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RURAL ELECTRIC POWER QUALITY ANALYSIS
DATA BASE DEVELOPMENT

FINAL REPORT

by

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ABSTRACT

The actual cost of poor quality electric power is difficult to accurately determine. Such cost information is important in determining the extent to which power quality enhancement techniques should be applied. This report presents data compiled to help determine the quantity and type of electrical and electronic equipment at risk in rural Alaska and repair frequency of this equipment. Costs attributable to poor electric power quality are identified. Methods of electric power quality improvement and their relative costs are presented.

INTRODUCTION

This report presents a data base developed to help determine actual costs of poor quality electric power in state owned and operated public facilities and costs to other power users as well. The emphasis is on rural locations characterized by relatively small power distribution systems supplied primarily by diesel engine-driven generators in the 50 to 1,000 kVA range.

The compiled data are presented in eight individual files. A combined data file containing the individual files in one large matrix is also available on a 5.25 inch floppy disk. LOTUS 1-2-3 spreadsheet software was utilized to prepare this disk for maximum flexibility in adding future data updates, if desired.

Three broad areas of information are of interest. First is an inventory of equipment at risk and the sophistication levels of that equipment. Second is the frequency with which equipment must be repaired or replaced. Third is the cost associated with equipment repair or replacement. Whenever possible, equipment failure attributable to poor electric power quality was identified and reported.

This report also contains a section on electric power improvement techniques and compares their capabilities and costs.

DEFINING ELECTRIC POWER QUALITY

An ideal AC electric power system in North America provides a perfect sine wave of rated voltage at 60 Hz regardless of load until overcurrent protection device limits are exceeded. In reality, such an ideal voltage source does not exist because of the presence of power system impedance, which can be excessively large if inadequately-sized transformers and power line conductors, and non-ideal governors and voltage regulators are part of the power supply system. Poor maintenance and improper system operation may also contribute to reduced electric power quality as can user-generated disturbances caused by motor starting, other load switching and faults.

Electric power quality problems are typically subdivided under the following categories.

1. Over/under frequency.
2. Long-term average (RMS) voltage level (RMS = root mean square value of voltage waveform).
3. RMS value of each AC cycle compared with the long-term average. A single-cycle measurement lower than the long-term average is a sag. A higher single-cycle measurement is a surge.
4. Transient impulses with duration between 0.5 and 800 microseconds.
5. Outages, defined as loss of line voltage for periods greater than five seconds.

ESTABLISHED ACCEPTABLE POWER QUALITY LIMITS

Several references define acceptable power quality limits for computer systems [4, 6, 10, 12 for example] and at least one addresses communications systems [6]. General agreement exists that +6% and -13% rated voltage steady-state limits are necessary, although at least one computer manufacturer is reported to require ±4% tolerance [4]. Opinions about acceptable power quality differ for transients lasting less than 2 seconds. The American National Standards Institute (ANSI) Standard C84.1 requires +15% and -20% voltage tolerance for transients between 0.05s and 0.5s duration and +20% and -30% voltage tolerance for transients between 0.008s and 0.05s duration as reported in [4]. A different tolerance envelope is suggested in [12] resulting from U.S. Navy tests and computer manufacturers' information. It is generally more restrictive than the C84.1 standard for voltage surges and impulses with the tolerance boundary rising smoothly from +6% rated voltage for a 2s disturbance to +30% for 8.33 ms, +100% for 1 ms and +200% rated voltage limit on a 100 μs disturbance. The undervoltage limits of this tolerance envelope include -13% rated voltage for a 2s disturbance, -30% for 0.5s, -42% for 0.1s, -70% for 16.7ms and -100% for an 8.33ms disturbance.

Frequency tolerance for a 60 Hz source is reported to be ±0.5 Hz in some instances [4], although at least one major computer company specifies ±1.0 Hz.

Voltage and frequency fluctuations are known to cause detrimental effects in electric motors, but the authors have not found an electric motor manufacturer or supplier who is willing or able to provide information relating such power anomalies to motor damage or reduced service life. Some users of motors in small communities have devised protective schemes utilizing voltage and frequency relays.

An earlier report [1] and corresponding paper [2] established that power quality can be a problem in small, isolated Alaskan electric power systems. Data from that report compared with studies conducted in the continental United States [3] show 41.4 times more impulses measured in the Alaskan locations than in the continental United States, even though a 67% higher threshold was used in obtaining Alaskan data. Approximately eight times more outages were recorded in Alaska with about 11 times the average duration of continental United States outages. Frequency deviations from 60 Hz also appear to be a greater problem in small, isolated systems than in the larger interconnected ones prevalent in the continental United States. These data encouraged additional electric power quality analyses in Alaska.

DESCRIPTION OF COMPILED DATA

The compiled data presented in this section are subdivided into eight files.

	File name	File contents
1.	PWR-GEN	Population and utility information
2.	PWR-SUR	Results of utility survey
3.	MUN-INV	Municipality and borough inventory information
4.	MO-ST-BL	Inventory of motors in Northern Region state-built buildings (from DOT&PF as-built blueprints)
5.	VIL-MO	Results of village sewer and water system motor survey
6.	SCH-DIST	Inventory and repair information from survey of school districts
7.	ST-TV	Data from state TV transmitter/receiver (TX/RX) repair reports
8.	ALASCOM	Alascom earth station repair reports

As previously noted, the above eight files have been combined in a LOTUS 1-2-3 spreadsheet named TOT-FILE. All nine files exist on a 5.25 inch floppy disk in LOTUS 1-2-3 format. A copy has been provided to the Department of Transportation and Public Facilities (DOT&PF). The speadsheet format has been used to encourage future use and expansion of the data base.

DETAILED DATA FILE DESCRIPTIONS

1. PWR-GEN

The PWR-GEN file, shown on pages 6 through 8, provides population and power generation data for 113 Alaskan communities, excluding Anchorage and Fairbanks. The source of generation data was Alaska Electric Power Statistics, 10th Edition, December 1985, Alaska Power Authority [15]. Power survey data from file PWR-SUR are shown if they conflict with Power Authority data for that community. Generation data provided include: name and type of utility, installed capacity (kW), annual energy production (MWH/YR), peak load (MW) and type of generator prime mover. Alaska utility abbreviations are defined on page 5 [15].

2. PWR-SUR

The power survey file, appearing on pages 9 and 10, tabulates data received from 28 utilities in response to a survey form, shown on page 23, that was sent to all utilities listed with the Alaska Public Utilities Commission. Specific data shown in this file are: community population, type of utility, installed capacity (kW), annual energy production (MWH/YR), peak load (MW), type of generator prime mover, generator voltages, system transmission voltages, number of outages per year, average outage duration (minutes) and total outage time per year (hours). The survey questionnaire promised to delete community names from this file to encourage more response. Therefore, communities are identified by population size only.

ALASKA UTILITY ABBREVIATIONS

AEC	Andreanof Electric Corporation (Atka)	Private	(SW)
AEU	Akutan Electric Utility (Dutch Harbor)	Municip.	(SW)
AEL&P	Alaska Electric Light & Power Company (Juneau)	Private	(SE)
AML&P	Anchorage Municipal Light & Power Department	Municip.	(SC)
APA-E	Alaska Power Administration-Eklutna (Anchorage)	Federal	(SC)
APA-S	Alaska Power Administration-Snettisham (Juneau)	Federal	(SE)
APASG	Alaska Power Authority-Solomon Gulch (CVEA/Valdez)	State	(SC)
APASL	Alaska Power Authority-Swan Lake (KPU/Ketchikan)	State	(SE)
APATL	Alaska Power Authority-Terror Lake (KdEA/Kodiak)	State	(SC)
APATy	Alaska Power Authority-Tyee (Petersburg, Wrangell)	State	(SE)
APC	Aniak Power Company	Private	(SW)
AP&T	Alaska Power & Telephone Company (Craig, Hydaburg, Skagway, Tok, Dot Lake) [1]	Private	(SE, Y)
AVEC	Alaska Village Electric Cooperative, Inc. (48 villages)	Coop.	(SC, Y, SW, A-NW)
AUI	Arctic Utilities, Inc. (Deadhorse)	Private	(A-NW)
BU&EC	Barrow Utilities & Electric Cooperative, Inc.	Coop.	(A-NW)
BUC	Bethel Utilities Corporation, Inc.	Private	(SW)
BL&P	Bettles Light & Power, Inc.	Private	(Y)
CE	Circle Electric	Private	(Y)
CEA	Chugach Electric Association, Inc. (Anchorage Area)	Coop.	(SC)
CEC	Cordova Electric Cooperative, Inc.	Coop.	(SC)
ChE	Chignik Electric	Municip.	(SW)
COM	City of Manokotak	Municip.	(SW)
CTP	Chistochina	Private	(SC)
	Cold Bay (see G&K)		
CVEA	Copper Valley Electric Association, Inc. (Glennallen, Valdez)	Coop.	(SC)
EL&P	Egegik Light & Power [2]	Private	(SW)
EPC	Eagle Power Company (cert.appl.1-85)	Private	(Y)
FMU	Fairbanks Municipal Utilities System	Municip.	(Y)
	Fort Yukon (see GZUC)		
G&K	G & K, Inc. (Cold Bay) [3]	Private	(SW)
GHEA	Glacier Highway Electric Association, Inc. (Juneau Area)	Coop.	(SE)
GVEA	Golden Valley Electric Association, Inc. (Fairbanks Area)	Coop.	(Y)
GZUC	Gwitchyaa Zhee Utility Company (Ft. Yukon) [4]	Private	(Y)
HEA	Homer Electric Association, Inc. (Kenai Peninsula)	Coop.	(SC)
HL&P	Haines Light & Power Co. Inc.	Private	(SE)
HuP&L	Hughes Power & Light (certif. application-1984)	Private	(Y)
I-NEC or INNEC	Iliamna Newhalen Nondalton Electric Coop., Inc.	Coop.	(SW)
KC	Kotlik City	Municip.	(Y)
KCC	King Cove City	Municip.	(SW)
KdEA	Kodiak Electric Association, Inc. (Kodiak, Pt. Lions)	Coop.	(SC)
KEU	Klukwan Electric Utility	Municip.	(SE)
KI	Kwethluk, Inc. (Kuiggluum Kallugvia)	Municip.	(SW)
KtEA	Kotzebue Electric Association, Inc.	Coop.	(A-NW)
KPU	Ketchikan Public Utilities	Municip.	(SE)
LBES	Larson Bay Electric System	Private	(SC)
LEC	Levelock Electric Cooperative, Inc.	Coop.	(SW)
	Manokotak (see COM)		
M&DE	M&D Enterprises (Galena)	Private	(Y)
MEA	Matanuska Electric Association, Inc. (Palmer-Talkeetna Area and Unalakleet) [5]	Coop.	(SC, A-NW)
MUC	Manley Utility Co., Inc. (Manley Hot Springs)	Private	(Y)
MP&L	Metlakatla Power & Light	Municip.	(SE)
MGL&P	McGrath Light & Power	Private	(SW)
MKEC	Middle Kuskokwim Electric Coop., Inc. (pending) (Chuathbaluk, Crooked Creek, Sleetmute, Stony River)	Coop.	(SW)
NEA	Naknek Electric Association, Inc. [2]	Coop.	(SW)
NEC	Nushagak Electric Cooperative, Inc. (Dillingham)	Coop.	(SW)
NIPC	Napakiak Ircinaq Power Co. (SWGR Service from BUC)	Private	(SW)
NiP&L	Nikolski Power & Light Co. (Umnak Is.)	Private	(SW)
NJUB	Nome Joint Utilities Board (was NL&P)	Municip.	(A-NW)
NLEC	Nelson Lagoon Electric Coop. (cert.appl.3-1-85) (Port Moller)	Coop.	(SW)
NP&L	Northway Power & Light, Inc.	Private	(Y)
NSBP&L	No. Slope Borough Power & Light System (Atkasook, Kaktovik, Wainwright, Point Hope, Point Lay, Nuiqsut, Anaktuvuk Pass)	Municip.	(A-NW)
PLI	Paxson Lodge, Inc.	Private	(SC)
PMP&L	Petersburg Municipal Power & Light	Municip.	(SE)
PUC	Pelican Utility Company (Pelican and Sand Point)	Private	(SE, SW)
SED	Sitka Electric Department	Municip.	(SE)
SES	Seward Electric System	Municip.	(SC)
SS	Semloh Supply (Lake Minchumina)	Private	(Y)
TB	Thorne Bay	Municip.	(SE)
TePC	Teller Power Company	Private	(A-NW)
T-HREA	Tlingit-Haida Regional Electrical Authority (Angoon, Hoonah, Kake, Kasaan, Klawock)	Coop.	(SE)
TPC	Tanana Power Company	Private	(Y)
TSU	Tenekee Springs	Private	(SE)
UE	Unalaska Electric (was COU)	Municip.	(SW)
UVEC	Unalakleet Valley Electric Cooperative [5]	Coop.	(A-NW)
WML&P	Wrangell Municipal Light & Power	Municip.	(SE)
WTC	Weisner Trading Co. (Rampart)	Private	(Y)
YPI	Yakutat Power, Inc.	Private	(SE)

[1] Tok-Dot Lk. intertie operating and Dot Lk. powerplant decommissioned in 1983.
[2] EL&P separated from NEA in 1983.
[3] G&K purchased No.Pwr.& Engr.Corp. in 1984.
[4] GZUC purchased Ft.Yukon Util. 11-7-83.
[5] UVEC is in process of taking over the Unalakleet electric function from MEA

DEMOGRAPHICS		POWER GENERATION					
COMMUNITY	POPU-LATION	POWER UTILITY	TYPE	INSTALLED CAP (KW)	OUTPUT MWH/YR	PEAK (MW)	TYPE GEN
AKUTAN	188	PRIVATE		90	240		
ALAKANUK	546	AVEC	C	825	772	0.2	D
ALEKNAGIK	232	NEC	C	3850	11377	2.3	D
AMBLER	217	AVEC	C	420	586	0.2	D
ANAKTUVUK PASS	250	NSBPL	C	930	1092	0.4	D
ANGOON	562	THREA	C	900	1133	0.2	D
ANIAK	351	APC	P	1260	1500	0.4	D
ANVIK	115	AVEC	C	200	203	0.1	D
ATKA	93	AEC	P	115	120	--	H,D
ATQASUK	84	NSBPL	C	695	1204	0.4	D
AUKE BAY	--	GHEA	C	6000	59	4.8	D,GT
BARROW	2882	BU&EC	C	9000	25054	5	GT
BETHEL	3683	BUC	P	9400	24500	4.3	D
BETTLES	60	BL&P	P	2640	1000	0.2	D
CHEVAK	513	AVEC	C	810	890	0.2	D
CHIGNIK	178	CHE	P	2450	3550	1.3	H,D
CIRCLE	81	CE	P	250	100	--	D
COLD BAY	250	G&K	P	2000	2960	0.6	D
CORDOVA	3000	CEC	C	10803	17156	3.9	D
CRAIG	604	AP&T	P	1750	4449	0.7	D
DEADHORSE	64	AUI	P	6200	16539	3.5	D,GT
DUTCH HARBOR	250	AEU	M	275	200	0.1	D
EEK	686	AVEC	C	156	365	0.1	D
EGEGIK	148	EL&P	P	75	200	0.1	D
ELIM	225	AVEC	C	231	436	0.1	D
EMMONAK	581	AVEC	C	775	876	0.2	D
FORT YUKON	270	GZUC	P	1350	1838	0.6	D
GALENA	847	M&D	P	760	1200	0.4	D
GAMBELL	432	AVEC	C	460	974	0.2	D
GLENNALLEN	511	CVEA	C	7642	14530	3.4	D
GOODNEWS BAY	248	AVEC	C	175	387	0.1	D
GRAYLING	211	AVEC	C	250	398	0.1	D
HAINES	1980	HL&P	P	3920	8609	1.7	D
HOLY CROSS	285	AVEC	C	285	406	0.1	D
HOONAH	866	THREA	C	1220	2285	0.5	D
HOOPER BAY	651	AVEC	C	775	1159	0.3	D
HUGHES	85	HUP&L	P	25	160	0.1	D

POWER UTILITY: SEE ATTACHED SHEET FOR UTILITY ABBREVIATIONS.

TYPE: P-PRIVATE, M-MUNICIPAL, C-COOPERATIVE, S-STATE, F-FEDERAL

NOTE: A "TYPE" LETTER INDICATES GENERATION DATA CAME FROM APA ALASKA ELECTRIC POWER STATISTICS, 10TH EDITION, DECEMBER 1985. WHERE DATA CONFLICT, POWER SURVEY INFORMATION TAKES PRECEDENCE

TYPE GEN: D-DIESEL, H-HYDRO, GT-GAS TURBINE

DEMOGRAPHICS POWER GENERATION

COMMUNITY	POPU-LATION	POWER UTILITY	TYPE	INSTALLED CAP (KW)	OUTPUT MWH/YR	PEAK (MW)	TYPE GEN
HUSLIA	241	AVEC	C	285	442	0.1	D
HYDABURG	412	AP&T	P	740	1300	0.3	D
ILIAMNA	102	I-NEC	C	960	1260	0.5	D
JUNEAU	22030	APA-S,AEL&P	F,P	122482	248509	48.5	D,H,GT
KAKE	679	THREA	C	1430	2010	0.5	D
KAKTOVIK	214	NSBPL	C	655	809	0.2	D
KALTAG	246	AVEC	C	285	484	0.1	D
KASAAN	70	THREA	C	180	107	--	D
KASIGLUK	328	AVEC	C	613	1150	0.3	D
KETCHIKAN	8293	KPU, APASL	M,S	50750	109857	21.6	H,D
KIANA	364	AVEC	C	875	895	0.2	D
KING COVE	527	KCC	M	600	360	0.1	D
KIVALINA	253	AVEC	C	610	596	0.2	D
KLAWOCK	433	THREA	C	1300	1592	0.4	D
KLUKWAN	--	KEU	M	685	300	0.1	D
KODIAK	5873	KDEA, APATL	C,S	48775	65000	12.7	D,H
KOTZEBUE	2470	KTEA	C	6625	14703	2.7	D,GT
KOYUK	183	AVEC	C	270	430	0.1	D
KWETHLUK	467	KI	M	560	400	0.1	D
LARSEN BAY	180	LBES	M	220	300	0.1	D
LEVELOCK	95	LEC	C	135	300	0.1	D
LOWER KALSKAG	260	AVEC	C	470	629	0.2	D
MANLEY HOT SPRIN	60	MUC	P	185	220	0.1	D
MANOKOTAK	299	COM	M	600	325	0.1	D
MARSHALL	226	AVEC	C	260	496	0.1	D
McGRATH	498	MGL&P	P	1200	2078	0.6	D
MEKORYUK	250	AVEC	C	325	516	0.1	D
METLAKATLA	1120	MP&L	M	6000	19666	5.7	H,D
MINTO	200	AVEC	C	235	368	0.1	D
MOUNTAIN VILLAGE	601	AVEC	C	1090	1685	0.4	D
NAKNEK	318	NEA	C	6700	12000	3.3	D
NEW STUYAHOK	337	AVEC	C	305	399	0.1	D
NIKOLSKI	50	NIP&L	P	110	170	0.1	D
NOATAK	273	AVEC	C	275	641	0.1	D
NOME	3430	NJUB	M	6700	20595	4	D
NONDALTON	176	I-NEC	C	320	1.6	--	D
NOORVIK	518	AVEC	C	775	1042	0.2	D

POWER UTILITY: SEE ATTACHED SHEET FOR UTILITY ABBREVIATIONS.

TYPE: P-PRIVATE, M-MUNICIPAL, C-COOPERATIVE, S-STATE, F-FEDERAL
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TYPE GEN: D-DIESEL, H-HYDRO, GT-GAS TURBINE

DEMOGRAPHICS | POWER GENERATION

COMMUNITY	POPU-LATION	POWER UTILITY	TYPE	INSTALLED CAP (KW)	OUTPUT MWH/YR	PEAK (MW)	TYPE GEN
NORTHWAY	73	NP&L	P	920	1299	0.4	D
NULATO	353	AVEC	C	725	669	0.1	D
OLD HARBOR	355	AVEC	C	310	579	0.1	D
PAXSON	30	PLI	P	375	750	0.3	D
PELICAN	185	PUC	P	1025	2802	0.8	H,D
PETERSBURG	3040	PMP&L	M	6750	22280	4.8	H,D
PILOT STATION	337	AVEC	C	366	680	0.2	D
POINT HOPE	544	NSBPL	C	930	1642	0.4	D
POINT LAY	51	NSBPL	C	400	825	0.2	D
QUINHAGAK	427	AVEC	C	385	663	0.2	D
RAMPART	50	WTC	P	150	60	--	D
SAINT MARYS	442	AVEC	C	1500	1956	0.4	D
SAINT MICHAEL	295	AVEC	C	340	593	0.1	D
SAND POINT	797	PUC	P	3350	4957	1.6	D
SAVOONGA	477	AVEC	C	650	1056	0.2	D
SCAMMON BAY	251	AVEC	C	290	462	0.1	D
SELAWIK	602	AVEC	C	650	921	0.2	D
SELDOVIA	733	HEA	C	2100	86	--	D
SEWARD	1839	SES	M	4000	2000	--	D
SHAGELUK	132	AVEC	C	200	251	0.1	D
SHAKTOOLIK	160	AVEC	C	200	339	0.1	D
SHISHMAREF	425	AVEC	C	600	922	0.2	D
SHUNGNAK	214	AVEC	C	580	674	0.1	D
SITKA	8223	SED	M	32640	101391	21	H,D
SKAGWAY	790	AP&T	P	3750	4706	1	H,D
STEBBINS	321	AVEC	C	275	557	0.1	D
TANANA	486	TPC	P	800	1670	0.5	D
TELLER	206	TEPC	P	445	600	0.2	D
TENAKEE SPRINGS	141	TSU	P	300	200	0.1	D
THORNE BAY	316	TB	M	950	1092	0.4	D
TOGIAK	507	AVEC	C	460	1021	0.3	D
TOK	589	AP&T	P	3525	7679	1.4	D
TOKSOOK BAY	357	AVEC	C	600	582	0.2	D
TUNUNAK	302	AVEC	C	300	438	0.1	D
UNALAKLEET	604	UVEC	C	1890	3211	0.6	D
UNALASKA	1922	UE	M	3860	3150	0.7	D
VALDEZ	3698	CVEA, APASG	C,S	22004	36169	--	D,GT,H
WAINWRIGHT	436	NSBPL	C	1060	1528	0.5	D
WALES	129	AVEC	C	155	212	0.1	D
TOTAL POP:	105144						

POWER UTILITY: SEE ATTACHED SHEET FOR UTILITY ABBREVIATIONS.

TYPE: P-PRIVATE, M-MUNICIPAL, C-COOPERATIVE, S-STATE, F-FEDERAL

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TYPE GEN: D-DIESEL, H-HYDRO, GT-GAS TURBINE

POWER SURVEY

COMMUNITY	POPULATION	TYPE	INSTALLED CAP (KW)	OUTPUT MWH/YR	PEAK (MW)	TYPE GEN
1	188		90	240		
2	562	C	900	1133	0.2	D
3	--	C	6000	59	4.8	D,GT
4	3683	P	9400	24500	4.3	D
5	60	P	2640	1000	0.2	D
6	3000	C	10803	17156	3.9	D
7	604	P	1750	4449	0.7	D
8	64	P	6200	16539	3.5	D,GT
9	148	P	75	200	0.1	D
10	511	C	7642	14530	3.4	D
11	866	C	1220	2285	0.5	D
12	412	P	740	1300	0.3	D
13	22030	F,P	122482	248509	48.5	D,H,GT
14	679	C	1430	2010	0.5	D
15	433	C	1300	1592	0.4	D
16	5873	C,S	48775	65000	12.7	D,H
17	498	P	1200	2078	0.6	D
18	318	C	6700	12000	3.3	D
19	3430	M	6700	20595	4	D
20	176	C	320	1.6	--	D
21	185	P	1025	2802	0.8	H,D
22	1839	M	4000	2000	--	D
23	790	P	3750	4706	1	H,D
24	486	P	800	1670	0.5	D
25	316	M	950	1092	0.4	D
26	589	P	3525	7679	1.4	D
27	1922	M	3860	3150	0.7	D
28	462	P	2320	4182	0.9	D

TYPE: P-PRIVATE, M-MUNICIPAL, C-COOPERATIVE, S-STATE, F-FEDERAL

TYPE GEN: D-DIESEL, H-HYDRO, GT-GAS TURBINE

POWER SURVEY

COMMUNITY	GENERATOR VOLTAGES	TRANSMISSION VOLTAGES (KV)	OUTAGES /YR	AVG MIN OUT	HRS OUT /YR	STDBY ONLY?
1	480	0.120/0.240	3	40	2	0
2	240/480	7.2/12.47	0	0	0	0
3	4160	69/12.5	3	20	6	1
4	2400	7.2/2.4	5	15	2	0
5	2400	2.4	1	20	0	0
6	2400/12470	12.47/2.4	16	15	4	0
7	2400	2.4	20	15	20	0
8	480/4160	4.16/12.47	4	15	1	0
9	480	7.2/12.47	5	15	1	0
10	2400/4160	138/14.4	8	20	3	0
11	2400/4160	7.2/12.47	17	60	17	0
12	2400	2.4	20	30	10	0
13	2400/4160	69	1	20	1	0
14	2400	7.2/12.47	18	40	12	0
15	2400/4160	7.2/12.47	19	91	30	0
16	4160	138/69	0	0	3	0
17	2400	2.4	8	3	1	0
18	440/2400	14.4/7.2	1	15	0	0
19	2400/4160	--	0	0	0	0
20	2400	2.4	1	30	24	0
21	480	2.4	28	15	7	0
22	2300/4160	115/69/24.9	27	40	20	1
23	2400	2.4	20	30	20	0
24	2400	2.4	9	10	6	0
25	480	0.480/2.4	2	2	0	0
26	2400	12.47/7.2/2.4	20	45	20	0
27	480/4160	34.5/12.47/4.16	4	2	0	0
28	2024	2.4/4.16	6	60	6	0

3. MUN-INV

The municipality/borough inventory file on page 12 represents the result of sending 25 letters to municipalities and boroughs. Responses are shown from the North Slope Borough, City/Borough of Juneau, City of Palmer and the City of Valdez. The quantity and estimated value of several categories of electrical and electronic equipment owned by those entities are shown if known. The categories are: computers, office equipment, motors (industrial), motors (appliance), communications equipment, audio/visual equipment and miscellaneous electronic equipment.

4. MO-ST-BL

This file, shown on page 13, provides an inventory of motors, categorized by size, in state-built buildings in the Northern Region. This information was taken from DOT&PF as-built blueprints. This inventory is further separated into non-school and school facilities with any overlap with the school district survey eliminated. Twenty-five communities are represented.

5. VIL-MO

The village water/sewer motor survey results are shown in this file, appearing on page 14. Forty-five responses were received out of 129 survey forms mailed. A copy of the survey form appears on page 25. Motors are categorized according to size and the number repaired per year and the associated repair costs are given if known.

MUNICIPAL/BOROUGH INVENTORIES

		NORTH SLOPE BOROUGH	CITY/ BOROUGH JUNEAU	CITY OF PALMER	CITY OF VALDEZ	TOTALS
COMPUTERS	NUMBER	365	197	6	28	596
	VALUE	$1,151,266	$465,119	--	$116,525	$1,732,910
OFFICE EQUIPMENT	NUMBER	499	--	14	77	590
	VALUE	$911,785	--	--	$147,079	$1,058,864
MOTORS (INDUSTRIAL)	NUMBER	178	--	6	53	237
	VALUE	$589,525	--	--	$139,136	$728,661
MOTORS (APPLIANCE)	NUMBER	128	--	1	64	193
	VALUE	$304,688	--	--	$57,494	$362,182
COMMUNICATIONS EQUIPMENT	NUMBER	112	--	--	21	133
	VALUE	$210,458	--	--	$54,274	$264,732
AUDIO/VIDEO EQUIPMENT	NUMBER	333	--	--	113	446
	VALUE	$499,972	--	--	$96,618	$596,590
MISCELLANEOUS ELECTRONIC	NUMBER	266	--	1	10	277
	VALUE	$822,924	--	--	$5,675	$828,599
TOTALS		1881	197	28	366	2472
		$4,490,618	$465,119	--	$616,801	$5,572,538

MOTORS IN NORTHERN REGION STATE-BUILT BUILDINGS (NONSCHOOL)

COMMUNITY	0.00- 0.99	1.00- 4.99	5.00- 19.99	20.00- -->	UNKNOWN SIZE	TOTALS
CHUGIAK	2	0	1	0	0	3
DELTA JUNCTION	2	0	0	0	6	8
EAGLE	2	0	0	0	2	4
FORT YUKON	7	2	1	1	2	13
HEALY	6	2	0	0	0	8
KAKTOVIK	1	2	1	0	0	4
KOTZEBUE	57	10	2	0	2	71
NOME	46	9	6	0	3	64
NOORVIK	0	0	0	0	4	4
SELAWIK	3	1	0	0	0	4
TELLER	6	3	0	0	1	10
TOK	18	2	0	0	0	20
VALDEZ	10	24	13	1	0	48
WAINWRIGHT	3	2	0	0	0	5
TOTALS	163	57	24	2	20	266

MOTORS IN NORTHERN REGION STATE-BUILT BUILDINGS (SCHOOL)*

COMMUNITY	0.00- 0.99	1.00- 4.99	5.00- 19.99	20.00- -->	UNKNOWN SIZE	TOTAL
DELTA JUNCTION	14	4	2	0	2	22
DOT LAKE	3	0	0	0	0	3
HOLY CROSS	2	2	0	0	0	4
KAKTOVIK	29	17	0	0	0	46
KALTAG	24	6	0	0	2	32
LIME VILLAGE	6	0	0	0	4	10
McGRATH	6	0	0	0	0	6
MENTASTA LAKE	3	4	0	0	0	7
MINTO	20	1	0	0	0	21
NORTHWAY	20	2	1	0	3	26
NULATO	36	10	1	0	0	47
TANANA	10	8	2	0	0	20
TELIDA	7	0	0	0	2	9
WAINWRIGHT	18	1	0	0	0	19
TOTALS	198	55	6	0	13	272

* NO OVERLAP WITH SCHOOL DISTRICT SURVEYS

VILLAGE WATER/SEWER MOTORS & REPAIRS/YR

		MOTOR SIZE (HP)						
		0.00-	1.00-	5.00-	20.00-		NUMBER	
POP.	COMMUNITY	0.99	4.99	19.99	-->	TOTAL	REPAIRED	COST
232	ALEKNAGIK	0	1	0	0	1	0	$0
216	ALLAKAKET	4	2	1	0	7	6	--
250	ANAKTUVUK PASS	0	0	0	0	0	0	$0
351	ANIAK	99	10	0	0	109	0	$0
200	ATMAUTLUAK	2	3	0	0	5	0	$0
80	BEAVER	0	7	0	0	7	3	$747
147	BREVIG MISSION	13	3	0	0	16	0	$0
178	CHIGNIK	0	6	0	0	6	0	$0
81	DOT LAKE	15	0	0	0	15	4	--
111	EKWOK	0	25	0	0	25	0	$0
225	ELIM	2	1	3	0	6	0	$0
181	GRAYLING	0	2	12	0	14	4	--
285	HOLY CROSS	3	7	2	0	12	7	$10,080
440	HOUSTON	0	0	0	0	0	0	$0
85	HUGHES	--	--	--	--	7	0	$0
412	HYDABURG	0	0	2	0	2	2	$2,000
214	KAKTOVIK	0	2	0	0	2	0	$0
70	KASAAN	0	0	0	0	0	0	$0
364	KIANA	0	4	2	0	6	1	--
253	KIVALINA	4	1	0	0	5	0	$0
260	KONGIGANAK	0	0	4	0	4	0	$0
2,470	KOTZEBUE	10	14	23	2	49	10	$8,815
124	KOYUKUK	0	0	2	0	2	0	$0
42	KUPREANOF	0	0	0	0	0	0	$0
467	KWETHLUK	0	2	0	0	2	0	$0
1,120	METLAKATLA	1	0	0	1	2	0	$0
601	MOUNTAIN VILLAG	1	5	6	0	12	0	$0
503	NENANA	1	8	5	0	14	0	$0
337	NEW STUYAHOK	1	5	2	0	8	0	$0
58	PLATINUM	--	--	--	--	1	2	$375
427	QUINHAGAK	0	4	0	0	4	4	$1,754
220	RUBY	0	1	0	0	1	0	$0
567	SAINT PAUL	0	2	0	0	2	1	$640
251	SCAMMON BAY	0	4	2	0	6	3	--
143	SHELDON POINT	0	6	0	0	6	1	--
214	SHUNGNAK	0	6	0	0	6	3	--
790	SKAGWAY	0	0	2	3	5	1	$1,700
48	TAKOTNA	2	4	0	0	6	2	$600
35	TELIDA	0	0	0	0	0	0	$0
141	TENAKEE SPRINGS	0	0	0	0	0	0	$0
507	TOGIAK	0	11	11	0	22	1	--
604	UNALAKLEET	10	10	10	0	30	1	$350
2,184	WASILLA	1	0	7	1	9	1	$1,500
115	WHITE MOUNTAIN	0	0	0	0	0	0	$0
292	WHITTIER	0	0	0	9	9	0	$0
16,895	TOTALS	169	156	96	16	445	57	$28,561

6. SCH-DIST

The school district inventory/repairs file on pages 16 and 17 gives results of sending the questionnaire shown on page 26 to 53 school districts. Thirty-three responded. Inventory and repairs per three year period are categorized under the headings: computers, office equipment, motors (industrial), communications equipment, audio/video equipment and miscellaneous electronic equipment.

7. ST-TV

This file, shown on pages 18, 19 and 20, provides data obtained from state TV transmitter/receiver (TX/RX) repair reports over the time interval between March 1983 and June 1985. Two hundred communities are represented. Repair reports are tabulated by community, as are the number of repairs definitely attributable to AC power problems and the number of TX/RX replaced.

Estimated cost multipliers are $220 (per repair report due to AC power problems) and $160 (per other repair reports). Cost multipliers were determined by examining DOT&PF communications repair shop records from July 1979 to July 1985 and calculating average repair time for each of the above categories and assuming $40/hr labor cost. Travel and per diem costs have not been included in these cost multipliers because faulty TV TX/RX have usually been shipped to a state electronics maintenance shop for repair. If travel to remote Alaskan communities is necessary for system maintenance or repair, travel and per diem costs may be as high as $1,000 per day if aircraft charters are included. Repair personnel estimated that 50% of the problems requiring replacement of a TX/RX unit (and its subsequent repair) are caused by poor AC power quality. This is in addition to the number due to AC specified in the second column. Thus, for example, Perryville required six TX/RX units replaced between March 1983 and June 1985, plus another repair due to AC power problems. Three of the six TX/RX units requiring replacement were estimated to be damaged by poor AC power quality. Each transmitter/receiver is estimated to cost $4,200.

SCHOOL DISTRICT INVENTORY/REPAIRS

SCHOOL DISTRICT	COMPUTERS NUMBER	COMPUTERS REPAIRS /3YR	OFFICE EQUIP NUMBER	OFFICE EQUIP REPAIRS /3 YR	MOTORS (INDUS) NUMBER	MOTORS (INDUS) REPAIRS /3 YR
ADAK REGION SCHOOLS	60	7	7	7	145	10
ANNETTE ISLAND SCHOOLS	52	17	6	6	100	18
BERING STRAIT SCHOOLS	65	0	25	0	400	50
CORDOVA CITY SCHOOLS	31	6	6	6	20	9
CRAIG CITY SCHOOLS	16	0	4	0	57	0
GALENA CITY SCHOOLS	14	0	3	2	127	12
HOONAH CITY SCHOOLS	26	0	2	0	5	2
HYDABURG CITY SCHOOLS	14	0	2	2	79	6
KENAI PENINSULA SCHOOLS	527	0	105	36	2380	140
KING COVE CITY SCHOOLS	21	1	2	2	--	--
KLAWOCK CITY SCHOOLS	45	20	6	6	20	6
KODIAK ISLAND SCHOOLS	95	18	14	4	613	82
KUSPUK SCHOOLS	90	10	25	3	400	45
LAKE AND PENINSULA SCHOOLS	40	6	18	3	300	13
LOWER KUSKOKWIM SCHOOLS	--	130	--	50	--	152
LOWER YUKON SCHOOLS	147	51	19	6	220	65
MATANUSKA-SUSITNA SCHOOLS	525	465	96	7500	2750	150
NOME CITY SCHOOLS	94	10	5	0	311	55
NORTHWEST ARCTIC SCHOOLS	255	11	25	25	525	225
RAILBELT SCHOOLS	52	4	8	8	115	10
SAINT MARYS SCHOOLS	28	5	4	10	85	15
SAND POINT SCHOOLS	7	3	9	2	122	7
SKAGWAY SCHOOLS	21	3	1	1	5	2
SOUTHEAST ISLAND SCHOOLS	138	0	74	0	--	--
TANANA CITY SCHOOLS	17	0	2	6	90	35
UNALASKA CITY SCHOOLS	18	3	3	3	23	9
WRANGELL CITY SCHOOLS	75	28	8	2	317	12
YAKUTAT CITY SCHOOLS	32	0	3	0	--	--
YUKON FLATS SCHOOLS	30	7	17	17	--	--
TOTALS	2535	805	499	7707	9209	1130

NOTE: COMMUNITY WITHIN EACH SCHOOL DISTRICT IS OBVIOUS EXCEPT FOR THE FOLLOWING DISTRICTS.

ANNETTE ISLAND: METLAKATLA

BERING STRAIT: UNALAKLEET, ELIM, ST. MICHAEL, BREVIG MISSION, DIOMEDE, GAMBELL, GOLOVIN, TELLER, KOYUK, SAVOONGA, SHAKTOOLIK, SHISHMAREF, STEBBINS, WALES, WHITE MOUNTAIN.

KENAI PENINSULA: SOLDOTNA, TYONEK, ANCHOR POINT, COOPER LANDING, ENGLISH BAY, HOMER, HOPE, KENAI, MOOSE PASS, NIKISHKA,NINILCHIK, PORT GRAHAM, SEWARD, STERLING, SELDOVIA, KASILOF.

KUSPUK: ANIAK, CHAUTHBALUK, CROOKED CREEK, UPPER KALSKAG, STONY RIVER, SLEETMUTE, LOWER KALSKAG, RED DEVIL.

LAKE & PENINSULA: KING SALMON, CHIGNIK BAY, CHIGNIK LAGOON, CHIGNIK LAKE, EGEGIK, IGIUGIG, IVANOF BAY, KOKHANOK, ILLIAMNA, NONDALTON, PEDRO BAY, PERRYVILLE, PILOT POINT, PORT ALSWORTH, PORT HEIDEN.

SCHOOL DISTRICT INVENTORY/REPAIRS (Continued)

SCHOOL DISTRICT	COMM EQUIP		AUDIO/VIDEO		MISC ELEC	
	NUMBER	REPAIRS /3 YR	NUMBER	REPAIRS /3 YR	NUMBER	REPAIRS /3 YR
ADAK REGION SCHOOLS	33	4	15	3	--	--
ANNETTE ISLAND SCHOOLS	3	0	30	8	--	--
BERING STRAIT SCHOOLS	35	0	60	0	200	10
CORDOVA CITY SCHOOLS	2	2	16	3	--	--
CRAIG CITY SCHOOLS	13	0	21	0	--	--
GALENA CITY SCHOOLS	8	10	8	2	--	--
HOONAH CITY SCHOOLS	6	0	22	0	--	--
HYDABURG CITY SCHOOLS	1	1	10	1	--	--
KENAI PENINSULA SCHOOLS	52	0	142	0	--	--
KING COVE CITY SCHOOLS	7	1	9	2	--	--
KLAWOCK CITY SCHOOLS	13	1	9	1	--	--
KODIAK ISLAND SCHOOLS	387	30	141	34	3	6
KUSPUK SCHOOLS	44	0	18	3	--	--
LAKE AND PENINSULA SCHOOLS	15	0	125	4	--	--
LOWER KUSKOKWIM SCHOOLS	25	10	--	60	--	10
LOWER YUKON SCHOOLS	12	12	171	60	--	--
MATANUSKA-SUSITNA SCHOOLS	125	84	650	310	54	700
NOME CITY SCHOOLS	3	0	18	0	--	--
NORTHWEST ARCTIC SCHOOLS	15	2	60	11	--	--
RAILBELT SCHOOLS	31	2	18	3	--	--
SAINT MARYS SCHOOLS	2	0	30	8	--	--
SAND POINT SCHOOLS	8	2	26	9	--	--
SKAGWAY SCHOOLS	3	0	3	0	--	--
SOUTHEAST ISLAND SCHOOLS	--	--	116	0	--	--
TANANA CITY SCHOOLS	5	3	24	0	--	--
UNALASKA CITY SCHOOLS	13	2	8	0	--	--
WRANGELL CITY SCHOOLS	63	1	44	5	--	--
YAKUTAT CITY SCHOOLS	11	0	9	0	--	--
YUKON FLATS SCHOOLS	2	2	30	9	--	--
TOTALS	937	169	1833	536	257	726

LOWER KUSKOKWIM: BETHEL, KASIGLUK, NUNAPITCHUK, PLATINUM, NEWTOK, CHEFORNAK, EEK, ATMAUTLUAK, KIPNUK, KONGIGANAK, KWETHLUK, KWIGILLINGOK, TUNTUTULIAK, NAPAKIAK, TOKSOOK BAY, MEKORYUK, OSCARVILLE, TUNUNAK, QUINHAGAK, GOODNEWS BAY, NAPASKIAK, NIGHTMUTE.

LOWER YUKON: MOUNTAIN VILLAGE, ALAKANAK, EMMONAK, HOOPER BAY, KOTLIK, MARSHALL, PILOT STATION, PITKAS, POINT, RUSSIAN MISSION, SCAMMON BAY, SHELDON POINT.

MAT-SU: PALMER, TALKEETNA, TRAPPER CREEK, WASILLA, WILLOW.

NW ARCTIC: KOTZEBUE, AMBLER, BUCKLAND, DEERING KIANA, KOBUK, KIVALINA, NOATAK, NOORVIK, SELAWIK, SHUNGNAK.

RAILBELT: HEALY, ANDERSON, CLEAR, CANTWELL.

S.E. ISLAND: KETCHIKAN, EDNA BAY, PETERSBURG, HOLLIS, KASAAN, MEYERS CHUCK, PORT ALEXANDER, SITKA, THORNE BAY.

YUKON FLATS: FORT YUKON, ARCTIC VILLAGE, BEAVER, CENTRAL, CHALKYITSIK, CIRCLE, RAMPART, STEVENS VILLAGE, VENETIE.

STATE TV TX/RX REPAIRS 3/83-6/85

COMMUNITY	# REPAIR REPORTS	# DUE TO AC	# TX/RX REPLACED	ESTIMATED % REPAIRS DUE TO AC
ADAK	2	0	1	25
AKHIOK	2	1	1	75
AKUTAN	3	0	1	17
ALAKANUK	4	1	1	38
ALLAKAKET	5	0	4	40
AMBLER	3	0	1	17
ANAKTUVUK PASS	2	1	0	50
ANCHOR POINT	3	0	0	0
ANGOON	5	2	3	70
ANIAK	2	1	0	50
ANVIK	1	0	1	50
ARCTIC VILLAGE	3	1	1	50
ATKA	5	0	0	0
ATKASUK	2	0	0	0
BARROW	9	0	4	22
BEAVER	4	0	0	0
BETTLES	5	0	0	0
BIRD CREEK	7	3	3	64
BUCKLAND	3	1	1	50
CAMPBELL	1	0	1	50
CANTWELL	3	2	0	67
CAPE POLE	2	0	2	50
CENTRAL	2	0	2	50
CHALKYITSIK	2	1	0	50
CHEFORNAK	1	0	0	0
CHEVAK	6	1	2	33
CHIGNIK	1	0	1	50
CHIGNIK LAGOON	2	0	0	0
CHIGNIK LAKE	2	0	0	0
CHITINA	6	5	2	100
CHUATHBALUK	4	0	1	13
COLD BAY	2	0	1	25
COOPER LANDING	2	2	0	100
CORDOVA	7	1	2	29
CRAIG	3	0	2	33
CROOKED CREEK	1	0	0	0
DEERING	3	0	3	50
DELTA JUNCTION	4	2	1	63
DENALI PARK	4	0	1	13
DIOMEDE	4	3	1	88
DOT LAKE	1	1	0	100
DUTCH HARBOR	1	0	0	0
EAGLE	18	1	6	22
EEK	5	1	2	40
EGEGIK	1	0	0	0
EIGHT FATHOMS	1	0	1	50
ELIM	2	0	1	25
EMMONAK	10	4	3	55
ENGLISH BAY	1	0	1	50
ERNESTINE	3	0	2	33

COMMUNITY	# REPAIR REPORTS	# DUE TO AC	# TX/RX REPLACED	ESTIMATED % REPAIRS DUE TO AC
FALSE PASS	2	0	0	0
GALENA	1	0	0	0
GAMBELL	4	0	3	38
GIRDWOOD	10	0	4	20
GOLOVIN	7	1	6	57
GOODNEWS BAY	6	0	3	25
GRAVINA ISLAND	2	0	0	0
HAINES	4	0	2	25
HALIBUT COVE	1	0	0	0
HEALY	3	1	1	50
HOBART BAY	3	1	2	67
HOLY CROSS	7	2	3	50
HOMER	11	2	4	36
HOONAH	3	0	1	17
HOOPER BAY	3	1	2	67
HUGHES	5	1	4	60
HUSLIA	8	0	4	25
HYDABURG	9	2	2	33
HYDER	4	1	1	38
ILIAMNA	1	0	1	50
INDIAN	3	0	3	50
KAKE	7	0	0	0
KALTAG	1	0	1	50
KARLUK	1	0	1	50
KASAAN	6	2	2	50
KASIGLUK	6	2	2	50
KENAI	2	0	0	0
KETCHIKAN	3	0	1	17
KIANA	5	1	2	40
KING COVE	3	0	2	33
KING SALMON	1	0	0	0
KIPNUK	2	0	0	0
KIVALINA	3	0	3	50
KLAKANUK	1	0	0	0
KLUKWAN	3	0	1	17
KODIAK	6	2	1	42
KOLIGANEK	2	0	2	50
KONGIGANAK	2	0	1	25
KOTZEBUE	1	0	0	0
KOYUK	4	1	2	50
KWETHLUK	3	1	1	50
KWIGILLINGOK	1	0	1	50
LARSEN BAY	2	0	2	50
LEVELOCK	4	0	1	13
LOWER KALSKAG	2	0	0	0
MANLEY HOT SPR	2	0	0	0
MANOKOTAK	1	0	0	0
MARSHALL	4	0	2	25
McGRATH	5	0	4	40
MEKORYUK	7	0	6	43

STATE TV TX/RX REPAIRS 3/83-6/85 (Continued)

COMMUNITY	# REPAIR REPORTS	# DUE TO AC	# TX/RX REPLACED	ESTIMATED % REPAIRS DUE TO AC	COMMUNITY	# REPAIR REPORTS	# DUE TO AC	# TX/RX REPLACED	ESTIMATED % REPAIRS DUE TO AC
MENTASTA LAKE	2	1	0	50	SAND POINT	2	0	1	25
METLAKATLA	1	0	0	0	SCAMMON BAY	1	0	1	50
MINTO	8	1	3	31	SELAWIK	7	1	2	29
MOUNTAIN VILL	6	2	3	58	SELDOVIA	5	1	2	40
NAKNEK	3	0	1	17	SEWARD	1	1	0	100
NAPASKIAK	4	2	1	63	SHAGELUK	2	1	2	100
NELSON LAGOON	7	0	4	29	SHISHMAREF	4	2	3	88
NENANA	2	1	1	75	SHUNGNAK	4	0	2	25
NEW STUYAHOK	5	2	3	70	SITKA	3	0	0	0
NEWTOK	1	0	1	50	SKAGWAY	1	0	1	50
NIGHTMUTE	4	1	0	25	SKIN HILL	1	0	0	0
NIKOLAI	2	0	2	50	SLANA	1	1	0	100
NIKOLSKI	1	0	1	50	SLEETMUTE	1	0	1	50
NINILCHIK	2	0	0	0	SOLDOTNA	5	0	0	0
NOATAK	8	0	6	38	SOUTH NAKNEK	1	0	0	0
NOME	2	0	0	0	SPARREVOHN	1	0	1	50
NONDALTON	1	1	0	100	STEBBINS	1	0	1	50
NOORVIK	3	1	1	50	STEVENS VILL	1	0	1	50
NORTHWAY	6	0	1	83	STONEY RIVER	4	0	3	38
NULATO	7	1	3	36	SUTTON	1	0	0	0
OLD HARBOR	6	0	6	50	TAKOTNA	2	0	1	25
PAXSON	2	0	0	0	TALKEETNA	1	0	0	0
PEDRO BAY	3	1	2	67	TANANA	2	0	1	25
PELICAN	2	0	1	25	TATITLEK	1	0	1	50
PERRYVILLE	7	1	6	57	TELIDA	7	1	2	29
PETERSBURG	2	0	0	0	TELLER	7	1	5	50
PILOT POINT	6	2	0	33	TENAKEE SPRG	2	0	0	0
PILOT STATION	2	0	2	50	TETLIN	1	0	1	50
PITKAS POINT	7	0	4	29	THORNE BAY	2	1	1	75
PLATINUM	3	2	1	83	TOGIAK	3	0	0	0
POINT BAKER	2	1	0	50	TOK	2	1	0	50
POINT CAMPBEL	1	0	0	0	TOKSOOK BAY	4	1	2	50
POINT HOPE	2	0	1	25	TOLSONA	4	0	0	0
POINT LAY	1	0	1	50	TRAPPERS CRK	2	0	0	0
PORT ALICE	3	0	2	33	TULUKSAK	2	1	1	75
PORT ALSWORTH	9	2	5	50	TUNTUTULIAK	3	1	0	33
PORT GRAHAM	6	0	2	17	TUNUNAK	3	2	0	67
PORT HEIDEN	2	0	2	50	UNALASKA	1	0	0	0
PORT LIONS	3	0	1	17	VALDEZ	2	1	1	75
PORT MOLLER	2	0	1	25	VENETIE	3	0	2	33
PORT PROTECT	1	0	0	0	WAINWRIGHT	5	0	0	0
QUINHAGAK	6	1	2	33	WALES	8	1	4	38
QUZINKIE	1	1	0	100	WASILLA	2	0	2	50
RAMPART	4	1	1	38	WHALES PASS	3	1	1	50
RED DEVIL	1	0	1	50	WHITE MNTN	4	0	2	25
RUBY	4	0	2	25	WHITESTONE C	1	0	0	0
RUSSIAN MISSI	2	1	0	50	WHITTIER	5	0	0	0
SAINT GEORGE	3	0	1	17	WOMANS BAY	3	0	3	50
SAINT MICHAEL	2	0	1	25	WRANGELL	7	0	1	7
SAINT PAUL	5	0	2	20	YAKUTAT	1	0	0	0
					TOTALS	677	101	274	

STATE TV TX/RX REPAIRS 3/83-6/85

ESTIMATED COST MULTIPLIER (PER REPAIR REPORT)

DUE TO AC QUALITY: $220

OTHER REPORTS: $160

THE MULTIPLIER WAS DETERMINED IN THE FOLLOWING MANNER. REPAIR CARDS FROM THE DOTPF COMMUNICATIONS REPAIR SHOP IN FAIRBANKS FOR THE PERIOD 7/79 - 7/85 WERE EXAMINED. THE TOTAL NUMBER OF REPAIRS AND REPAIR HOURS FOR BOTH AC RELATED PROBLEMS AND OTHER PROBLEMS WAS TABULATED. AN AVERAGE REPAIR TIME FOR BOTH CATEGORIES WAS DETERMINED. THIS TIME WAS THEN MULTIPLIED BY $40/HR (ESTIMATED LABOR COST) TO DETERMINE A FINAL COST PER REPAIR. THESE ESTIMATES, THEREFORE, DO NOT INCLUDE TRAVEL OR PER DIEM COSTS.

IT IS ESTIMATED THAT HALF OF THE PROBLEMS MAKING IT NECESSARY TO REMOVE A TRANSMITTER AND SEND IT IN FOR REPAIRS ARE CAUSED BY POOR AC POWER QUALITY. THIS NUMBER IS IN ADDITION TO THE # DUE TO AC SPECIFIED IN THE DATA.

ESTIMATED COST OF EACH TRANSMITTER IS $4,300

8. ALASCOM

Alascom earth station repair reports are compiled in this file, shown on page 22. Thirty-nine communities are represented. The total number of repairs per community is given as well as the number of repairs attributable to AC power problems. Repair costs in wages and travel considered due to poor AC power quality is also shown.

Alascom has approximately 180 earth stations in Alaska. The estimated cost of equipment in each earth station subject to AC power quality problems is $150,000. This represents a total investment of $27 million at risk for Alascom earth stations alone.

ALASCOM EARTH STATION REPAIR REPORTS

COMMUNITY	TIME PERIOD	# OF REPORTS	# DUE TO AC	COST WAGES	COST TRAVEL	TOTAL COST
				COST DUE TO POOR AC ONLY		
ALLAKAKET	1/82-5/85	37	8	$2,295	$6,394	$8,689
AMBLER	1/83-6/85	33	11	$2,620	$7,803	$10,423
ATKASUK	1/83-6/85	35	6	$1,550	$2,191	$3,741
BEAVER	2/83-6/85	27	6	$555	$1,601	$2,156
BIRCH CREEK	10/83-5/85	11	0	$0	$0	$0
BUCKLAND	1/83-5/85	30	1	$160	$450	$610
CENTRAL	3/83-5/85	49	11	$1,905	$4,756	$6,661
CHALKYITSIK	5/83-5/85	23	3	$567	$2,195	$2,762
CIRCLE	3/83-6/85	38	5	$0	$0	$0
COUNCIL	1/83-6/85	19	0	$0	$0	$0
DEERING	1/83-5/85	35	8	$1,570	$4,164	$5,734
GAMBELL	1/83-4/85	33	3	$1,320	$3,765	$5,085
GOLOVIN	1/83-6/85	71	8	$1,443	$3,915	$5,358
HUGHES	2/83-6/85	42	8	$1,327	$4,195	$5,522
HUSLIA	1/83-7/85	52	6	$677	$1,771	$2,448
KALTAG	1/83-5/85	31	6	$1,237	$2,567	$3,804
KIANA	1/83-6/85	30	0	$0	$0	$0
KIVALINA	1/83-4/85	22	3	$460	$1,215	$1,675
KOBUK	1/83-6/85	25	4	$627	$2,004	$2,631
KOYUK	1/83-3/85	31	2	$260	$915	$1,175
KOYUKUK	1/83-6/85	31	2	$153	$463	$616
MANLEY HOT SPRINGS	2/83-7/85	32	0	$0	$0	$0
MENTASTA LAKE	11/84-6/85	4	1	$213	$717	$930
NOATAK	1/83-7/85	39	11	$2,246	$4,677	$6,923
NOORVIK	1/83-6/85	33	11	$1,457	$4,063	$5,520
NULATO	1/83-5/85	41	12	$973	$1,512	$2,485
POINT HOPE	1/83-2/85	29	8	$1,280	$4,148	$5,428
POINT LAY	1/83-7/85	35	3	$0	$0	$0
RAMPART	5/83-6/85	29	2	$0	$0	$0
SAINT MICHAEL	1/83-6/85	28	5	$260	$670	$930
SAVOONGA	1/83-5/85	30	5	$0	$0	$0
SELAWIK	1/83-7/85	37	8	$974	$2,992	$3,966
SHAKTOOLIK	11/83-6/85	27	6	$1,417	$4,412	$5,829
SHUNGNAK	1/83-7/85	25	1	$130	$545	$675
STEBBINS	1/83-4/85	23	2	$180	$690	$870
TANANA	1/83-6/85	82	10	$1,323	$3,727	$5,050
UNALAKLEET	2/83-7/85	105	11	$3,237	$8,250	$11,487
VENETIE	2/83-6/85	25	4	$637	$2,434	$3,071
WHITE MOUNTAIN	2/83-5/85	34	5	$920	$2,955	$3,875
TOTALS		1363	206	$33,973	$92,156	$126,129

NOTE: ALL OF THE ABOVE COMMUNITIES HAVE A SMALL ALASCOM EARTH STATION. THE ESTIMATED COST OF EQUIPMENT SUBJECT TO POOR POWER QUALITY, PER STATION, IS $150,000. ALASCOM HAS APPROXIMATELY 180 SUCH EARTH STATIONS STATEWIDE.

DATA INFORMATION REQUEST FORMS

Six different survey forms were used as part of the data collecting effort for this project. They are: (1) electric utility survey form, shown on page 24. A utility survey form was sent to every electric utility listed with the Alaska Public Utilities Commission. Twenty-eight were returned, with results appearing on pages 9 and 10 of this report. (2) Village electric motor survey form, shown on page 25. A motor survey form was sent to 129 villages. Forty-five villages responded, with results appearing on page 14 of this report. (3) School district survey form, shown on page 26. This form was sent to 53 school districts. Thirty-three responses were received, with results appearing on pages 16 and 17 of this report. (4) Electric motor inventory and failure survey form, shown on page 27. This was sent to Alaska Department of Transportation and Public Facilities road maintenance camps. The five responses were not included in this report. (5) and (6) Repair survey forms, shown on pages 28 and 29, were made available to 32 companies which make repairs to electronic equipment or motors. Three completed forms were received. These results were not included in this report.

ELECTRIC UTILITY SURVEY
RURAL ELECTRIC POWER QUALITY STUDY -- PHASE 2

Note: This survey will be used to help determine electric power quality within the state of Alaska. Any information you can supply is intended to be used for purposes of statistical analysis only. After it has been determined that information from each community has been entered into the database only once, the specific locations will be discarded and only community size will be stored with the power quality information. In this way the names of utilities supplying information will be isolated from specific power quality data.

Please complete this form for each independent electric power system operated by your company.

What community is serviced by this system?

________________________________ Population?____________

What is the total output of the system per year?____________kwh

By how much does the output frequency of the system deviate from 60 hz in the course of a normal day?

60 hz +/-__________%

What is end user voltage under usual loading conditions?

120 +/-__________V

What transmission line voltages are used throughout the system?

__________V & __________V

What is the output voltage of your generator(s)? ____________V

Rated generating capacity? ____________kw

How many power outages do your customers experience per year?

____

What is the average length of a power outage? __________min.

What is the total outage time per year? __________hrs.

If you have any additional power quality data for this system, we appreciate your including these data with this form.

Thank you for your help!

Ken Woodruff, UAF EE Dept., 124 Duckering Bld., Fairbanks, AK 99701

Message Phone 474-7137

VILLAGE ELECTRIC MOTOR SURVEY

Rural Electric Power Quality Study -- Phase 2

Name of Village ______________________________

How many electric motors are in use in the local water supply system?

____

What is/are the horsepower ratings of these pump motor(s)? (number of motors and horsepower: Example 3 motors @ 30 h.p., 1 motor @ 10 h.p.)

____

Does the sanitation system in this village include use of pumping stations? How many?

__________ __________

Please give number and size of the pump station motors. (number of motors and horsepower: Example 2 motors @ 10 h.p., 1 motor @ 10 h.p.)

____

Please give size and number of other motors, larger than 1/2 h.p., being used in your village.

____

____

How many of these motors (water system, sanitation system and other) were repaired or replaced during the past year?

____

What was the total cost of these repairs and/or replacement?

____

Please give the name of the person in charge of the village water and sewer systems.

Water: ______________________________

Sewer: ______________________________

Thank you for your help!

Ken Woodruff, UAF EE Dept., Fairbanks, AK 99701

Please indicate below the numbers of the various types of equipment used by your district, and the number which it has been necessary to replace or repair during the past three years.

Please Type or Print	Number In Use	Number Repaired/ Replaced
Computers/Word Processors (Educational) .	________	________
Computers/Word Processors (Administrative)	________	________
T.V. Monitors.	________	________
Video Cassette Recorders	________	________
Radios (Communication Sets)	________	________
Radios (AM, FM, SW).	________	________
Electric Motors	________	________
Relays/Motor Controls	________	________
Generation Units	________	________
Telephone/Intercom	________	________
Photocopy Machines	________	________
Other________________ . . .	________	________

Who is responsible for maintaining this equipment? If maintenance is done under contract, please state name, address and phone number of the contracting company.________________________

____

At which location does your school district experience the most frequent failures (requiring repair) of electric/electronic equipment?________________________________

____

What types of failures are occurring there?________________

____

Do any of the schools in your district generate their own electric power?__________At which locations?________________

____

Please give name, job title, and phone number of person completing this form.

Name________________________Title______________Phone____________

ELECTRIC MOTOR INVENTORY AND FAILURE SURVEY
RURAL ELECTRIC POWER QUALITY STUDY -- PHASE 2

Please indicate below the number of the various types of electric motors being used at this location, and the number which it has been necessary to repair or replace during the past year.

	Number In Use	Number Repaired	Number Replaced
Electric Motors Smaller Than One h.p.	________	________	________
Electric Motors Between One and Five h.p.	________	________	________
Electric Motors Larger Than Five h.p.	________	________	________

Do you experience any recurring problems with the quality of electric power at this location?________

What types of problems?

Undervoltage_____ Overvoltage_____ Underfrequency_____

Overfrequency_____ Voltage Spikes_____ Other________________

Do you suspect poor quality 120 V AC power as the cause of any failures of electric or electronic equipment used at this location?______ Please give list of failed (due to AC) equipment.

____

____

Please give a brief list of any electronic equipment in use at this location.

____

____

____

We are interested in your comments on AC power quality and related equipment failures. How big of a problem, in terms of equipment failure, is poor quality electric power? (Use back of form if additional space is needed.)

____

____

____

Thank you for your help!

Ken Woodruff, UAF EE DEpt., 124 Duckering Bld., Fairbanks, AK

REPAIR SURVEY FORM
RURAL ELECTRIC POWER QUALITY STUDY -- PHASE 2

Date of Failure______________ Date of Repair______________

Repairing Company____

Type of equipment being repaired: Typewriter_____ Computer_____
Cash Register_____ Photocopier_____ Adding Machine_____
Other____

Approximate age of equipment_________ yrs.

Location equipment was used______________________________________

Could this particular failure have been the result of poor quality 120 V power? (Voltage sags, surges, spikes, outages, etc)
Yes_____ Possibly_____ No_____ Impossible to Tell_____

Estimate cost of repair (to determine relative cost of poor quality electric power)__________

Repaired by________________________________

Thank you for your help!
Ken Woodruff, UAF EE Dept., 124 Duckering Bld., Fairbanks, AK 99775

REPAIR SURVEY FORM
RURAL ELECTRIC POWER QUALITY STUDY -- PHASE 2

Date of Failure______________ Date of Repair______________

Repairing Company____

Type of equipment being repaired: Typewriter_____ Computer_____
Cash Register_____ Photocopier_____ Adding Machine_____
Other____

Approximate age of equipment_________ yrs.

Location equipment was used______________________________________

Could this particular failure have been the result of poor quality 120 V power? (Voltage sags, surges, spikes, outages, etc)
Yes_____ Possibly_____ No_____ Impossible to Tell_____

Estimate cost of repair (to determine relative cost of poor quality electric power)__________

Repaired by________________________________

Thank you for your help!
Ken Woodruff, UAF EE Dept., 124 Duckering Bld., Fairbanks, AK 99775

REPAIR SURVEY FORM
RURAL ELECTRIC POWER QUALITY STUDY -- PHASE 2

Repairing Company____

Date of Failure______________ Date of Repair______________

Type of equipment being repaired:

Motor Control_____ AC Motor_____ Other___________________________

Approximate age of equipment_________

Approxivate value of equipent___________

Location equipment was used_______________________________________

Could this particular failure have been the result of poor quality 120 V power?
Yes_____ Possibly_____ No_____ Impossible to Tell_____

Type of Failure:
Starting Switch______ Starting Capacitor______

Starting Winding_____ Main Winding_____ Wound Rotor______

Cause of Failure:

Overloaded______ Over Voltage______ Under Voltage_______

Generation System:
Size [kw] (if known)______

Private______ Public______ Village Owned______

Estimate cost of repair (to determine relative cost of poor quality electric power)__________

Repaired by________________________________

Thank you for your help!

Ken Woodruff
Research Assistant
University of Alaska-Fairbanks
Electrical Engineering Dept.
Fairbanks, AK 99775

Message Phone: 474-7137

ELECTRIC POWER QUALITY IMPROVEMENT TECHNIQUES

Electric power supplied to sensitive loads such as computers, office equipment and consumer electronic items containing integrated circuit or other semiconductor components may need conditioning to improve its quality and reduce or eliminate the possibility of equipment malfunction or destruction due to power disturbances. However, electric motors, battery chargers and other seemingly robust electrical equipment and even insulation can be damaged or destroyed by improper voltage levels.

Types of power line disturbances and their characteristics have been already defined earlier in this report. Power conditioning equipment is manufactured that covers a wide range of both effectiveness and cost. A 1982 paper [4] provides a summary of power problem solving effectiveness of several power conditions based upon disturbance data reported in [3]. See Table 1.

TABLE 1. Power conditioner effectiveness in blocking power system disturbances as reported in [4].

Type of Conditioner	Effectiveness (%)
Voltage impulse suppressor	0.75
Regulator	8.25
Regulator with impulse suppressor	9
Shielded isolation	25
Isolation with impulse suppressor	25.75
Regulation, isolation and impulse suppressor	34
Motor alternator set	99.7
Uninterruptible power supply (UPS)	99.8
Magnetic synthesizer	99.6

Thus, a voltage impulse suppressor is able to isolate a load from less than 1% of the total power disturbances while an uninterruptible power supply (UPS) will satisfactorily block almost 99% but costs much more than the impulse suppressor.

Power system disturbance data reported in [3] were measured at 29 locations in the continental United States for 109 monitor-months. As summarized in [4], this study showed that approximately 49% of all disturbances were decaying oscillatory transients, about 40% were voltage impulses, about 11% were undervoltages (sags) and about 0.5% were outages. There were no overvoltages (surges) reported. By contrast, a similar study conducted in Alaska and reported in [1] and [2], found 41.4 times more impulses/month in isolated Alaskan power system even with the monitoring equipment set at a 67% higher threshold voltage. Also, the Alaskan data show approximately eight times more outages/month with approximately 11 times the average duration as those reported in the continental United States data. A direct comparison between actual numbers of sags and surges is not easily done, since worst-case data only are provided in the Alaskan study. However, overvoltages and surges were a problem in Alaska and significant frequency deviations were also noted, in contrast to the continental United States study. In both data sets, disturbances were strongly site dependent.

Reference [4] also compared nine different power conditioners in terms of installation and maintenance costs, operating efficiency, energy cost per year and total cost per year. A so-called performance cost index, determined by taking the ratio of % total effectiveness to % relative cost, was calculated for each conditioner. The results shown in Table 2 were based on 100 kVA output, continuous operation, $0.35 per kilowatt-hour cost of electric energy and five-year straight-line depreciation.

To give an Alaskan user more relevant data for smaller loads, 1986 price information for several types of power conditioners by a major manufacturer is provided in Table 3 (VA = volt-ampere, kVA = kilovolt-ampere, 1ϕ = single-phase).

CONCLUSIONS

These conclusions are based upon results of surveys previously presented in this report and on equipment inventories and repair reports. This project sought information in three broad areas to help assess actual costs of poor quality electric power in state owned and operated public facilities. These information areas are: (1) inventory of equipment at risk and sophistication levels of that equipment; (2)

TABLE 2. Power conditioning costs from reference [4].

	Spike suppressor	Regulator	Regulator with spike suppressor	Shielded isolation xfmr	Isolation xfmr with spike suppressor	Isolation xfmr with regulator and spike suppressor	Motor-alternator set	Uninter-ruptible power supply	Magnetic synthesizer
Installation cost	$3,000	$25,000	$26,000	$4,500	$6,000	$28,000	$40,000	$130,000	$25,000
Maintenance cost	---	1,000	1,100	100	100	1,000	1,000	8,000	100
Operating efficiency	---	96%	96%	97%	97%	93%	83%	85%	91%
Energy cost/year	---	12,780	12,780	9,489	9,489	23,090	62,840	54,140	30,340
Total cost per year	600	18,780	19,080	10,489	10,790	29,690	71,840	88,140	35,440
Total effectiveness	0.75%	8.25%	9%	25%	25.75%	34%	99.7%	99.8%	99.6%
Relative cost	1.7%	53%	54%	30%	30%	84%	203%	249%	100%
PCI*	44	16	17	83	86	40	49	40	100

Basis: 100 kVA output; Continuous (24 hr) operation; $0.35 per kWh cost of power; five-year straight-line depreciation.

* Performance-cost index (PCI) = $\frac{\text{\% total effectiveness}}{\text{\% relative cost}} \times 100$

TABLE 3. Small capacity power conditioner costs.

Power conditioner	Effectiveness	Power rating	Cost per kVA	Total cost
Impulse suppressor	voltage impulses and transients		\$60-\$500	\$60-500
isolation transformer with impulse (spike) suppressor	voltage impulses and transients	250 VA (1φ) 1 kVA (1φ) 10 kVA (1φ)	\$820 530 262	205 530 2,620
Voltage regulator	voltage fluctuations	1 kVA (1φ) 8 kVA (1φ)	\$595 325	595 2,600
Isolation transformer with regulator and impulse suppressor	voltage impulses and transients, voltage fluctuations	250 VA (1φ) 1 kVA (1φ)	\$1,720 655	430 655
Uninterruptible power system (UPS)	voltage impulses and transients, voltage fluctuations, power outages, frequency variations	500 VA (1φ) 65 minute battery backup	\$11,650	5,825
		1 kVA (1φ) 35 minute battery backup	6,290	6,290
		10 kVA (1φ) 20 minute battery backup	2,704	27,040

frequency of equipment repair or replacement; and (3) cost associated with equipment repair or replacement. In addition, part of the electric utility survey requested power quality information.

Twenty-eight utilities responded to the power survey. Results of this survey are shown on pages 9 and 10. Outages per year totaled 266 as reported by the 28 utilities for an average of 9.5 outages per year per reporting utility or 0.8 outages/month. The average reported outage duration per utility ranged from two minutes to approximately 90 minutes. These reported average outage durations were, in turn, averaged with the result being 23.9 minutes average outage duration. (The average of the AVG MIN OUT column on page 10.) However, the sum of products of (outages/yr) x (average min out) for all reporting utilities is 8,730 minutes (145.5 hours) of outages for 28 utilities per year. Since a total of 266 outages were reported by the 28 utilities, the average outage duration by this measure is (8,730 minutes)/(266 outages) = 32.8 minutes/outage. This is about 37% higher than the 23.9 minutes/outage value previously computed. Yet another value of average output duration may be determined by finding total hours out per year (sum of HRS OUT/YR column entries = 216) and dividing by number of outages (266). This results in 0.81 hours or 48.7 minutes per outage.

Total outage time per year reported on page 10 is 216 hours for 28 locations resulting in an average of 7.7 outage hours/location/year. However, if the above 8,730 total minutes of outages is used, it corresponds to 5.2 outage hours/location/year, which is 32% lower than the 7.7 hour figure.

The 0.8 outages per month at an average duration of between 24 and 49 minutes per outage may be compared with the earlier Alaskan study [1] in which an average of 4.9 outages per month with an average outage duration of 10.9 minutes was measured with disturbance analyzers at four separate power systems for a total of more than 1,000 days. As a further comparison, reference [3] reported 0.6 outage per month with a 1.0 minute mean outage time for large interconnected continental Unites States power systems. In any event, outages may be a significant factor in considering power conditioning equipment for Alaskan applications.

Estimating the cost of power outages can be complicated because some cost components can be obvious while others may be very subtle. In a rural Alaskan community, generation costs may average $0.50 per kilowatt-hour. Using this figure, every hour a 100 kW generator is out of service represents $50 in lost revenue. More subtle are societal costs ranging from inconvenience to life threatening situations. A home-owner's routine evening activities might be interrupted or an emergency medical procedure might be halted at a critical moment. If an outage is protracted, frozen perishables may be damaged by warming in nonoperating refrigerators or freezers. Alternatively, in cold weather, freezing may damage heating and plumbing systems.

Thus, long-term outages may be responsible for tens of thousands of dollars in losses. In the short term, perhaps a person-day could be consumed setting clocks and restarting/resetting other loads requiring manual attention. Recovery of lost data and files in computers experiencing outages could involve several person-days of effort. The cost of starting and operating emergency generators for essential services also must be considered.

Municipality/borough inventories are shown on page 12 for the North Slope Borough, the City/Borough of Juneau, the City of Palmer and the City of Valdez. These inventories show a total of $1.73 million in computers, $1.06 million in office equipment, $1.09 million in motors, $0.265 million in communications equipment, $0.597 million in audio/video equipment and $0.829 million in miscellaneous electronic equipment. Total inventory in these categories is $5.57 million. In all categories except computers the values shown are for only the North Slope Borough and the City of Valdez. No equipment values are shown for the City of Palmer. On a per capita basis, assuming North Slope Borough population to be 8,308 (most recent estimate for revenue sharing purposes) and the City of Valdez population to be 3,698 (page 8), values of equipment in all above categories is $541/person in the North Slope Borough and $167/person in the City of Valdez. It should be stressed that this includes municipal/borough equipment only and not private equipment.

The file shown on page 13 gives an inventory of motors in state facilities in 25 communities. Alaska Department of Transportation and Public Facilities as-built blueprints were the source of this information. There were 361 fractional horsepower (hp) motors, 112 motors in the 1 to 5 hp range, 30 motors in the 5 to 20 hp range and 2 motors greater than 20 hp. The ratings of 33 motors were unknown. Assuming fractional hp motors averaged $160 each, 1 to 5 hp motors averaged $400 each, 5 to 20 hp motors average $800 each, the motors larger than 20 hp cost $1,600 each and each motor with unknown rating cost $300, total motor value represented on page 13 is $139,700 or an average of $5,590 per community.

The file on page 14 presents results of a village water/sewer motor survey. Forty-five villages are represented, having responded to the questionnaire on page 25. Total number of motors in various size ranges are: 169 fractional hp motors, 156 motors in the 1 to 5 hp range, 96 motors in the 5 to 20 hp range and 16 motors larger than 20 hp. The total number of motors is 445. Using the same cost assumptions as in the previous paragraph yields a total motor value of $192,000 in the 45 villages. Fifty-seven motors are repaired annually at a reported cost of $28,561. Eight villages did not provide repair cost figures on 23 reported motor repairs. If average cost per repairs is (28,561)/(34) = $840, a more realistic annual repair cost is ($840)(57) = $47,900. Fifty-seven motors is 13% of the 445 total, and the adjusted annual cost of repairs is approximately 25% of the estimated total motor value. The fraction of motor repair cost attributable to poor AC electric power quality is estimated to be 20% of the total repair cost because of the repair experience from state TV transmitters/receivers and Alascom repair records.

Fifty-three school districts were sent a copy of the questionnaire shown on page 26. Thirty-three responses were received, with 29 providing data shown on pages 16 and 17. The 29 school districts encompass 144 communities. Six separate categories of electrical and electronic equipment are represented in the inventory and repair records. Again, 20% of all repairs are assumed to result from poor power quality. A summary of the inventory and repair records follows.

Computers: twenty-eight school districts reported owning 2,535 computers or 90.5 computers/district. Computer repairs totaled 805 in a three year period. This represents 268.3 repairs/year or 9.3 computer repairs/year/school district. Nine percent of all computers are repaired annually, if the Lower Kuskokwim school district repairs are not included because the amount of equipment from that district was not reported.

Office Equipment: 499 pieces of office equipment were reported from 28 school districts or 17.8 per district. Reported repairs totaled 7,707 for a three year period or 2,569 repairs per year or 88.6 repairs/year/school district. Subtracting the Lower Kuskokwim school district response, since the number of pieces of equipment was not provided, indicates that 512% of all office equipment is repaired annually. If repairs reported by the Matanuska-Susitna school district are also not included, 157 repairs/three years remain for 403 pieces of equipment which is 13% per year repair rate.

Industrial Motors: 9,209 motors were reported from 24 school districts for an average of 384 motors per district. Repairs reported for a three year period were 1,130 for an average of 377 repairs per year or 15 repairs/year/school district. Subtracting the Lower Kuskokwim school district response indicates that 3.5% of all motors were repaired annually.

Communications Equipment: 937 pieces of communications equipment were reported from 28 school districts for an average of 33.5 pieces of equipment per district. Repairs reported for a three year period were 169 or 56 repairs per year were indicated. This is equivalent to two repairs/year/school district. Eighteen percent of all communications equipment was repaired every three years or 6% annually.

Audio/Video Equipment: 1,833 pieces of audio/video equipment were reported from 28 school districts or 65.5 units per district. Repairs totalled 536 per three years or 179 repairs per year were also reported (6.2 repairs/year/school district). Subtracting the Lower Kuskokwim school district response, since the amount of equipment was not provided, indicates that 26% of all audio/video equipment is repaired every three years or 8.7% annually.

Miscellaneous Electrical/electronic Equipment: 257 units not fitting the other categories were reported from three school districts or an average of 86 units per district. Repairs reported over a three year period totalled 726, corresponding to an average of 242 repairs per year, or 81 repairs/year/school district. Again, subtracting the Lower Kuskokwim school district response shows that 93% of all equipment in this category is repaired annually.

The file on pages 18, 19 and 20 gives data obtained from state TV transmitter/receiver (TX/RX) repair reports between March 1983 and June 1985, a total of 28 months. A total of 667 repair reports were recorded from 200 villages; 101 of these or 15.1% of the total were attributed to AC power problems. Transmitter/receiver units not able to be repaired in the field totaled 274. Persons responsible for repair of these units estimated that 50% (or 137) of those situations requiring TX/RX replacement were caused by poor quality AC electric power. (101 + 137) = 238 repairs needed because of AC power problems. This is 36% of the total number of repair reports or 238 repairs/28 months = 8.5 repairs/month occurring because of AC power problems. Assuming each repair costs $220 shop time plus an estimated $610 in travel and wages (Alascom earth station average figures), the 238 repairs due to AC power problems cost approximately $198,000 or $7,060/month. However, since

TABLE 4. Percent communities within ranges of estimated percent repairs of state TV (TX/RX) due to AC power quality.

Percent communities	Range of estimated percent repairs due to to AC power quality
4.04	90 - 100
1.52	80 - 89
3.54	70 - 79
4.54	69 - 69
29.3	50 - 59
3.54	40 - 49
9.60	30 - 39
14.1	20 - 29
6.1	10 - 19
23.7	0 - 9

these data were obtained from 200 sites, this corresponds to $35.30/site/month. The estimated cost of each transmitter/receiver is $4,300 for a total capital cost of $860,000 for all 200 villages. The percentage of repairs attributable to AC power problems on a per community basis ranged from 0% to 100%. Table 4 shows the percentage of communities within ranges of estimated percent repairs of state TV transmitters and receivers due to AC power quality. An estimated 0 to 29% of all repairs were caused by AC power problems in 44% of the communities, 0 to 49% of all repairs were caused by AC power problems in 57% of the communities and 50 to 100% of all state TV transmitter/receiver repairs were estimated to be caused by AC power problems in 43% of the communities listed on pages 18 and 19.

The file on page 22 provides data from Alascom earth station repair reports. These data were accumulated over a total of 1,113 months (92.75 years) in 39 villages for an average of 28.5 months/village. A total of 1,363 repair reports were filed during 1,113 months or 1.23 reports per month. Of these, 206 or 15.1% were attributable to AC power problems. Average cost of wages for each AC power-related report was $165. The corresponding travel cost was $474 per report for a total travel and wage cost of $612 per AC power-related repair report. 206 reports per 1,113 months corresponds to 0.19 reports per month or 0.00475 reports per month per village for only AC power-related repair reports. This is equivalent to 211 months (17.6 years) per such report per village.

Seven communities, shown in Table 5, appear in the data file on page 14 (village water/sewere motors and repairs), in the data file on pages 18 and 19 (state TV TX/RX repairs) and in the data file on page 22 (Alascom earth station repair reports). Table 5 combines elements of all three files for easier comparison between files for a specific community. Demographic and power generation information are provided, if available.

Table 5 does not provide a consistent relationship between motor, TV and earth station repairs. The community with the largest number of motors needing repair also is one of two communities having the largest number of Alascom earth station repairs attributed to AC power problems. An estimated two transmitters/receivers also needed replacing at this

TABLE 5. Data for communities common to VIL-MO, ST-TV and Alascom files.

Community	Population	Installed capacity (Kw)	Output MWH/YR	Peak MW (D)=diesel gen.	Village water/sewer motors			State TV TX/RX			Alascom		
					Quantity	Number repaired	Repair cost	Repair reports	due to AC	TX/RX replaced	Repair reports	due to AC	Cost
Allakaket	216				7	6	---	5	0	4	37	8	$8,689
Beaver	80				7	3	$747	4	0	0	27	6	$2,156
Hughes	85	25	160	0.1(D)	7	0	0	5	1	4	42	8	$5,522
Kiana	364	875	895	0.2(D)	6	1	---	5	1	2	30	0	0
Kivalina	253	610	596	0.2(D)	5	0	0	3	0	3	22	3	$1,675
Shungnak	214	580	674	0.1(D)	6	3	---	4	0	2	25	1	$ 675
White Mtn.	115				0	0	0	4	0	2	34	5	$3,875

location because of AC power problems. Another community had as many Alascom repairs attributed to low AC power quality as the first (8), had the highest number of state TV repairs attributed to AC power problems, yet indicated no motor repairs. Table 6 shows marginal consistency between state TV and Alascom repair records.

TABLE 6. Estimated percent repairs due to AC power problems.

	State TV TX/RX	Alascom
Allakaket	40%	22%
Beaver	0%	22%
Hughes	60%	19%
Kiana	40%	0%
Kivalina	50%	14%
Shungnak	25%	4%
White Mountain	25%	15%

WHAT IS THE CURRENT COST OF POOR ELECTRIC POWER QUALITY TO ALASKA?

This section provides an estimate of the annual statewide AC-power related equipment repair costs in Alaska. All assumptions are stated so that if the reader disagrees with any of them, a substitute assumption may be inserted and the cost calculations redone. It is, in general, extremely difficult to know with certainty that specific electrical equipment damage has been caused by AC power disturbances when that equipment has been operating under normal field conditions. To prove this would require careful instrumentation of the equipment and simultaneous measurement of disturbances in the connected AC electric power system. In addition, it should again be observed that power system disturbances may be caused by the user as well as by the utility providing electric energy.

School district repair data were used to estimate the percentage of equipment repaired annually in all sectors of the Alaskan economy. The most well documented percentages of equipment repairs related to AC power problems were obtained from Alascom and state TV repair records. Thirty-six percent of state TV transmitter/receiver repairs were attributed by Division of Telecommunications personnel to AC power problems. Alascom earth station repair reports indicate 15% of all repairs are attributable to AC power disturbances. Based on their data, we estimate 20% of all equipment repairs to be attributable to AC power problems.

School district repair records are provided on pages 16 and 17 of this report. Twenty-nine school districts encompassing 144 communities are represented. Table 7 is taken from these data which have been summarized on pages 37 and 38.

Additional repair data were obtained from the village water/sewer motor survey summarized on pages 36 and 37. Thirteen percent of these motors were reportedly repaired each year at an annual repair cost of 25% of the motors' value. Continuing with the assumption that 20% of equipment repairs are due to AC power system disturbances yields (0.13)(0.2)(100%) = 2.6% motors repaired/year because of AC power problems at an annual repair cost of (0.25)(0.2)(100%) = 5% of motor value.

TABLE 7. School district repair experience.

Item	% repaired/year	% repairs assumed due to AC power problems (20% of total)
Computers	9	1.8
Office equipment	13	2.6
Industrial motors	3.5	0.7
Communications equipment	6	1.2
Audio/video equipment	8.7	1.7
Misc. electrical/electronic equipment	93	18.6

The inventory of motors in state facilities reported on page 13 indicates an average of $5,600 worth of motors/community. There are approximately 290 communities in Alaska. However, state TV transmitters/receivers are listed for 200 villages and 180 communities have Alascom earth stations. Therefore, for purposes of extending data obtained from several dozen villages to encompass the whole state, 200 communities in Alaska are assumed. Thus, motors in state facilities statewide are assumed to have a value of ($5,600/community)(200 communities) = $1.12 million. Annual cost of repairs due to AC power disturbances ia assumed to be (a) ($\$1.12 \times 10^6$)(0.05) = $56,000 using village water/sewer motor data; and (b) ($\$1.12 \times 10^6$)(0.007) = $7,800 using school system repair data.

Two municipal/borough inventories are reported on page 12 which provide equipment values in several categories. Using the populations given on page 36 for the city of Valdez and the North Slope Borough (NSB) yields $53.17 worth of motors/person in Valdez and $108 worth of motors/person in the NSB. Assuming the Valdez figures to be more conservative and representative of the state as a whole and further assuming a state population of 500,000, ($53.17)(500,000) = $26.6 million worth of motors in all boroughs/municipalities statewide. Again, annual cost of repairs of these motors due to AC power disturbances is assumed to be (a) ($\$26.6 \times 10^6$)(0.05) = $1,330,000 using village water/sewer motor data; and (b) ($\$26.6 \times 10^6$)(0.007) = \$186,000 using school system repair data.

Annual cost of repairing motors owned and used by private citizens of Alaska is estimated by assuming 125,000 households in Alaska (4 persons/average household) and an average of three fractional horsepower motors costing \$160 each per household. Thus, total value of these motors is (125,000 households)(3 motors/household)(\$160/motor) = \$60 million. Annual cost of repairs due to AC power disturbances is estimated to be (a) ($\$60 \times 10^6$)(0.05) = \$3,000,000 using village water/sewer motor data; and (b) ($\$60 \times 10^6$)(0.007) = \$420,000 using school system repair data.

Cost of motor repair in Alaskan schools was estimated by noting that 24 school districts representing 122 communities reported 9,209 motors. Seventy-two percent of these motors were assumed to be fractional horsepower costing \$160 each, 22% were assumed to be 1 to 5 horsepower costing \$400 each and 6% were assumed to be 5 to 20 horsepower costing \$800 each. These percentages by size agree with the reported state inventory. Assuming 200 community schools in Alaska, the annual motor repair costs due to AC power disturbances in those schools is estimated at

$$[(9{,}209)(0.72)(\$160) + (9{,}209)(0.22)(\$400) + (9{,}209)(0.06)(\$800)]\left(\frac{200}{122}\right)(0.007) = \$26{,}600$$

The statewide annual cost of reparing private household television (TV) sets and radios damaged by AC power disturbances was estimated by assuming 130,000 TV sets and 130,000 radios in Alaska (approximately one per household). Using the school district modified repair rate of 1.7% units repaired annually because of AC power problems and assuming \$100 per average repair, (130,000 + 130,000)(0.017)(\$100) = \$442,000 is the estimated annual cost of private TV/radio repair in Alaska due to AC power quality problems.

Annual cost of repairing audio/video (A/V) equipment owned by municipalities and boroughs was estimated by using the Valdez inventory information showing (113/3698) = 0.03056 A/V units/person (the corresponding North Slope Borough figure was 31% higher) and assuming it to be representative of the whole state. Average unit repair cost was estimate to be $100 and the school system modified repair rate of 1.7% was again used. Thus, the statewide annual cost of repairs due to AC power problems in A/V equipment owned by municipalities/boroughs is estimated to be (0.03056 A/V units/person)(500,000 persons)(0.017 repair rate)($100/repair) = $26,000. Computer repairs in schools required because of AC power disturbances is estimated to be (2,535 computers/122 community schools)(200 communities)(0.018 repair rate) = 75 computers/200 communities repaired annually. Assuming $200 average repair charge yields (75)($200) = $15,000 annual cost of these repairs. Assuming one computer per 10 households in Alaska, (125,000 households)(0.1 computer/household)(0.018 repair rate)($200 average repair charge) = $45,000 annual repair cost to repair private household computers in Alaska assumed damaged by AC power system disturbances.

Four hundred ninety-nine pieces of office equipment were reported for 122 community schools or 4.1 units per office. Assuming a repair rate of 2.6%, 200 communities and an average repair cost of $100, gives (400 units/school)(200 schools)(0.026)($100/repair) = $21,300 estimated annual cost of AC related repairs of office equipment in 200 community schools. Assuming 10,000 businesses in the state with an average of 4.1 units of office equipment per business and the same repair rate as above, the estimated annual cost of Alaskan private business office equipment repairs required by AC power system disturbances is (10,000 businesses)(4.1 units/business)(0.026 repair rate)($100/repair) = $107,000. Using the Valdez inventory for office equipment and the same assumptions as above gives (77 units/3,698 persons)(500,000 persons)(0.026 repair rate)($100/repair) = $27,000 annual estimated repair costs due to AC power system disturbances for office equipment owned by municipalities/boroughs statewide.

Communication equipment in the Valdez inventory is 21 units/3,698 persons. Extending this statewide, using a 1.2% repair rate from school district information and assuming $50/repair yields (21 units/3,698 person)(500,000 persons statewide)(0.012 repair rate)($50/average repair) = $1,700 annual estimated repair cost due to AC power system disturbances for communication equipment owned by municipalities/

boroughs statewide. School data indicate 937 units of communication equipment in 122 communities. Repeating the above assumptions gives (937 units/122 communities)(200 total communities)(0.012 repair rate)($50/repair) = $920 annual estimated statewide repair cost due to AC power system disturbances in 200 community schools.

As noted on page 39, state TV repairs attributable to AC power system disturbances total ($7,060/month)(12 months) = $85,000 annually for 200 communities.

Alascom repair data also summarized on page 39 indicate 0.00475 repair reports/village/month for AC power-related repairs. (0.00475 reports/month/village)(180 stations)(12 months/year) = 10.26 reports/year. Assuming $200 repair parts cost per report and $612 travel and wage cost per report gives ($612 + $200)(10.26) = $8,000 (rounded) as the annual repair cost attributable to AC power system disturbances for 180 Alascom earth stations.

SUMMARY OF ESTIMATED STATEWIDE ANNUAL COST OF REPAIRS

DUE TO AC POWER SYSTEM DISTURBANCES

Motors	Statewide annual cost of repair due to AC related problems: From school system data	Statewide annual cost of repair due to AC related problems: From village water/sewer motor data
a) In state facilities	$ 7,800	$ 56,000
b) In municipalities/boroughs	186,000	1,330,000
c) In private households	420,000	3,000,000
d) In schools (in addition to (a))	26,000	
Motor subtotal	$640,000	$4,400,000

Item	Statewide annual cost of repair due to AC related problems
TV/radios in private households	$442,000
Audio/Video equipment in municipalities/boroughs	26,000
Computers	
a) in schools	15,000
b) in households	45,000
Computer subtotal	$60,000
Office equipment	
a) in schools	21,300
b) commercial	107,000
c) in municipalities/boroughs	27,000
Office equipment subtotal	$155,000
Communication equipment	
a) in municipalities/boroughs	1,700
b) in schools	900
c) state TV	85,000
d) Alascom	8,000
Communication equipment subtotal	$95,600

GRAND TOTAL: 1.42M using school system motor data

5.2M using village water/sewer motor data

REPAIR PERSONNEL COMMENTS

Repair and maintenance personnel have provided their views on the AC power quality issue on several occasions. A summary of these opinions follows.

1. Undervoltage and underfrequency conditions are very hard on battery chargers.

2. It is very difficult for a company to prove, beyond reasonable doubt, that AC power problems were solely responsible for equipment damage.

3. Refrigerator compressor motors are among the most fragile items regarding an ability to withstand voltage fluctuations for even short periods of time.

4. Low voltage is the largest single problem in some areas, often caused by operator errors such as letting diesel generators run out of fuel or improperly transferring loads. Poor maintenance is also cited.

5. Better training of power plant operators, including certification programs, has been urged.

6. Computer and other electronic equipment repair personnel have said:

   a. surge protectors or isolation transformers should be used on all computers;
   b. for especially sensitive or critical systems, UPS should be installed;
   c. faulty building wiring should be blamed for many problems now attributed to electric utilities;
   d. inadequate system grounds and lack of effective static protection are important causes of problems;

e. 30% to 40% of all computer repairs are AC power related, but are not usually the fault of the local electric utility;

f. one major computer company requires that power line conditioners be installed on all equipment covered by a service agreement with that company; and

g. voltage impulses change states in ROM (read-only memory) controlling cash registers, memory typewriters and word processors.

SUMMARY AND RECOMMENDATIONS

1. Outage data from electric utilities (page 10) show fewer outages of longer duration when compared with an earlier Alaskan study [1].

2. Municipal/borough inventories reported in this report (page 12) indicate a per capita value of between $167 and $541 for computers, office equipment, motors, communications equipment, audio/video equipment and miscellaneous electronic equipment.

3. An inventory of motors in state facilities in 25 communities, taken from Alaska Department of Transportation and Public Facilities as-built blueprints, shows approximately $5,600 of motors per community.

4. 445 water/sewer motors were reported in 45 communities for an average of approximately 10 per community. 13% of these motors are reportedly repaired annually at a cost of approximately 25% of the total estimated motor value. It is not known explicitly what fraction of these repairs may be attributed to AC power problems, but as noted on page 37, is estimated to be 20% of total repairs.

5. 29 school districts representing 144 communities reported an average of 91 computers/district with a 9% annual repair rate. An average of 18 pieces of (electronic) office equipment/district had a 512% annual repair rate. Not including one school district dropped this to a 13% annual repair rate. 384 motors/district were

reported with an annual repair rate of 3.5%. 34 pieces of communication equipment/district had a 6% annual repair rate. 66 units of audio/video equipment per district showed an 8.7% annual repair rate. Three districts reported an average of 86 pieces of miscellaneous electrical/electronic equipment with 93% requiring annual repair. It is not known explicitly what fraction of all school district equipment repairs are attributable to AC power problems, but as noted on page 37, is estimated to be 20% of total repairs.

6. 667 repair reports from 200 communities were filed over a 28 month interval for the state television system. 36% of these repairs were, in the opinion of repair personnel, caused by AC power problems. This is equivalent to 8.5 repairs/month at an estimated cost of approximately $7,000/month or $35/site/month. At an estimated $4,300 per transmitter/receiver, these units have a total capital cost of $860,000 for all 200 communities.

7. Alascom earth station repair reports were compiled for a total of 1,113 months (92.75 years) in 39 communities. 15% of the total of 1,363 repair reports were attributable to AC power problems. Average wage and travel cost per repair report was $612. The approximately 180 Alascom earth stations in Alaska have an estimated cost of equipment subject to AC power problems of $150,000 per station for a total of $27 million.

8. Tables 1, 2 and 3 provide effectiveness and cost information for power conditioners that can help protect sensitive loads. Unfortunately, effectiveness is proportional to cost. Small units are generally more expensive per volt-ampere rating than larger ones.

9. AC power system disturbances are strongly site dependent.

10. Statewide annual cost of electrical equipment repairs due to AC power system disturbances is estimated to be between $1.4 million and $5.2 million.

11. Recommendations for further work:

    a. continue power quality data base development utilizing second-generation instrumentation for direct in-field measurements;
    b. obtain the most promising power conditioning equipment types for evaluation and testing; and
    c. characterize effectiveness of power conditioners in response to power system disturbances measured in rural Alaska. Develop a guide for matching conditioners with anticipated disturbances and loads.
    d. Prepare results of (c) in a form easily used by state agency personnel with responsibility for design and procurement.
    e. Develop a user awareness of adequate electric utility distribution systems, and good building wiring and grounding practices.

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IMPLEMENTATION STATEMENT

The report "Rural Alaska Electric Power Quality" was published in 1985 and constituted the first investigation into the power quality issue by DOT&PF. In the Implementation Statement of that report I stated that no immediate implementation work was warranted until more quantitative investigations could begin to assess the cost implications of poor power quality. The results of that continued research effort are presented in this report and it is clear that the cost implications are quantitatively significant.

It is also clear that costs incurred by poor power quality are shared by a number of segments of society in Alaska. Beside the DOT&PF virtually all State and local government entities share this cost burden along with the private sector. Poor power quality in rural Alaska is clearly everyone's' problem and should be addressed in a comprehensive manner. Unfortunately, problems which are defined as "everyone's" are often addressed by "no one" simply because the overlap of responsibility produce programmatic cracks through which important issues fall out of sight and out of mind. We must not let this happen with the rural power quality issue.

Through the work presented here we in DOT&PF can begin to implement specific solutions to a limited number of power quality problems through our design standards development and through the Division of Maintenance and Operations. At the same time we are continuing our research work to improve our understanding of the magnitude of the problem and the most productive solution strategies. Also, we will attempt to develop, both within the state and through federal sources, an inter-agency and inter-disciplinary approach to support future investigations and solutions of this fundamental Alaskan problem.

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