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WIND POWERED HIGHWAY SIGNS

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16. Abstract

This study was designed to evaluate the use of a wind powered electrical system to provide power for highway warning lights at a remote location. The location was at the Red Creek slide area on S. H. 50 east of Gunnison, Colorado. The electrical system was intended to provide electrical power to two flashing yellow highway beacons to alert motorists to an unpaved rough section of the roadway.

The generator selected was a 2 KW wind generator manufactured by the Whirlwind Power Co. The installation was completed in September 1981. During the winter 1981-1982 the system had numerous failures. On June 28, 1982, the system suffered major damage and in September 1982 the decision was made to terminate the study.

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INTRODUCTION

The purpose of this project was to select, install, and evaluate a wind powered system that would provide electrical power for illumination of warning lights or warning signs at highway hazardous zones in remote areas where commercial sources of electrical power is not economically available.

A site selected was on S.H. 50 east of Gunnison, Colorado. There was a requirement for warning motorists of a rough unpaved section of the highway in the vicinity of slide area where frequent earth movement prevents the highway from being stabilized and paved.

SUMMARY

The Whirlwind Power Co. A-120 generator was installed September 18, 1981 at the Red Creek Slide Area on S.H. 50 and put in full operation on October 2, 1981 powering the warning lights. There were problems with the lead-acid storage batteries, and two batteries were removed on December 2, 1981. The system was operating the lights for about one week. Two new batteries were installed on December 8, 1981. On December 11, 1981, the system was not charging batteries properly and all ten batteries were removed. Three more batteries were determined to have bad cells. At this time it was determined that two different capacity of batteries were being used.

The generator was not powering the warning lights from January 1 to March 17, 1982. The Generator was placed back in operation, but the batteries were discharged and there was no reserve standby power. On May 4, 1982 the yaw drive vane and mounting was broken. The entire yaw drive stalk was replaced, and the system was put in operation; but the batteries were apparently overcharging. On June 22, the control box was replaced, and system was checked out and operating properly.

On June 28, 1982 the generator suffered catastrophic failure. One blade was broken off, and the yaw drive gear box mount had fractured and separated from the main pedestal mounting. The generator was removed and disassembled, and batteries and other control components were removed.

A decision was made to terminate the study in September, 1982.

The use of wind power to operate the warning lights at the Red Creek Slide Area was not successful.

Frequent component failure and control irregularities prevented continuous operation of the system and contributed to undependable operation of the storage batteries.

The Colorado Highway Department does not recommend the use of this type of wind energy for electrical power at an unattended site.

THE SYSTEM

1. SITE SELECTION

The main factors considered in selecting the site were:

- the need for warning illumination over an extended period of time, i.e., years;
- that commercial electrical power was not economically feasible;
- there was adequate wind resource available, i.e., velocity and duration to provide the needed power capacity.

The site selected was at the Red Creek Slide Area, on S.H. 50 east of Gunnison, Colorado. The slide area results in a continuous movement of the highway base such that it is impractical to pave this section. It also always presents a rough unpaved section of S.H. 50 to the motorist. The highway has a 50 mph speed limit with a warning sign system used to reduce speed and notify the motorist of the rough section of highway ahead. There is no nearby commercial electrical power available. Estimated cost to bring in commercial power was over $151,500.

The choice of the position of the generator at the site had to be made. If the generator was positioned close to the roadway, it would have easy accessibility and the cable runs would be shorter. The instability of the ground near the roadway and the fact that a high visibility position was not desirable because of esthetic considerations for the National Recreation Area led to consideration of a more distant location for the generator. A selection was made to position the generator on the north side of the highway on a high point above the slide area, about 110 feet above and 750 feet from the roadway. At this location, the generator would be practically unnoticeable from the roadway and the equipment building would not be visible from the roadway. See Figure 1.

An anemometer was placed at the proposed generator location to collect wind data to evaluate the wind energy potential of the site.

2. EQUIPMENT SELECTION

It was determined that the system was to provide continuous electrical power to illuminate two standard 25 watt flashing warning lights, one at each end of the slide areas to alert the motorist to the warning signs.

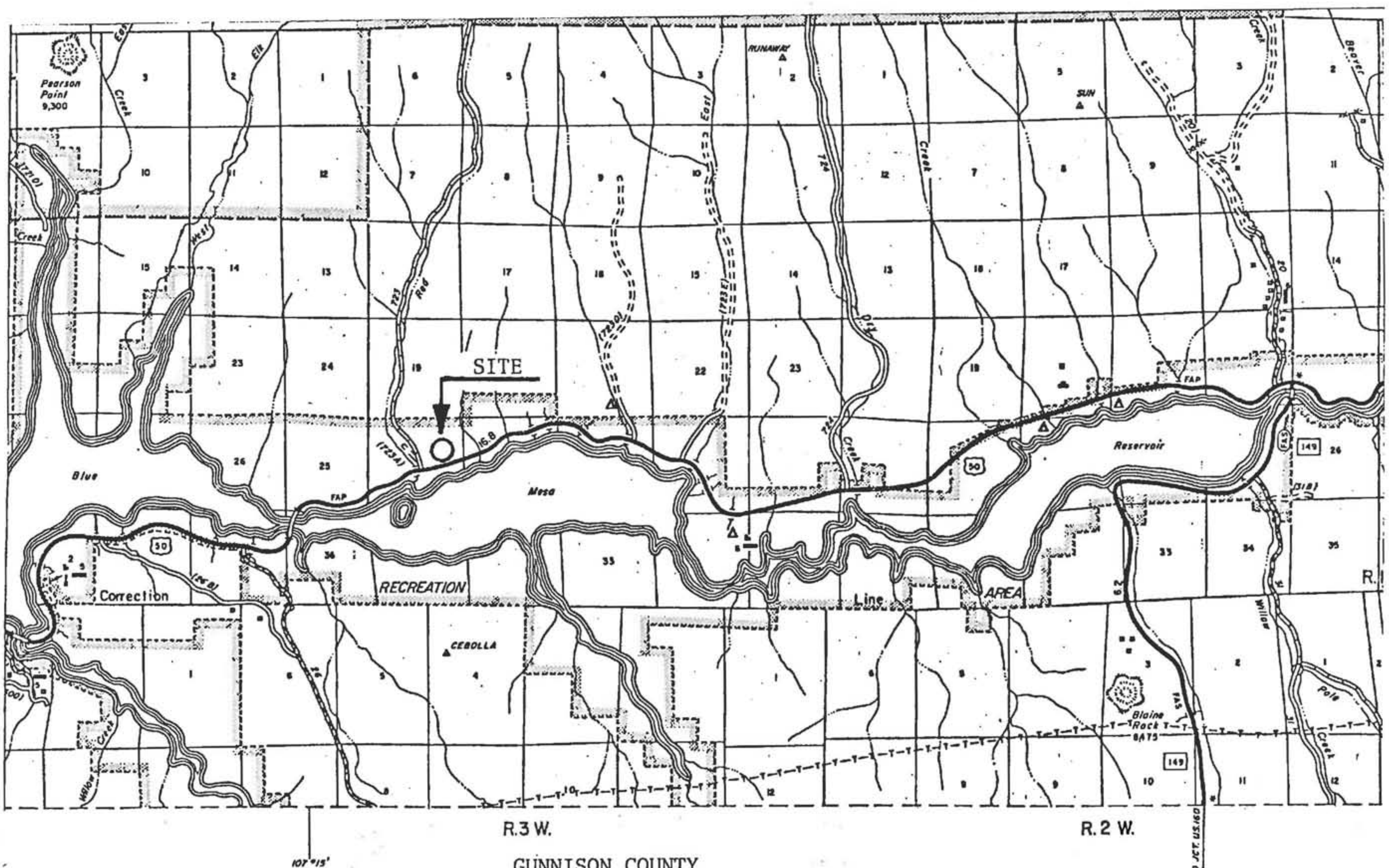
Due to the intermittent nature of wind energy, it was decided to use lead-acid batteries as a storage and backup source of electrical power for periods of little or no wind.

Since the cable running from the equipment building to the roadway would be over 1500 feet, a 120 VDC system was selected.

For generator selection a 2 kw size was considered a minimum in order to provide adequate reserve capacity. A 120 VDC storage battery system would provide the necessary storage capacity and supply a normal 120 V source for the standard lights.

Of many available wind genrators currently manufactured, the Whirlwind 2 kw model A120 was selected. The generator is a 3-phase, AC alternator using a direct drive, one piece, two bladed, wood propellor. The control system provided with the generator would provide an output of 120 VDC. The bank of ten 12-volt deep-cycle heavy duty lead-acid storage batteries connected in series would give sufficient capacity for the battery system. The batteries were rated at 105 ampere hour capacity and would provide approximately

WIND GENERATOR LOCATION



GUNNISON COUNTY

FIGURE 1

one week or 150 hours of operating time if the generator should malfunction, or in case of insufficient wind.

The tower selected was a 40 foot high by 4 inch diameter steel pole. The tower is hinged at the base so the generator can be lowered to ground level for maintenance and repair.

Equipment List

Item	Supplier	Cost
A120 Generator System	Whirlwind Power Co.	$2,295
40' Self Erecting Tower	Tilton Aviation Co.	830
10 - 12-volt Storage batteries	Hensely Battery Co.	650
1500' Direct Burial Cable		4,860
Signal Lights (2)	Eagle Signal Co.	84
	Total	$8,719

3. WIRING PLAN

Several factors were considered in the wiring layout at this site. Since the site is located within the Curecanti National Recreation Area it was agreed between the National Park Service and the Colorado Highway Department that during installation at this location there would be minimal disturbance of the natural terrain. The soil at the site was very rocky and trenching by hand to bury the cable would be almost impossible. Use of trenching machinery would be unacceptable due to damage to the ecology. The cabling from the wind tower to the battery/control enclosure was laid on the surface and covered with 1"-2" of soil. The cabling from the wind tower to the lights was placed in a PVC Pipe and laid on the surface for about 100'; then the conductors were laid on the surface as shown in Figure 2. Due to local code requirements the cable runs were later changed as shown in Figure 3.

ORIGINAL WIRING LAYOUT

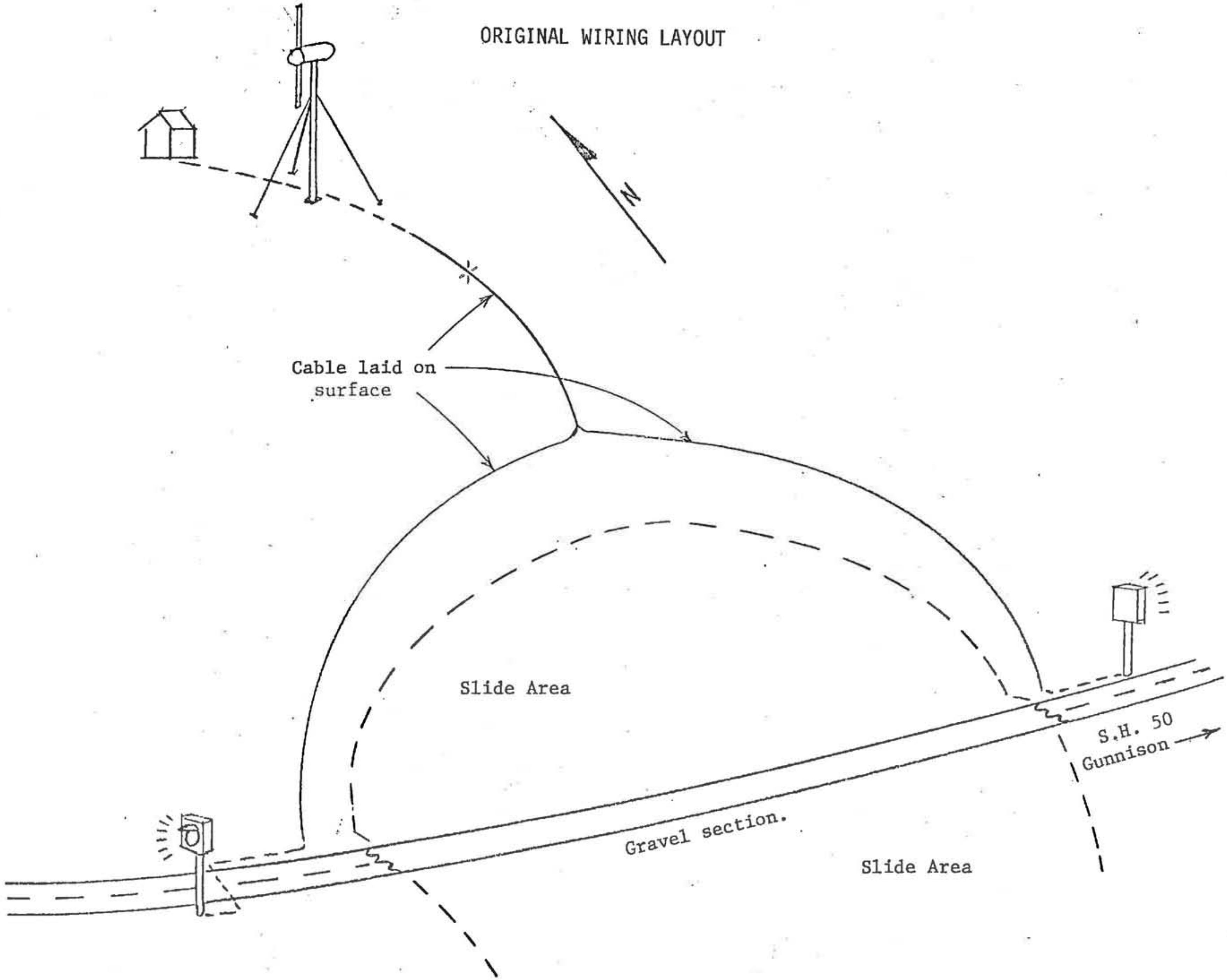


FIGURE 2

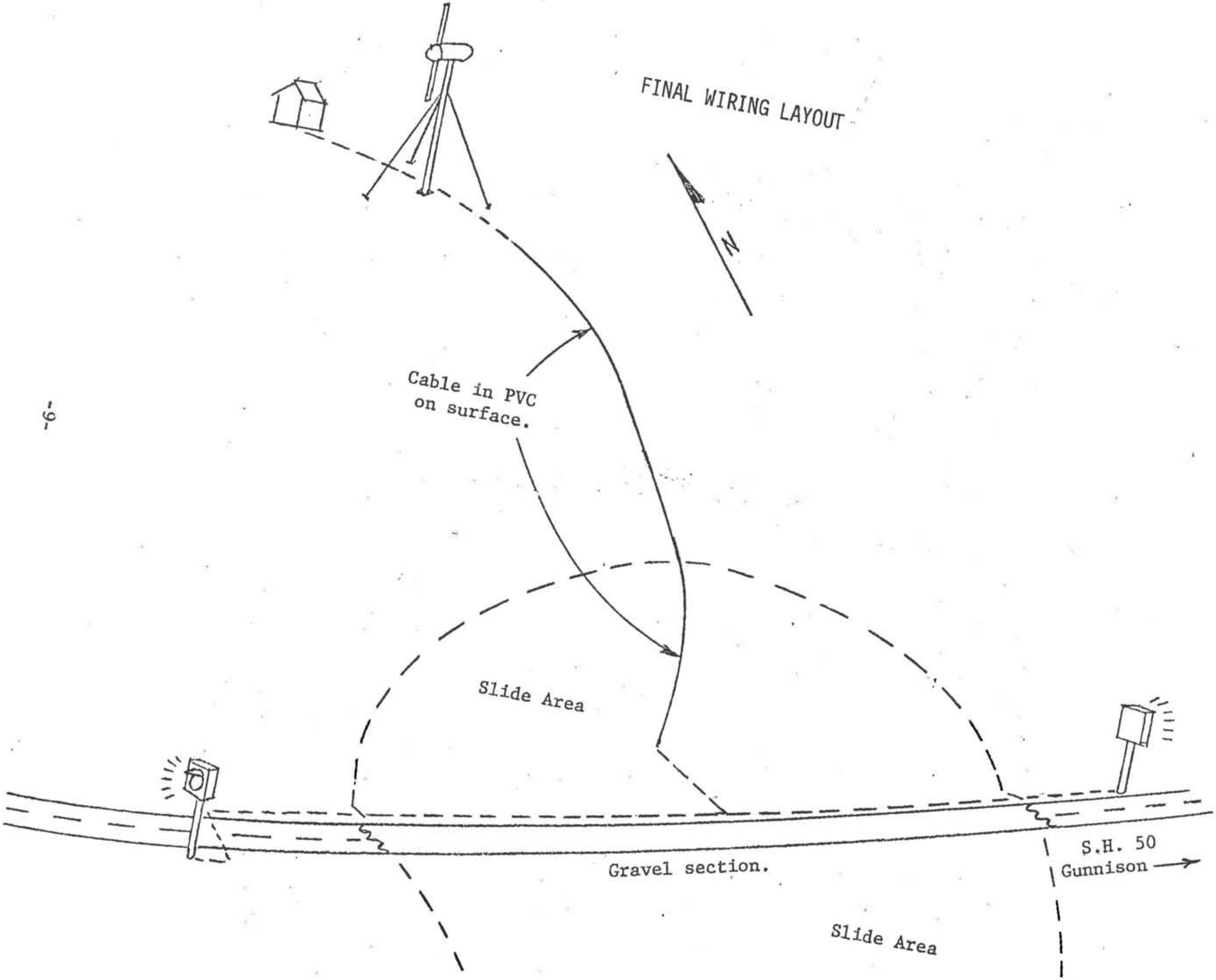

FINAL WIRING LAYOUT
N
Cable in PVC on surface.
Slide Area
Gravel section.
S.H. 50
Gunnison
Slide Area

FIGURE 3

4. MONITORING SYSTEM

Initial collection of wind data at the site was accomplished by use of a Campbell CR-21 micrologger. A digital record of wind speeds for 8-hour periods from May 1, 1981 to June 5, 1981, was recorded. Data from the micrologger was transferred to Cassette tape then to a computer for data analysis. The final wind data is shown in Appendix A.

Upon installation of the wind generator, an MRI weather station replaced the micrologger and anemometer. The MRI weather station is a clock operated chart recorder that continuously records wind run, wind direction, and temperature. The data from the recorded charts was processed manually for final analysis.

A Rustrak chart recorder was used to collect data on wind generator performance. The recording ammeter would reflect battery charging current, indicating that sufficient power was being generated to operate the flashing lights and charge the batteries. A sample chart reproduction is shown in figure 4. The chart record also indicates wind condition as it affects the operation of the generator.

In May, 1982, the MRI weather station was replaced with a Campbell CR-21 micrologger set up to record wind velocity and wind direction. A digital record of 1-hour averages of wind velocity data was obtained through June 19, 1982.

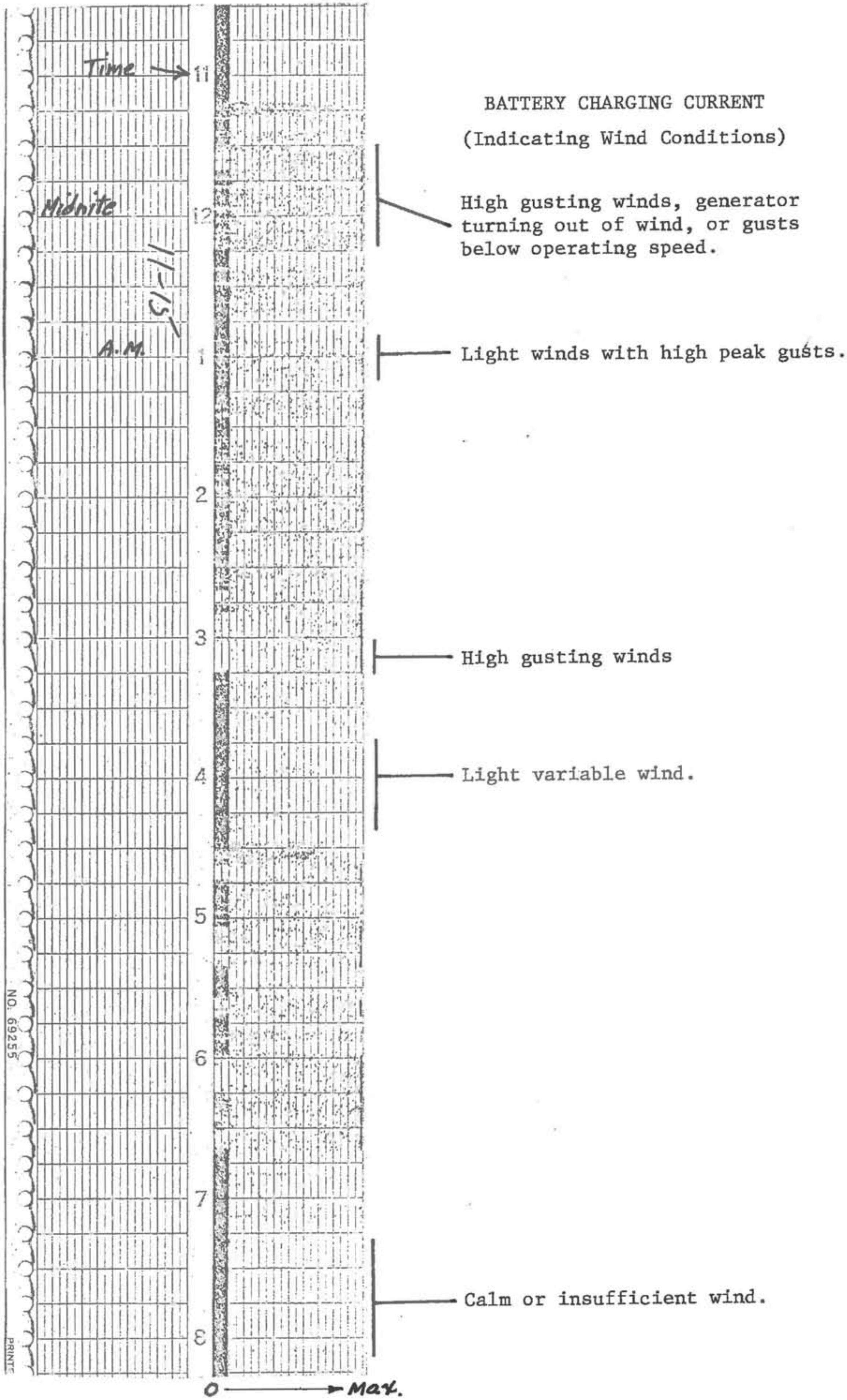

BATTERY CHARGING CURRENT
(Indicating Wind Conditions)
Time
11
Midnite
12
A.M.
1
2
3
4
5
6
7
8
NO. 69255
High gusting winds, generator turning out of wind, or gusts below operating speed.
Light winds with high peak gusts.
High gusting winds
Light variable wind.
Calm or insufficient wind.
0 → Max.

Figure 4

INSTALLATION

A front loader was used to transport the equipment and supplies needed from the highway to the site. The concrete was mixed on site and the guy wire anchor pads and tower pier were poured on September, 1981. The tower was assembled and erected and the equipment structure was constructed on September 9. Appendix B shows the layout plan. The generator was installed September 17, and on October 1 the wiring was complete and the system was put into operation. The system wiring diagram is shown in Figure 5.

The site and equipment location are shown in photographs on pages 14 through 17.

SYSTEM DIAGRAM

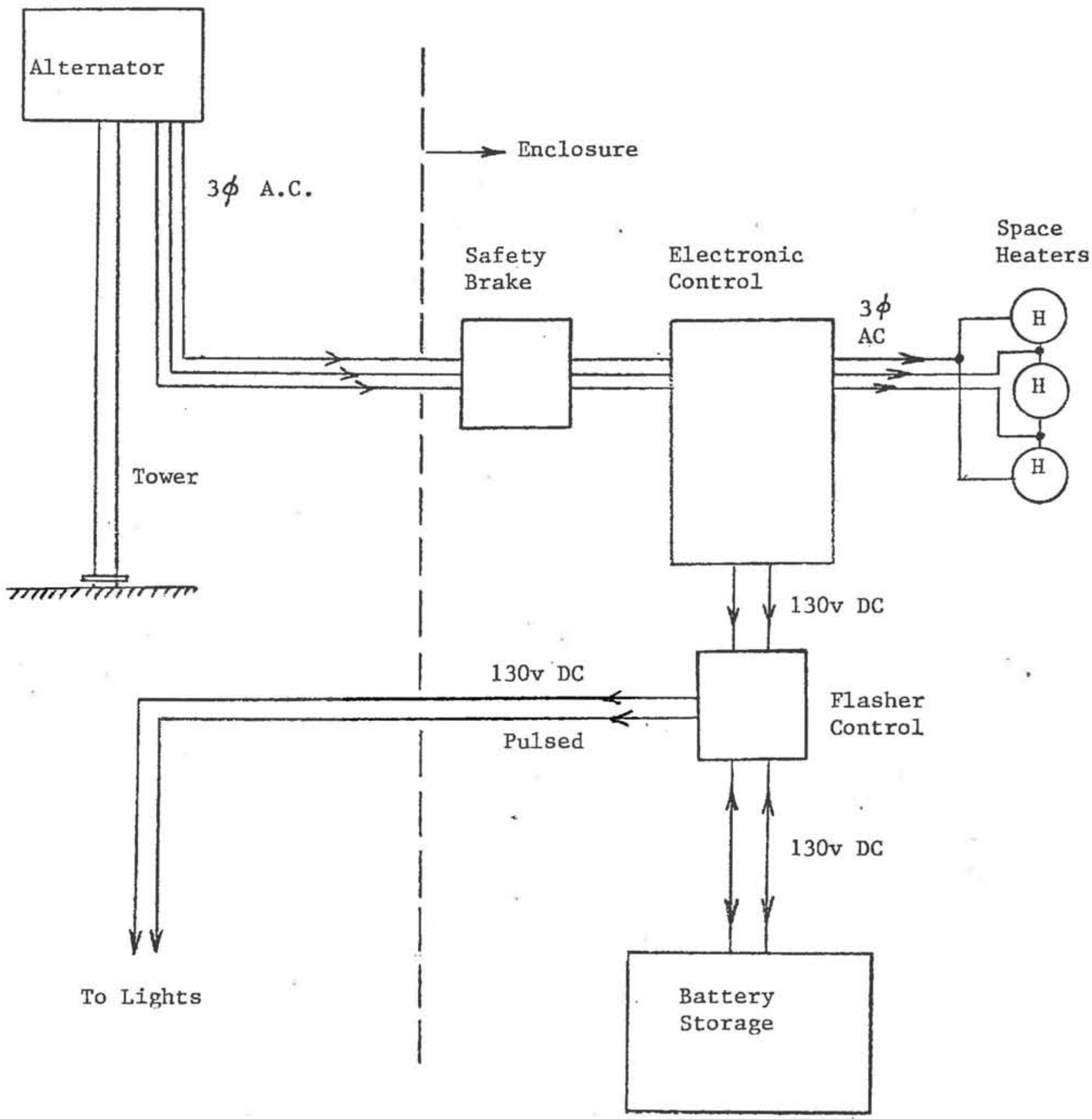


FIGURE 5

Aerial view of site. S.H. 50 is at lower right and slide area is graded portion above roadway.Battery and control enclosure is at upper center of photo.

This photo shows the generator mounted, the control structure and the PVC conduit on the ground going to the lights.

Aerial Photo of Wind Power Generator site along US 50, north of Blue Mesa Reservoir. At left is anemometer to monitor winds. Wind Power Generator is on pole to right.

Wind Generator in place atop 40 foot tower.

Tower lowered to allow servicing of the generator.

A standard yellow beacon is mounted over a warning sign.

SYSTEM EVALUATION

Initially, the operation of the system was monitored by the maintenance personnel at Gunnison. They were available in the area to frequently check the operation of the generator and other components of the system.

On October 1, 1981, a strip chart recorder was used to record the D.C. charging current to the batteries. This data was useful for indicating the period of time that the system was generating power in excess of the flashing light requirements, and a sample trace of the recording is shown in Figure 5.

The control system used resistive space heaters to dissipate power when the batteries were fully charged and the generator was operating. The system does not provide for automatic shutdown when power is not needed.

There are two normal situations when the generator will not operate and provide no electrical output. One is where there is insufficient wind-velocity below start-up speed. The other is when there is excessive wind and the yaw drive system turns the generator out of the wind to prevent overspeed of the propellor and to prevent exceeding the stress limits of the generator components.

As a feature of the system's fail-safe operation, most malfunctions of the yaw drive system result in the yaw drive turning the generator out of the wind, thus stopping the generator. There were several failures of the yaw drive vane spring. Appendix C is two service bulletins issued by the Whirlwind Company for solving the spring problem. When the spring failed, it effectively shut down the generator until the condition was noted by the monitoring personnel. This resulted in long periods of "down time" for the generator. Replacement parts had to be obtained from the Whirlwind Power Company in Denver and the mast had to be lowered to correct or replace the spring and this resulted in additional "down time". Approximately four hours were required to lower the mast, correct the problem, and raise the mast again. A minimum of three persons is required to raise and lower the mast safely.

During the period December 5 through December 11, the winds were calm or insufficient to be utilized by the generator. The backup storage batteries were severely discharged and the system was shut down to remove the batteries and have them checked and recharged.

On May 7, 1982, the system was returned to service. On June 17, 1982, the electronic control unit was malfunctioning and overcharging the batteries. The control unit was replaced and the system was put back in service on June 22. During a severe windstorm on the early morning of June 28, 1982, the generator lost a propellor blade and suffered major damage to the yaw drive gear box.

Subsequently, the generator unit was disassembled and inspected. An estimated cost of $1460 for repairs was obtained from the Whirlwind Company. A decision was made to terminate the study in view of the cost of the repairs and of the history of problems encountered in the operation of the wind generator system.

CONCLUSIONS

At the present state of the art, the use of this type of wind power system at a remote, unattended location would be at high risk.

The Whirlwind Power Co. System does not have a high enough safety factor to warrant its use as a reliable source of electric power for highway warning signs.

If the wind system was located at a more accessible site, and frequent inspections could be conducted by maintenance personnel, some of the problems encountered on this installation would have been minimized and much of the down time of the generator would have been eliminated.

The generator was mounted on a guyed, 4 inch diameter, 40 foot high steel mast. The mast is a hinged, self-erecting type that can be lowered to ground level so that maintenance may be performed on the generator. However, on several occasions where minor work was necessary on the generator, the wind conditions were unfavorable and it was deemed unsafe to lower the mast. In these cases, a provision for tower-top maintenance would have been beneficial. This would entail installing climbing steps on the mast, allowing maintenance personnel to climb the mast for routine checking and correction of minor problems.

It is considered as a post defacto evaluation that the particular site selected experienced extreme wind conditions of high velocity gusts and extreme direction changes under certain meteorlogical conditions. These extreme wind conditions imposed stress factors that the systems was not designed to accommodate.

A discussion of possible mechanical failures and malfunctions is contained in Appendix B.

A cost comparison can be made for the various types of electrical power at this type of remote site:

Cost of the Wind Generator system:	$ 8,365
Cost of Solar Voltaic System:	$ 1,750
Estimated Cost to obtain Commercial Power:	$151,500

RECOMMENDATIONS

1. A wind powered highway lighting system as tested in this study is not recommended for a remotely located site.

2. The system is not 100% fail-safe and personnel should be available to frequently observe the operation of the generator and to shut the system down in the event of any observable malfunction and to anticipate severe wind conditions.

3. At the selected site severe cold temperatures as low as -20 degrees F, and long periods of insufficient wind allowed the storage batteries to become discharged and subject to damage from the low temperatures. A method of recharging the storage batteries from some outside source must be provided.

4. Easy access to the wind generator atop the supporting mast is necessary for this type equipment in order to reduce the down time required for maintenance and minor repair. Climbing steps mounted on the supporting mast would provide this easy access if adequate measures are taken to minimize access to unauthorized persons to prevent vandalism.

5. The Colorado Department of Highways has been highly successful in the use of solar photo-voltaic powered systems where remotely located reliable electricl power is required for warning sign illumination. A photo-voltaic solar system is recommended for this type installation.

IMPLEMENTATION

Frequent component failure and control irregularities prevented continuous operation of the system and contributed to undependable operation of the storage batteries.

The Colorado Highway Department does not recommend the use of this system for electrical power at an unattended site.

APPENDIX A

Blue Mesa Wind Data

APPENDIX A

May 1 –

BLUE MESA WIND DATA

JULIAN DAY	HOUR	WIND SPEEDS MINIMUM	MAXIMUM	AVERAGE
		(8-HOUR INTERVALS)		
121	1600	1.83	32.70	11.54
122	0	1.00	45.16	12.87
122	800	1.00	8.80	3.97
122	1600	2.64	36.67	12.30
123	0	1.33	32.85	10.62
123	800	1.00	21.26	8.42
123	1600	1.66	33.78	13.67
124	0	6.07	63.16	19.14
124	800	1.18	21.17	8.23
124	1600	1.30	30.85	8.22
125	0	1.95	27.76	11.69
125	800	1.00	12.47	4.40
125	1600	2.31	32.34	11.33
126	0	4.40	33.56	17.17
126	800	1.00	20.19	7.78
126	1600	1.69	36.90	13.15
127	0	1.09	38.57	18.42
127	800	5.05	26.50	16.69
127	1600	6.39	48.38	27.09
128	0	4.72	50.64	18.88
128	800	1.00	12.20	4.83
128	1600	1.77	59.52	24.44
129	0	4.16	39.14	18.94
129	800	3.68	34.49	19.28
129	1600	2.52	31.84	13.52
130	0	1.00	31.45	13.75
130	800	1.00	8.92	4.20
130	1600	3.14	32.85	13.51
131	0	1.00	29.42	10.33
131	800	1.03	13.42	6.12
131	1600	1.89	38.48	14.27
132	0	6.04	48.97	21.72
132	800	1.00	15.12	5.86
132	1600	1.98	23.49	10.31
133	0	1.45	33.95	10.83
133	800	1.42	20.13	6.68
133	1600	3.89	28.59	14.91
134	0	1.00	27.34	11.10
134	800	1.21	7.94	4.59
134	1600	3.62	44.95	11.70

BLUE MESA WIND DATA

APPENDIX A

JULIAN DAY	HOUR	WIND SPEEDS MINIMUM	MAXIMUM	AVERAGE
		(8-HOUR INTERVALS)		
135	0	2.07	30.80	11.90
135	800	1.03	23.52	6.96
135	1600	1.30	45.55	9.16
136	0	1.24	21.32	8.44
136	800	1.00	19.17	7.22
136	1600	1.00	58.69	18.88
137	0	2.28	38.28	13.27
137	800	6.54	26.06	16.40
137	1600	7.65	37.44	27.81
138	0	8.03	30.20	17.03
138	800	4.04	24.51	15.15
138	1600	3.53	26.30	16.96
139	0	1.00	25.58	9.41
139	800	1.00	7.76	3.53
139	1600	2.16	21.50	8.87
140	0	1.66	32.52	13.55
140	800	1.30	17.65	7.53
140	1600	5.17	48.53	23.29
141	0	4.93	37.59	21.19
141	800	2.13	29.69	14.20
141	1600	6.09	41.70	27.92
142	0	5.41	34.76	16.36
142	800	1.95	25.40	10.80
142	1600	4.01	37.53	14.17
143	0	1.51	26.21	9.49
143	800	1.00	9.16	3.94
143	1600	1.74	27.01	12.36
144	0	1.00	21.97	6.13
144	800	1.00	7.91	2.99
144	1600	1.27	29.75	10.92
145	0	1.00	42.09	14.82
145	800	1.00	7.73	3.39
149	800	1.00	14.32	6.65
145	1600	1.95	44.77	14.60
146	0	1.03	31.27	8.58
146	800	1.00	6.33	2.84
146	1600	1.80	22.21	8.82
147	0	2.55	26.00	13.63
147	800	1.00	15.69	6.37
147	1600	1.42	31.81	16.92
148	0	1.00	41.14	11.09

1 B L U E M E S A W I N D D A T A

JULIAN DAY HOUR WIND SPEEDS MINIMUM MAXIMUM AVERAGE
(8-HOUR INTERVALS)

1 B L U E M E S A W I N D D A T A

JULIAN DAY	HOUR	WIND SPEEDS MINIMUM	MAXIMUM	AVERAGE
		(8-HOUR INTERVALS)		
148	800	1.00	25.70	7.09
148	1600	2.19	18.76	8.58
149	0	1.72	31.30	12.62
149	1600	2.49	31.42	8.94
150	0	1.74	35.24	11.76
150	800	1.00	8.45	3.41
150	1600	2.28	25.40	10.07
151	0	1.39	31.21	17.75
151	800	1.03	23.32	6.30
151	1600	1.27	40.96	16.43
152	0	1.00	34.22	10.15
152	800	1.00	9.70	3.39
152	1600	3.53	33.75	15.55
153	0	2.04	28.53	11.37
153	800	1.00	10.44	4.99
153	1600	1.21	27.96	10.11
154	0	1.18	35.40	14.75
154	800	1.00	36.07	9.76
154	1600	1.42	25.01	8.52
155	0	2.61	24.80	14.02
155	800	1.00	14.52	6.35
155	1600	1.00	27.07	11.99
156	0	1.95	30.26	14.78
156	800	1.00	9.76	4.22

1

	MEAN	STANDARD DEVIATION
MIN WINDSPEED	2.19	1.65
MAX WINDSPEED	28.87	11.76
AVG WINDSPEED	11.85	5.50

STOP
/

APPENDIX B

FAILURE OF THE WIND GENERATOR

APPENDIX B

FAILURE OF THE WIND GENERATOR

Based on the observation of the wind generator during the period of this study, and the physical damage sustained by the wind generator, the following possibilities as to the cause and sequence of mechanical failures are presented.

The generator failed at about 1:30 a.m. on June 18, 1982. This is established by a strip chart record which showed the generator generating power at the time of failure. The record also indicated that the wind at the time was strong and gusty. These weather conditions were corroborated by local citizens around Gunnison who gave information as to a storm passage during the night which blew over trees and caused roof damage to homes in the area. Photographs B-1 and B-2 show the generator as it appeared soon after the damage.

The major damage to the generator was the separation of the YAW DRIVE GEAR assembly from its mounting at the rear of the generator assembly. This could cause the damage to the other parts of the system. The other parts damaged were the propeller, a piece was broken off, and the pivot mast, which was bent. Photographs B-3 through B-8 show the damaged components after generator was disassembled.

A possible sequence of events follows: Just prior to the failure, the generator was rotating at a high rate of speed. Strong, gusty wind conditions would cause the generator to turn to keep the propeller RPM in safe limits. As the wind changes direction relative to the propeller, a condition of "blade flutter" occurs. This is caused by the blades of the propeller operating in an aerodynamically unbalanced condition. This alone does not create excessive stress on the generator, but it creates strong vibration throughout the tower structure, which in turn could create high dynamic forces on the yaw drive gear mounting. This mounting is cast aluminum, and is the most likely part to fail. With the failure of the yaw drive, the generator is free to swivel, and does not have any limit to overspeeding. With the propeller overspeeding, the blades and other components are subject to distructive forces.

Second possible sequence: At a time when the propeller is at a high RPM and a rapid change of wind direction causes the Yaw Drive System to rapidly yaw the generator around, very high gyroscopic forces are produced which tend to rotate the generator in a vertical plane perpendicular to the plane of the rotating propeller. These forces are transmitted to the mounting mast and would cause it to bend. Any bending of the mast could result in disengaging of the yaw drive gear from the gear on the mounting attached to the tower. At this occurrence, the generator would lose all ability to control blade RPM. The propeller would overspeed, overstress the blade(s) and cause blade failure. Blade failure would instantly produce very high unbalanced stresses on the generator assembly and cause the yaw drive gear box to separate from its mount as in the first sequence.

A third possible sequence, a foreign object, i.e., piece of wood, small pebble, etc., striking a propeller blade that is rotary at a high RPM, could cause failure of the blade resulting in the severe unbalanced condition and vibration in the tower structure as in the first sequence. The missing piece of propeller blade has not been recovered. Photographs B-9 through B-12 show the broken propeller blade stub.

Of the three main components that failed, evidence showed that the <u>initially</u> failing component would be:

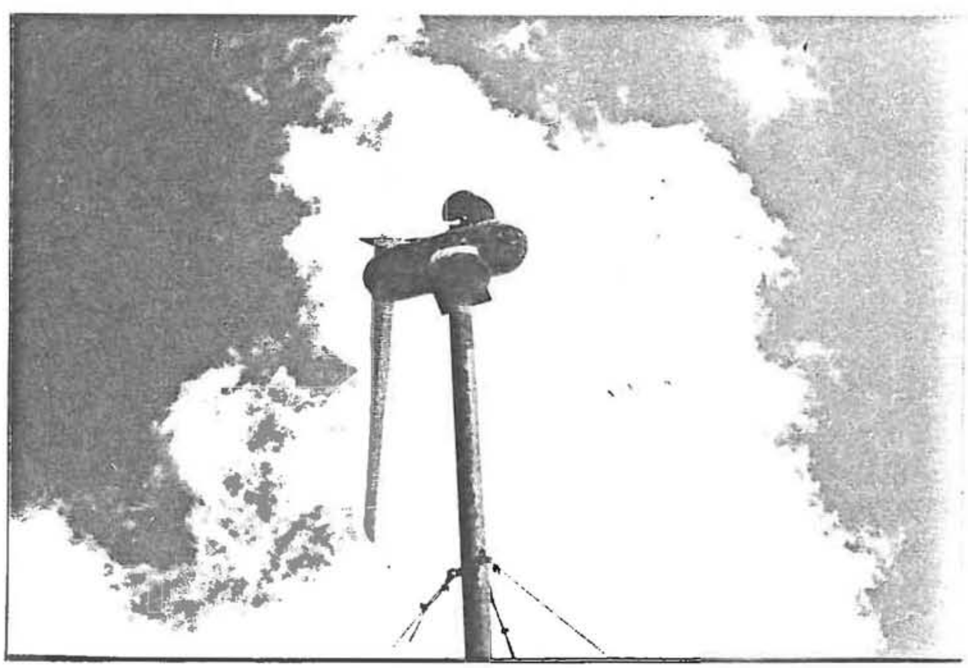
1st - The yaw drive gear box - most probable.

2nd - Blade separation, next probable.

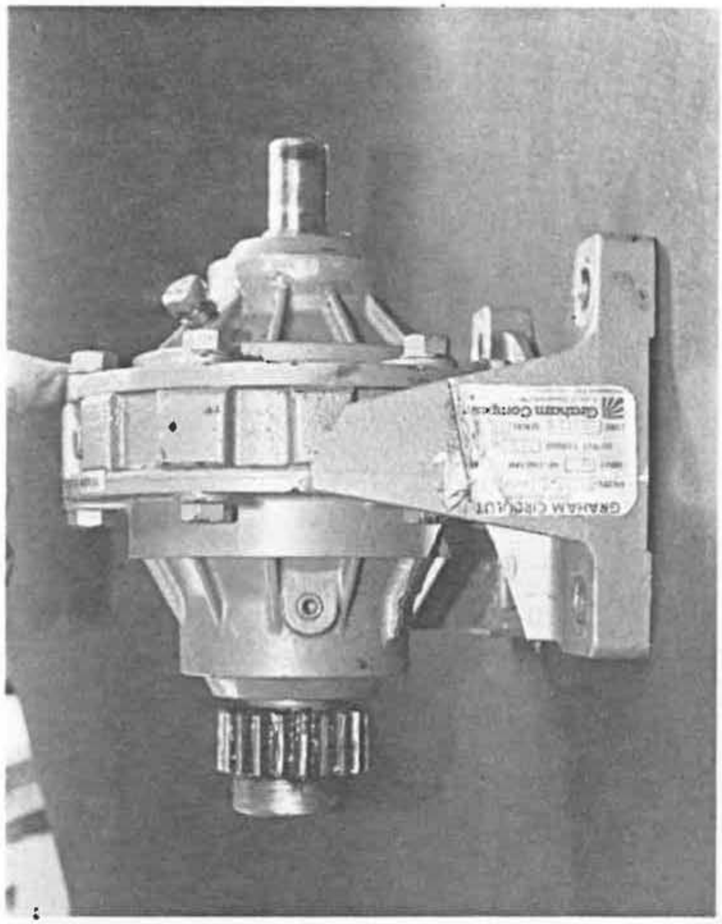
3rd - Bending of the pivot mast - least probable.

A detailed stress analysis of failed parts and metalurgical analysis of the yaw drive mounting was not made.

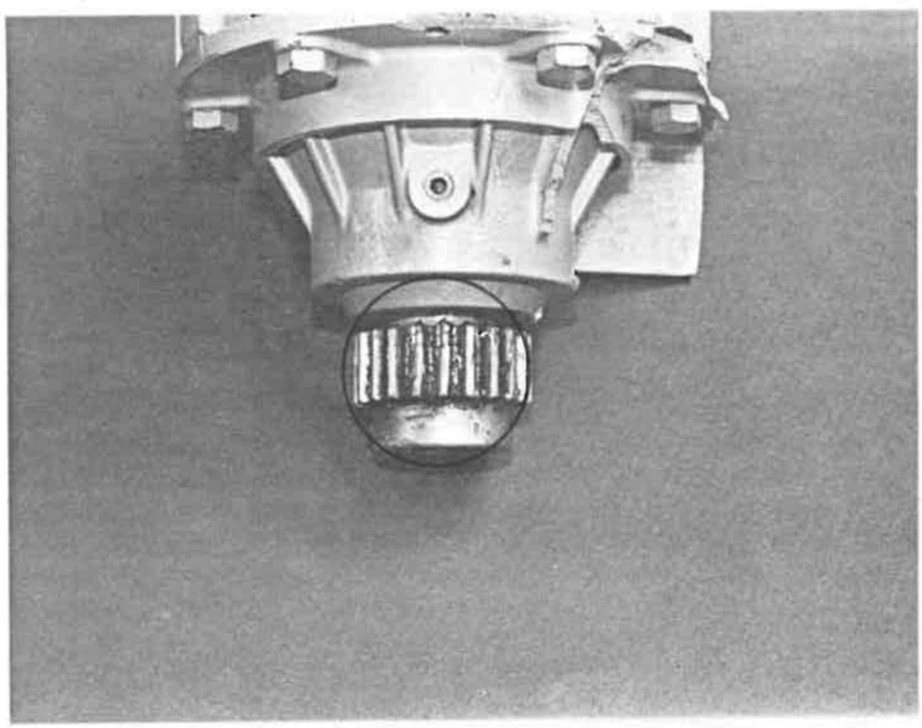
Damaged wind generator atop mounting mast. The yaw vane stalk is broken and yaw drive is free to move.



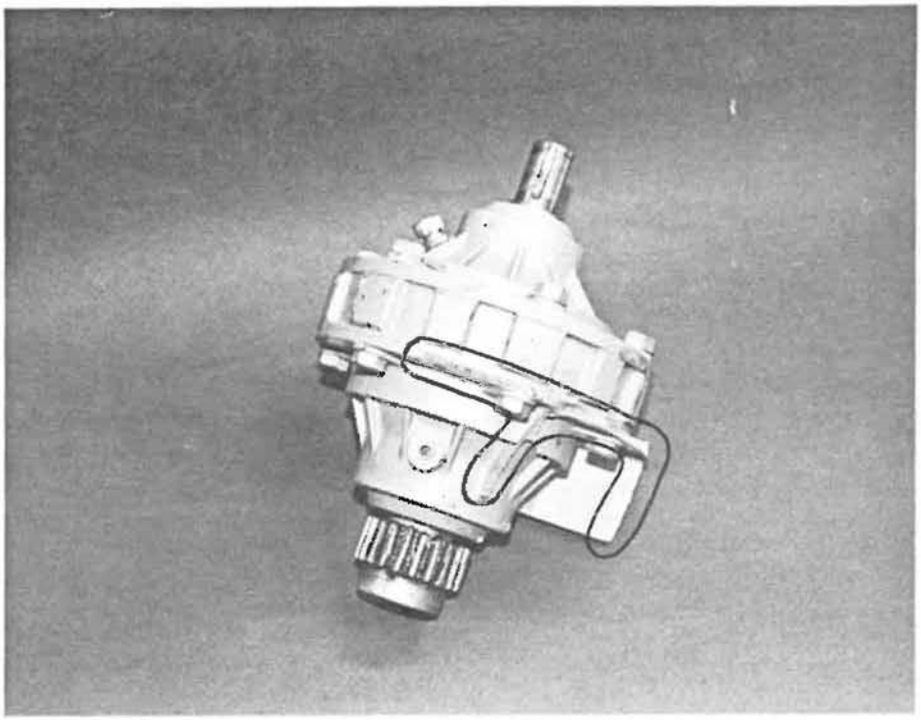
This view shows the yaw drive vane projecting into the plane of propellor rotation.



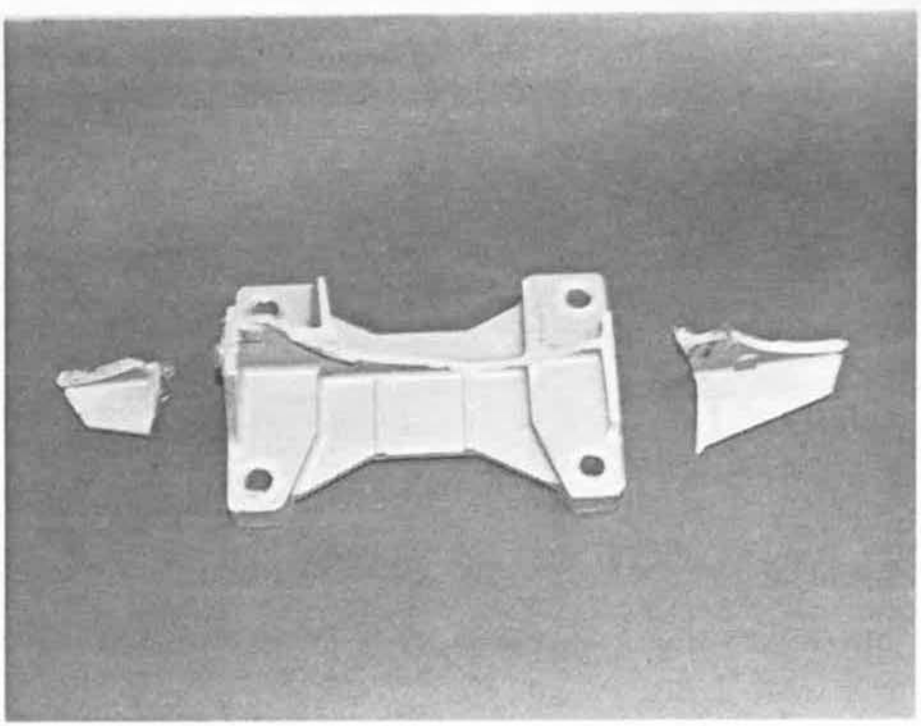
Yaw Drive Gear Box.
The yaw drive stalk is attached to the shaft at top. The gear at the bottom meshes with a fixed gear on the tower mount.



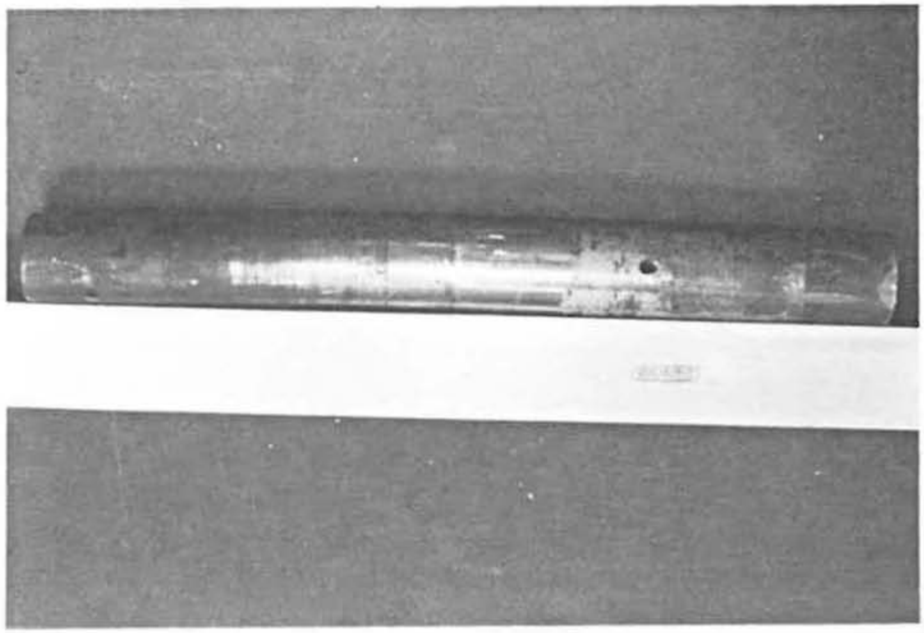
Damaged gear teeth on the yaw drive gear.



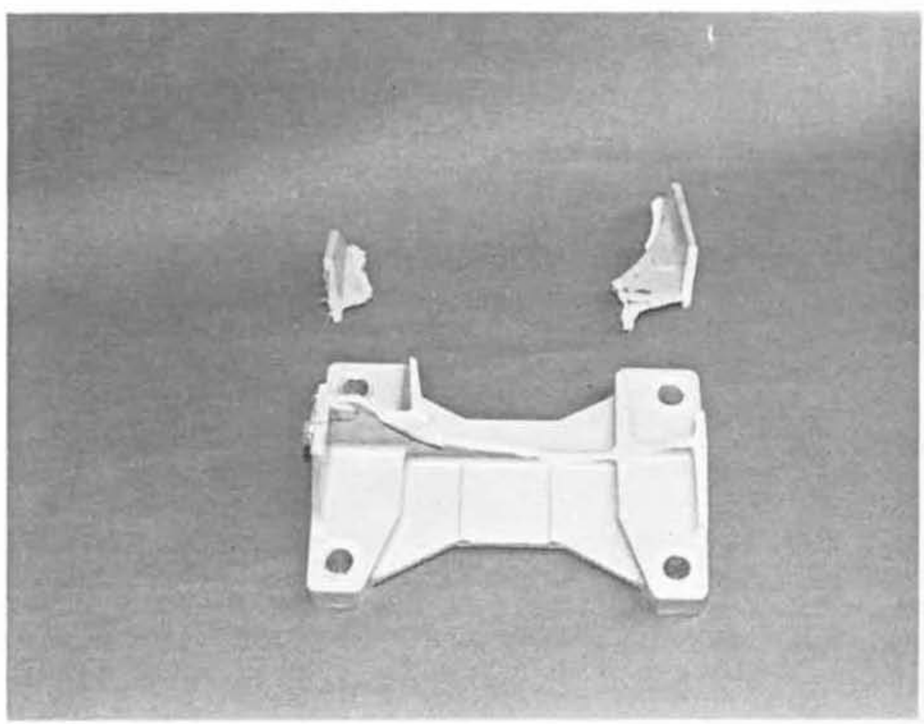
Yaw drive gear box. The mounting flanges are broken off.
The flanges are is cast integrally with the gear housing.
Fracture areas are outlined.



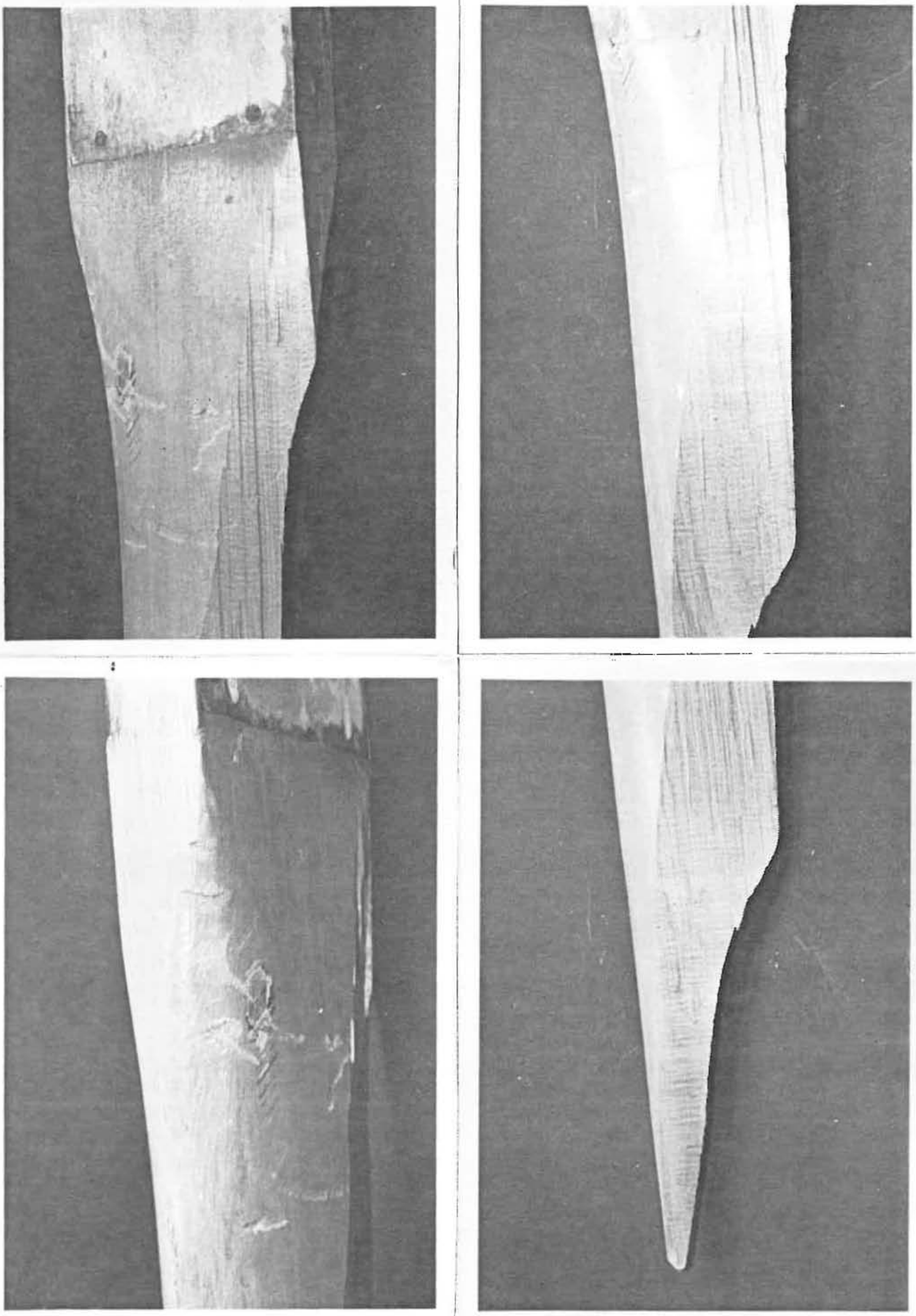
Fractured mounting flanges.



The main pivot shaft is bent. The straightedge indicates the amount of deformation.



Fractured mounting flanges.



Propeller damage and showing rotational marks on stub end of propeller.

APPENDIX C

SERVICE BULLETIN

WHIRLWIND POWER CO.

Elliott Bayly, PhD EE
Research & Development
Edward Wall
Business Manager

Service Bulletin Number 1

19 February 1982

To: All WhirlWind Series 2000 and Series 3000 Owners

Subject: Yaw Return Spring Replacement (Replacement part enclosed)

The yaw return spring furnished with all Series 2000 and Series 3000 wind generators shipped prior to 19 February 1982 was incorrectly manufactured and may be subject to breakage due to a condition known as hydrogen embrittlement because of incorrect plating.

An improved spring made of stainless steel is enclosed and is a direct replacement for the original spring. Please install the new spring at your next maintenance interval or when required. Breakage of the original spring is indicated when the wind generator remains sideways to the wind direction under all wind conditions..

WHIRLWIND POWER CO.
5030 York St.
Denver, CO 80216
303-595-8491

Elliott Bayly, PhD EE
Research & Development
Edward Wall
Business Manager

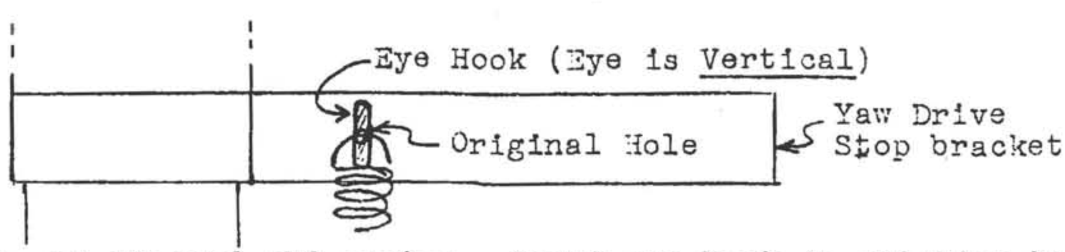
Service Bulletin Number 82-2
12 April 1982
To: All WhirlWind Series 2000 and Series 3000 Owners
(Dealers, please forward this Bulletin and parts to owners.)

CAUTION! Warranty coverage will not apply to machines that are not modified according to this bulletin. Perform this work immediately.

1) To reduce shock to yaw drive assembly, replace the original nylon stop bumpers with the rubber bumpers (enclosed). Remove nylon bumpers by unscrewing with a pair of sturdy pliers and push or screw the replacement rubber bumpers on the 5/16" stop rod to the bottom of the predrilled hole. Readjust the bumper rod positions by loosening the locknut to properly position the yaw drive assembly at each end of its travel.

2) Carefully inspect the yaw drive tail stalk which is the 18" long piece of ½" by ½" angle iron that supports the aluminum tail fin. Some machines may have tail stalks with poor welds. Inspect for any signs of bending, fatique cracks or poor or broken welds. Failure of this part will, of course, result in loss of high wind shut-down with subsequent possible loss of the propellor. If there is any sign of damage or weakness in the tail stalk, please return entire yaw drive assembly less fan blade to WhirlWind for replacement of the original stalk with a new stalk of square tube design. WhirlWind will make repairs in about 3 working days and pay postage both ways. We will also make this replacement free of charge on any machine whose stalk shows no sign of damage, if the owner wishes.

3) We sincerely regret that the yaw return spring replacement sent out with Service Bulletin Number 1 did not solve the breakage problem. The fault is corrected by modifying the attachment of the spring to the yaw drive assembly stop bracket per the figure below:



Remove and discard old spring. Mount eye hook in existing hole in the yaw drive assembly stop bracket with eye hook vertical. Jam nut goes on first followed by nylon insert lock nut. Tighten securely. Install new yaw return spring with square end in frame hole and round end in eye hook..

WHIRLWIND
POWER CO.
2458 W. 29th Ave.
DENVER, CO 80211
(303) 477-6436

Elliott Bayly, PhD EE
Research & Development
Edward Wall
Business Manager

Charlie Smith
Colorado Dept. of Highways
4201 E. Arkansas Room 212
Denver, CO 80222
3 August 1982

Dear Charlie:

Examination of your wind generator Model 2112 shows no evidence of faulty workmanship or materials. This machine could easily be repaired by either yourself or us. These are the parts required:

P12	12 Foot Propellor	$ 400.00
MSL	Mast and Slip Ring Assembly	120.00
YGBM	Yaw Gear Box, Main	400.00
YGS	Yaw Drive Gear, Small	30.00
SRR	Shroud, Rear	200.00
	Total Parts	$1150.00

If WhirlWind were to make the repairs, the labor charges would be approximately $320.00.

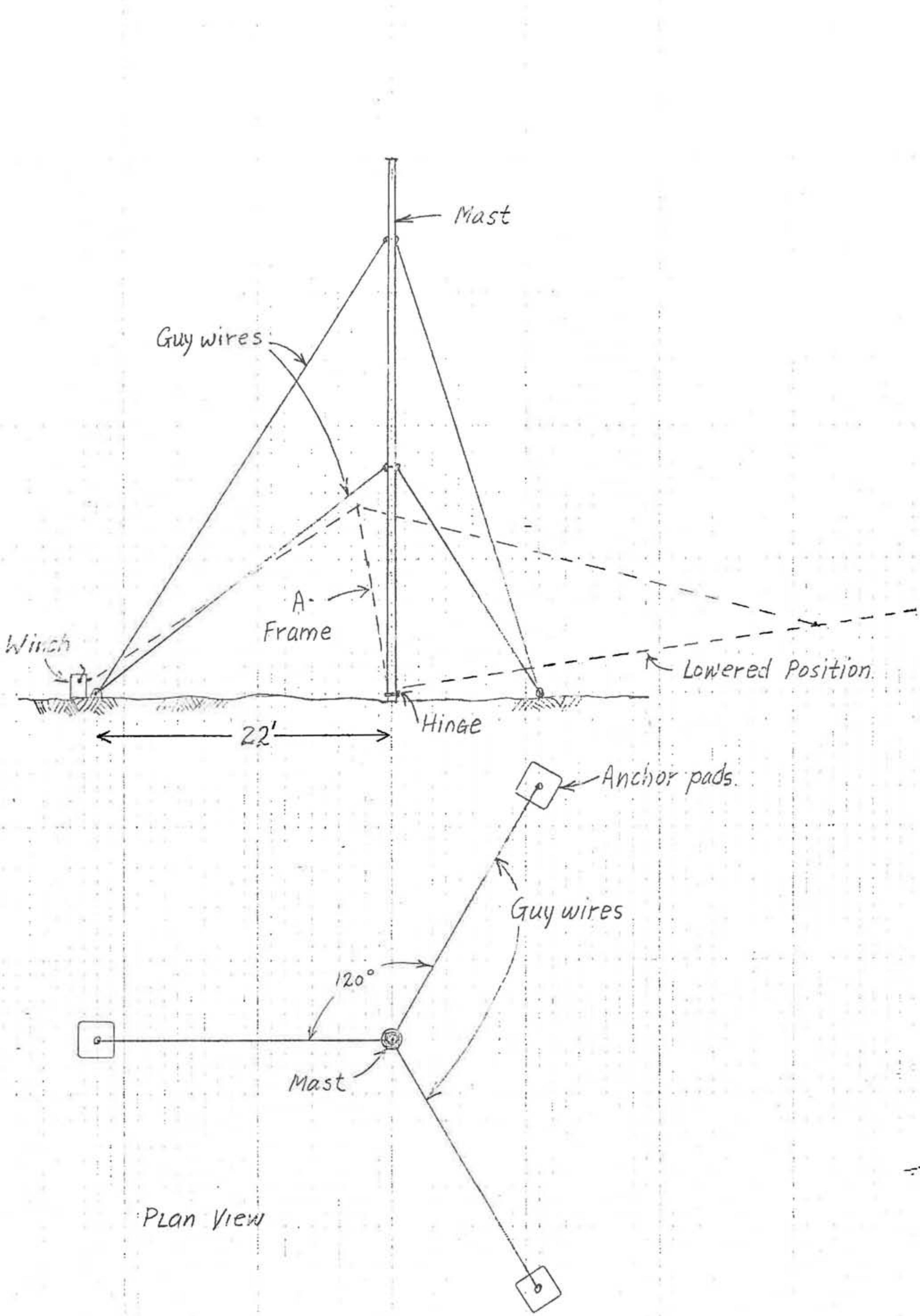
Let us know how you wish to proceed.

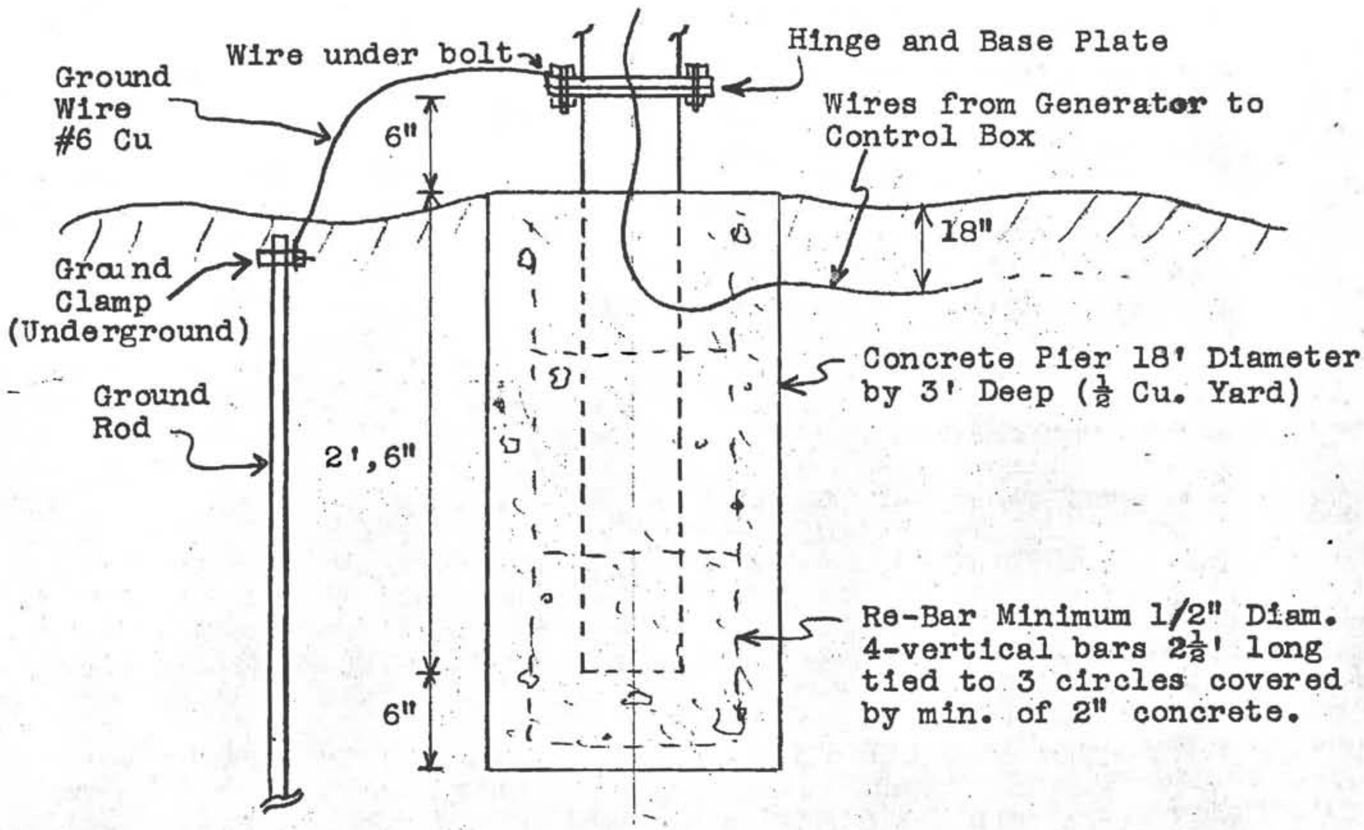
Sincerely,

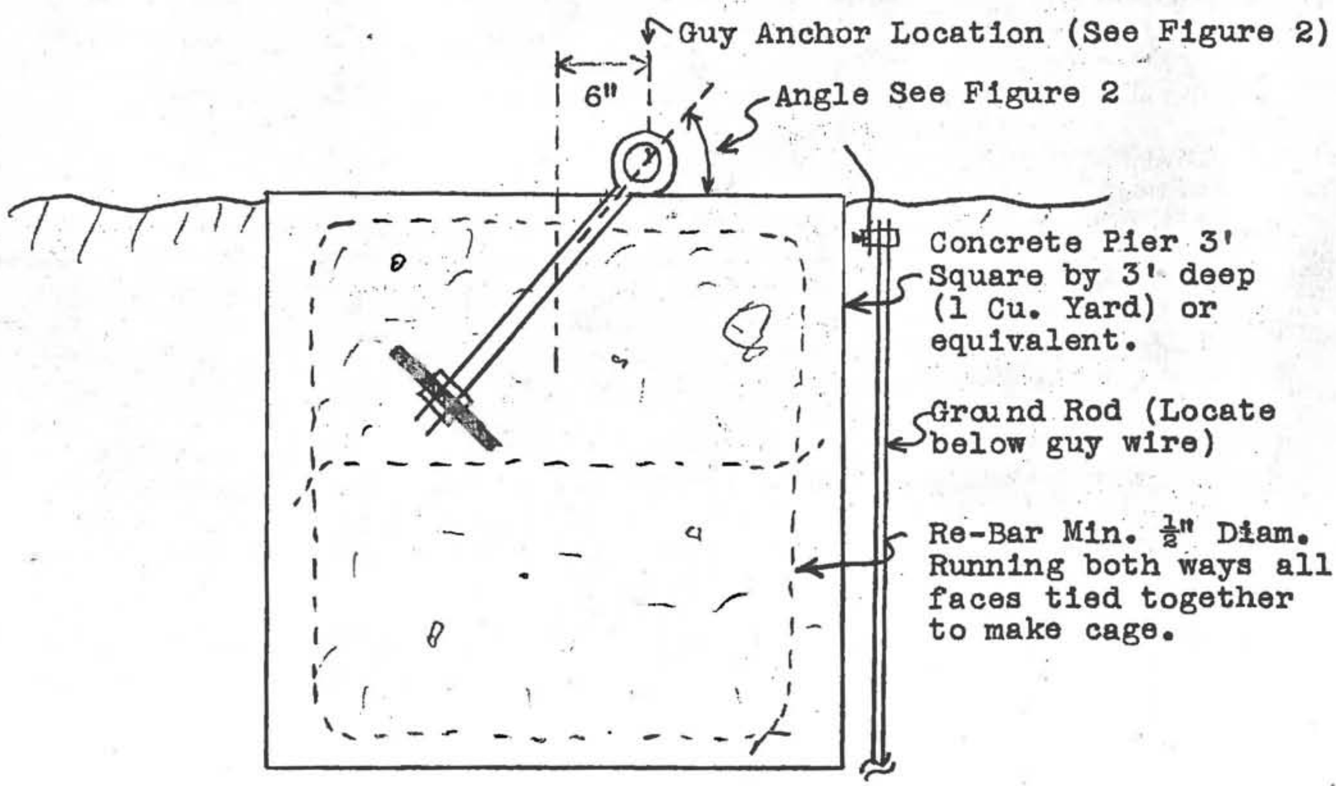
Elliott Bayly,
President

APPENDIX D

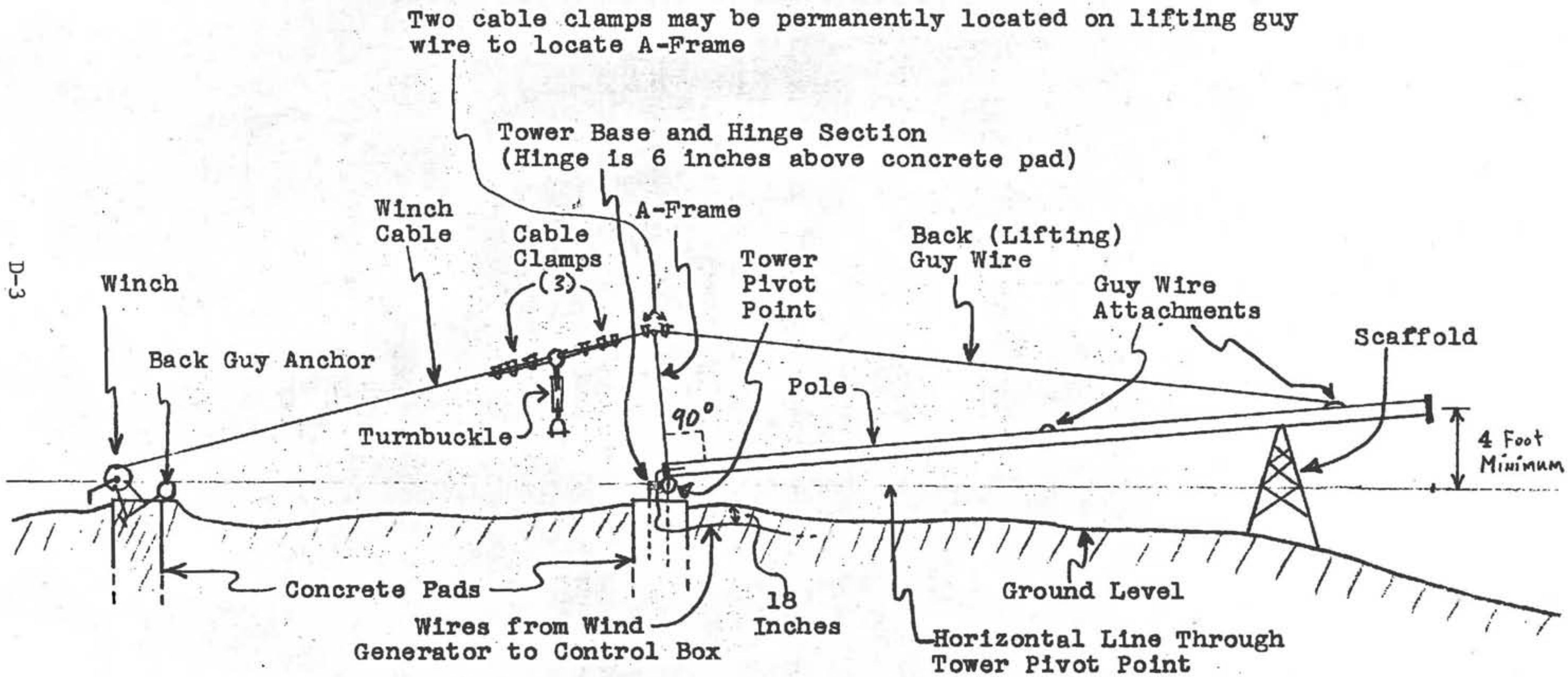
LAYOUT AND ERECTION PLANS


Mast
Guy wires
A-
Frame
Winch
Lowered Position
Hinge
22'
Anchor pads
Guy wires
120°
Mast
Plan View





Foundation Holes and Concrete



Self-Erecting Guyed Pole Ground Level Variation Requirements. Winch center must be no lower than 1 foot below the Horizontal Line Through Tower Pivot Point. A-Frame feet must be in line with tower base hinge and resting on supports at the same level as the Horizontal Line Through Tower Pivot Point. Tower Hinge must be exactly perpendicular to the Horizontal Line Through Tower Pivot Point.

APPENDIX E

CHRONOLOGY OF EVENTS

CHRONOLOGY

Mar. 11, 1981	Study approved.
Apr. 27, 1981	Installed micrologger to obtain wind data at site location.
Jun. 5, 1981	Completed wind data monitoring.
Jun. 18, 1981	Site location selected and equipment ordered.
Aug. 8, 1981	Started site preparation.
Sep. 1, 1981	Poured concrete for tower pier and guy anchors.
Sep. 8, 1981	Erected tower and installed control equipment and wiring.
Sep. 17, 1981	Installed generator.
Oct. 1, 1981	Installed flashing Light and data monitoring equipment.
Oct. 10, 1981	Put generator into operation and checked system.
Oct. 27, 1981	Lowered tower for first month's inspection. Replaced broken yaw drive spring.
Dec. 2, 1981	Two defective storage batteries removed. The generating system performing satisfactorily.
Dec. 8, 1981	Defective batteries replaced with new batteries.
Dec. 11, 1981	System was not charging batteries. All batteries removed to Gunnison Maintenance garage for charging.
Jan. 7, 1982	Three defective batteries were found and also determined that 85 Ampere hour batteries and 105 Ampere hour batteries intermixed in the system. The generator was put back in operation without the batteries. System would operate lights only when sufficient wind was occurring.
Mar. 3, 1982	Site visit. The generator was not operating due to broken yaw drive spring.
Mar. 17, 1982	Lowered tower and replaced yaw drive spring. Installed 10, 105 Ampere hour batteries. System returned to full operation.
Apr. 7, 1982	Wind generator not operating. Rewired flasher circuit. Wind conditions not favorable to lowering tower for repairs.

CHRONOLOGY

May 4, 1982	Tower lowered and found yaw drive stalk broken. Stalk removed. The batteries were recharged by portable generator at the site.
May 7, 1982	New yaw drive stalk installed with new yaw drive spring. Tower raised and system returned to normal operation.
May 20, 1982	System checked and operating satisfactorily.
Jun. 17, 1982	System checked and charging system inoperative. Batteries were low on water. Control circuit is not working properly. One cup on anemometer blew off.
Jun. 22, 1982	Control box was replaced and batteries were serviced. Anemometer was replaced. System was checked and was operating properly.
Jun. 28, 1982	Generator failed at 1:30 a.m. as determined from recorded data.
July 15, 1982	Received notice in Denver that generator was not operating.
July 30, 1982	Tower was lowered and generator was removed and returned to Denver. Remaining components remain at Gunnison. Generator sustained severe damage. Estimate of repairs was $1,470.00.
Sep. 9, 1982	The decision was made to discontinue the study. A recommendation was made to District 3 to plan a solar-voltaic installation to replace the wind generator system at Red Creek.