POTENTIAL FOR WIND ENERGY UTILIZATION IN HAITI

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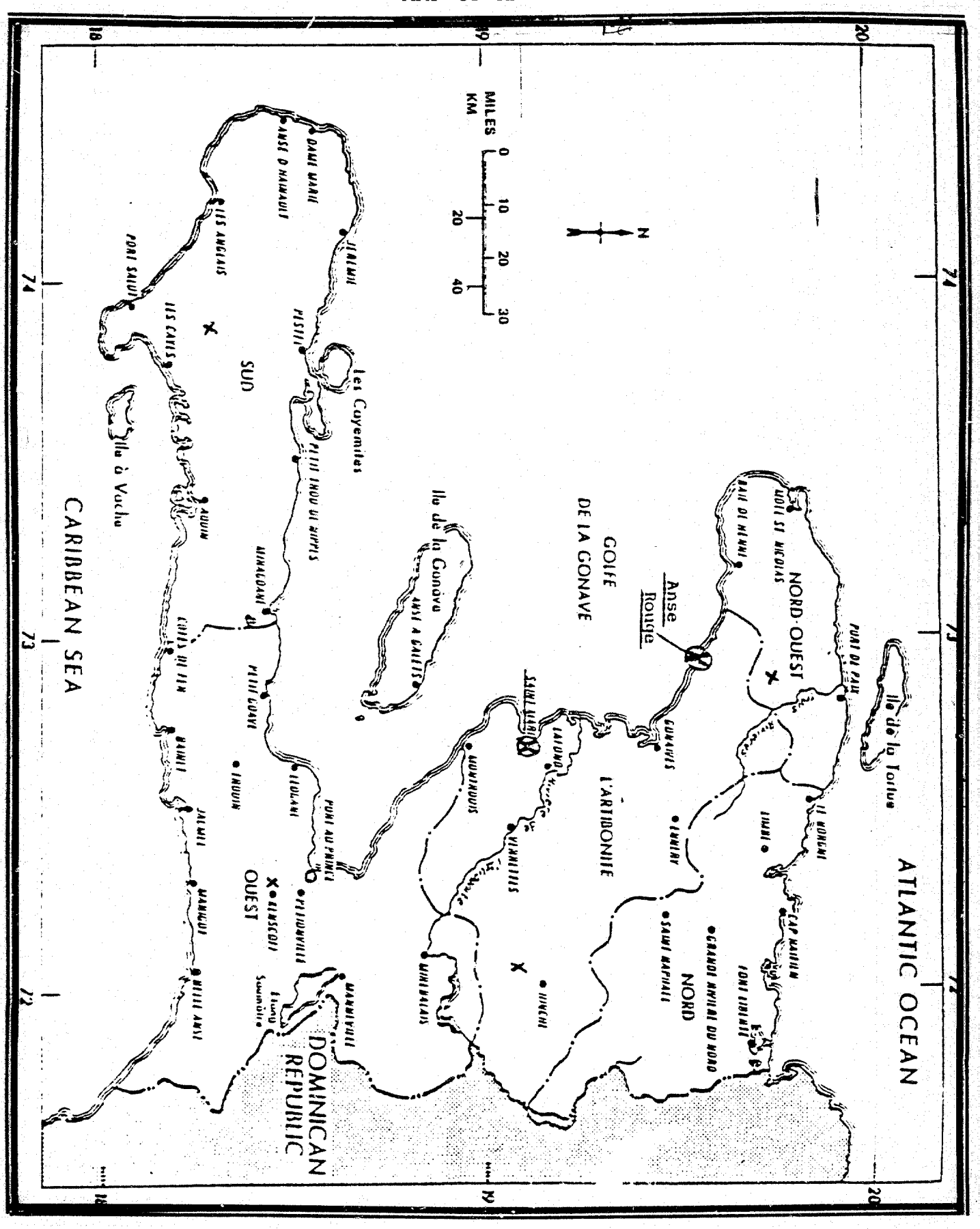
MAP OF HAITI

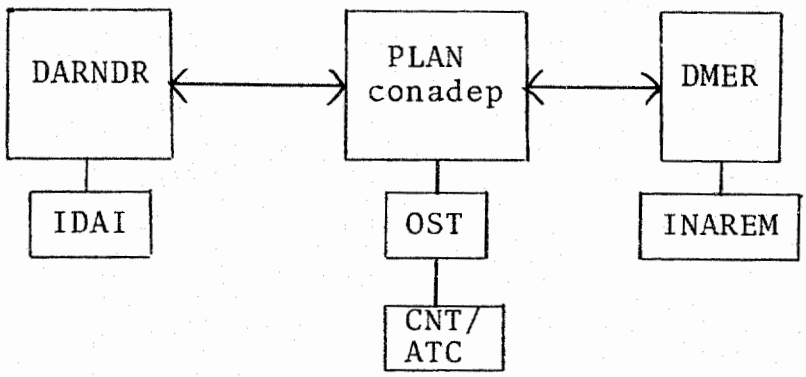

ATLANTIC OCEAN
Ile de la Tortue
NORD-OUEST
GOLFE
DE LA GONAVE
Anse
Rouge
L'ARTIBONITE
NORD
Les Cayemites
Ile de la Gonave
SUD
Ile à Vache
CARIBBEAN SEA
OUEST
DOMINICAN
REPUBLIC
MILES
KM
N
20
19
18
74
73
72

HAITI

Haiti is located in the Western Hemisphere. Its population of about 7 million (1981) is 85 percent rural. Adult literacy is estimated at 25 percent. It is a mountainous country, so there are many remote areas. Agriculture is the important activity. But agricultural output is now insufficient to feed its population. This critical situation has been noted by DOE and a study by NASA picked out two special projects.

Organizations and Projects

A) Government



B) Private

Private voluntary organizations are very active in renewable energy efforts in Haiti:

- Methodist Church of Haiti and Oxfam-Canada
- HACHO
- COUMBITE, etc.

The list would be long if I would name all of these organizations. Now, I shall also mention the work being done by the religious groups.

Objectives and Strategies

The objectives of this project are to supply drinking, domestic use and irrigation water to the remote village communities and to provide them with electricity.

It is a way of stopping the great flow of people to the cities and encouraging them to stay in their regions by improving the life standard of the rural areas.

At the same time a scientific and technological system is setting that will surround all the country like a framing net.

Some Wind Data

- Prevailing annual wind regime 4 m/s (8.9 mph)
- For this regime, the hours per year at a given windspeed are:

Windspeed	m/sec	4.5-6.8	6.8-9	9-11.2
Distribution	m/sec	10-15	15-20	20-25
Hours per Year		1900	481	75
Total Hours per Year				2456
Total Days per Year				103

Thus, useful windspeed should be expected for 103 days of the year; that is allowing the extraction of enough energy to supply the annual energy requirement, taking into account some other factors.

The use of wind energy in the remote and rural areas in Haiti could be very efficient. Two hundred seventy-five sites have been located in a project with USAID. Each will be a 2.2 kW system supplying a rural clinic with water or electricity. Rural people in Haiti could use wind energy to pump water, to run electrical appliances and even do many other applications. In some areas they are already involved in the use of wind energy.

It is then important that the people responsible for meeting the energy needs of these areas are as well informed as possible about wind energy technology.

At this point, I would like to address a special thanks to:

- The Directorate of "Office National de Technologie"
- The USAID Staff in Port-au-Prince, Haiti
- The TAET Program Staff

for giving me this opportunity. I would like to encourage them in going this way.

Hence, this work will let me become aware of wind turbine technology, including: design, manufacturing and evaluation in the purpose of future applications in Haiti.

This is a summary overview of the design of a 1.2 kW wind turbine manufactured by a group of participants of Session 7 of the TAET Program, TREEO Center, University of Florida, Gainesville.

With that team were:

Ing. Ibrahim Hussein Rabie, Egypt

Dr. Marwan Mahmoud, Jordan

Tanay Uyar, Turkey

Kawther Abdelgadir, Sudan

It contains also some data of testing results taken during group project workshop time schedule.

Objectives

According the the report of that team, the 1.2 kW small wind energy conversion system was designed to be manufactured with simple technology in rural residential areas in the Middl - East where relatively low (3-6 m/sec) mean annual wind speeds prevail.

The present wind turbine a similar air foil segmented blades (NACA 4312 model) takes aim on economics and easy manufacturing rather than aerodynamic performances. Hence, its performances will be less than a continuously contoured blade turbine. But it will give the flexibility to allow the same building blocks to be used for a variety of applications.

Description

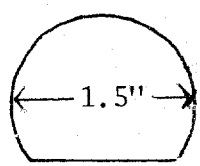
It is a horizontal axis, three blade wind turbine (R = 78.2", radius). It consists essentially of a hub on which the three blades are mounted.

Hub

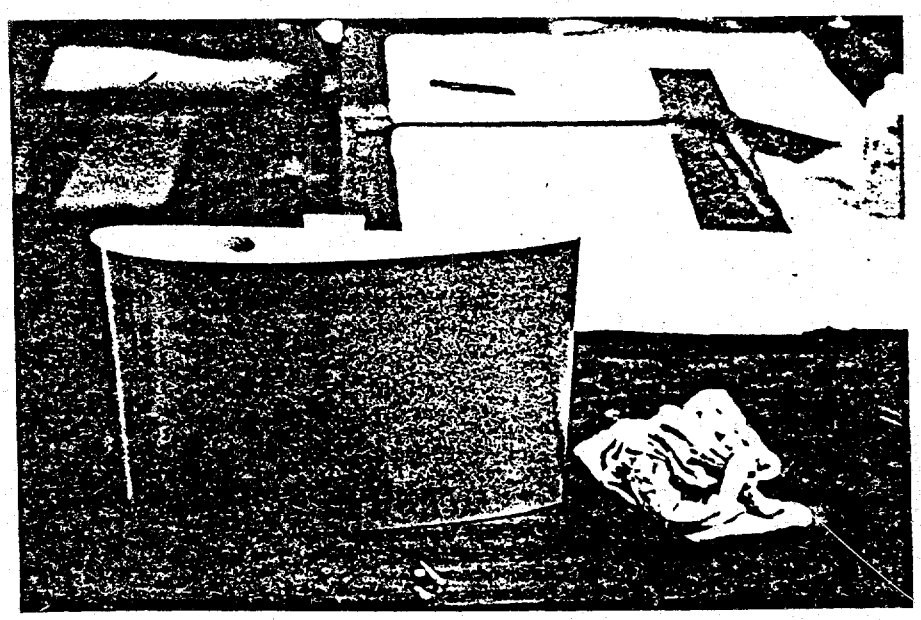
The hub is a 12" flat disk (see Fig. 2). It can be fixed on the shaft of the gear box (see Fig. 2).

Blades

The three blades are mounted each with two "U" bolts (¼" diameter). Each blade consists of 6 segments of air foil NACA 4312, 11.65 inch width, 12° angle of attack, mounted on 1.65" diameter aluminum pipe and mounted on 1.5" diameter aluminum rod (see Fig. 3). Note that the portion of the aluminum rod in contact with the hub is flat on one side. That helps to keep the blade tight to the hub. It also has two slots for fitting the steel U-bolts.



- The end plates were made from aluminum-sheets (thickness 0.21 inch) and cemented to both sides of the air foil.



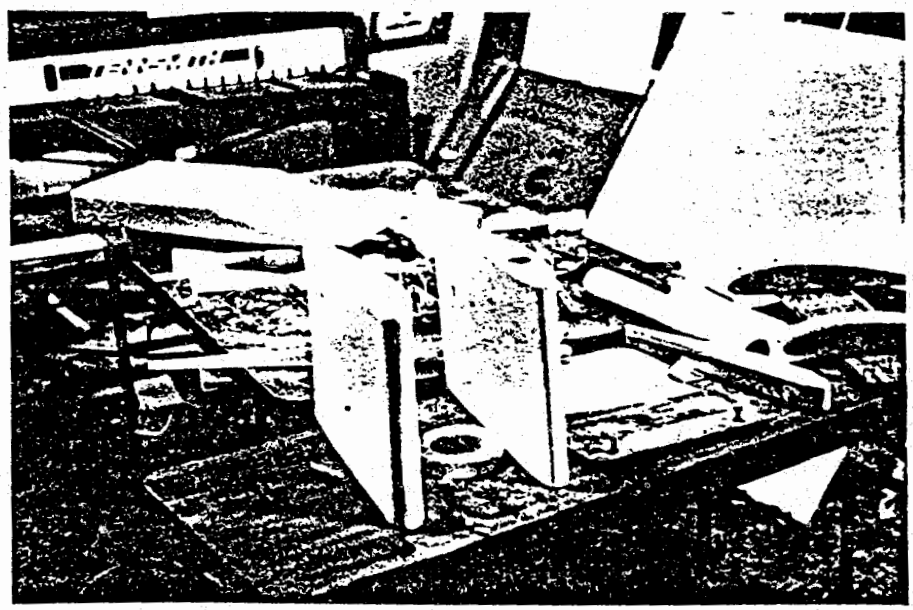
- The hub was made from aluminum (details are given in Fig. 2).
- Each six airfoil segments were mounted on an aluminum-pipe (diameter 1.625 inch) which is fixed on an aluminum-rod (diameter 1.5 inch). This rod is fixed to the hub with two U-bolts (bolts diameter 1/4 inch).
- The twist angle of each airfoil segment was adjusted according to Table 1. Now the wind turbine is ready to be mounted on the truck for testing.

Testing of the Wind turbine:

- The wind turbine was mounted on the truck and connected to a transmission system which connects the wind turbine to the electric generator. The testing equipments were mounted also on the truck.

Manufacturing process:

- The air foil material is urethane foam, which was chosen because of availability, cheap, light and easy to manufacture.
- The cutting process was carried out with a thin blade saw using a wooden airfoil model.



- A hole was then cut through the approximate aerodynamic centre of the air foil section by using a pipe with a serrated end.
- The air foil sections were painted with a plastic paint (weather-shedder, gloss latex).
- The air foil sections were wrapped with aluminum sheet (0.008 inch thickness) which is available as a waste of the newspaper press (area: 31 x 22.6 inch). This was done by blind rivets and then applied a self-adhesive aluminum tape on the connections to provide protection from weather and ultraviolet rays.

All of this study is based on the formula established by J. Betz. The maximum power available in a wind section is evaluated:

$$P_{max} = \frac{16}{27} \times \frac{1}{2} S \quad A \; V^3$$

Where:

S = air density

A = area of the given section

V = wind velocity

This formula assumes that the turbine should be ideal and does not take care of some other factors.

Thus a power coefficient should be considered for each turbine and each established system.

For this turbine they have assumed a power coefficient ranged from 0.2 to 0.4.

(Power coefficient $C_p = \frac{\text{power produced by the machine}}{\text{theoretical power in the wind}}$)

Hence the tip speed ratio T_R (i.e. the ratio of the blade tip velocity over the wind velocity $T_R = \frac{RW}{V}$

R = radius of the blade measured from the center of the hub

W = angular velocity of the turbine

V = wind velocity)

ranges from 2 to 5. $T_R = 3$ (tip speed ratio) have been assumed. From this tip speed ratio the number of blades can be determined. The number of blades is set at three.

The diameter of the turbine (and then R) has been determined from the formula:

$$P = \frac{16}{27} \times \frac{1}{2} \times C_p \times S\ A\ V^3$$

Known = P (power)

C_p (ranges from 0.2 to 0.4)

S (air density)

V (air velocity 4 m/sec)

A is then computed and

$$A = \frac{\pi D^2}{4} \quad \text{or} \quad A = \pi R^2$$

$$\Rightarrow R = 6.5 \text{ ft.}$$

For fixing the segments of air foil on the blades rode support they had to complete the angle of twist of each segment.

For that they determined the rotation speed of the wind turbine.

W (radians/seconds) Assuming before

$$T_R = 3$$

$$3 = \frac{RW}{V}$$

$$W = 6.8 \text{ rad/sec}$$

The angle of twist β is determined by subtracting from the angle of apparent relative wind α, the angle of attack which is 12° for this air foil.

$$\tan \alpha = \frac{V}{RW} \qquad \text{(Fig. 4)}$$

$$\beta = \alpha - 12^o$$

They repeated the same calculations for each segment in determining R as the distance of the center of each hub to the center of each air foil (see Fib. 3).

Example--

For the first segment

$R_1 = 13.85$ inches

$R_1W = \frac{13.85}{12} \times 6.8 = 7.88$ ft/sec

$\tan \alpha = \frac{V}{RW}$, or $\tan\alpha = \frac{14.80}{7.88}$

$\tan \alpha = 1.878$

$\alpha \simeq 62^o$

Twist angle

$\beta = \alpha - 12^o$

$\beta = 62^o - 12^o \qquad \beta = 50^o$

Radius/inch	α	β	
*R_1 = 13.85	62°	50°	1st segment
R_2 = 25.55	45.6^o	33.6^o	2nd segment
R_3 = 37.25	35.0^o	23.0^o	3rd segment
R_4 = 48.95	28.0^o	16.0^o	4th segment
R_5 = 60.65	23.27^o	11.27^o	5th segment
R_6 = 72.35	19.83^o	7.83^o	6th segment

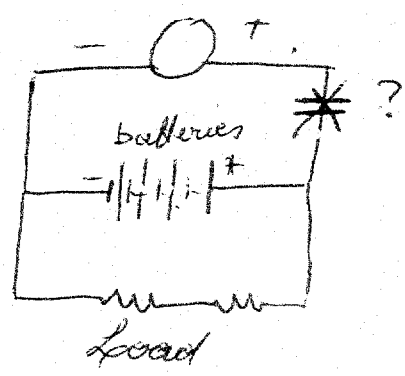
As the five other segments are locked to each other and to the first segment, we will set the position of only the first segment. Hence, the position of the others are automatically determined.

The different setting angles will be:

	Twist angle β					
Segment	I	II	III	IV	V	VI
40°	40°	23.6^{o}	13°	6.0^{o}	1.27^{o}	-2.17^{o}
50°	50°	33.6^{o}	23°	16.0^{o}	11.27^{o}	7.83^{o}
60°	60°	43.6^{o}	33°	26.0^{o}	21.27^{o}	17.83^{o}
70°	70°	53.6^{o}	43°	36.0^{o}	31.27^{o}	27.83^{o}

Figure 5 shows a diagram of the wind data instrumentation.

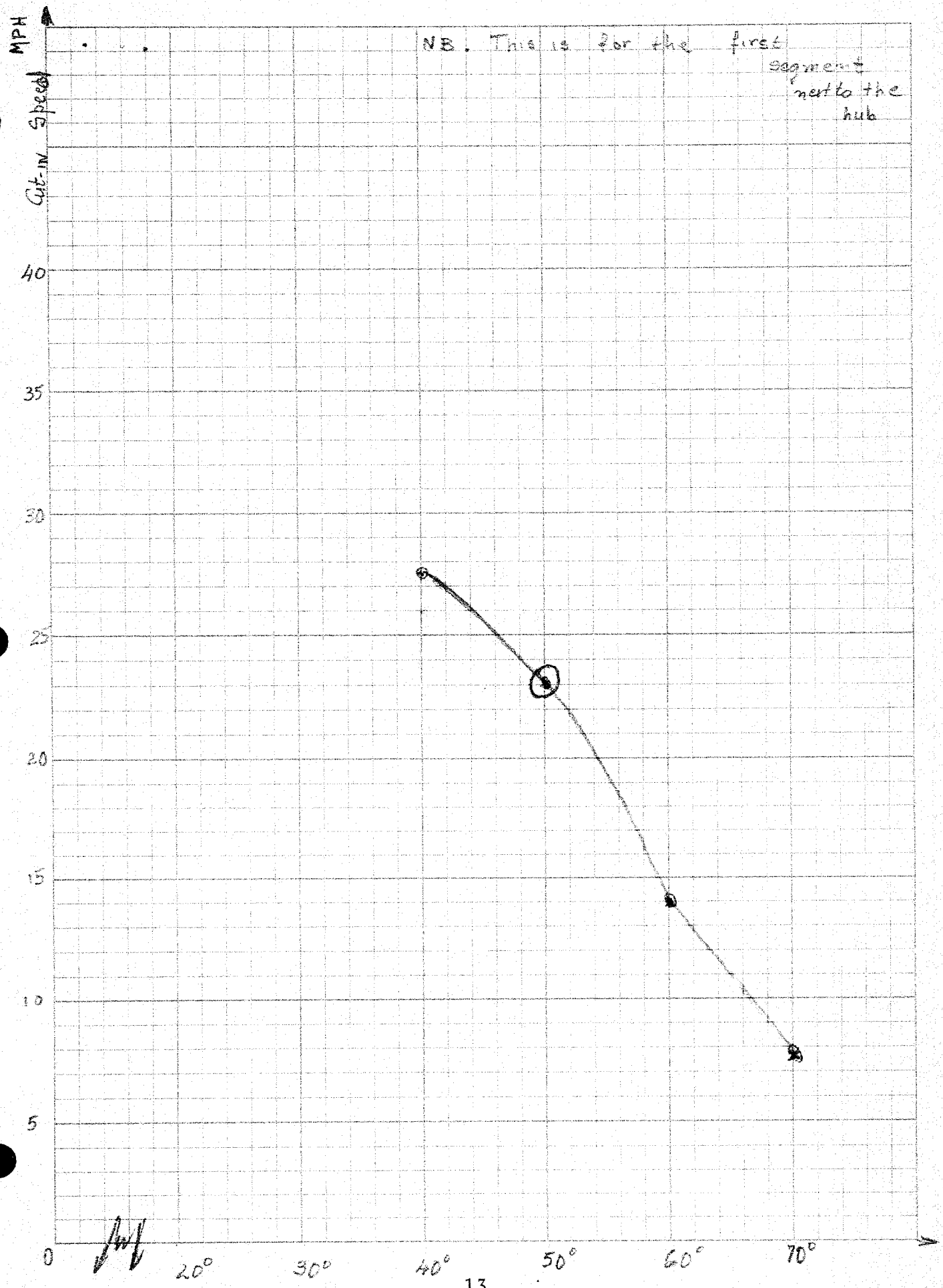
Remarks

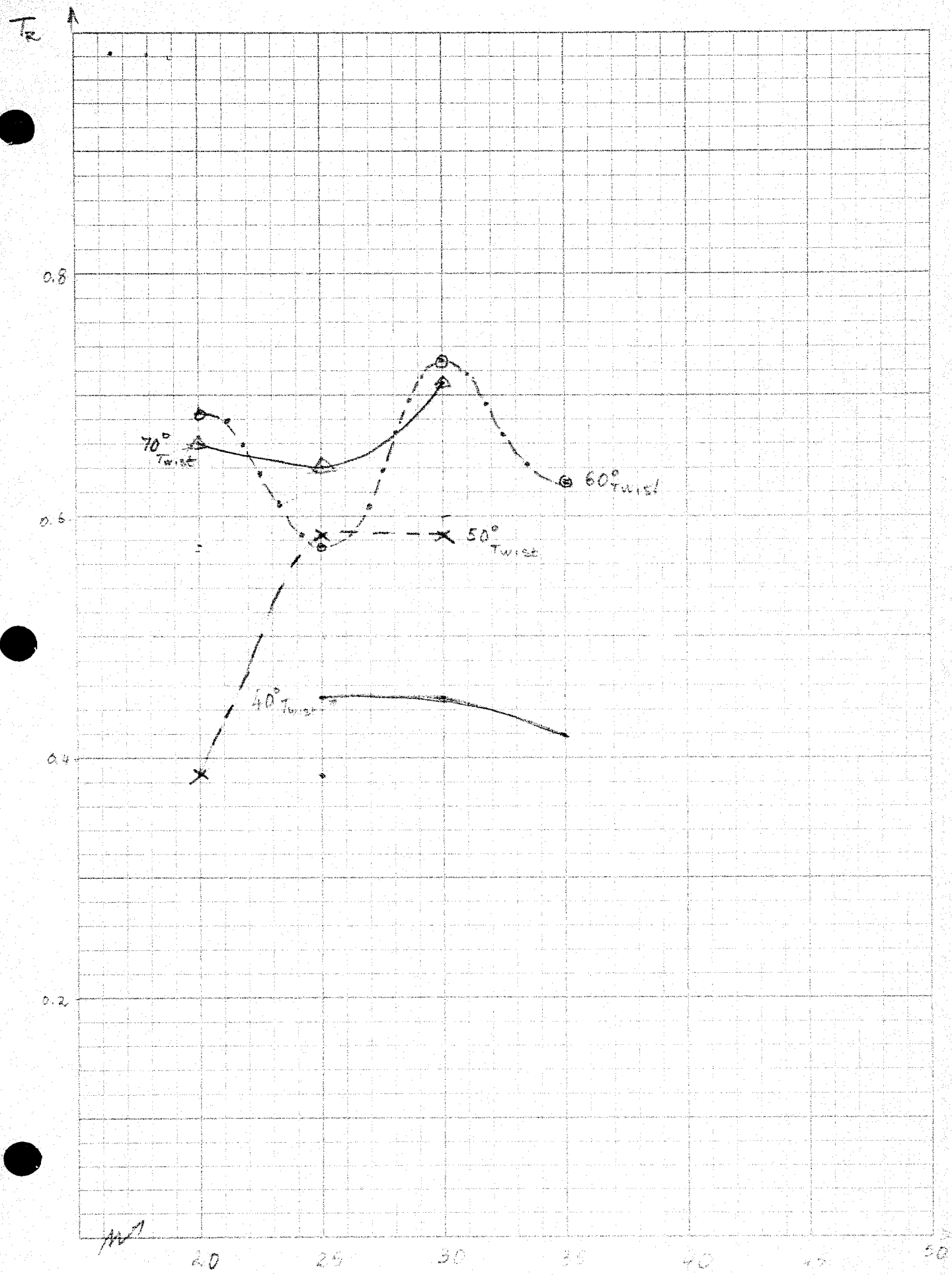


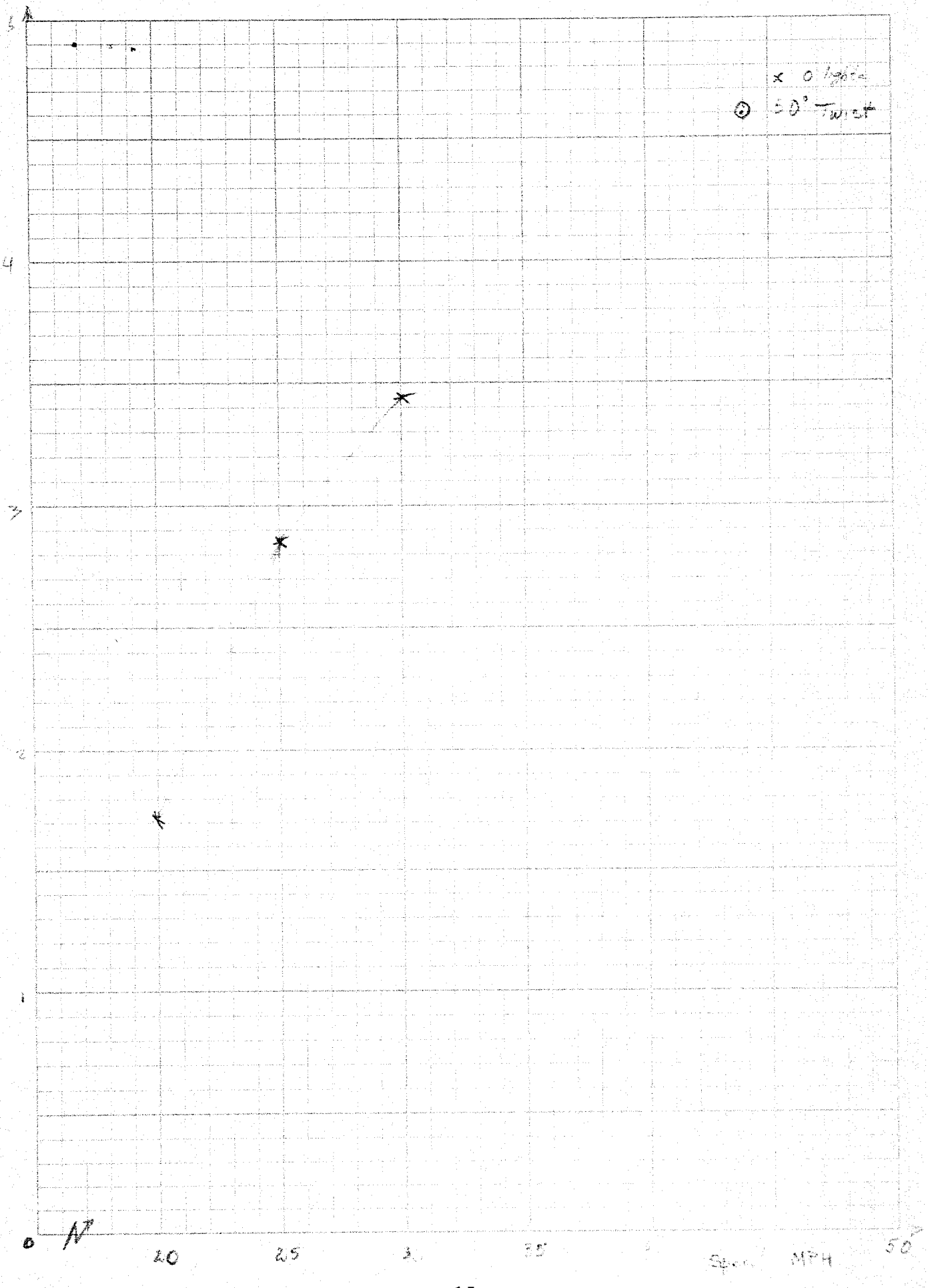
	V mpH	Volts	I Amp	N RPM	Load Nbre of lites (250W)	P Gen W	P Heavy Wind Betz W	T_R	$C_{P\%}$ System	$C_{P\%}$ Rotor
40°	25	12.5	1.5	16.8	0	18.75	6640	0.46	0.28	0.57
		11.8	1.8	16.5	2	21.24		0.45	0.30	0.62
40°	30	12.8	5.5	19.8	0	70.4	11370	0.45	0.6	1.02
		12.1	7.0	20.1	2	84.7		0.46	0.7	1.21
	35	13.4	8.0	21.7	0	107.2	17940	0.42	0.60	0.96
		12.7	11.0	21.7	2	139.7		0.42	0.78	1.23
		11.9	5.5	21.7	4	65.45		0.42	0.36	0.62
50°	20	13.0	2.5	11.35	0	32.5	3330	0.387	0.97	1.73
	25	12.7	9.5	21.4	0	120.65	6640	0.584	1.8	2.86
	30	14.2	18.0	27.5	0	255.6	11370	0.62	2.2	3.45
		12.7	8.0	22.1	2	101.6		0.50	0.89	1.43
		12.7	20.0	27.0	3	254.0		0.61	2.2	3.43
		12.7	16.0	25.3	4	203.2		0.57	1.78	2.76
60°	15	12.7	–	16.1	0	–	1420	–	–	–
	20	13.7	5.8	20.6	0	77.14	3330	0.70	2.3	3.73
		12.5	5.0	19.7	1	62.5		0.67	1.8	3.07
	25	13.4	7.0	21.8	0	93.8	6640	0.59	1.4	2.26
		12.7	6.0	19.9	1	76.2		0.54	1.1	1.86
		12.8	15.0	23.3	2	192.0		0.64	2.8	4.47
		12.0	6.0	19.5	3	72.0		0.53	1.	1.77

V mph	Volt	I Amp	N RPM	Nbre of Lights	P_{Gen} W	P_{max} Wind (Betz) W	Cp System %	Cp Rotor %	T_R
30	15.4	22.0	29.8	0	338.8	11370	2.97	4.54	0.68
	13.4	12.4	22.9	1	167.5		1.47	2.29	0.52
	14.4	20.0	25.7	2	288.0		2.53	3.88	0.58
	12.5	15.0	23.9	3	187.5		1.65	2.56	0.54
	12.6	25.0	26.4	4	315.0		2.77	4.23	0.60
35	16.0	26.0	32.7	0	416.0	17940	2.32	3.53	0.64
	12.5	30.0	31.9	6	375.0		2.1	3.19	0.62
20	13.3	5	19.9	0	66.5	3330	1.997	3.25	0.678
	12.4	6	19.3	1	74.4		2.2	3.60	0.658
	12.6	4.5	18.5	2	56.7		1.7	2.81	0.63
25	13.9	15.0	22.9	0	208.5	6640	3.1	4.84	0.625
	12.9	12.9	23.7	2	166.41		2.5	3.89	0.646
30	16.2	19.0	31.3	0	307.8	11370	2.7	4.14	0.71

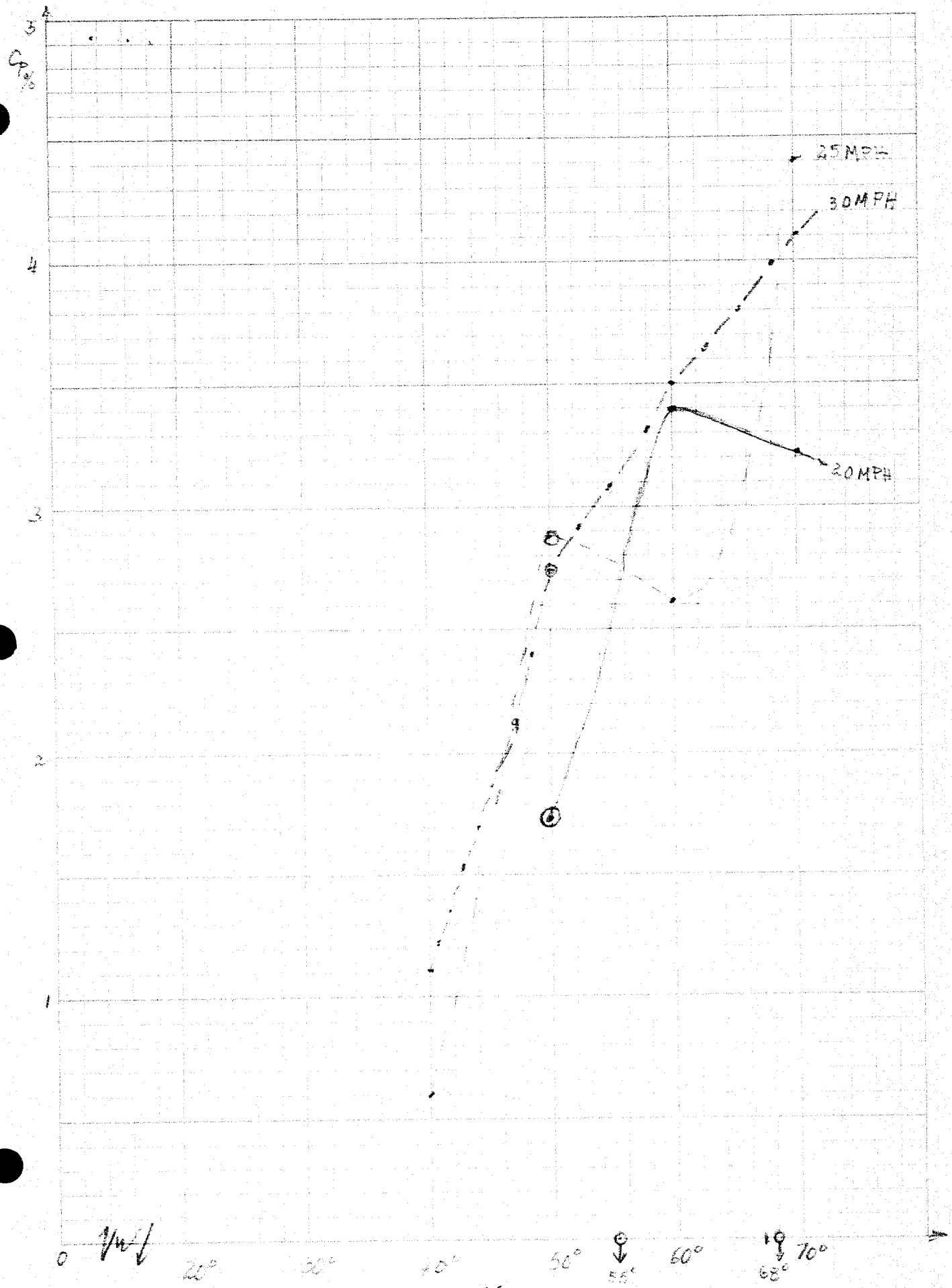
20°


MPH
Cut-in Speed
NB. This is for the first segment next to the hub
40
35
30
25
20
15
10
5
0
20°
30°
40°
50°
60°
70°


T_R
0.8
0.6
0.4
0.2
70° Twist
60° Twist
50° Twist
40° Twist
20
25
30
35
40
45
50



x 0 lights
⊙ 50° Twist
4
3
2
1
0
20
25
35
50
MPH



$C_{P\%}$
25 MPH
30 MPH
20 MPH
0
20°
30°
40°
50°
55°
60°
68°
70°

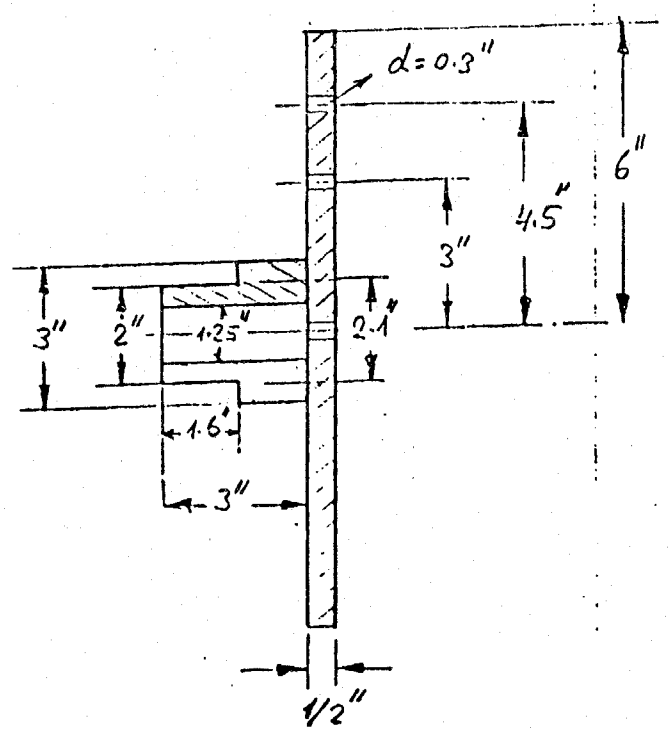
Conclusion

- This turbine needs to be improved. Because of its low cut-in speed it could possibly be used for pumping water. But some other factors must be taken in to consideration when a wind turbine is used for water pumping. For example, the variation of the water bed level compared to the variation of wind velocity.

- It is recommended for DC production.

- Build a good tower and the system must be strong enough for some high gusts (high speed velocity).

Please be careful.



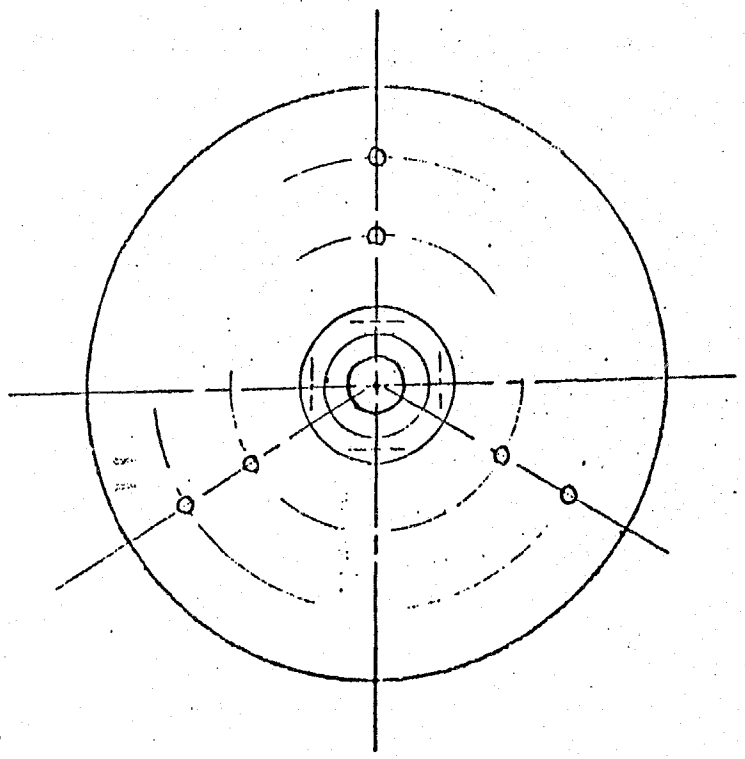


Fig. 2

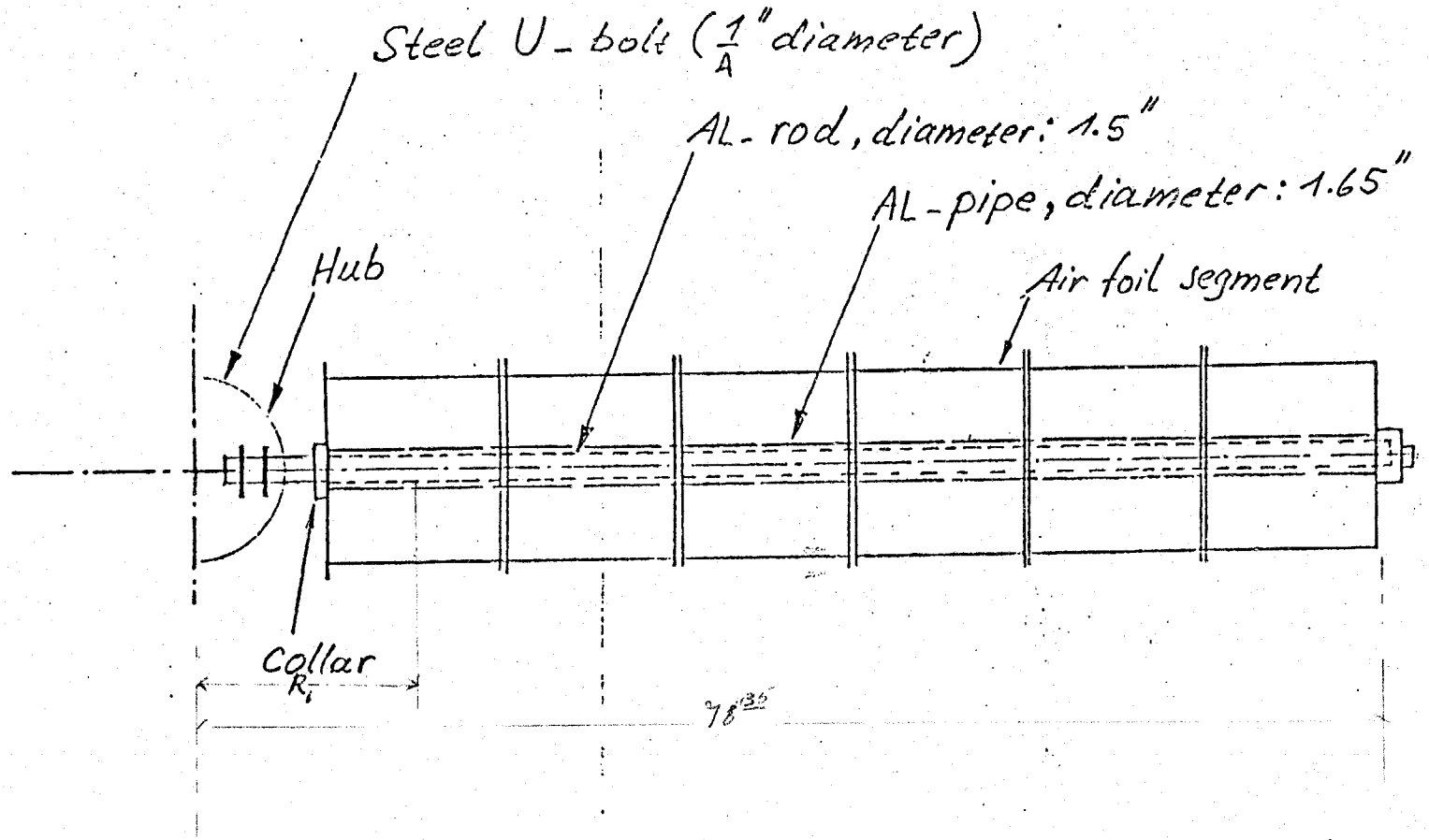
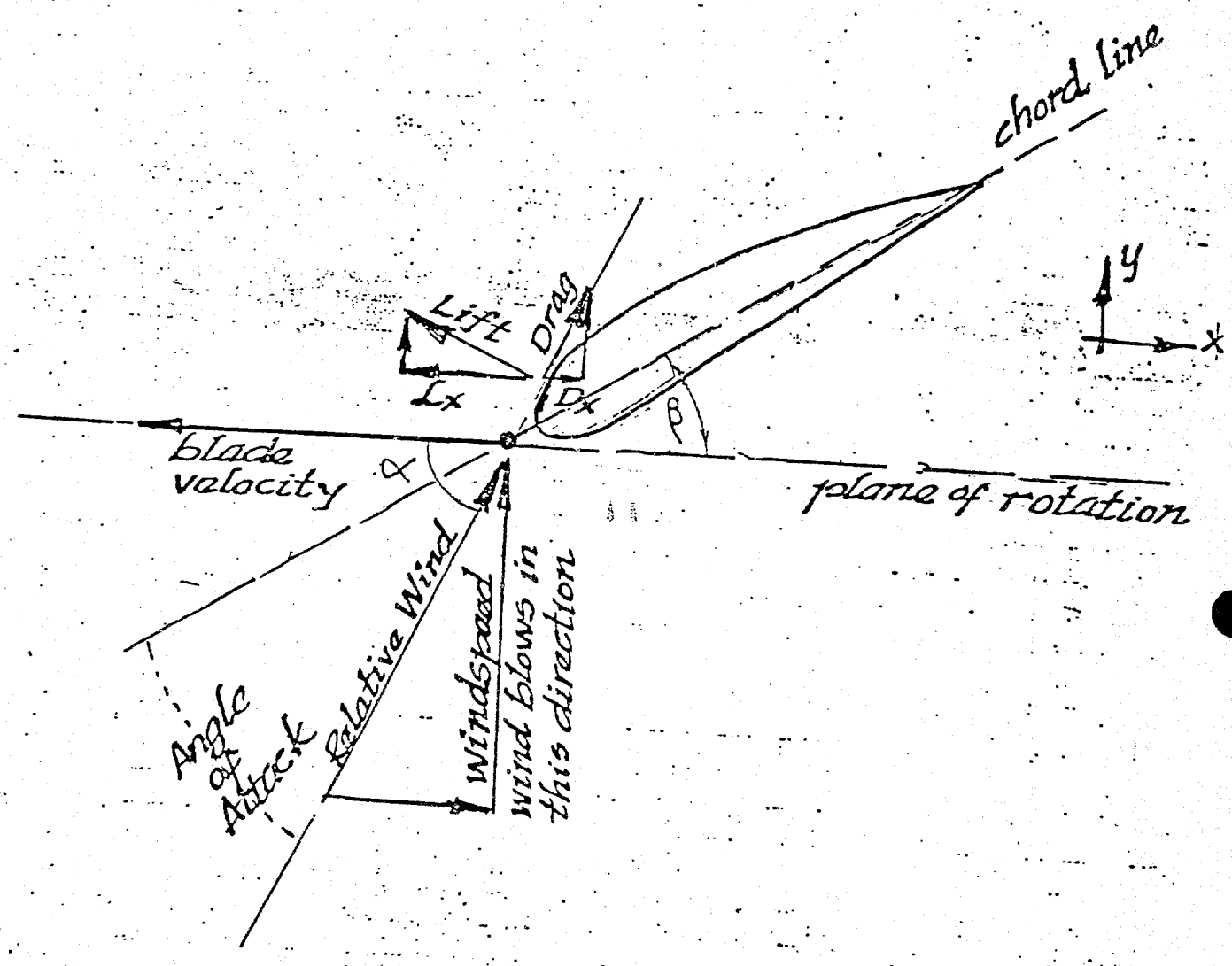

Steel U-bolt (1/4" diameter)
AL-rod, diameter: 1.5"
AL-pipe, diameter: 1.65"
Hub
Air foil segment
Collar
R_i
78.35

Fig (3)



Airflow at a Single Rotor Blade

Fig. 4

WIND DATA INSTRUMENTATION

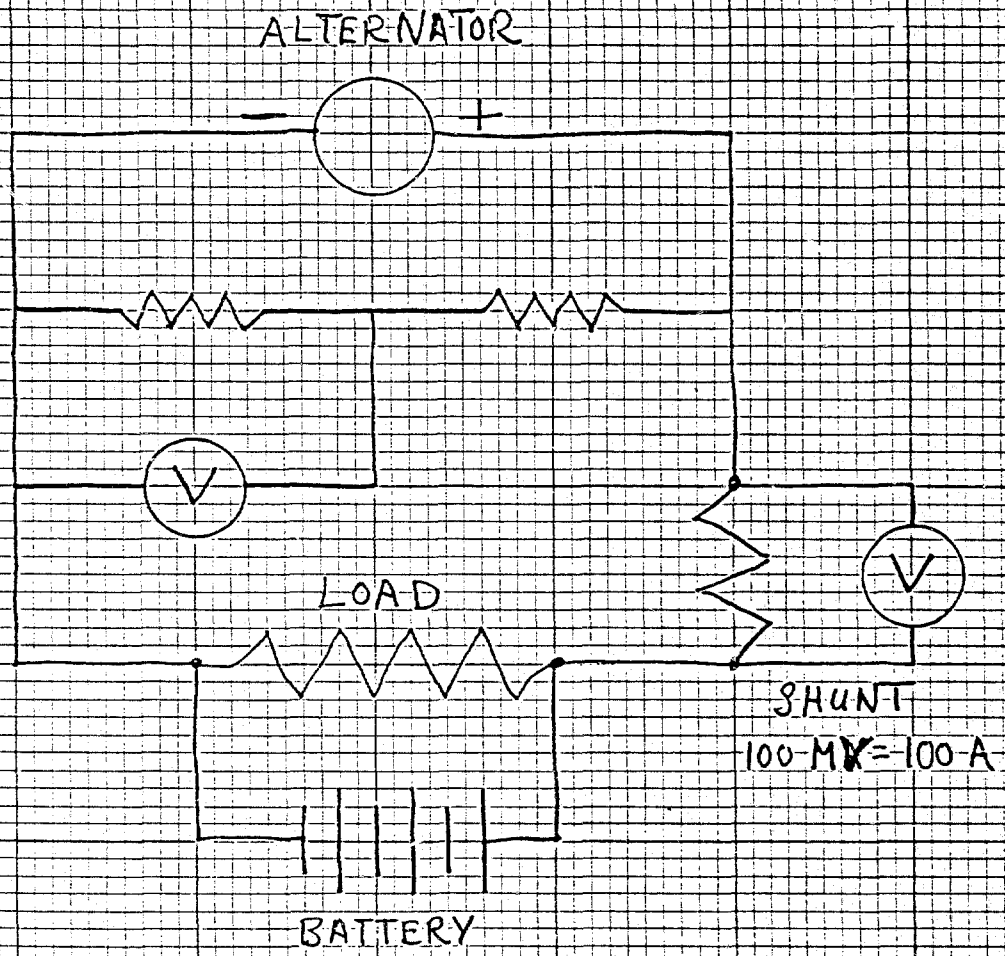


Figure 3