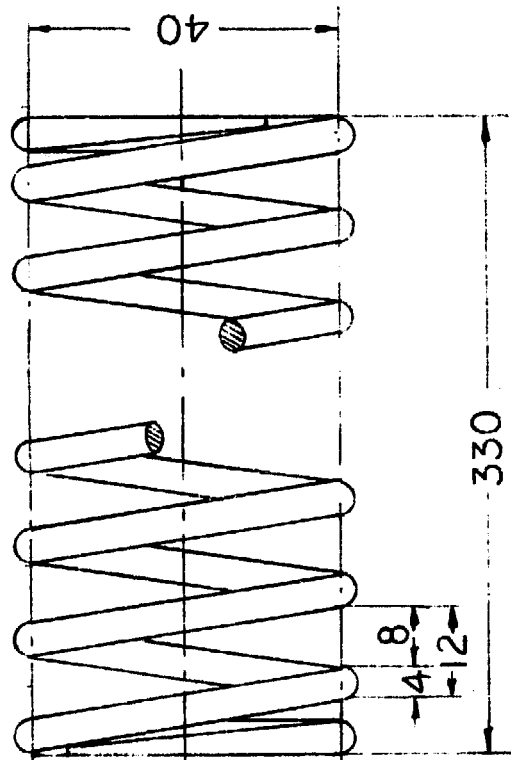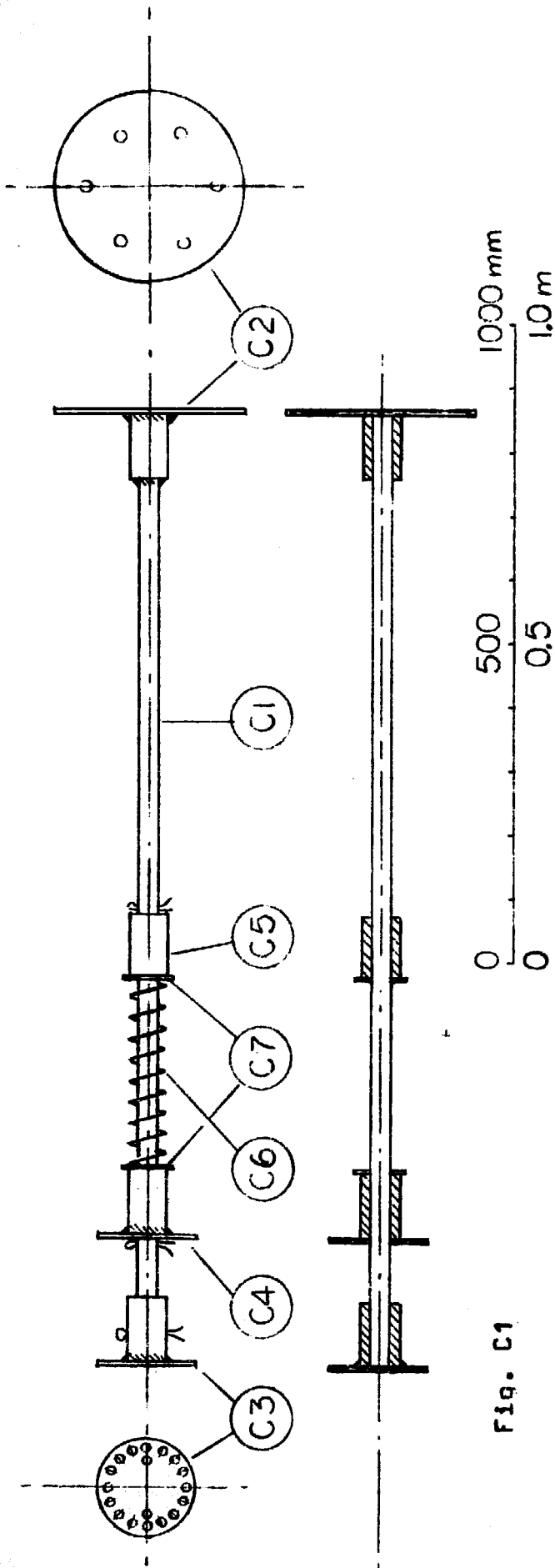
C2

C1

C5

C7

C6

C4

C3

1000 mm
1.0 m

500
0.5

0
0

Fig. C1

40

330

8
2
4

Fig. C2 - Control spring

several holes
for adjustment

C8
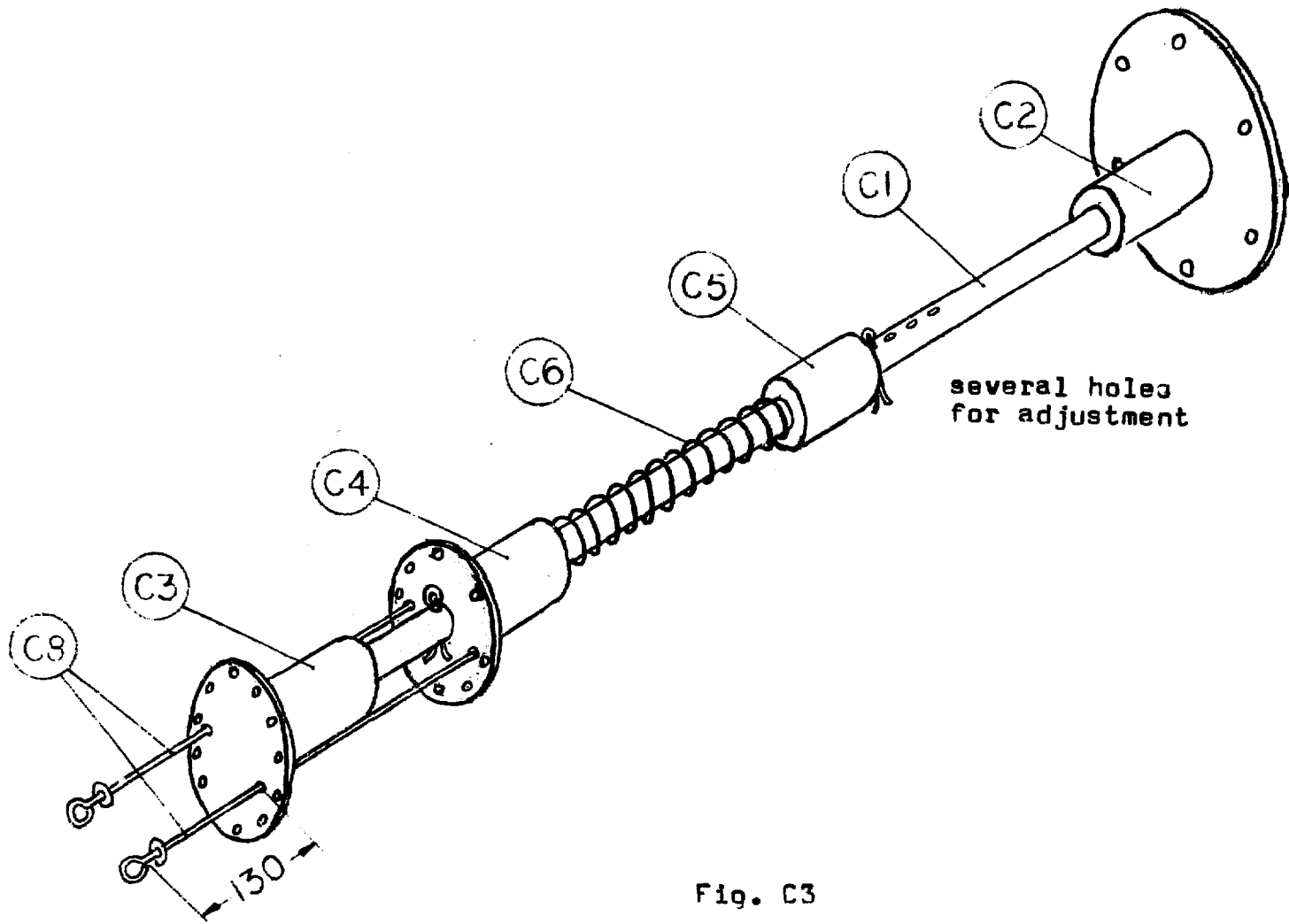
C3

C4

C6

C5

C1

C2

130

Fig. C3

ROTOR ASSEMBLY

Lay center plate (R1) of rotor on blocks to raise it
approximately 0.5 m from the ground. (Side to which the spokes
are welded "up"). Temporarily bolt the control shaft in place
by two bolts through plates (C2) and (R1). Make sure control
shaft is exactly vertical.

Connect the 16 wires or cables (R13) to the 16 holes of
centerplate (C3).

Connect the 8 wires or cables (R12) to the 8 holes of
control plate (C4).

Connect the 16 wires from (C3) to the holes in (R5) at the
tips of the spokes (Fig. R4). Tighten the wires (or cables) at
each spoke until the spoke is horizontal, then fasten wire securely.
Note: do this simultaneously at opposing sides of the rotor to
avoid bending of the control shaft. Do not proceed to next step
unless all spokes are horizontal while control shaft is exactly
vertical.

With wire or rope tied to (C3) pull (C4) up against the
cotter pin. Connect the 8 wires from (C4) to the rubber strips
on every second blade (Fig. R6). Adjust the wire length until
the blade has the required angle (Figs. R3, R7), with the trailing
edge of the blade tip 230 mm below the plane of ..e spokes
(leading edge angle with that plane 42° at the tip). Fasten
wire securely.

Using wire or cable (R11), connect all rubber strips (R9)
with each other (Figs. R6, R7). Work in the direction shown,
holding up every second blade in the correct position when connecting
it. When the circle is completed, all blades must be at the same
angle.

TURNTABLE

Part number	Quantity	Remarks (See Figs. T1, T2)
T1	1	Frame welded together from steel channel, approximately 50 to 80 mm wide. Frame is exactly square. Note: Dimension"D" (distance of brackets (T2), wheel distance, and outer diameter of circular track) depends on location of leaf spring mounts on car axle.
T2	2	Brackets made from angle iron (about 5 to 8 mm wall thickness). Drill pattern corresponds to that of leaf spring mounts on car axle.
T3	8	Steel plate approximately 4 to 10 mm thick.
T4	1	Steel plates approximately 5 to 10 mm thick.
T5	4	Steel axles 20 to 30 mm diameter. Thickwalled pipe can be used.
T6	4	Use whatever can be found. Diameter of wheel body (T6a) should not be less than 50 mm. Rim diameter (T6b) should be approximately 40 mm greater than that of (T6a). Prefer ball bearing, or bronze bearing, but simple steel cylinder (T6a) acceptable. Grease cavity recommended in this case. Weld or bolt rim (T6b) to (T6a).
T7	8	Spacers. Pieces of pipe, or several washers.
T8	20	Washers (can be made from sheet metal 1 - 2 mm thick).
T9	1	Circular track. Ribbon steel, approximately 30 mm wide, 5 to 10 mm thick. Bend and weld together to form ring of outer diameter "D". Ring must be exactly circular to avoid derailing of turntable.
T10	8	Brackets made from angle iron, or bent (heat!) ribbon steel approximately 5 to 8 mm thick.
	8	Cotter pins, or wire or nails.

Construction of Turntable and Track

Prepare wheel assembly (parts (T4) - (Tb)). Make sure wheels rotate with little friction.

Weld frame (T1) together.

Weld brackets (T2) onto frame such that car axle is exactly centered on the frame when mounted to the brackets (T2).

Weld part (T3) onto frame.

Bend and weld circular track (T9) and weld 8 brackets (T10) to its inside. Lay track on flat surface and make sure it has no waves and is perfectly horizontal.

Clamp wheel assemblies lightly to frame, with wheel rims facing outward. Set frame up on blocks on the circular track on a flat floor, with all wheels resting on the track. Weld parts (T4) to the frame, checking repeatedly that all wheels rest on track.

Wheels should have axial play of approximately 1 mm. Adjust by adding or removing washers.
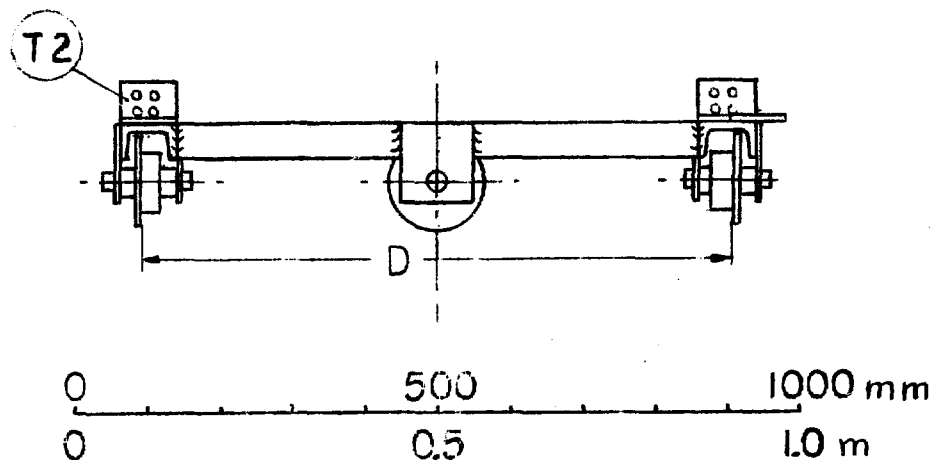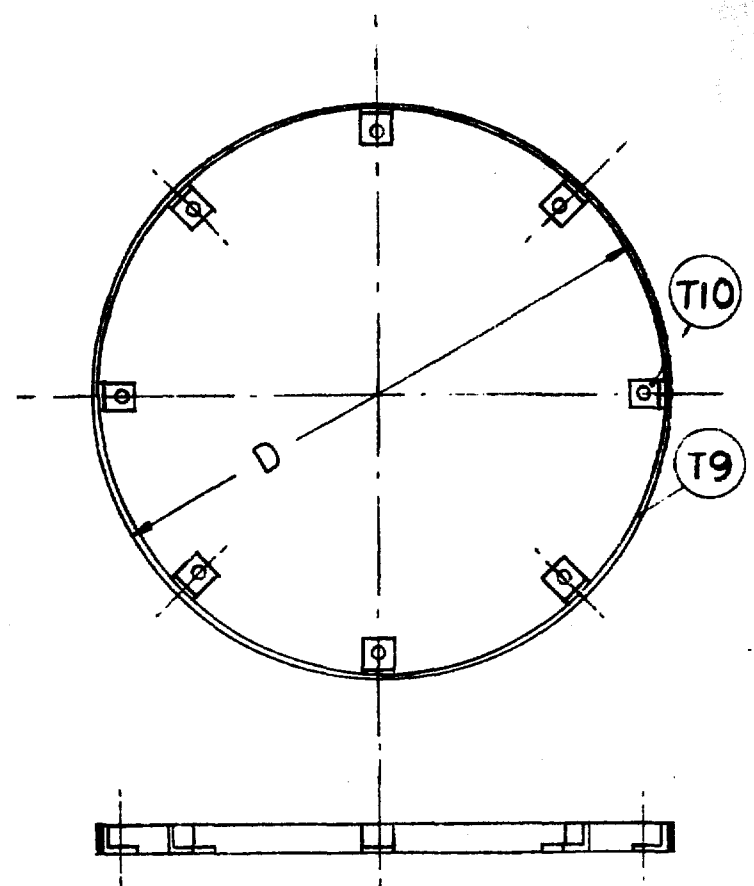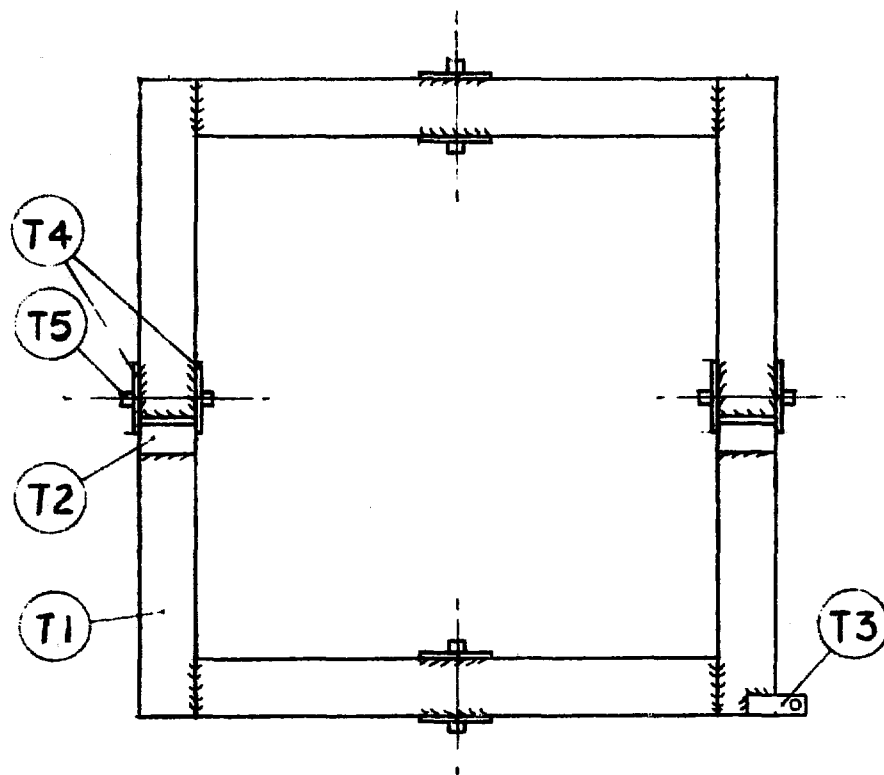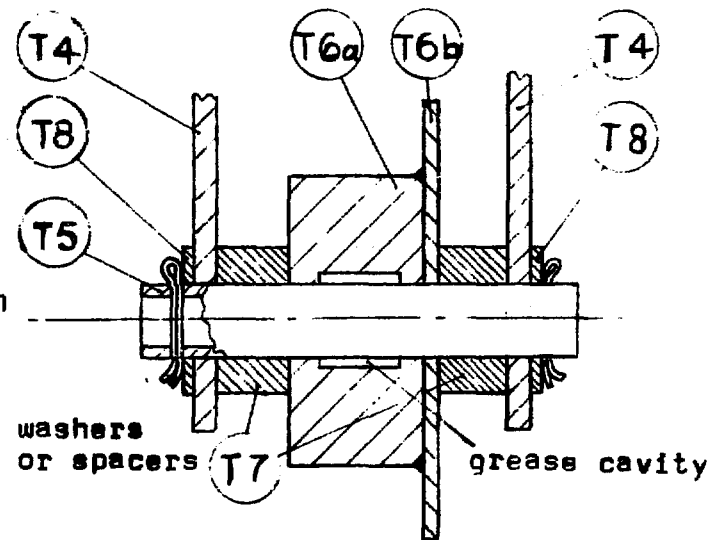
T4
T5
T2
T1
T3
T2
T10
T9
D
T4   T6a T6b   T4
T8   T8
T5
T7
washers
or spacers   grease cavity

0   500   1000 mm
0   0.5   1.0 m

Fig. T1

0
20
40
60
80
100
mm

23

Fig. T2

T1

T2

T4

T3
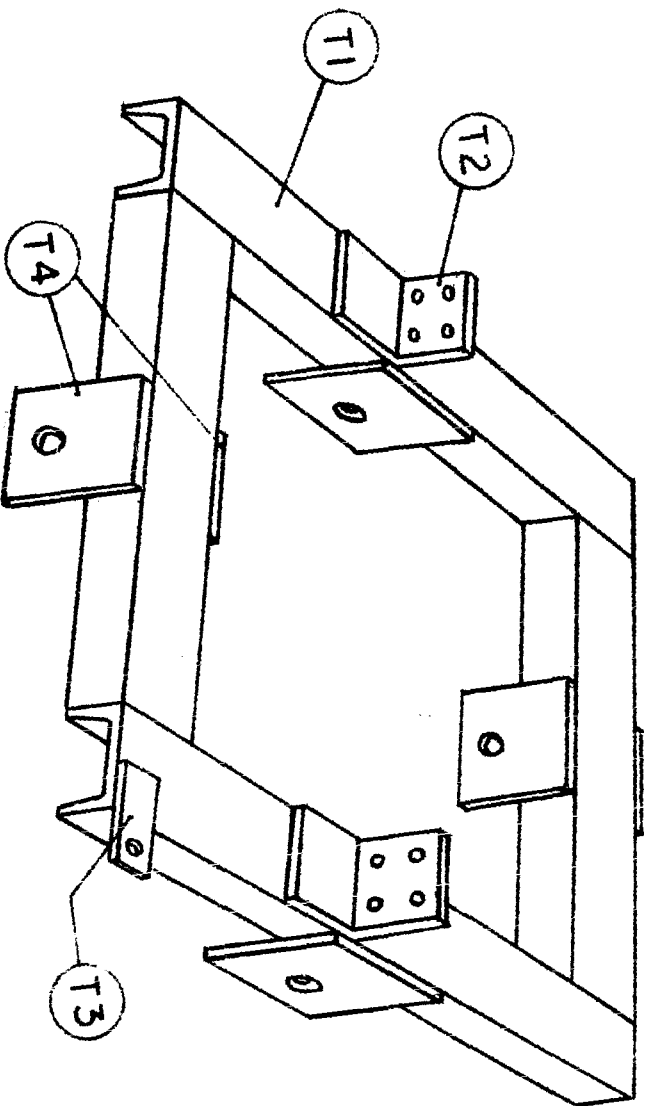
VANE

Part number	Quantity	Remarks (See Figs. V1 - V4)
V1	1	Steel channel, approximately 50 to 80 mm wide, 3 to 5 mm wall thickness, 1.10 m long. Drill two holes to fit two wheel bolts on the wheel drum, and two holes for bolt supporting brake handle (V8).
V2	1	Angle iron, approximately 20 x 20 mm "L" shape, 2 to 3 mm wall, 3.30 m long.
V3	1	Angle iron, approximately 20 x 20 mm "L" shape, 2 to 3 mm wall, 2.50m long.
V4	1	Angle iron, approximately 20 x 20 mm "L" shape, 2 to 3 mm wall, 2.60m long.
V5	1	Ribbon steel, approximately 20 to 30 mm wide, 2 to 3 mm thick, 1.30 m long.
V6	1	Galvanized sheet metal, approximately 0.5 mm thick, 2.60 m x 1.50 m.
V7	1	Clamp made from ribbon steel approximately 30 to 40 mm wide, 2 to 4 mm thick. To fit over car axle. Weld to part (V2). Provide holes for clamping bolt.
V8	1	Brake handle. Ribbon steel, or angle iron, approximately 20 to 40 mm wide, 2 to 4 mm thick, 400 mm long. Hole for supporting bolt is to be approximately 2 mm wider than bolt diameter.
V9	1	Brake handle stop. Flat piece about 3 to 6 mm thick. Weld to (V1).
V10	2	Support wires or cable, approximately 2 to 3 mm diameter, each 3 m long.
		Rivets or small nuts and bolts to fasten sheet metal to vane frame (wire could also be used).

Vane Construction

Prepare parts (V1) - (V10). Bend (V2) 10 degrees, to one side.

Weld (or bolt) together parts (V1) - (V5), (V7) and (V9).

Fasten sheet metal (V6) to vane frame using rivets, small nuts and bolts,o or wire no more than 300 mm apart.

Connect brake handle (V8) to channel (V1) (Fig. V3). Note: Hole in (V8) must be large enough to permit handle to be lifted over the stop (V9).

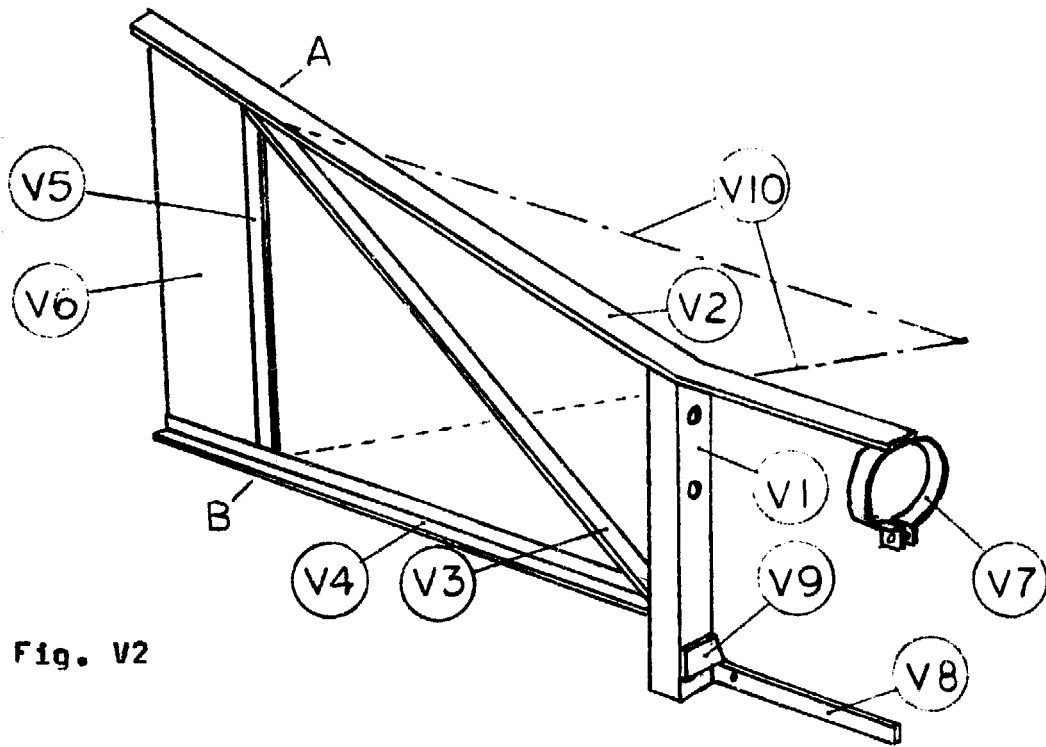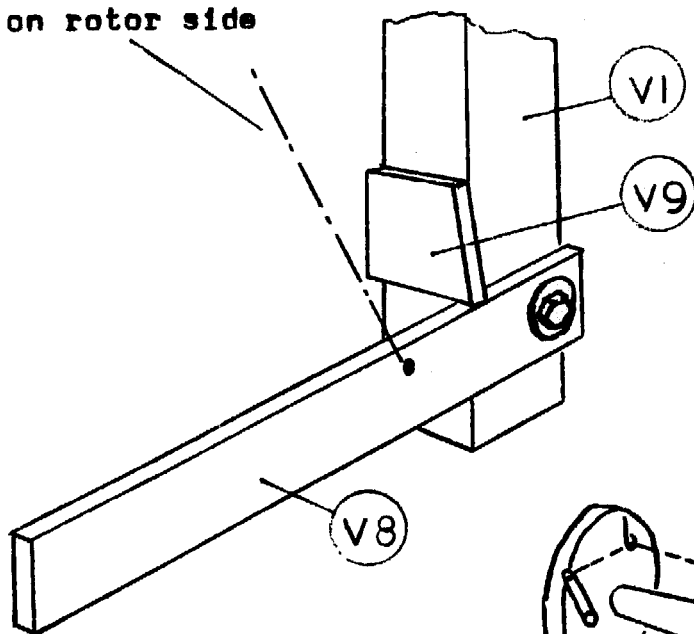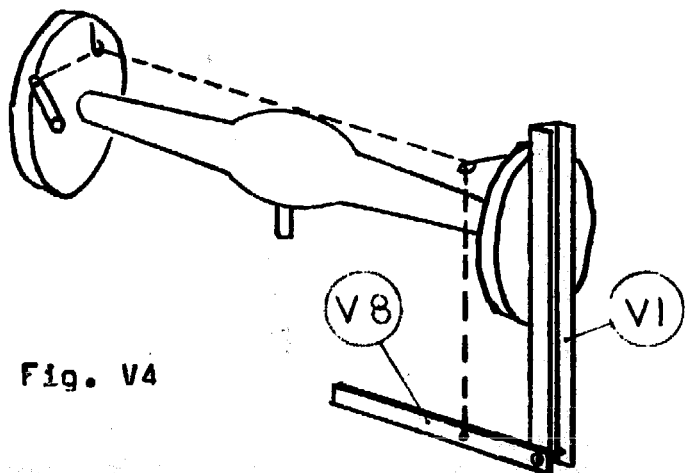Connect wires (V10) to points "A" and "B".

to wheel brake
on rotor side

Fig. V1

Fig. V2

to wheel brake
on rotor side

Fig. V3·

Fig. V4

PLATFORM AND TOWER

Part number	Quantity	Remarks (See Figs. P1, P2)
P1	1	Beam or pole, 6 to 12 m long, approximately 10 cm x 15 cm, or 15 - 20 cm diameter. Shape upper end to 10 cm x 15 cm.
P2	1	Platform: Thick plywood, or thick boards. Cut out 15 cm x 15 cm central hole. Note: diameter of platform depends on diameter of track (dimension "D").
P3	1	Galvanized sheet metal cover, somewhat larger than platform.
P4	1	Beam, approximately 4 cm x 8 cm.
P5	2	Beam, approximately 4 cm x 8 cm.
P6	2	Beam, approximately 4 cm x 8 cm.
P7	1	Piece, approximately 4 cm x 8 cm.
P8	2	Beam, approximately 4 cm x 8 cm.
P9	2	Beam, approximately 4 cm x 8 cm.
P10	10 - 20	Steps, approximately 4 cm x 8 cm x 35 cm.
		Nails approximately 10 cm long (galvanized, if available).
		Nails approximately 4 cm long (galvanized, if available).

Construction of Platform and Tower

Build platform from parts (P2),(P4) - (P7), with a 15 cm x 15 cm centerhole.

Shape upper end of tower beam so it fits into the space between (P4), (P5), and centerhole.

Nail platform to tower using parts (P8) and (P9).

(Reinforce joints by nailing strips of sheet metal over them with 4 cm nails).

Cover top of platform with sheetmetal and nail it down on the platform and over the sides.

Mount circular track (use nuts and bolts) so that its center coincides with the center of the square hole. Check roundness of the circle.

Nail steps to tower beam approximately 30 cm apart.

(P7)   (P5) (P6)

(P4)

view from below

(P2)

(P8)

(P9)

(P10)

(P1)
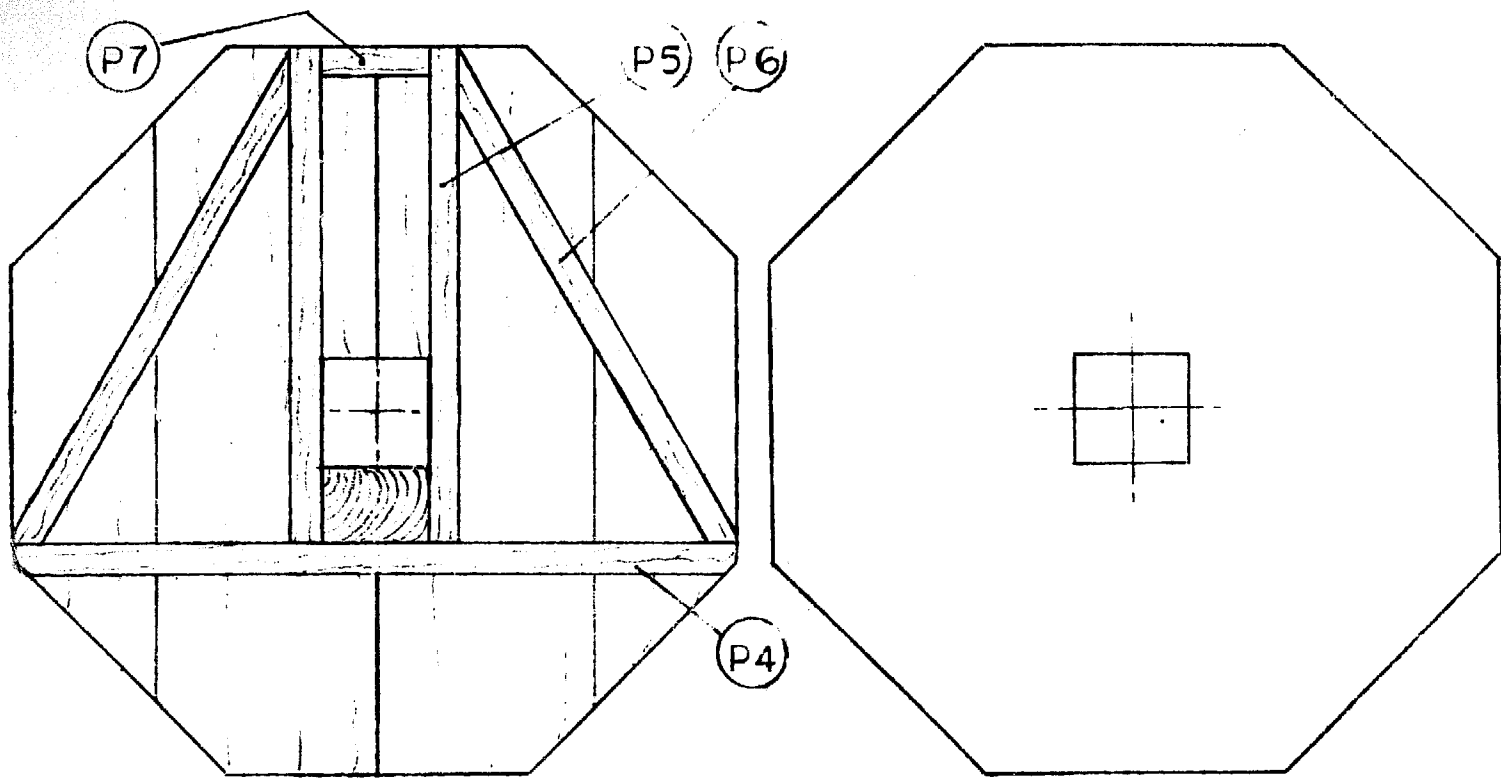
Fig. P1

0   500   1000 mm

0   0.5   1.0 m

Fig. P2

WINDMILL ASSEMBLY

The best way to assemble the windmill will depend on local conditions, and on labor, cranes, ladders, scaffolds available. The steps in the assembly should be well thought through beforehand, and all assistants should be fu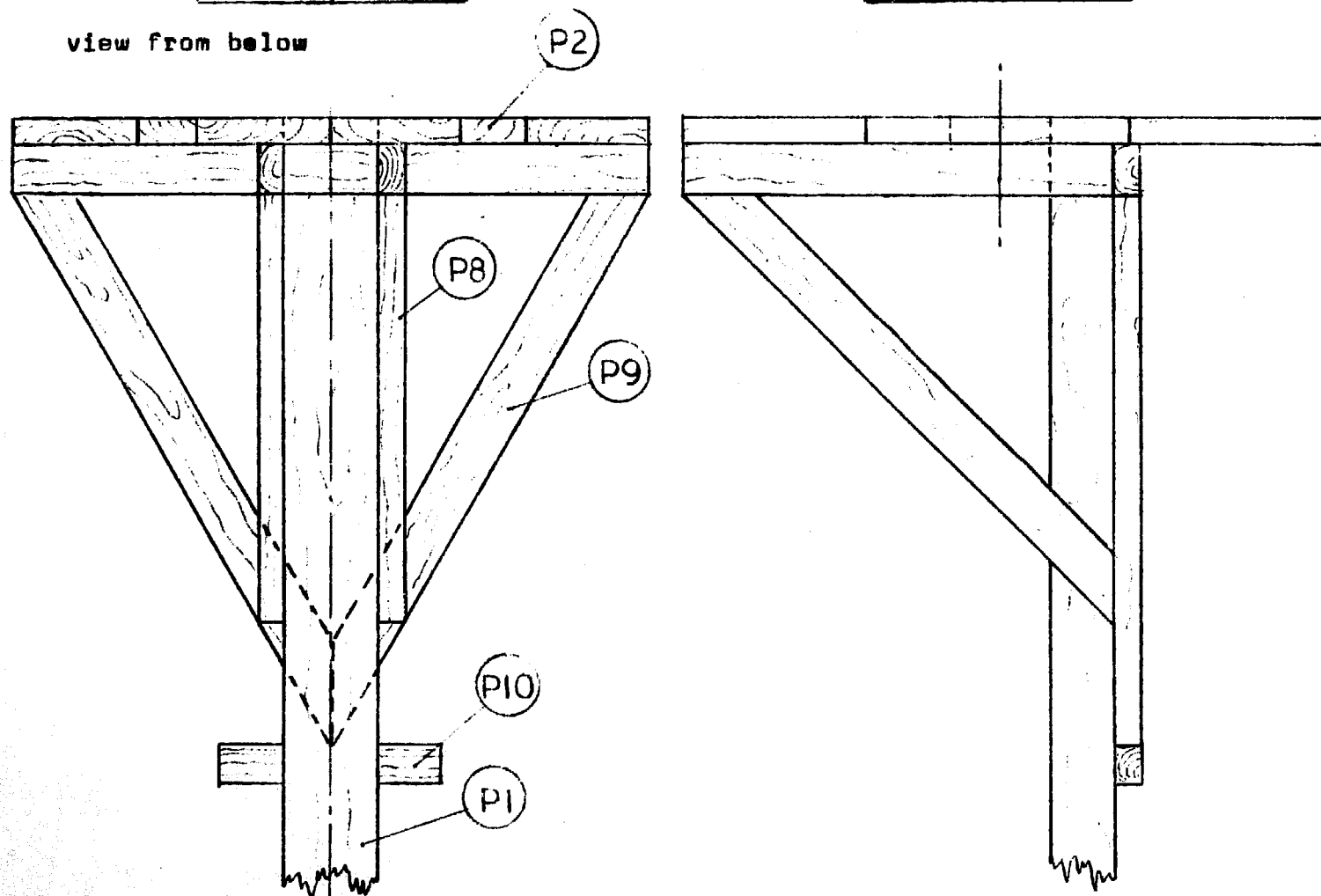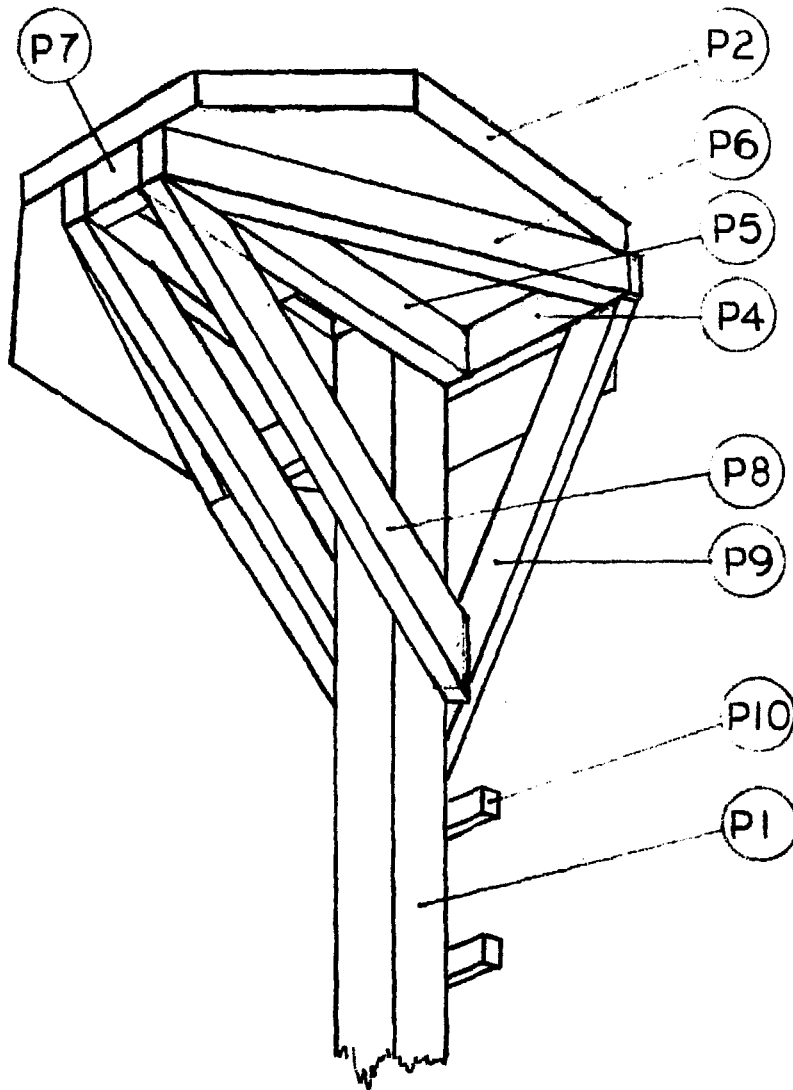lly familiar with the planned procedure. The windmill should be erected on a calm day. The following is one possible assembly procedure.

Soak tower structure in creosote for a day, in particular the lower part which goes into the ground. If creosote is not available, burn the outside of the lower part to a depth of approximately 1/2 cm.

Dig a hole approximately 20% of tower height deep (less in rocky soil, more in sandy soil). Place tower vertically in hole, and fill hole with rocks and/or concrete, compacting thoroughly and repeatedly in the process. It is recommended that the tower be anchored also by at least 3 cables (mount at a low enough position on the tower so that they do not interfere with the rotor).

Mount the turntable on the circular track, and secure turntable to tower by wire or rope (temporarily but very rigidly).

Grease all sliding or rotating parts, and fill differential 1/3 full with heavy oil or light grease. Rustproof all metal parts (except aluminum or galvanized) by protective paint.

Mount car axle (drive shaft removed) on turntable.

Mount vane on one side of axle and connect the two wires or cables (V10) firmly from the vane (points "A" and "B") to part (T3) on the turntable.

Connect a cable from the wheel brake lever on the rotor side to the brake handle (V8) on the vane. Use wire or cable loops fixed to the drum or other means to achieve the necessary 90° change in cable direction (Fig. V4). Adjust the cable length so that rotor wheel is completely braked when handle (V8) has been pulled down to rest against stop (V9). Pull the brake handle, braking the rotor wheel.

Remove the temporary wires holding parts (C3) and (C4) of the control shaft together. Raise the rotor assembly. Remove the two temporary bolts holding parts (C2) and (R1) together (but keep control shaft in position). Bolt control shaft (C2) and rotor (R1) to the axle, tightening wheel bolts well.

Remove restraining wires cautiously from the turntable, watching for imbalance. If rotor appears much heavier than vane assembly, secure heavy rocks or pieces of scrap metal on the vane side of the turntable.

Release brake, and rotate rotor slowly, watching spoke and blade alignment. Make corrections where required. Pull brake.

Connect drive shaft and load.

Run windmill cautiously at first, checking for vibration, loose parts, misalignment etc., and making immediate adjustments.

MAINTENANCE AND OPERATION

Grease or oil all sliding or rotating parts monthly. Add oil to differential. Check for loose components. Always repair immediately, if breakages or misaligments occur.

Rustproof all metal parts (except galvanized or aluminum parts) once a year. Remove rust and chipped paint by wire brush, and scraper, then paint with protective paint. In some climates, new rigging wires may be required yearly.

Always brake rotor fully when windmill is unloaded or not in use.

If rotor blades feather at wind speeds considered too low, increase the precompression in the control spring.

If rotor blades feather at wind speeds considered too high, decrease the precompression in the control spring.

SPECIFICATIONS FOR A 2-METER WINDMILL

Construction essentially identical to that of 4 m VITA windmill, except that dimensions are to be adjusted accordingly. Listed below are the major changes; other secondary changes will be obvious to the builder.

PERFORMANCE DATA

Compared to the data for the 4 meter windmill:

> rotor speed becomes _twice_ that for the 4 meter windmill

> rotor torque becomes _one eighth_ (1/8) that for the 4 meter windmill

> starting torque becomes _one eighth_ (1/8)that for the 4 meter windmill

> power becomes _one fourth_ (1/4) that for the 4 meter windmill

> altitude effects remain the same.

Feathering Information

Remains the same for control spring of spring constant 0.75 kg_f/cm precompressed to 3.5 kg_f.

Fig. I1 - Rotor diameter becomes 2 m. Control shaft becomes half as long, vane becomes half as long and half as high.

Fig. A1 - All speeds of revolution become twice that shown.

VANE

Reduce height of vane to one half (approximately 0.75 m at tail).

Reduce length of vane to one half (approximately 1.3 m).

No change in vane angle (10°).

ROTOR

Outer diameter of ring (R2) becomes 0.69 m (length of rod 2.18m).

Length of spokes (R3) becomes 0.87 m.

Blades (R6) made from 8 pieces 0.65 m × 0.4 m.

New dimensions:

Blade bending rig for 2 m rotor (see new Fig. R3/2) has same angles as before, but all major linear dimensions are reduced to one half.

CONTROL SHAFT

Length of control shaft (C1) reduced to one half (0.75 m).

Compression spring (C6) changed to 165 mm long. Spring constant 0.75 kg_f/cm (i.e. a compression of 1 cm for a weight of 0.75 kg).

If suitable spring cannot be found, make spring of same dimensions as for 4 m rotor, except use 3 mm steel wire.

Control spring precompression changed to 3.5 kg_f.

Change indicated length of wires (C8) from 130 mm to 65 mm.(Fig. C3).

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blade root shape

rotor axis

plane of rotor

21°

80

blade trailing edge

35°

150

57°

35

100

25

blade root

27°

650

170

hinge line

25

blade tip

35°

27°

rotor axis

21°

110

plane of rotor

blade tip shape

Fig. R3/2
2 meter
VITA windmill

Suggestion for
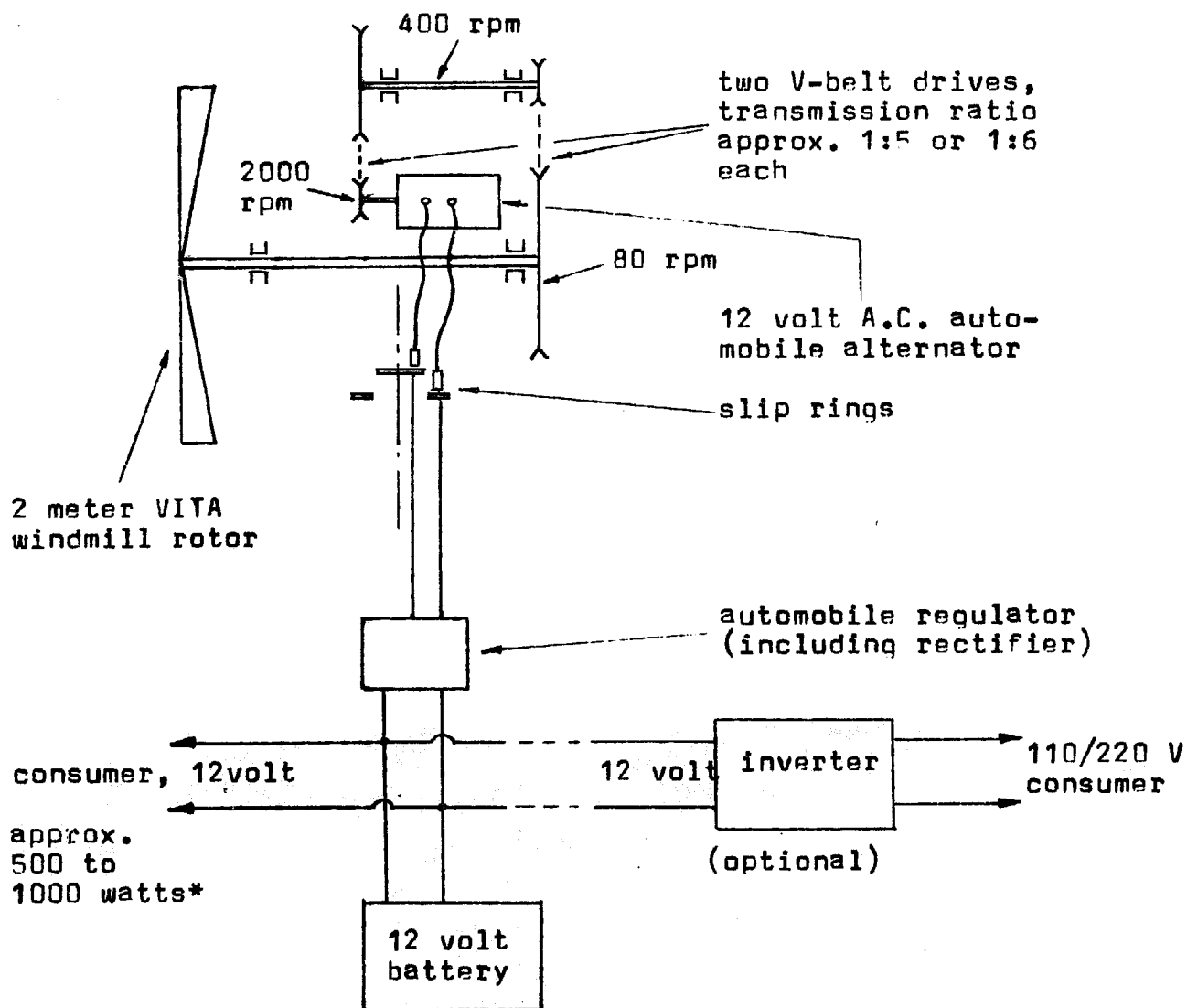
Electric Power Generation Using VITA 2 meter Windmill

400 rpm

two V-belt drives,
transmission ratio
approx. 1:5 or 1:6
each

2000
rpm

80 rpm

12 volt A.C. auto-
mobile alternator

slip rings

2 meter VITA
windmill rotor

automobile regulator
(including rectifier)

consumer, 12volt

12 volt   inverter   110/220 V
consumer

approx.
500 to
1000 watts*

(optional)

12 volt
battery

*depends on alternator used

Suggestion for

Electric Power Generation Using VITA 4 meter Windmill

40 rpm

blocked

160 rpm

4 meter VITA
windmill

640
rpm

2000 to
3000
rpm

automobile
rear axle

blocked

automobile
transmission
in low gear

A.C. generator
110/220 volts
1 to 3 kW