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WIND DATA ANALYSIS

Submitted by:

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I. INTRODUCTION

There is little doubt that as we enter the 21st century we will have to rely heavily on renewable resources for a large part of the world's energy and chemical needs. The resources we have come to rely upon, oil, natural gas, coal and uranium, are becoming more scarce, difficult to use in an environmentally sound manner. Thus, over the past several years scientists and engineers, government officials and the public have directed increasing attention to such renewable energy resources as: solar, wind, photovoltaic, biomass and hydro-power.

As the present energy crisis has deepened, many leaders have taken a second look a wind energy as an alternative source of energy or at least in the light of providing some of their energy needs. All over the world, private enterprises, independent research organizations, and universities are involved too in improving existing technology and rapidly developing new methods of harnessing the power of the wind. Their work ranges almost as far as the wind itself, from developing more efficient, wind driven generators for use in independent home systems or creating giant machines that may some day power entire cities. All of this money and effort is well worth it, to develop such renewable source of power to ensure the energy needs of future generations both near and distant.

The eneven heating of the earth's surface by the sun gives rise to large and small scale motions of the atmosphere referred to as the wind. The wind thus represents solar energy temporarily converted into the kinetic energy of the air. This kinetic energy is continually replenished by solar radiation and continually dissipated by frictional forces that result in atmospheric heating.

There are many possible ways of extracting useful energy from the wind. For instance, the mechanical power derived from wind turbines, which may very in size from several feet to several hundred feet in diameter, can be used to drive electrical generators or pump water or air to perform other useful work.

The economic viabilities of all of these systems are strongly dependent not only on such factors as system reliabilities, lifetimes, costs and prices of energy derived from competing energy sources, but also on the time distribution of wind velocity at the specific geographical location chosen.

II. BRIEF CHRONOLOGICAL DEVELOPMENT OF WIND SYSTEMS

Persians	First known wind machines used to grind grain predate the Christian civilization.
France & England -	Use of wind energy recorded in the 12th century.
Throughout Europe -	Use of wind energy throughout Europe in 13th century.
Grandpa's Knob near Rutland, Vermont	Second largest wind turbine ever built. Concerned by Palmer Putnam. Ran from 1941-1945, when it was shut down after a blade failure.
Holland	Large octagonal drainage mill or polder mill, with internal scoop wheel built in the middle ages.
Holland Drainage Mill	Built in 1761, the Your blade windmill is one of the mills of the Zype and Haze polder.
Russians	100 kw wind turbine built in 1931 near Yalta on the Black Sea.
Dawes	After World War II Danish Gedsar mill wind-turbine with 200 kw rated power at 33 mph wind speed was developed.
British	Designed by John Brown in Great Britain on Cape Costa in the Orkney Islands; 100 kw at 35 mph rated wind speed.
French	Built and operated several large wind powered electrical generators in the period from 1958 to 1966. A unit of this type was operated near Paris from 1958-1963. It was designed to generate 800 kw in winds of 37 mph.
Germans	Introduced a number of improvements in the design of wind-powered generators, including light-weight constant-speed rotors that were controlled by variable-pitch propellar blades. The units operated successfully for more than 4000 hours during the period 1957-1968.

France	A family of vertical-axis wind turbines was invented by G.J.M. Darrieus in France in 1920's. The Darrieus-type rotors are lift devices and they have relatively low starting tongues, high tip-to-wind speeds and, their high power outputs per given rotor weight and cost.
Americans	Federal support is being provided to the wind energy conversion system (WECS) program to accelerate the design, construction, and operation of the large types of WECS units (in MW, or more, rated capacity). The first such system was built by ERD NASA at Plus Brook, Ohio, and was put into operation in September 1975.

III. WIND RESOURCE ASSESSMENT FOR GENERATING ELECTRICAL ENERGY

The thought of using wind as an alternative source of energy could be very attractive. But in spite of its many advantages, one should always be aware that wind energy could only be practical in a few well defined cases. Two obvious practical requirements are: that it should be the least cost alternative source of energy and, secondly, that the wind resource must be available at the site. Most people are very apt to believe that they have plenty of wind. In wind energy projects, this would lead to miserable failures if it is not true.

This section will describe procedures for assessing wind potential, give an overview of the sources and types of wind data that are usually available, and comment on instrumenting a local site to gain knowledge about local winds.

The primary objective of any kind of wind resource assessment is to determine the energy (and power) that is available in the winds at a particular site. Once this is determined, whether accurately or in a crude manner, it is possible to compare these values with one's energy needs. Analysis of this sort allows one to decide the size of the system needed for a desired function, the storage capacity that would be necessary, or just simply whether wind is a practical alternative for their purpose. Before going any further, let us quickly state some facts about wind energy conversion systems.

Some Facts About Wind Energy Conversion Systems

The major components or a Wind Energy Conversion System are:

1. The wind energy machine itself
2. A storage system, such as, a bank of batteries
3. Conversion devices (mechanical gear boxes, inverters, rectifiers, etc.)
4. An optional backup system, such as, a gas generator

The amount of electricity that can be generated from a wind machine depends on:

1. The amount of wind blowing on it
2. The diameter of the propellar
3. The size of the generator
4. The efficiency of the whole system

Some Considerations In Machine & Resource Assessment

Wind resource considerations include:

1. Windspeed (annual and monthly averages)
2. Prevailing wind directions
3. Wind shear (tendency of the windspeed to increase with height)
4. Topography (nearby hills, valleys, trees, buildings, etc.)

Wind machine considerations include the following to the weather:

1. Wind gust peaks
2. Gale, hurricane, and tornado expectations
3. Ice, sleet, hail, snow, freezing rain
4. Airborne contaminants (fly ash, cement dust, sand, salt water spray, etc.)

Wind machine considerations also include

1. Separation distance to inhabited buildings
2. Soil conditions for foundation design
3. Seismic stability
4. Migratory birds, deer trails, etc.
5. Local social, legal, and environmental conditions

Now that we have reviewed some facts about wind energy conversion systems, it is necessary to increase our understanding of wind energy and power. We will approach this subject by presenting some relationships.

Energy in The Wind

It is important to distinguish between energy and power. Mechanical energy, often called work, is measured in horsepower-hours; electrical energy is measured in kilowatt-hours. Power is the rate of doing work or the rate at which energy is transferred. Mechanical power is measured in horsepower, and electrical power is measured in kilowatts. Electrical systems must be specified in terms of both energy capacity (kw-hr) and power capacity (kw). We will first discuss the former.

The theoretical energy available in the wind is given by its kinetic energy as a result of the air motion and may be expressed as

$$KE = \frac{1}{2} mv^2$$

The mass of air in this case is proportional to the cross section area of the rotating blades, where

$$A = \left(\frac{\pi D^2}{4}\right) \qquad (2)$$

$$KE = 1/2\, m\left(\frac{\pi D^2}{4}\right)v^2$$

Translating this kinetic energy to useful work, or power, which can be done by the invisible tube of wind in one second times the distance, v, through which it moves:

$$\text{Power} = (KE)(v) = \frac{1}{2} m\left(\frac{\pi D^2}{4}\right)v^2(v) \tag{4}$$

$$\text{Power} = \frac{1}{2} m \left(\frac{\pi D^2}{4}\right)v^3 \tag{5}$$

Power Extracted From the Wind

The above expression cannot be used to determine the continuous extraction of energy from the wind because if one were to extract all the energy from the wind at any given moment, the wind would have to change from velocity v to zero. It was Betz, a German, who demonstrated that the maximum fraction of power that could be extracted from a continuous wind stream is 16/27, or 59.3 percent of the total power in the wind column. Therefore,

$$\text{Power} = \frac{.593}{2} m \left(\frac{\pi D^2}{4}\right)v^3 \tag{6}$$

Two important points that should be observed in Equations (5) and (6) are: 1. That the power is proportional to the cube of the wind speed, i.e. if you double the wind speed you will increase your power output 8 times; 2. The power is proportional to the square of the diameter swept by the windmill blades, i.e., if you double the diameter you will increase the power output by 4 times.

IV. WIND DATA ANALYSIS FOR A VERY WINDY SITE IN THE USA

The table below shows annual wind data for a very windy site. Construct the wind duration curve for this location.

SPEED MPH DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≧58	%	MEAN WIND SPEED
N	.1	.3	1.3	1.1	1.0	.5	.2	.1	.0	.0	.1	4.8	15.8
NNE	.2	.1	.5	.7	.9	.8	.6	.1		.0	.0	3.8	19.8
NE	.2	.1	.6	.8	1.2	.8	.7	.1	.0	.1		4.5	19.4
ENE	.1	.1	.3	.8	1.3	1.5	1.2	1.0	.3	.2	.9	7.7	30.0
E	.2	.4	1.1	1.9	1.5	1.0	.9	1.0	1.0	.3	.2	9.5	23.7
ESE	.1	.1	.5	1.0	1.3	1.3	1.1	.8	.8	.7	.1	7.9	27.4
SE	.1	.3	.6	.7	1.1	1.6	1.3	.9	.4	.3	.1	7.6	25.1
SSE	.0	.2	.3	.2	.3	.4	.4	.7	.5	.6	.3	3.9	32.1
S	.3	.3	.6	.9	1.0	.7	.7	.8	.5	.4	.2	6.4	24.9
SSW	.1	.1	.5	.6	.4	.7	.7	.3	.0	.2	.2	3.7	24.9
SW	.1	.2	.6	1.2	.9	1.1	.9	.5	.3	.2	.2	6.3	23.9
WSW	.0	.2	.8	.9	1.1	1.1	.9	.6	.3	.2	.0	6.1	23.0
W	.2	.3	.7	.9	1.3	1.4	.9	.4	.1	.1		6.3	20.7
WNW	.2	.3	.5	1.1	1.0	1.1	.7	.6	.2	.1		6.0	21.3
NW	.3	.4	1.7	1.9	1.4	1.4	.7	.6	.2	.0		8.7	18.1
NNW	.0	.2	.8	1.7	1.5	1.1	.4	.2	.0	.1		6.0	18.6
VARBL													
CALM												.9	
t_D%	2.3	3.7	11.4	16.4	17.3	16.6	12.2	8.7	4.8	3.7	2.1	100.0	23.0
t_D hrs	201	324	998	1436	1515	1454	1069	762	420	324	184	8760	

The annual average wind speed in this site is 23 mph. To construct the wind duration curve for this location, we can use the Rayleigh distribution formula.

Rayleigh Distribution Curve:

to $(V_1 > V_2)$ to $e^{aV_1^2}$

where:

$a = \pi/4V'^2$

& V' = mean wind speed

from the table:

$V' = 23$ mph

$a = -\pi/4V'^2$

$= -0.0014847$

$\therefore t_D = t_o \exp(-0.0014847\ V_1^2)$

$= 8760 \exp(-0.0014847\ V_1^2)$ hrs./yr.

By applying this formula, we can obtain the Rayleigh Distribution Curve as follows:

		f(V)
t_o	- 8760	
		13
t_1	= 8747	
		39
t_2	= 8708	
		64
t_3	= 8643	
		89
t_4	= 8554	
		114
t_5	= 8440	
		137
t_6	= 8304	
		159
t_7	= 8145	
		179
t_8	- 7965	
		199
t_9	= 7767	
		216

t_{10} =	7551	
		232
t_{11} =	7319	
		246
t_{12} =	7073	
		258
t_{13} =	6816	
		268
t_{14} =	6548	
		276
t_{15} =	6272	
		282
t_{16} =	5990	
		286
t_{17} =	5703	
		289
t_{18} =	5414	
		289
t_{19} =	5125	
		288
t_{20} =	4837	
		286
t_{21} =	4551	
		281
t_{22} =	4269	
		276
t_{23} =	3993	
		269
t_{24} =	3724	
		261
t_{25} =	3463	
		253
t_{26} =	3210	
		243
t_{27} =	2967	
		233
t_{28} =	2735	
		222
t_{29} =	2513	
		211
t_{30} =	3302	
		199
t_{31} =	2103	
		188
t_{32} =	1915	
		176
t_{33} =	1739	
		165
t_{34} =	1574	
		153

t_{35} =	1421	
		142
t_{36} =	1278	
		131
t_{37} =	1147	
		121
t_{38} =	1026	
		111
t_{39} =	915	
		101
t_{40} =	814	
		92
t_{41} =	722	
		84
t_{42} =	638	
		76
t_{43} =	562	
		68
t_{44} =	494	
		61
t_{45} =	433	
		55
t_{46} =	378	
		49
t_{47} =	329	
		43
t_{48} =	286	
		38
t_{49} =	247	
		34
t_{50} =	214	
		30
t_{51} =	184	
		26
t_{52} =	158	
		23
t_{53} =	135	
		20
t_{54} =	115	
		17
t_{55} =	98	
		15
t_{56} =	83	

And we can also construct the frequency distribution curve as follows:

Frequency Distribution Curve

V_{mph}	F(V)
0-1	13
1-2	39
2-3	64
3-4	89
4-5	114
5-6	137
6-7	159
7-8	179
8-9	199
9-10	216
10-11	232
11-12	246
12-13	258
13-14	268
14-15	276
15-16	282
16-17	289
17-18	289
18-19	289
19-20	288
20-21	286
21-22	281
22-23	276
23-24	269
24-25	261
25-26	253
26-27	243
27-28	233
28-29	222

V_{mph}	F(V)
29-30	211
30-31	199
31-32	188
32-33	176
33-34	165
34-35	153
35-36	142
36-37	131
37-38	121
38-39	111
39-40	101
40-41	92
41-42	84
42-43	76
43-44	68
44-45	61
45-46	55
46-47	49
47-48	43
48-49	38
49-50	34
50-51	30
51-52	26
52-53	23
53-54	20
54-55	17
55-56	15

Rayleigh Distribution : $t_D = t_o \cdot \exp(-0.0014847\, U^2)$.

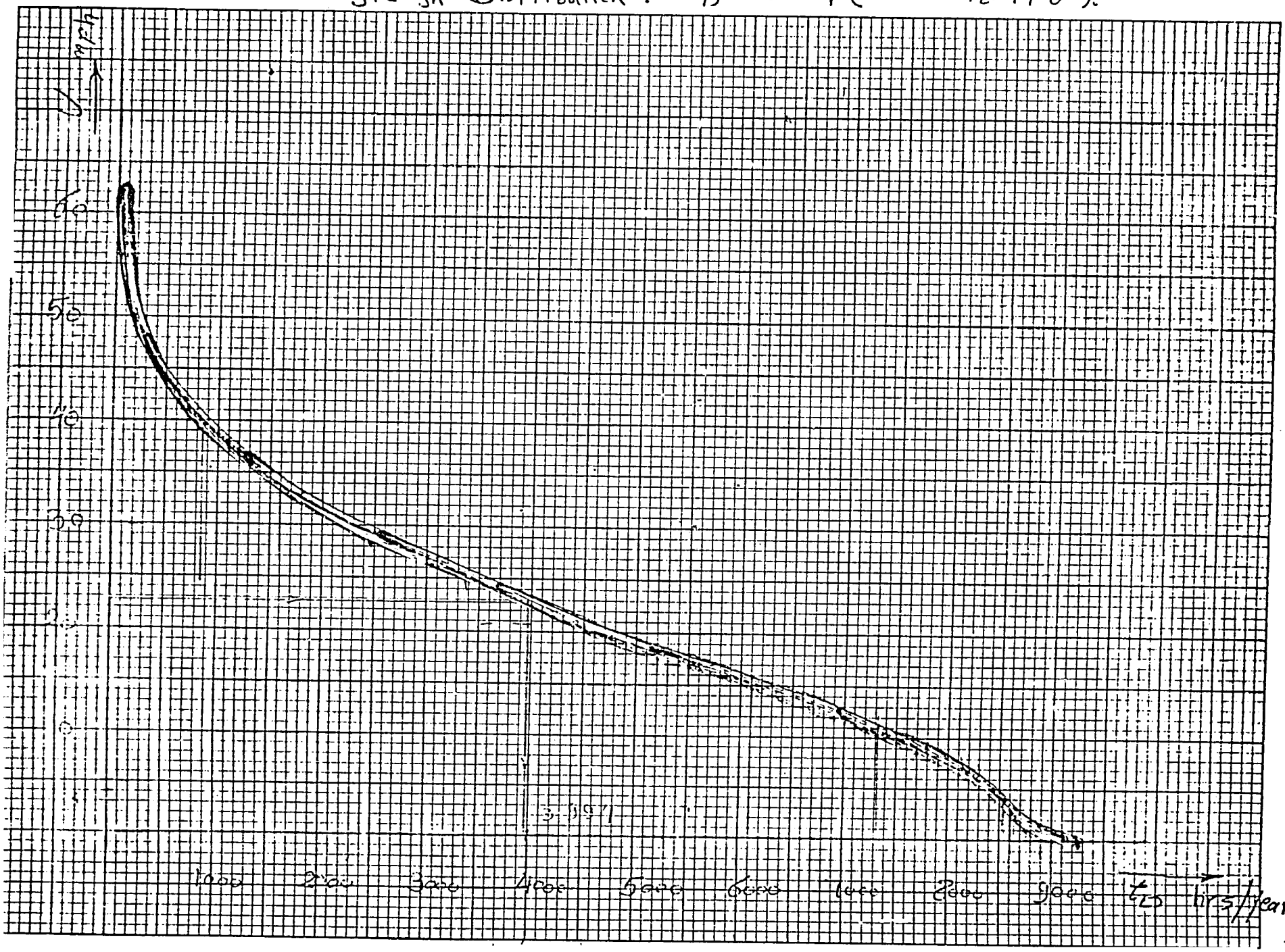
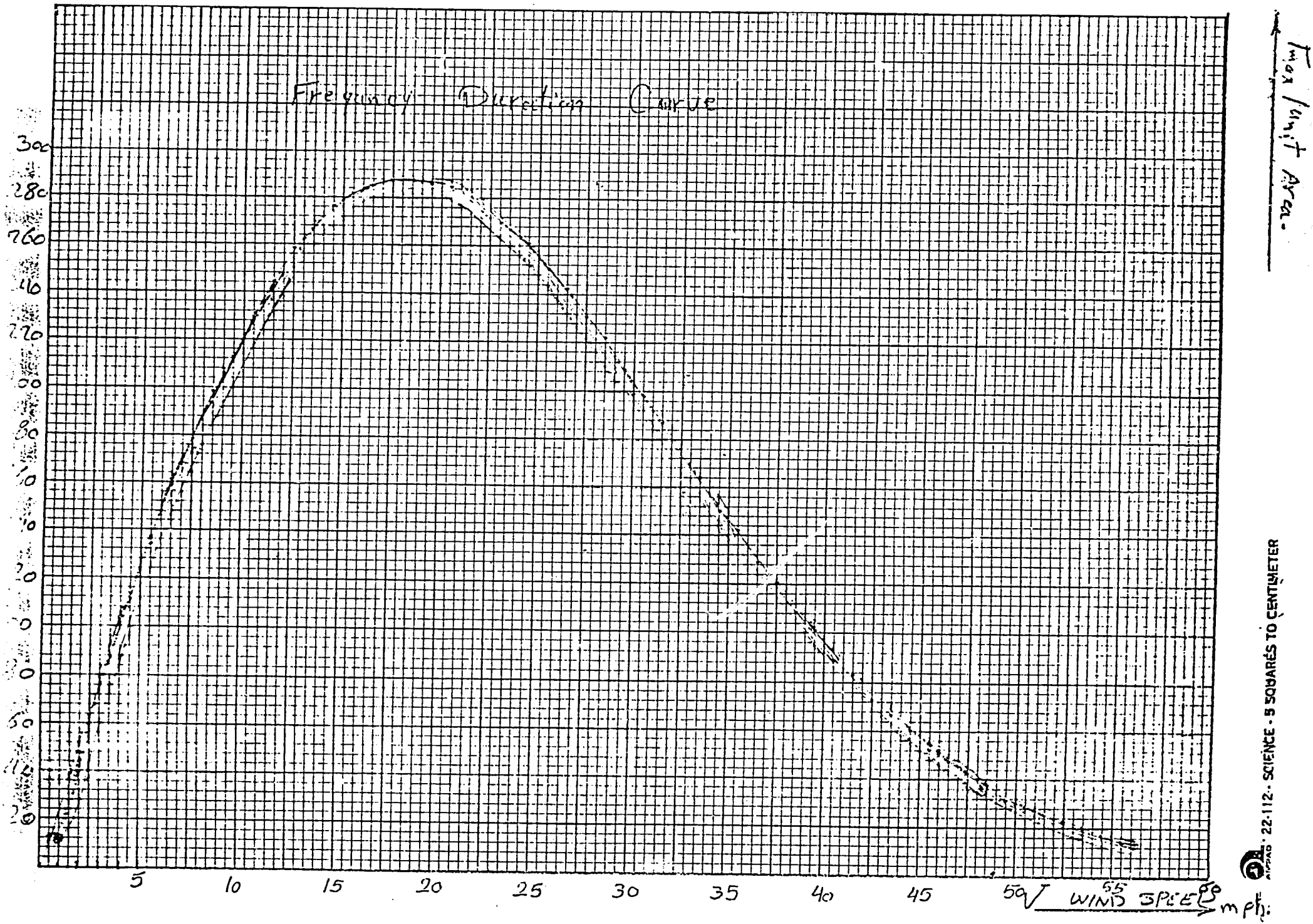


FIG (1)

AMPAD 22-112 · SCIENCE · 5 SQUARES TO CENTIMETER

V ESTIMATION OF THE GENERATED POWER AND ENERGY FROM THE WIND MACHINE AND WIND POWER

V_{mph}	Δt_{hr}	P_{mach_W}	Energy mach kWh	Wind Power W	C_p
6	159	25	4.77	179.388	0.139
7	179	35	7.16	238.76	0.147
8	199	55	9.95	365	0.151
9	216	80	17.28	492	0.163
10	232	120	27.84	690	0.174
11	246	210	51.66	881	0.238
12	258	300	77.4	1167	0.257
13	268	390	104.52	1435	0.272
14	276	480	132.48	1825	0.263
15	282	580	163.56	2183	0.276
16	286	640	183.04	2692	0.283
17	289	650	187.85	3253	0.206
18	289	690	199.41	3799	0.182
19	288	720	207.36	4375	0.165
20	286	750	214.5	5174	0.145
21	281	780	219.18	5878	0.133
22	276	820	226.32	6644	0.123
23	269	840	225.96	7691	0.109
24	261	845	220.55	8604	0.098
25	253	850	215.05	9843	0.086
26	243	850	206.55	10916	0.078
27	233	850	198.05	12364	0.069
28	222	860	190.92	13609	0.063
29	211	880	185.68	15281	0.058
30	199	885	176.12	16713	0.053
31	188	840	157.92	18625	0.045
32	176	820	144.32	20255	0.040
33	165	845	139.43	22424	0.038
34	153	850	130.05	24266	0.035
35	142	920	130.64	26206	0.035
36	131	930	121.83	28773	0.032
37	121	900	108.9	30944	0.029
38	111	890	98.79	33808	0.026


Frequency Duration Curve
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
5
10
15
20
25
30
35
40
45
50
55
60
V WIND SPEED mph
Tmax/unit Area.
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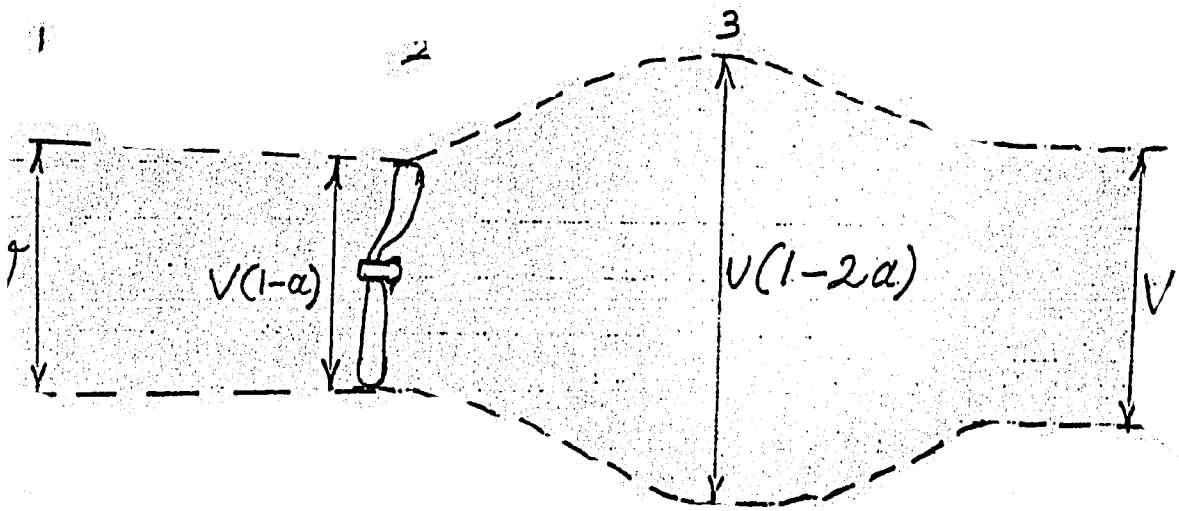
Betz Theorem



The power extracted will be given by the change in kinetic energy across the blade area. The velocity (V) in the unobstructed flow will be decelerated by a percentage (1-a) at the blades and by a further amount (1-2a) after energy is estracted.

$$KE = \frac{1}{2}\dot{m}V^2 \qquad \ldots(1)$$

where:

$$\dot{m} = PAV \qquad \ldots(2)$$

$$P_{max} = \frac{1}{2}[PAV\ (1-a)][V^2 - V^2(1-2a)^2]$$

$$= \frac{1}{2}PAV^3\ [(1-a)(1-(1-2a)^2]$$

and since $[(1-a)(1-1-4a^2 + 4a)]$

$$= (1-a)(4a-4a^2)$$

$$= (1-a)(1-a)\ 4a$$

$$\therefore P_{max} = 4\rho\frac{AV^3}{3}a\ (1-a)^2 \qquad \ldots(3)$$

and $a(1-a)^2 = a\ (1+1^2 - 2a)$

$$= a + a^3 - 2a^2$$

by differentiating;

eqn (3) for max point,

$$i\ \frac{\partial P}{\partial a} = 1 + 3a^2 - 4a$$

$$\therefore 3a^2 - 4a + 1 = 0$$

$$4 \pm 2$$

Substituting 1/3 for "a" in eqn (3)

$$\therefore P_{max} = 4\ P\frac{AV^3}{2} \cdot \frac{1}{3}\ (1 - \frac{1}{3})^2$$

$$= \frac{16}{27}\ P\frac{AV^3}{2}$$

$$= \frac{1}{2}\ PAV^3\ Cp$$

$$= 0.593\ P\frac{AV^3}{2}$$

$$\doteq 0.295\ PAV^3$$

$$\therefore P_{max}/\text{unit area} = 0.295\ PV^3$$

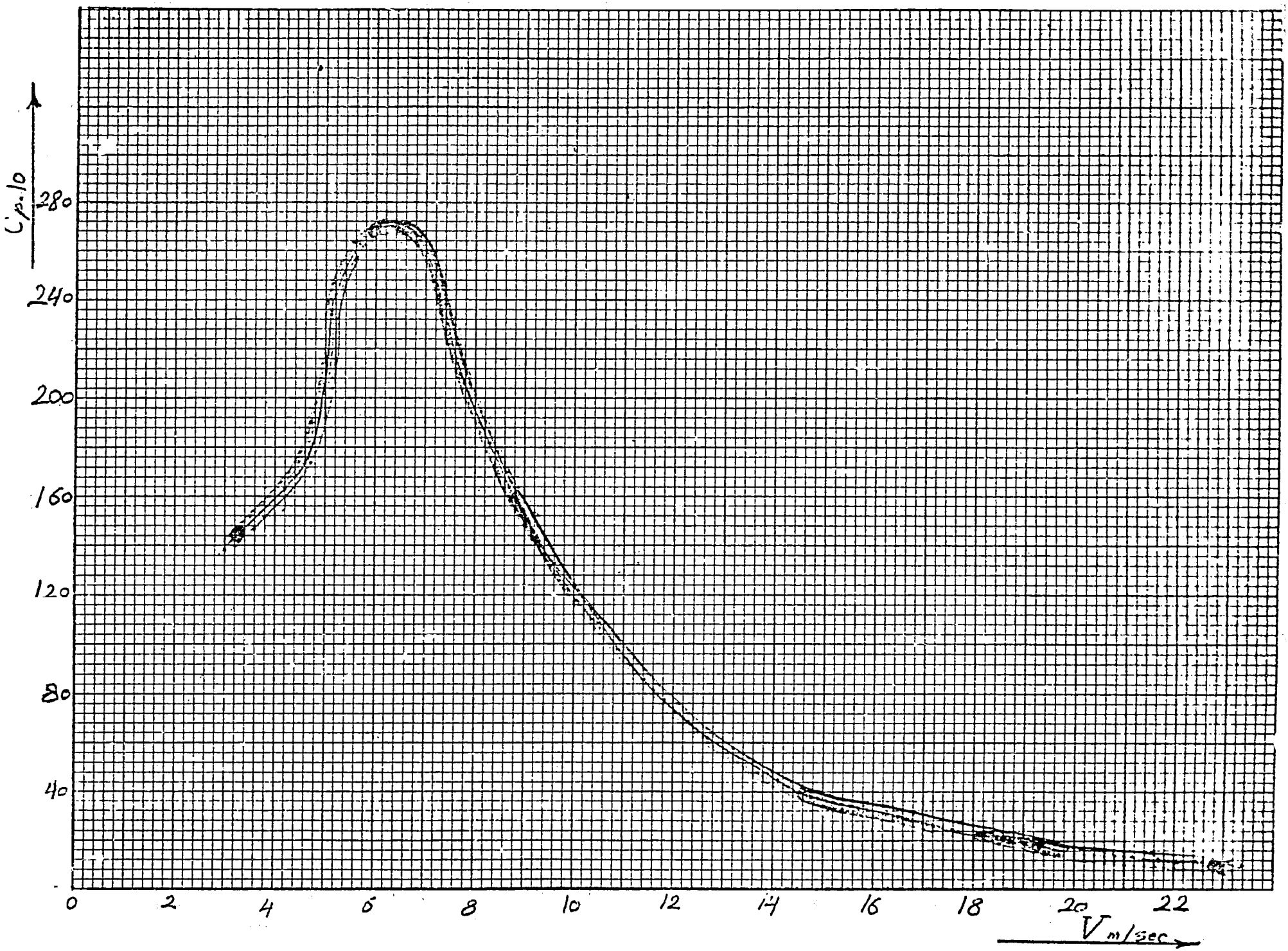
But this P_{max}/unit area would require a "perfect wind machine" therefore, we have to assume the power coefficient "C_p" where:

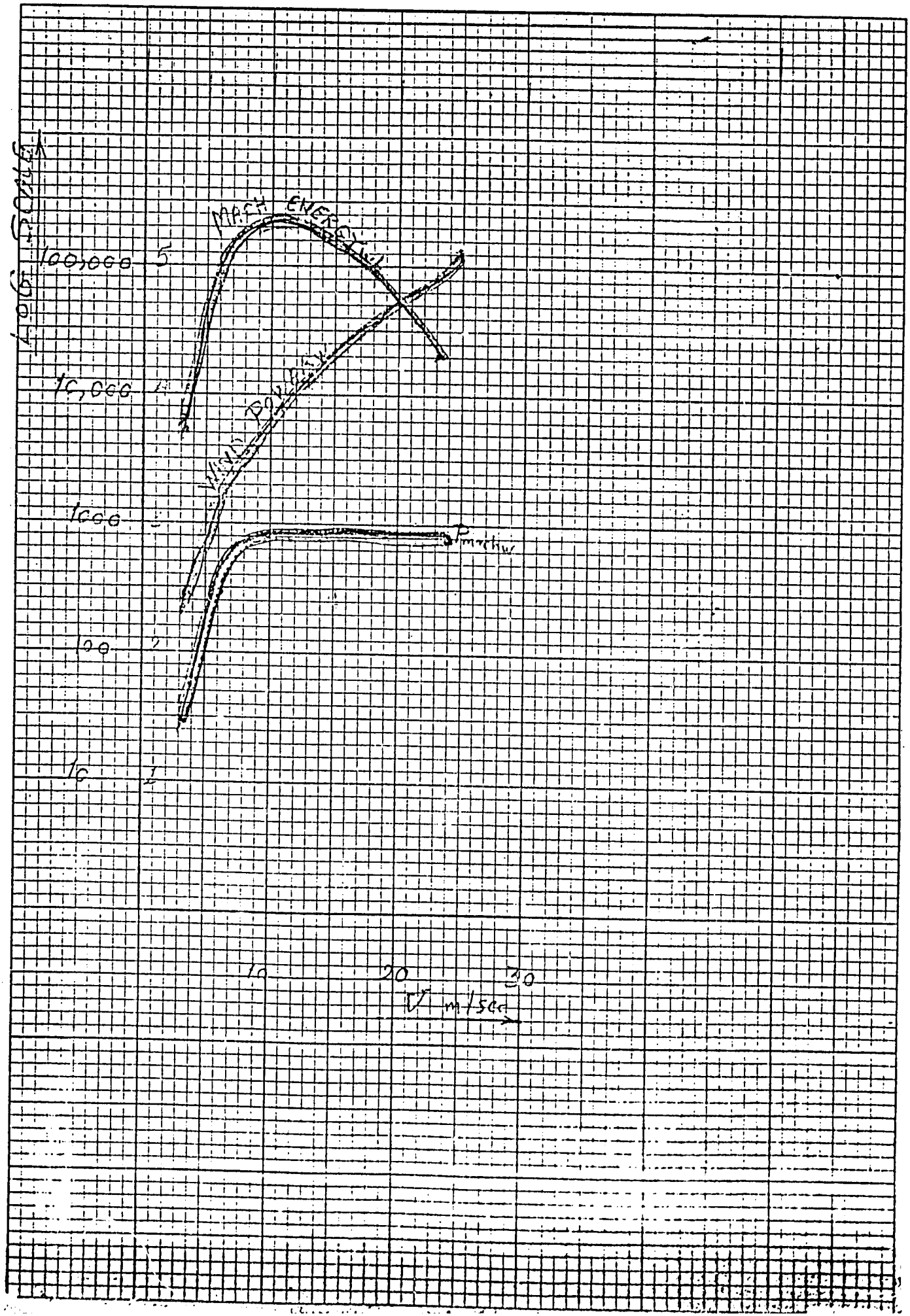
$$C_p = \frac{\text{Power produced by the machine}}{\text{Power contained in wind}}$$

C_p, has a range of values from (0) to 0.593 and it depends on the type of the machine as follows:

Type of Machine	Maximum Typical "C_p"
- Low Speed "Drag"	0.05 to 0.15
- Medium Speed	0.20 to 0.40
- High Speed	0.30 to 0.45

V_{mph}	Δt_{hr}	P_{mach_W}	Energy mach kWh	Wind Power W	C_P
39	101	890	90	36722	0.025
40	92	890	82	39397	0.023
41	84	890	75	42067	0.021
42	76	890	68	45571	0.020
43	68	890	60	48510	0.018
44	61	890	54	52359	0.017
45	55	890	49	55580	0.016
46	49	890	44	59789	0.015
47	43	890	38	63305	0.014
48	38	890	34	67890	0.013
49	34	890	30	71714	0.012
50	30	890	27	75679	0.012
51	26	890	23	80838	0.011
52	23	890	20	85129	0.010
53					
			Total: 5379.04		


Cp.10
280
240
200
160
120
80
40
0
2
4
6
8
10
12
14
16
18
20
22
V m/sec



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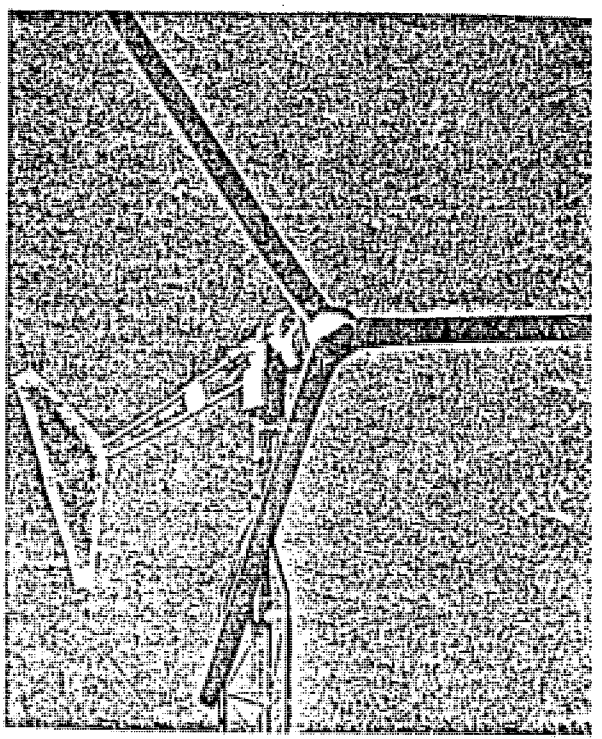
KEUFFEL & ESSER CO. MADE IN U.S.A.

AUGUST 1980

Rocky Flats Performance Summary

SENCENBAUGH Model 1000-14



MANUFACTURER'S SPECIFICATIONS

(See U.S. CONTACT for available options)

DESIGN OUTPUT:

1.0 kW @ 10.3 m/s (23 mph)

ROTOR SPEED CONTROL:

Mechanical, rotor turns edgewise to wind, activated by excessive thrust load.

OPERATING WIND SPEEDS:

CUT-IN: 2.7 m/s (6 mph)

CUT-OUT: 27 m/s (60 mph)

ROTOR CONFIGURATION:

ROTOR DIAMETER: 3.65 m (12 ft)

ROTOR TYPE: Horizontal axis, upwind, fixed-pitch.

NUMBER OF BLADES: 3

MATERIAL: Wood (Sitka spruce), bonded copper leading edge, epoxy finish.

GENERATOR/TRANSMISSION:

OUTPUT: 3-Ø, 6-pole alternator, rect. to dc.

GEARBOX: Helical, 3:1 ratio

MACHINE DESCRIPTION:

The Sencenbaugh is a lightweight machine manufactured by Sencenbaugh Wind Electric, Palo Alto, California. The blades are manufactured from Sitka spruce, with a bonded copper leading edge and a polyurethane finish. The main generator casting is 356T6 aluminum alloy. The alternator is coupled through a 3:1 helical gearbox, and is driven by a 3-bladed propeller 3.65 m in diameter. Overspeed control is provided by using the increasing wind pressure of the propeller (and the resultant propeller thrust) to swing the alternator assembly (which is offset from the bearing support column) out of the oncoming wind. The foldable tail automatically reopens as wind speed decreases due to gravitational forces on the tail assembly. Tail offset and inclination with respect to the rotor may be varied, thus changing the cut-in speed of the machine.

U.S. CONTACT:

SENCENBAUGH WIND ELECTRIC
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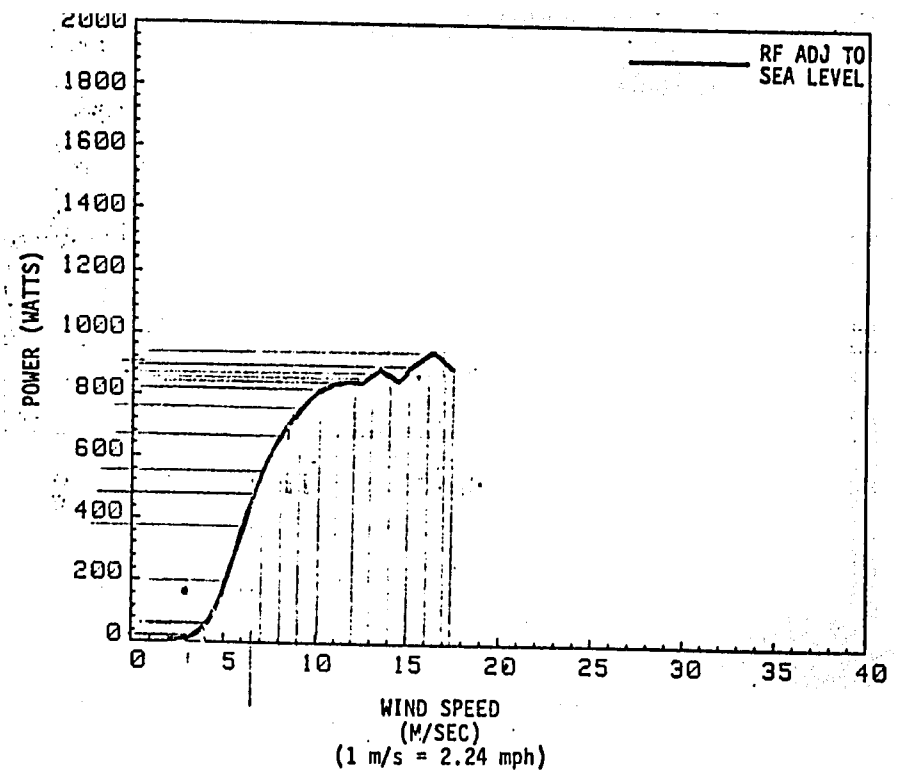
ROCKY FLATS PERFORMANCE DATA

SENCENBAUGH 1000-14

MEASURED CHARACTERISTICS
(ADJUSTED TO SEA LEVEL)

CUT-IN WIND SPEED.....3 m/s (7 mph)
CUT-OUT WIND SPEED.....Not available
SURVIVAL WIND SPEED.....52.5 m/s (117 mph)
OUTPUT @ 9 m/s (20 mph).....780 Watts
OUTPUT @ 10.3 m/s (23 mph).....820 Watts
NOISE @ RATED OUTPUT.....Not available



ESTIMATED ANNUAL ENERGY PRODUCTION
(USING A RAYLEIGH WIND DISTRIBUTION)

AVERAGE WIND VELOCITY (m/s)	(mph)	ANNUAL ENERGY OUTPUT (kWh)
3.58	8	960
4.47	10	1750
5.36	12	2550
6.26	14	3270
7.15	16	3860

NOTE: *The annual energy output is based on the measured Rocky Flats power curve for this machine. The power curve is superimposed on a Rayleigh velocity duration curve to generate a power duration curve which is then integrated over time to obtain energy. Energy output will vary at specific sites due to variations in wind characteristics and other factors.*

SUMMARY

The Sencenbaugh Model 1000-14 WTG met or exceeded all manufacturer claims of survivability while undergoing atmospheric testing at Rocky Flats. The machine operated satisfactorily in wind speeds exceeding 52.5 m/s (117 mph). In addition, the Sencenbaugh operated in winds exceeding 22.5 m/s (50 mph) for 17 hours without incurring damage. However, performance data generated by atmospheric testing of the machine did not agree with manufacturer performance data over the entire wind speed range. It should be noted that the machine tested at Rocky Flats was tested under a

Estimation of the Total Cost/kW hr.

This case study will be considered to be carried out in Egypt, so the assumed total capital cost of the machine will include the cost of shipping to the stie in Egypt, and all the control equipment and accessories.

Assume that:

- 1 kW wind machine
- Capital cost $15,000.00
- O & M Cost = 10% capital cost
  = $1,500.00/yr.
- Assume 1 year to be built, with 12% investment ratio of the capital:

$$I = \frac{(1 + i)^{tc} - 1}{i} \cdot \frac{C}{tc}$$

where: tc : The construction time in yrs.

C : The capital cost

i : The investment

$$I = \frac{(1 + 0.12)^{1} - 1}{0.12} \left(\frac{15000}{1}\right)$$

$$= \$15,000.00$$

CRF (Capital Recovery Factor)

$$= \frac{i}{1 - (1 + i)^{-t}}$$

$$CRF\ (0.12,\ 20) = \frac{0.12}{1 - (1 + 0.12)^{-20}}$$

$$= 0.1338788$$

Annual Charge = I. CRF

= 15,000 (0.1338788)

= 2008.25 $/yr.

Average Annual Cost = Annual Charge + (O&M)

= 2008.182 + 1500

= 3508 $/yr.

- The Total Generated kW hr/yr

= 5379.04 kW hr/yr

So,

$$\text{The cost/kW hr} = \frac{\$3508}{5379.04}$$

$$= 65.216 \text{ ¢/kW hr}$$

$$\text{O \& M/kW hr} = \frac{1500}{5379.04}$$

$$= 27.9 \text{ ¢/kW hr}$$

By following the previous calculations we can differentiate between different types of wind machines and choose the best type which will give us the cheapest cost of generating kW hr.

VI THE ENERGY SCENE IN EGYPT

1- BACKGROUND AND JUSTIFICATION

1.1 The present arable land in Egypt is 30,000 sq.km representing less than 4% of the total surface area of the country.

1.2 Its population (presently 44 million) is expected to reach 65-70 million by the year 2000

1.3 Massive programmes for land reclamation and new communities are planned to absorb the surge in the population and redirect internal migrants who traditionally move to already congested cities.

1.4 The energy resources presently exploited on a commercial basis are mainly hydro (75% harnessed) or depletable fossil fuels (oil, gas and coal). Only 25% of the Government's share of the produced oil is exported at World prices. Domestic oil consumption (75% of produced oil) is subsidized at 14% of such price thus depriving the country's economy from valuable earnings.

1.5 In fifteen years time, based on the presently declared oil reserves and bearing in mind the introduction of nuclear power generation, the energy supply will fall short of domestic demand.

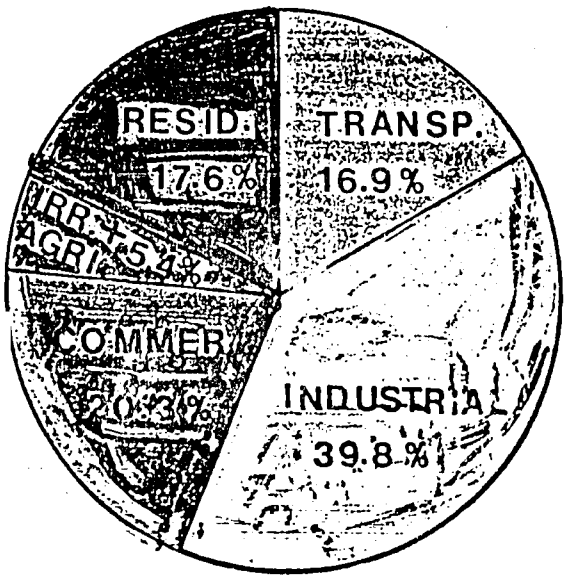
1.6 Energy Conservation as well as the development of New and Renewable Energy Sources, therefore become imperative.

2- THE ENERGY SCENE IN EGYPT

2.1 The Existing Situation

Energy consumption by primary energy sources in 1980 is indicated in Table 1 (see also Figure 1), which brings out both the continuing importance of non-commercial energy sources and the dominant role played by oil.

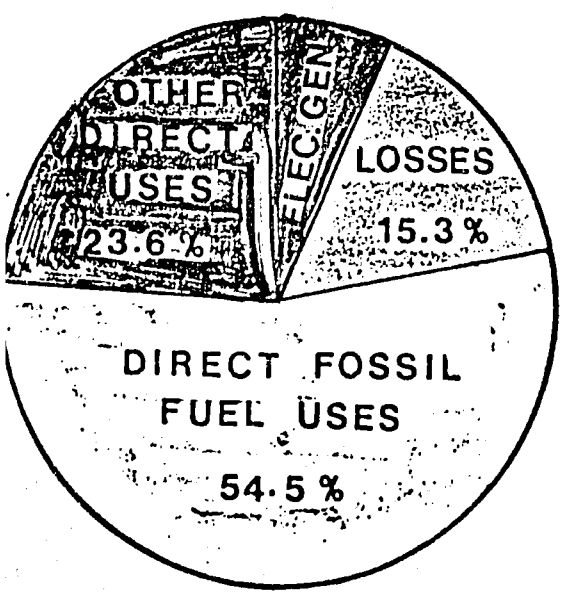
1980



14.8 MTOE

FIG. 1A - ENERGY CONSUMPTION BY SECTOR

1980



24.2 MTOE

FIG. 1B - ENERGY UTILIZATION SCENE

Table 1

PRIMARY ENERGY CONSUMPTION IN 1980

SOURCE	MILLION TONS OF OIL EQUIVALENT (MTOE)	%
Commercial		76.4
Oil	13.5	73.4
Coal	0.9	4.8
Gas	2.0	10.8
Hydropower	2.1	11.4
SUB-TOTAL	18.5	100.0
Non-commercial		23.6
Crop residues	4.4	77.2
Animal waste	1.1	19.3
Fuel wood, animate power, etc.	0.2	3.5
SUB-TOTAL	5.7	100.0
GRAND TOTAL PRIMARY ENERGY	24.2	100.0

Source: Qattara Hydro and Renewable Energy Projects Authority (QPA).

Total traded energy consumption in final uses in the same year can be estimated as 14.8* MTOE representing an overall distribution loss of about 20%. Table 2 gives an approximate breakdown of final energy use by sector and by fuel in 1980.

Table 2

TRADED ENERGY IN FINAL USES CONSUMPTION 1980 (MTOE)

SECTOR	OIL	NATURAL GAS	COAL	ELECTRICITY	TOTAL
Industry	3.5	0.7	0.7	1.0	5.9
Transport	2.5				2.5
Residential	2.0	0.3		0.3	2.6
Agricultural	0.7			0.1	0.8
Commercial	2.7	0.1	.....	0.2	3.0
TOTAL	11.4	1.1	0.7	1.6	14.8

Source: Qattara Hydro and Renewable Energy Projects Authority (QPA)

* A recent World Bank report, February 1982, gave 17.6 MTOE for total Energy Consumption.

2.2 The Future Situation

Official documents carry tentative estimates of primary energy requirements in the year 2000 of about 65 MTOE* of energy, almost a four-fold increase above the 1980 levels and sufficient to give each Egyptian about one TOE/year (as compared to 0.6 TOE/year in 1980) (see Figure 2). This energy will continue to come largely from oil estimated at about 30 MTOE, and from natural gas and coal, estimated together at about 11 MTOE. Nuclear power would be the major new contributor with around 11 MTOE. Hydropower would contribute around 5 MTOE (see Figures 1 and 3).

With this level of demand on oil, and according to the presently declared recoverable oil reserves of 2.9 x 10^9 barrels (as of January 1981), Egypt will be short of oil by 1997** (see Figure 4).

Therefore, measures which will bring about a reduction in oil consumption, while meeting the total energy demand at end-use, would be sought.

2.3 Introducing New Elements

Two main additional inputs in the Energy Scene qualify to bring about reduction in the use of fossil fuels, in general, and oil in particular.

2.3.1 Conservation Energy (CE)***

This is energy which would otherwise be lost. It is thus treated as an input to the total energy consumption. Its relative impact on the energy consumption can reasonably be estimated as 10% at least, although 20% would not be unattainable. Three types of conservation have been identified, the first two of which are not desirable:

i- Curtailment: This category is not desirable as it implies interruption of activities, namely factories, depending on shortages of supply. The country could be compelled to take such measures in the future if sensible actions are not taken now.

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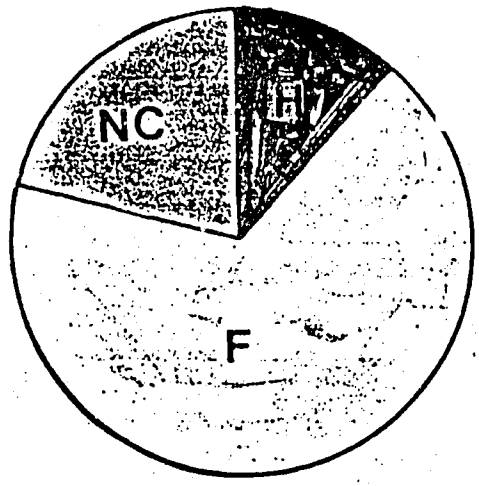
* This corresponds to a 6.6% rate of growth in the primary energy demand.

** Other dates will correspond to other GDP's different from 6.6%.

*** Terminology used in Harvard Business School Report entitled "Energy Future" by Robert Stobaugh and Daniel Yergin, 1979, Random House, USA to emphasize the recently recognized key role of conservation.

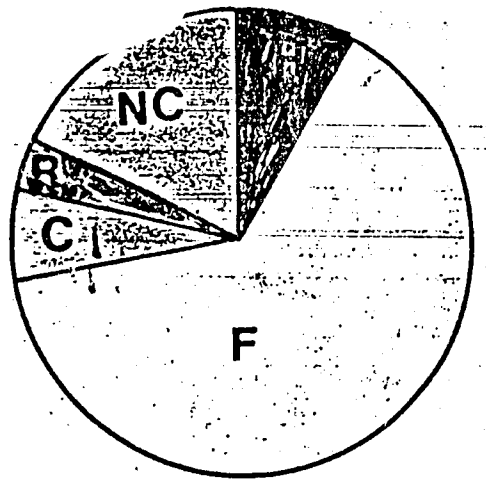
FIGURE 2 – THE FUTURE ENERGY SUPPLY SCENE

1980



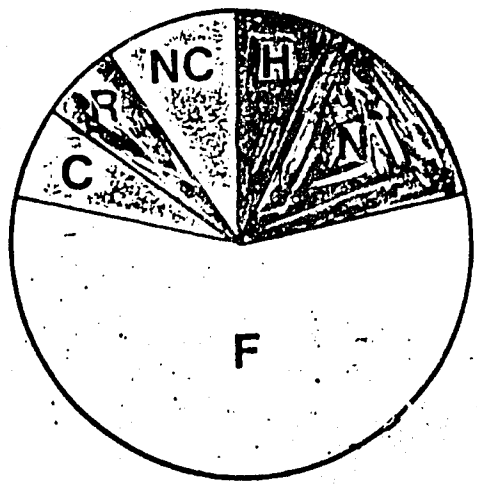
	MTOE
F	16.4
H	2.1
NC	5.7
	24.2

1985



F	22 (19)
H	3
NC	6
R	(1)
C	(2)
	31

2000



F	41 (30)
H	5
NC	8
N	11
R	(4)
C	(7)
	65

F: FOSSILE H: HYDRO NC: NON-COMMERCIAL R: RENEWABLE

N: NUCLEAR C: CONSERVATION

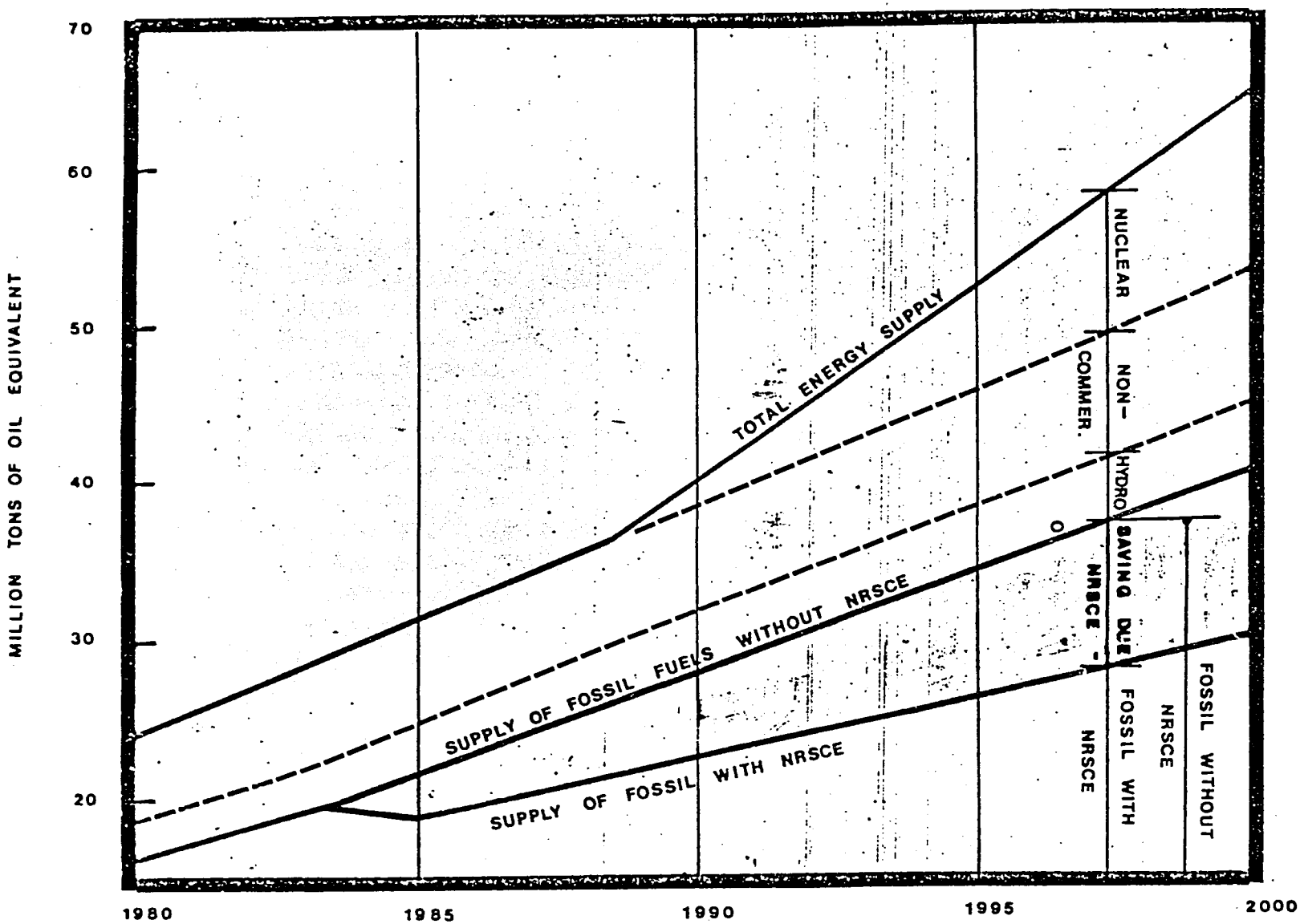


FIGURE 3 – ENERGY DEMAND SCENE
1980 – 2000

NRSCE = NRSE + CE

ii- Overhaul: This is also not desirable and would imply a dramatical change in the way of living and work, cutting back and rationing, etc.

iii- Adjustment: This is productive and desirable conservation, which could be obtained through good-housekeeping; encouraging daily behavior that promotes energy savings in a manner that is economically and socially non-disruptive; upgrading systems efficiency, and technological breakthroughs.

It requires a Plan of Action and a firm national commitment to conservation, requiring political decisions, new legislations and motivation.

There is a strong link between Conservation Energy and the Development of Renewable Sources of Energy, because they both serve as conserving elements of depletable fuels.

2.3.2 New and Renewable Energy Sources (NRSE)

Previous studies have given various roles to NRSE in the Egyptian energy scene. Conservatively, a relative impact of 5-7% on the total commercial energy supply by the year 2000, together with 10% contribution from conservation energy would prolong the oil supply by 2-3 years (see Figure 4).

The present thinking is to merge the potential use of NRSE programmes with future national energy plans by giving it a dual extended role in the energy scene stressing its conservation impact on future conventional energy use:

First: As the traditional alternative source of energy (e.g. in areas remote from the electric grid or fuel supply lines); and/or

Second: As backup or conservation element in future conventional electricity generation schemes.

Table 3 gives the status of NRSE World Technology.

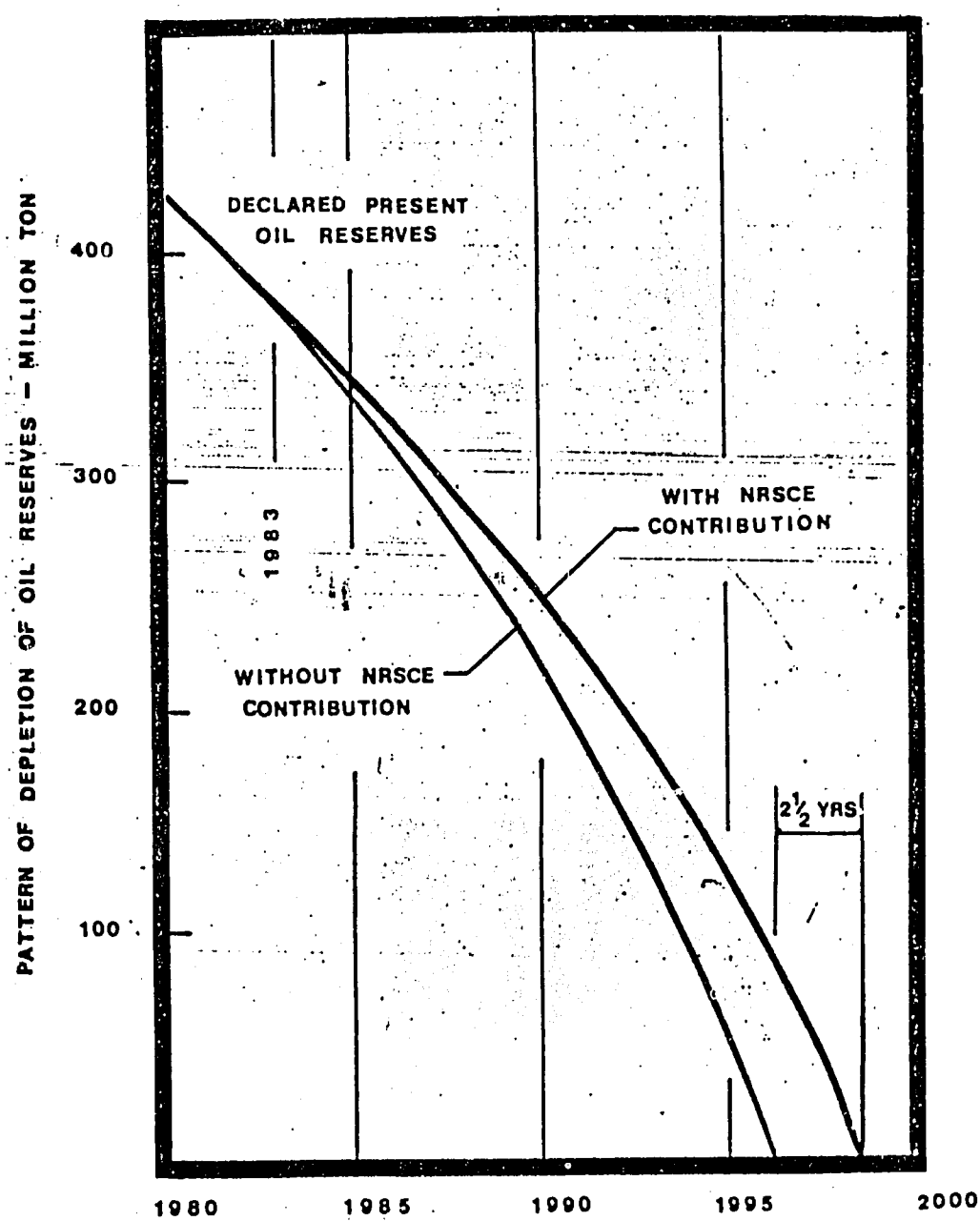


FIGURE 4 – EFFECT OF INTRODUCING NRSCE ON SAVING OIL FOR PREMIUM USES

3 THE SITUATION IN EGYPT

3.1 Introduction

Ancient Egyptians were the first to utilize wind-energy 5000 years ago to pump water, grind grains, and operate sail-boats in the Nile river. Towards the end of the 19th century wind-turbines were used in Egypt to pump the Nile water for irrigating the nearby arable land.

In 1952 the Military factories of Helwan produced wind pumpers for use by the bedouins in conjunction with the scattered wells in the North-West coastal zone. This programme did not continue due to two reasons. Firstly, most of the wind pumpers needed maintenance and repair which was not provided; secondly, the units were kept working without control so that over-pumping produced brackish water, and thirdly, diesel engine-driven pumps were introduced into the area while the fuel cost was very low.

Presently the situation is different. The World Technology for small WECS has improved, and it could easily be transferred to Egypt; the fuel value has increased tremendously beside becoming scarce and difficult to transport; remote areas in the country have started developing and wind-energy applications are suitable for such small communities; and Government plans to extend the electric grid everywhere would take sometime to materialize. Even then, WECS could be interlinked to form a regional or local electric grid which can be connected to the national grid as a measure for fuel conservation in the long term.

3.2 Previous Work

Wind data has been collected over the years by the Meteorological Authority and some Oil companies. In 1973 the Ministry of Electricity and Energy in collaboration with Oklahoma State University (U.S.A.) made measurements of wind velocities and directions of few locations*.

Recent studies** relied on the data by these two sources in assessing the wind energy potential in Egypt. Recently

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* Source: "Egyptian Energy Resources Study Project", Ministry of Electricity and Energy Cairo 1975 and 1979.

** Source: i- USDOE "Energy Assessment in Egypt", 1979
ii- MITRE CORP. "Renewable Energy Sources in Egypt: An Analysis of Options", 1980
iii- CESEN "Prefeasibility Study for the Egyptian Renewable

Mubarak et al.* collected all the available data in one report which showed that at some locations there was some discrepancy in the wind data.

3.3 Present Activities

The present activities are summarized as follows:

i- The National Research Centre is constructing a 6 m diameter wind turbine based on a modified design of the Intermediate Technology Development Group (U.K.). The end result would be pumping.

ii- Cairo University would be collaborating with an American University within the context of the USAID-Financed University Linkage Project to study the most suitable small WECS for rural Egypt.

iii- The Egyptian Electricity Authority is conducting a study on the North-West Coast to determine the reasons for the unsuccessful experiment to introduce wind pumpers in the sixties and make new recommendations.

4 PLAN OF ACTION

PHASE I (1983-1987)

4.1 Programme Portfolio

4.1.1 Inventory of Wind Energy Resources

i- Measuring wind data all over the country, particularly, the coastal zones and East-Oweinat at standard heights (10 and 50 km).

ii- Forming field groups to study and select the appropriate sites for large WECS.

4.1.2 Research, Development and Demonstration

i- Since wind technology is available on a world-wide basis, field demonstration should be encouraged. In parallel, the public should be informed of the systems and the problems associated with their uses.

ii- Forming Government specialized groups to follow-up the activities in this field and to promote R, D and D according to the Government national development plans.

Source: Mubarak et al "Wind Energy in Egypt", Cairo University. March 1982

iii- Co-ordinating all the external financial and technical assistance inputs with the Government contribution for promoting the utilization of WECS.

4.1.3 Recommendations

Since wind-technology (particularly small WECS) is not very complicated, most of WECS can be manufactured locally. It is recommended, thence, that the following steps be taken:

i- Development and manufacture of a series of small WECS (less than 5 kW) for irrigation purposes. This could be done at any one site by changing the turbine diameter and the height of the tower (3 sizes each would be enough).

ii- Same as in (i) except for larger WECS* (10, 50 and 100 kW) for electricity generation purposes and general end uses including tie-in with the electric grid.

4.2 Schedule and Required Investment

Figure 7 gives the schedule for WECS programme in Egypt till the year 2000 together with the corresponding required investments. It should be noted that beyond 1990, all the investments are tentative and subject to modifications pending other activities.

4.3 Execution of Programme

The Supreme Council for New and Renewable Sources of Energy will co-ordinate the activities with the appropriate organizations. It is expected that the Ministry of Electricity and Energy together with the National Research Centre and the Universities will be involved together with the local Governorates.

* According to Mubarak (see footnote cover page), it will take 33750 units of 100 kW and 75000 of 5 kW (or smaller) to provide 50% of the energy and power requirement on the coastal zones plus the East-Oweinat region by the year 2020.

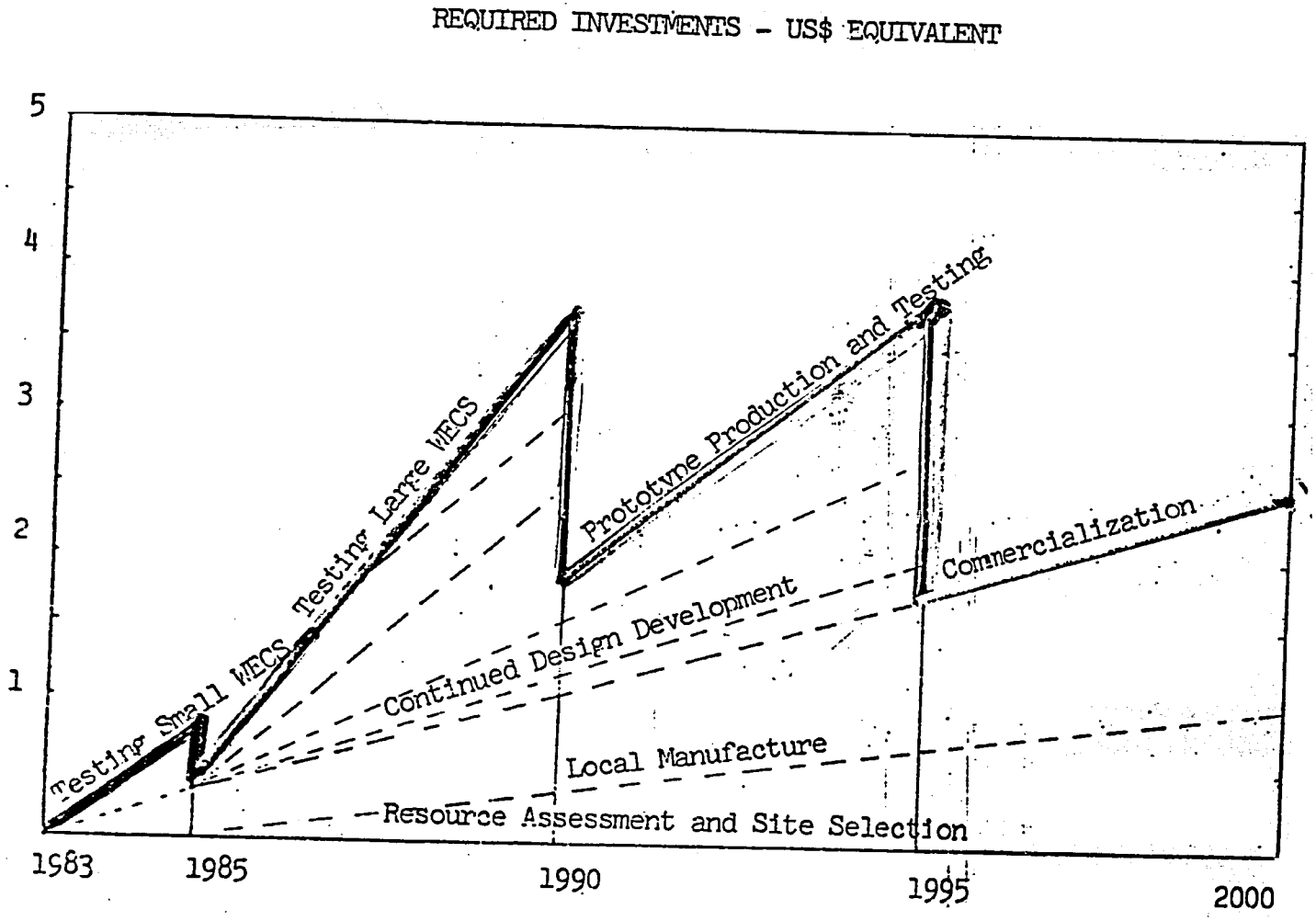

Figure 7 - Schedule and Required Investment

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MINISTRY OF ELECTRICITY AND ENERGY
UNITED NATIONS DEVELOPMENT PROGRAMME
UNITED NATIONS DEPARTMENT OF TECHNICAL COOPERATION FOR DEVELOPMENT,
NATIONAL STRATEGY FOR DEVELOPMENT AND UTILIZATION OF NEW AND RENEWABLE SOURCES OF ENERGY (NRSE)
ARAB REPUBLIC OF EGYPT,
JULY 1982