MASTER

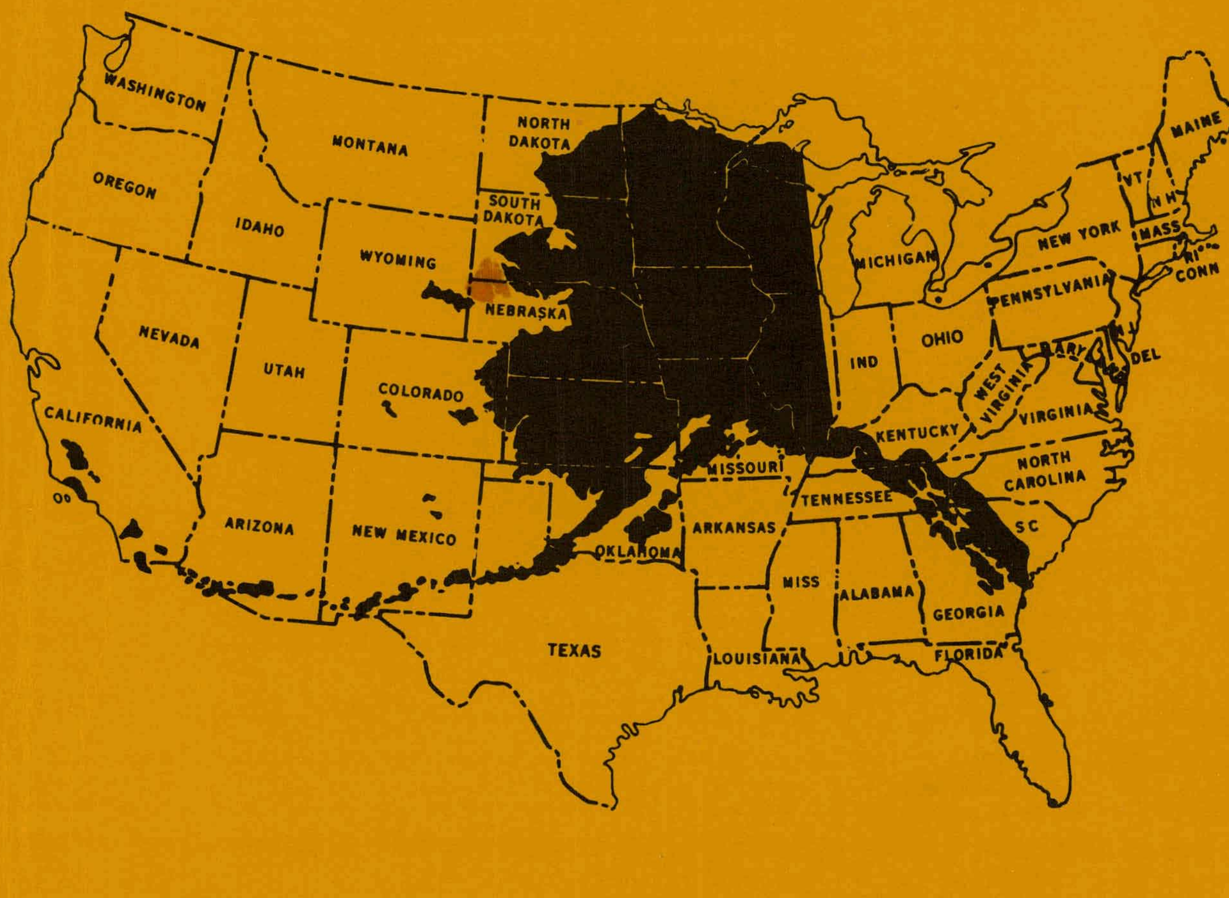
DEPD 81-001-3
DOE/EV/73002-1

ALASKA REGIONAL ENERGY RESOURCES PLANNING PROJECT

PHASE 2

COAL, HYDROELECTRIC AND ENERGY ALTERNATIVES

VOLUME III
ALTERNATIVE ENERGY SYSTEMS
AND
REGIONAL ASSESSMENT INVENTORY UPDATE



Prepared by:
Division of Energy and Power Development
Department of Commerce and Economic Development
State of Alaska

Prepared for:
Regional Impacts Division
Office of Environmental Assessment
U.S. Department of Energy
Under Contract AT06-77EV73002

ALASKA REGIONAL ENERGY RESOURCES PLANNING PROJECT

PHASE 2
COAL, HYDROELECTRIC AND ENERGY ALTERNATIVES

VOLUME III
ALASKA's ALTERNATIVE ENERGIES AND REGIONAL ASSESSMENT INVENTORY UPDATE

Prepared
by

Gene Rutledge
Darlene Lane
Greg Edblom

ALASKA DIVISION OF ENERGY AND POWER DEVELOPMENT

Donald Lyon, Project Manager
Clarissa Quinlan, Director

U. S. Department of Energy Contract #AT06-77EV73002
S. P. Mathur, Project Officer

1980

ALASKA REGIONAL ENERGY RESOURCES PLANNING PROJECT

PHASE 2

COAL, HYDROELECTRIC AND ENERGY ALTERNATIVES

CONTENTS

VOLUME III

ALTERNATIVE ENERGY SYSTEMS
AND
REGIONAL ASSESSMENT INVENTORY UPDATE

ALTERNATIVE ENERGY SYSTEMS

Chapter

REGIONAL ASSESSMENT INVENTORY UPDATE

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

FOREWORD

This second phase of the Alaska Regional Energy Resources Planning Project represents an in-depth look at the Beluga Coal District, hydroelectric development and the applicability of alternative energy systems. Specifically, this phase of the project will deal with the possible development of the Beluga Coal Fields, the construction and operation of hydroelectric facilities in Alaska as well as various alternative small scale energy systems such as geothermal, wind, fuel cells, small hydroelectric facilities and thermal application of energy conversion.

Since the beginning of this project in 1977, many important developments have occurred in the field of energy. The impact of the passage of the Clean Air Act amendments has yet to be felt, and changes in offshore federal lease sale schedules have yet to make a final impact within the economy of either Alaska or the continental United States. In addition, there is still considerable debate as to the disposition of the oil from the Trans-Alaska Pipeline System (TAPS) as well as the likelihood of a Trans-Alaska or Trans-Canada natural gas pipeline. Therefore, the reader must recognize that information and data concerning Alaska's resources, operations and issues are continually being supplemented and modified by changes in regulations, technology, economic factors and resource availability.

Since this report is based to a great extent upon scientific, geological and engineering work done by others, the reader is urged to obtain the original documentation for greater detail. This report does not attempt to establish State, Federal or Native corporation policies. This report does provide information which will assist policy makers in making informed decisions.

ACKNOWLEDGEMENTS

This report has benefited from contributions and input supplied by staff members from several state and federal agencies, Native corporations, utilities, libraries, industrial corporations, national laboratories, and consultants. A number, but not all, of the energy experts who assisted us are listed by name in various chapters of the text. Without the help of the many people who contributed, this report would not have been possible. It is hoped that all who assisted will also find this report useful.

The authors wish to express thanks to the other secretarial staff members who assisted in the preparation of this report, Brenda Hviding, Shelly Lynn, Paula Parker, Arlene Price, Peggy Skeers and Nancy Totten. The following individuals must be thanked for their support in research and numerous writing contributions necessary for the successful completion of the project: Carol Bennet, Steven Levi, Randall Montbriand, and especially Kyle Weaver.

Also, funding from the Department of Energy (formerly Energy Research and Development Administration) is acknowledged and appreciated. The continuing assistance of Dr. Paul Gerhardt, Regional Impacts Division, in the direction of the early stages of this project as well as his interest in the progress of this study was very helpful.

CHAPTER 12

INTRODUCTION

CHAPTER 12
ALTERNATIVE ENERGY SYSTEMS

INTRODUCTION

Alaska is a region rich in energy resources. The majority of the developed portion of these resources are being exported in the form of petroleum. Still, Alaskans have the highest rate of energy consumption in the nation, often importing high cost petroleum products to meet this demand.

This volume examines the historical background, current technological status, environmental impact, applicability to Alaska and siting considerations for a number of alternative systems. All of the systems considered use or could use renewable energy resources. While most of these resources have been used in some manner for centuries, they are once again receiving considerable attention due to diminishing fossil fuel reserves and technological advances.

It is clear that alternative energy technologies should be adopted to conserve and replace our dwindling petroleum and natural gas resources. An early move to conservation and renewable energy resources is encouraged by the generally more benign environmental impacts involved.

Unfortunately, the transition from traditional energy sources is often discouraged by economic factors or lack of experience with emerging technologies. However, both of these restraints are becoming less imposing obstacles and require constant re-evaluation to determine the propitious moment to shift to a newer technology.

That the State is concerned about its long-term energy future is evidenced by involvement in activities such as the wind power project in Nelson Lagoon and the geothermal project at Pilgrim Hot Springs. Alaska's relative lack of development may be an asset in the sense that less economic disruption will occur when changes in energy systems take place.

Future development can utilize up-to-date systems instead of being forced to bear the expense of conversion or replacement of existing systems to meet new conditions.

Systems applicable to both large and small communities are discussed. However, inclusion in this study does not necessarily imply that technological and economic conditions are appropriate for the implementation of a described system at a particular site. Nor does this volume attempt to include all Alaskan energy alternatives; solar is an obvious source of energy which is not within the scope of the study.

CHAPTER 13

VERY SMALL HYDROPOWER

CHAPTER 13
VERY SMALL HYDROPOWER

INTRODUCTION

The purpose of this chapter is to address the potential of small hydroelectric units for use in the rural and remote villages of Alaska. It is possible that a number of communities and villages have small streams in nearby hilly terrain which will give an adequate head to permit economical energy recovery.

This section on small hydroelectric potential is limited to combinations of flow and head that will give electrical energy production of about 12 Kw or less. This includes both high and low head (greater or less than 45 meters) applications. Other hydropower technologies are addressed in Hydroelectric Development volume of this report and also Phase I, of the project.

Interest in small hydroelectric technology in Alaska is strong as evidenced by large attendance at industrial seminars on the subject held throughout the state under the sponsorship of the Division of Energy & Power Development.

HISTORY

Small scale hydroelectric generation has been important to Alaskans since the early years of the twentieth century. Many resource exploitation and development activities were already utilizing the flow of water from streams, springs, waterfalls and rivers to produce mechanical power. As electrical generation technology made it feasible and the equipment became available, components to produce electricity were added to the existing energy production systems.

Water power can be captured as the water falls from one level to another level. The flow can be channeled and directed through gulleys, aqueducts or pipes. Pressure can be altered and increased through funnelling or diverting the rushing water into pipes or tubes of decreasing diameters.

It can be transported over long distances. The force of the water streaming from the open end can then be used directly in high pressure hydraulic applications or the flow can be directed onto a paddle wheel which produces mechanical power by rapidly spinning on its axis (Soltis, UD).

Growth of the Alaskan industries which began in the late 1880's was dependent on the availability of water and the energy that could be developed by harnessing the flow of the water. This was true for the gold mines at Douglas and Juneau, the copper mines on the slopes of the Wrangells, and especially for the placer mining districts in the interior regions; water power was essential for the expanding fish processing and canning plants; and, the logging companies and sawmill operators relied on the energy from water to provide power for mills and equipment (U.S. Dept. of Interior, 1952).

The use of hydroelectric power came in tandem with the use of water to produce mechanical power. While the first Alaskan gold production was beginning at Sumdum and Windham Bay, between Juneau and Petersburg, in 1870, Allen Pelton was changing the design of the flat paddle wheels, called "hurdy-gurdies", to increase their efficiency. He designed a double cup to replace the paddle for each of the spokes on the wheel. The cavities in the double cups keep the stream of water from splatterring as it strikes the surface, thereby capturing more of the kinetic energy from the high-velocity water stream. Greater rotation speeds were obtained which allowed mechanical systems to be combined with electrical generation equipment (Lindsley, 1977).

Pelton wheels were significantly changed and improved over the years of practical applications, but the initial cupping of the paddle was the major design advance for this equipment. The Pelton wheel is a free jet-impulse type of water turbine normally used on high operating heads (vertical fall). The Gilkes & Gordon, Ltd. brochure on Pelton wheels states that at present there is no practical limit to the maximum head for which a Pelton Wheel can be designed.

As the scale of early Alaskan business ventures increased, so did the demand for power. It was not uncommon for mining operations to produce power that was in excess of their operational needs. Often this surplus was sold to adjacent communities. In 1924, Joseph Dort, a hydroelectric engineer, reported that in Southeastern Alaska,

> a large number of small water-power projects have also been developed for use in operation of mines, salmon canneries, sawmills, etc., most of which are for mechanical power only, though at many plants a small generator is installed for electric lights, (U.S. Power Commission, 1924).

The survey that Dort compiled listed potential sites and an inventory of major applications of water power that existed in 1924. The following extracts from his report give an example of the extent of the water diversion systems and the technical specifications for a very small hydroelectric generation system:

ALASKA TREADWELL GOLD MINING CO.

> The Treadwell group of mines on the eastern side of Douglas Island along the shore of Gastineau Channel were operated by the Alaska Treadwell Gold Mining Co., these mines, as well as those of the Alaska Juneau Gold Mining Co., being controlled by identical interests. In connection with the operation of its mines, the former company has developed considerable mechanical water power on Douglas Island, and has hydroelectric plants at Nugget and Sheep Creeks on the mainland, respectively north and south of Juneau. The mines on Douglas Island gave out about 1921 and the hydroelectric power is now being used by the Alaska Juneau Gold Mining Co. at its mill located at the south end of the town of Juneau.
>
> The first water-power development of the Treadwell group was built during 1882 on Douglas Island and has been extended and improved from time to time to meet the increasing demand for power. There are two storage reservoirs on the island, Lake Cropley at the head of Fish Creek, at its northwesterly end, and the Ready Bullion reservoir on Bullion Creek, directly back of the mine, about 2 miles from Gastineau Channel. Water is brought from Lake Cropley through a covered ditch 5 feet wide by 2 1/2 feet deep and about 12 miles long and delivered at an elevation of 570 feet into pressure pipes that convey it to the water wheels at the various mills. Water from Bullion Creek is diverted directly into a pipe line for use at the mills. A total of about 4,000 mechanical horsepower has been developed on Douglas Island, but is not being used at the present time, all of the mines having been closed down. The entire water-power system is being maintained in good condition, however.

SHEEP CREEK PLANT

Location.--This plant is located at the mouth of Sheep Creek, about 4 miles southeast of Juneau, on the shore of Gastineau Channel, and it includes one 300-horsepower unit which furnishes power to the Alaska Gastineau Mining Co., the remainder of the generated power being used by the Alaska Juneau Gold Mining Co. There are no storage reservoirs on the creek, and occasionally the winter flow is so low that the plant is not able even to generate the 300 horsepower due the mining company.

Conduit.--There is a log-crib diversion dam at an elevation of 600 feet, with a 3 by 4 foot timber flume, 2,486 feet long, on a 0.4 percent grade, carrying the water to a riveted steel penstock 36 to 32 inches in diameter, and 2,687 feet in length. The plant operates under a static head of 600 feet.

Power house.--The building is a timber-frame structure with concrete foundations and floor and covered with corrugated iron, three hydroelectric units being installed. Each set of two of these units includes one 1,900-horsepower Pelton impulse wheel with two nozzles, operating at 400 revolutions per minute and controlled by a Pelton type O-1 governor, direct connected to one 1,000-kilowatt, 85 percent power factor, 3-phase, 60-cycle, 2,300-volt General Electric generator. There are two sets of exciters, each set including one 25-kilowatt, 125-volt, 1,200-revolutions-per-minute General Electric generator, direct connected to a 35-horsepower, 2,300-volt, 1,200-revolutions-per-minute General Electric motor and direct connected to a Pelton water wheel. The third unit includes a 225-kilowatt, at 90 percent power factor, Westinghouse generator, operating at 3 phase, 60 cycle, 2,300 volts, and 400 revolutions per minute, set between two water wheels, one of which is a 300-horsepower Pelton-Double wheel operating under a 600-foot head, while the other is a similar wheel operating under a 270-foot head, both being controlled by one O-1 Pelton governor (U.S. Federal Power Commission, 1924).

Though research on small hydro use has not been completed, evidence indicates that impulse turbines were used in mining operations throughout the State. Large Pelton wheels were seen at some of the operations areas in the Valdez Creek Mining District by John Beck, an archaeologist for the BLM.

Power generation and transmission equipment became increasingly sophisticated and installations became capable of providing larger and larger quantities of electricity to the consumers. Hydroelectric dams of megawatt production were constructed. Municipalities installed diesel, coal or gas fired turbines. Very small hydroelectric generation systems moved away from the cities and urban industrial applications and into remote areas not served by utility electricity service grids.

However, in many isolated areas, water is not available when power is needed. The lack of availability limited the application of small hydroelectric systems. As equipment became available for villages and remote communities, diesel generators became the most common source of electrical production.

Changing times have brought Alaskans back to this initial source of power. Many energy resources are no longer considered as reliable, economic or safe, as they once were. Water power is again receiving attention from engineers and consumers, and consequently a market is developing for very small hydroelectric systems. Although the Arctic and Northwest Regions and parts of the Interior Region would still have very limited areas and time periods for use, the total annual run off of Alaskan streams is estimated to be about 300 million acre-feet (U.S. Dept. of Interior, 1967). People in many parts of Alaska, especially in the Southcentral and Southeast regions, could effectively utilize small water power equipment most of each year.

The new equipment includes changes in impulse wheel design such as the more efficient Pelton wheels which use water's velocity; reaction turbines for low head applications where the mass of the water provides the power; improved electricity storage through small alternators, deep-discharge batteries, solid-state inverters, and Gemini power conversion units to change DC to AC as well as improved transmission hardware. At recreation sites and remote cabins these systems are used to provide small quantities of electricity for lighting and radios. Some systems are capable of providing enough electricity for a spectrum of uses. In some areas the new small turbines have even been used to provide mechanical power, as in the early utilization of water. This time water is used to directly run refrigeration compressors or drive pumps and machinery (Lindsley, 1977).

SMALL HYDROELECTRIC TECHNOLOGY AND APPLICABILITY TO ALASKA

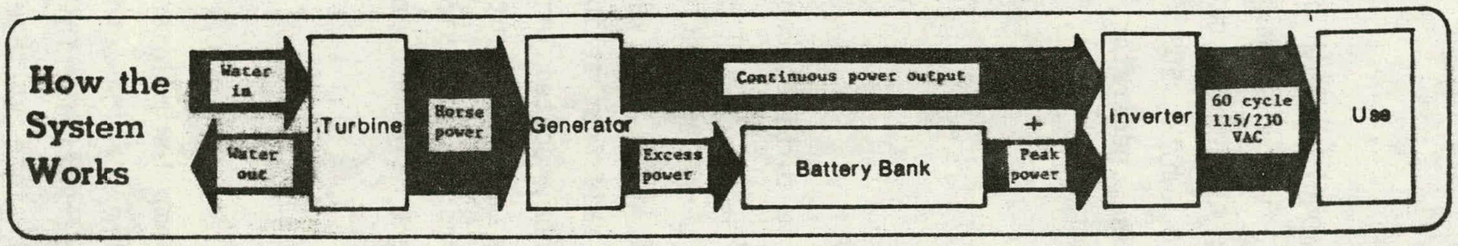
In Alaska, Independent Power Developers (IPD) has actively promoted the use of very small hydro electrical power units up to 20 Kw in size. While the president, William H. Delp, II, has sold about 40 units in the 3 to 18 Kw range throughout the world, to date none are in operation in Alaska (Delp, 1978). However, there is a very strong interest in these units throughout the state.

Alaska Wind and Water Power (AWWP) of Chugiak, Alaska has sold Pelton wheels to Alaskan customers. Also, AWWP engages in small hydro engineering services as well as distribution of small hydro components. Francis Soltis, owner of AWWP, will work with Alaskan customers both on a total system or part of a small hydroelectric system (Soltis, 1978).

Independent Power Developers (IPD) uses a technological approach used in wind electric systems. Rather than generate 60 cycle A.C. current directly, the systems first produce D.C. electricity. The D.C. power is stored in a battery bank (Figure 13-1). When power demand exceeds the generator output, power is drawn from the battery bank. When power demand falls below generator output, the excess power is used to charge the batteries. As power is required it is passed through an inverter which translates the D.C. current into steady state 60 cycle 115 Volt A.C. current used by most electrical appliances and motors. This type of system does not require a dam and is capable of using most of the power produced. Also, the system does not need to be oversized to meet peak power demands since the electrical energy can be stored.

All IPD hydroelectric power systems are designed to be owner installed and maintained. Since no dam is required, site preparation is reduced to preparing a simple inlet arrangement, installing the inlet and outlet pipe

Figure 13-1



Small Hydroelectric System

Source: Independent Power Developers.

and constructing a small enclosure to house the power plant. Hydraulic and electrical connections are standard and have been kept to a minimum to insure ease of installation. These power plants are rugged and durable according to the vendor.

The systems come in high head* and low head** models. Both the high and low head models are grouped according to the following maximum output classes: peaking output, 3Kw, 6Kw, 9Kw, 12Kw; continuous output, 300W, 700W, 1700W, 8500W; and monthly power output, 200 Kwh/Mo, 500 Kwh/Mo, 1200 Khw/Mo, 6000 Kwh/Mo. The systems include turbine, generator, batteries, inverter and all intersystem electrical hookups (Figure 13-2).

THE IPD SYSTEM COMPONENTS

Turbine

The high head turbines are 4' Pelton type impulse turbines capable of 80% efficiency which would produce a maximum of 3hp at 3500 rpm given the optimum hydraulic conditions. The units have been designed to give the maximum amount of use with a minimum amount of wear. The wearing parts are reduced to a minimum: the nozzle, which is made from stainless steel; and the runner or wheel which is cast aluminum, coated with epoxy to minimize wear from impact. This design insures minimum maintenance with increased reliability and unit life. The housings are corrosion-resistant cast aluminum and all hydraulic fittings are standard pipe thread couplings for easy water hook-up.

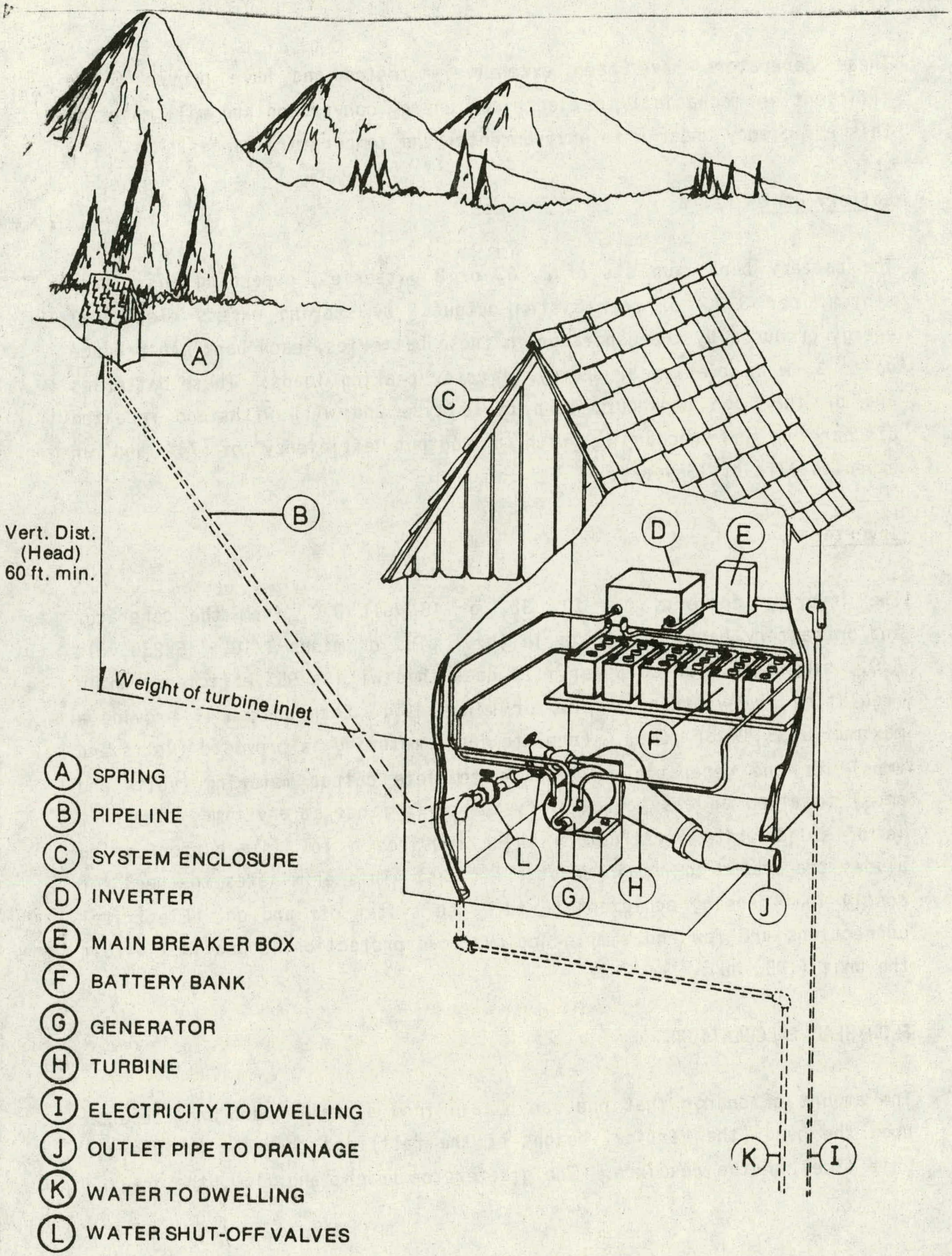
Generator

The DC generators are 12, 32, and 48 volt, 70 amp low maintenance brushless type. These units are built with solid steel casings and heavy duty permanently sealed roller and ball bearing construction. This insures a long service life as does the built-in solid state voltage regulator.

---

* Vertical distance head is 60 ft. minimum
** Vertical distance head is 5 ft. to 60 ft.

Figure 13-2



High Head Hydroelectric System Schematic

Source: Independent Power Developers

These generators have been extensively tested and have proven to be efficient in mechanical to electrical energy conversion and will maintain this efficiency under wide environmental and temperature ranges.

Battery Bank

The battery bank consists of 2, 6, or 8 batteries, depending on voltage system, per 3 Kw of peak system output. By storing excess electrical energy produced by the generator in these batteries, each bank can produce up to 3 Kw in electrical energy to cover peaking loads. These batteries are of the high amp-hour, deep cycle type and will withstand repeated discharging and recharging with an output efficiency of 75% and an expected life of 15 years.

Inverter

The inverter converts the 12, 32, or 48 volt D.C. from the generator and/or battery bank into 60 cycle (hz.) plus or minus 1/10, 115/230 volt A.C., single or 3-phase power. It does this with a 95% efficiency while regulating the voltage to plus or minus 10%. Each unit will provide a maximum of 3 Kw of power. Complete input metering is provided (volts and amps) for the generator as well as complete output metering (volts and amps) to allow an easy check of system performance at any time. The unit is of solid state construction which requires a low idle current which allows the system to remain on at all times. This eliminates the need for costly load sensing equipment to turn the system off and on. Electrical connections are few and simple and overload protection is provided within the unit (IPD, ND).

FLOW/HEAD CALCULATIONS

The amount of energy that one can obtain from a small hydro unit depends upon the head (the vertical height of the fall) and the flow (volume per unit time) of the resource. The greater the height and flow, the greater the potential energy conversion. Appendix 13-A provides specific instructions for determining the head and flow of a hydroelectric resource. A nomograph is shown in Figure 13-3 which gives the amount of power (watts) that one can obtain for various heads and flows.

ELECTRICAL CURRENT OPTIONS

The energy from small hydro units has been used in the past as mechanical energy to grind grain and drive machinery directly. Also, a few turbines have been coupled to refrigeration compressors. However, most tools, appliances, lights and heating units are designed to use alternating current or sometimes direct current; therefore, generation of electricity is usually preferred.

The advantages and disadvantages of various electrical options are given in Table 13-1.

HOUSEHOLD POWER DEMANDS

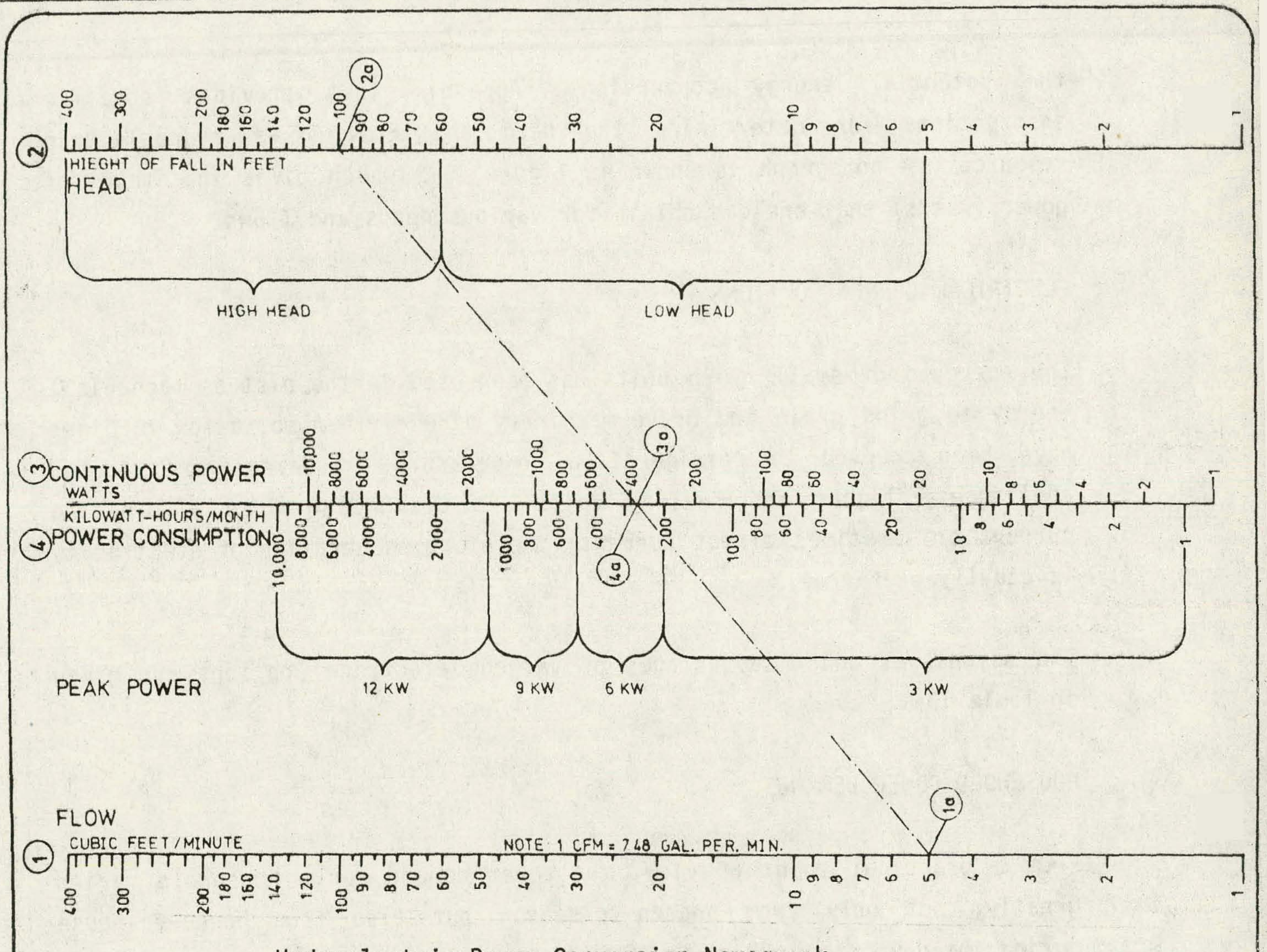
From a practical point of view, the power demand for a household varies greatly, not only from season-to-season but also from house-to-house during the day.

In Figure 13-4, an estimate has been made of what four households can do with a three, six, nine or twelve Kw peak power unit. Although the figure may not apply to specific Alaskan conditions, it is nonetheless useful as a general guideline.

ENVIRONMENTAL IMPACT OF VERY SMALL HYDROPOWER

Household hydroelectric power systems will cause a minimum of adverse environmental impacts. Although some systems may require elaborate installation procedures and some sites will require minor alteration for using this technology, the overall site changes would not be significant. This is especially true for the 3-12 Kw, DC - Inverter - AC systems, which are presently available and feasible for use in many Alaskan locations.

Figure 13-3



Hydroelectric Power Conversion Nomograph

HOW TO USE THE NOMOGRAPH

1. Locate your flow value on scale (1)
2. Locate your head value on scale (2)
3. Using a straight edge (ruler), draw a straight line through these two values.

(See the example on the nomograph using 5 C.F.M. flow (1a), and 100 ft. of head (2a).)

4. Your continuous power output appears where the line intersects scale 3. (For the example, the value is about 360 watts (3a).)
5. Scale 4 gives the equivalent total power consumption per month in KW hr./mo. you may expect. (For the example 360 watts (3a) of continuous output will produce 260 KW hr./mo. (4a) of usuable electricity).
6. The peak power output of the system is shown by the brackets. (For example the value is 6 KW.)

Source: Independent Power Developers

TABLE 13-1

DIRECT CURRENT VERSUS ALTERNATING CURRENT OPTIONS

DC/AC Option	Advantages	Disadvantages
Direct use of DC from alternator or generators	Least expensive DC motors have preferable tolerance to changing line voltage, variable speed control and starting characteristics.*	Heavy power lines required. Distribution over great distances difficult. Uneven voltage. Unit must be sized for peak load.
DC to batteries.	Compensates for uneven water flow. DC motors offer some advantages over AC motors.* Unit can be sized for mean load.	Unable to use AC appliances
DC to batteries to inverter to AC.	Permits energy storage and use in wider range of electrical appliances manufactured for AC.	Some power loss in DC-AC conversion. Inverters are expensive. Some inverters limited in handling surge demand, e.g. refrigerator motor startup.
DC to Gemini converter to AC.	Uses utility power line for energy demands beyond generating capacity.	Some power loss in DC-AC conversion.
Direct use of AC	Eliminates batteries, inverters and DC transmission problems.	Requires peak load generating capacity, dammed water reserve, and headwater control Requires governor to maintain AC frequency.

Source of Data: E. F. Lindsey, "Water Power for Your Home," Popular Science, May, 1977 unless otherwise noted.

*T. Wentink, "Power and Energy Productivity of Small Windmills in Alaska," Geothermal Energy and Wind Power...Alternative Energy Sources for Alaska, ed. Robert B. Forbes , 1975.

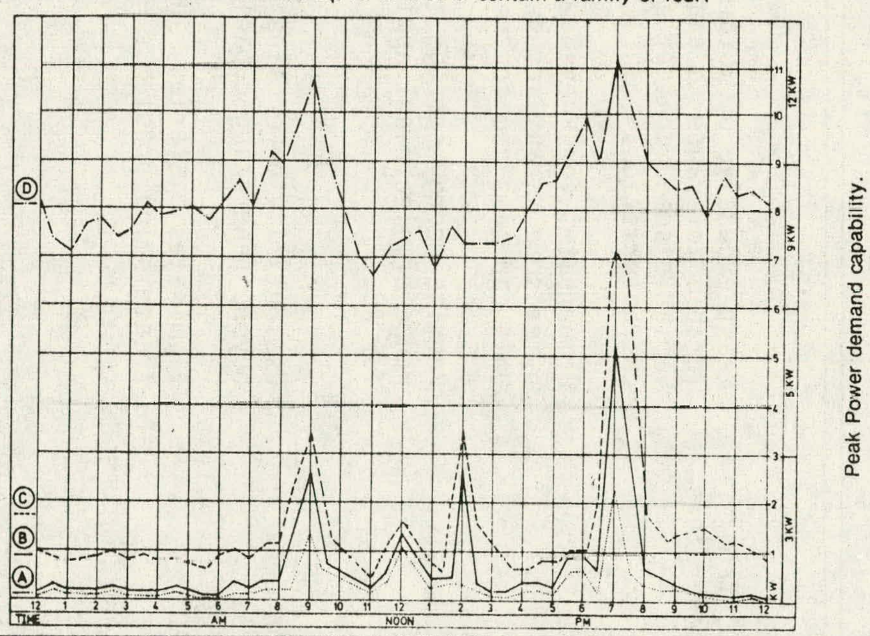
Figure 13-4

Representative Household Appliance Loads

Group	Peak power demand capability max.	Continuous power capability max.	Max. Total power consump.	APPLIANCE	Power (watts)	Avg. hours use/mo.	Total power consump. KW hr/mo.
Ⓐ	3 KW	280 Watts	200 KW hr./mo.	Lights	(3x75 w) 225 w	120	27
				Refrigerator	200 w	150	30
				Small hot water heater (20-30 gal.)	1200 w	89	107
				Water pump (½ H.P.)	460 w	44	20
				Washing machine (15 loads-/mo.)	250 w	6	1.5
				Small hot plate (single burner)	500 w	14	7
				Sewing machine	100 w	10	1
				Shop drill ¼" (1/6 h.p.)	250 w	2	.5
				Shop skill saw (1 h.p.)	1000 w	6	6
						Max. Total =	200 KW hr./mo.
Ⓑ	6 KW max	700 watts max	500 KW hr./mo. max	Med. size hot water heater (30-40 gal.)	add.800 = 2000 w	89	add 72
				Range, top only (all burners on full)	6000 w	10	60
				Clothes dryer	4856 w	18	86
				Vacuum cleaner	600 w	5	3
				Hair dryer (hand held)	400 w	5	2
				Record player	60 w	45	2.7
				Mixer	125 w	6	1
				Toaster	1150 w	4	5
				Shop table saw (1 h.p.)	1000 w	4	4
				Shop lathe (½ h.p.)	460 w	2	1
				Plus conveniences		Total =	236.7 KW
						Max Total =	500 KW
Ⓒ	9 KW max	1700 Watts max	1200 KW hr./mo. max	Large hot water heater 40-50 gal.	add 1000 w = 3000 w	89	add 89
				Portable electric heater	1250 w	350	437
				Iron	1100 w	12	13
				T.V., black and white	200 w	120	24
				Additional lights	(4-75 w)=225 w	120	27
				Coffee pot	700	10	7
				Oven (in addition to range top)	1200	7.5	89
				Plus conveniences		Total =	686 KW
						Max. Total =	1200 KW
Ⓓ	12 KW max	8500 Watts max	6000 KW Hr./mo. max	Large high recovery hot water heater	add 3000 w = 6000 w	89	add 267
				Electric heat	6000 w	250	1500
				Air conditioner	1566 w	74	116
				3 electric blankets	(3x177 w) = 531 w	73	39
				Color T.V.	332 w	125	42
				Plus conveniences		Total =	1964
						Max Total =	6000 KW

PEAK POWER DEMANDS OF FOUR HOUSEHOLDS

All households are 1200 sq. ft. in area & contain a family of four.



Source: Independent Power Developers
Based on monitored winter study conducted in Western Montana

Installation of the equipment would affect three areas: (1) establishment of the water inlet and laying a pipeline; (2) construction of a system enclosure for the generator and battery bank; and, (3) placement of the electric transmission cable to the dwelling or point of use (Delp, IPD brochure). Typically, there is no dam required; either a stainless steel drum is placed in the stream or a small settling pond is hand dug to provide a water inlet. The stream bank is not usually modified. The pipeline, constructed with PVC plastic pipe, lays on the ground or is sunk in the stream. Ground pipelines are sometimes sprayed with brown polyurethane foam for insulation to extend operational effectiveness. Housing for electrical generation and storage components can be in a simple structure, such as a shed, beside the stream (Delp, 1978). No special construction features are required, although there are some location limitations that necessitate careful review of transmission paths. These will vary as to the local topographical conditions. Power lines can be laid on the ground, but for the visual aesthetics and safety it is suggested that they be buried.

Water used in the system is not changed chemically nor thermally. There is no consumption of water. No bearings or other lubricated components are close to the water stream; during normal operation, there is no way for grease or lubricants to be discharged into the water (Delp, 1978).

The system is very quiet, although transformer hum and other components' low-level sounds will probably occur. If so, routine insulation of the system enclosure would reduce this noise. During operation of the system, there should be no noxious exhaust fumes produced in any of the air pollutant categories.

Small-scale hydroelectric generation can be harmonious with the natural surroundings. Environmental degradation can be kept to a minimum with reasonable planning and routine care in installation (Lindsey, 1977).

RECOMMENDATIONS

(1) A detailed inventory of hydro sites that could be harnessed for electrical energy production needs to be completed for all the remote and rural communities in Alaska. This inventory should include flow as a function of the season, head measurements and potential problems, such as icing, silting, and debris, that would affect development. The distance and characteristics of the land from the hydro resource source to the point-of-use needs to be determined.

(2) Once baseline data has been obtained and analyzed, a site specific evaluation should be done to determine the economics of off-the-shelf hardware installation.

(3) If the economics of small hydro technology are attractive and installation of hydro units becomes a reality, a training program for persons in the community should be implemented.

SUMMARY

In summary, many streams in the State exist with the proper combination of head and flow so that acceptable energy production is possible. Hardware for small hydroelectric units is available. This equipment is rugged, reliable, easily transported and fairly easy to maintain.

The economics and other characteristics of small hydroelectric production must be analyzed with respect to other available options. In rural Alaska, the diesel fueled electrical generator is usually the existing power source with which a comparison should be made.

KEY CONTACTS

Bill Delp
Independent Power Developers, Inc.
Route 3, Box 285
Sandpoint, Idaho 83864
(208) 263-2166

Dale W. Rusnell
Chief, Power Development
Division of Energy and Power Development
State of Alaska
7th Floor, MacKay Building
338 Denali Street
Anchorage, Alaska 99501
(907) 276-0508

Francis and Debbie Soltis
Alaska Wind and Water Power
Box G
Chugiak, Alaska 99567
(907) 688-2896

REFERENCES

Alaska, Division of Geological and Geophysical Surveys, Energy Resources Section (Klein, Robert M. and O'Connor, Kristina M.). "Review of EIS 74-90, Section F (Energy Alternatives) and an Evaluation of Energy Alternatives". 1975.

Alaska Water Study Committee. Alaska Water Assessment, Problem Information. Juneau, Alaska. November, 1976.

Beck, John (BLM archaeologist). Telecon to Kyle Weaver, August, 1978.

Delp, II, William H. (Independent Power Developers). Telecon to DEPD, June 30, 1978.

Gilkes & Gordon, LTD. "Pelton Wheels" Brochures M14A and M18. Craven House, Kingsway, London W.C.2. Undated.

Hawaii. Alternate Energy Sources for Hawaii. Report of the Alternate Energy Sources for Hawaii. Sponsored by University of Hawaii and State of Hawaii. Department of Planning and Economic Development. Undated.

Independent Power Developers (IPD). "Hydroelectric Power". Noxon, Montana: IPD.

Lindsley, E.F. "Water Power for Your Home," Popular Science. May 1977.

Soltis, Debbie. Telecon to DEPD, August 11, 1978.

Soltis, Francis. "The Pelton Wheel & Water Power." Brochure. Chugiak, Alaska: Alaska Wind & Water Power. Undated.

U.S. Department of the Interior. Alaska Natural Resources and the Rampart Project. 268-586-0-67-3. June 1967.

U.S. Department of the Interior. Bureau of Land Management. Alaska Outer Continental Shelf Office. Reference Papers #9 -Energy Alternatives. Anchorage, Alaska.

U.S. Federal Power Commission. Water Powers of Southeastern Alaska. by Joseph Cummings Dort. Washington, D.C.: Government Printing Office 1924.

Wentink, T. "Power and Energy Productivity of Small Windmills in Alaska," Geothermal Energy and Wind Power...Alternate Energy Sources for Alaska. ed. Robert B. Forbes. From the proceedings of the Alaska Geothermal and Wind Resources Planning Conference. Anchorage, Alaska: Prepared by the Geophysical Institute of the University of Alaska and the Alaska Energy Office, July 8-9, 1975.

APPENDIX 13-A

The following material, extracted from William Delp's Independent Power Developers brochure, lists specific insturctions for analyzing and evaluating a potential small-scale hydropower site.

Analysis of Site

The ability of a stream or spring to generate power is dependent upon two important factors, head and flow.

Head. Head is the vertical distance of fall in feet from the point where water enters the system (pipe orifice) to where it is ejected from the turbine housing.

How To Measure Head

You can employ a surveyor to determine head for you by simply asking him to find the vertical distance from your water source to the proposed location of the power plant. Or, you can determine head yourself using a carpenters level, a stand (tripod or saw horse) and a tape measure. See Figure 13-A-1.

1. Set the level on a stand, making sure the level is horizontal (level) and at the same elevation as the spring.
2. Sight down the level to a spot on a nearby object which can be reached for measuring.
3. Have your partner measure the distance from the point sighted (A) to the base of the object (BO and record this number.
4. Repeat this procedure until you end up at the same elevation as the proposed power plantsite.
5. If more than one set-up was required, add the distances measured to give the total head.

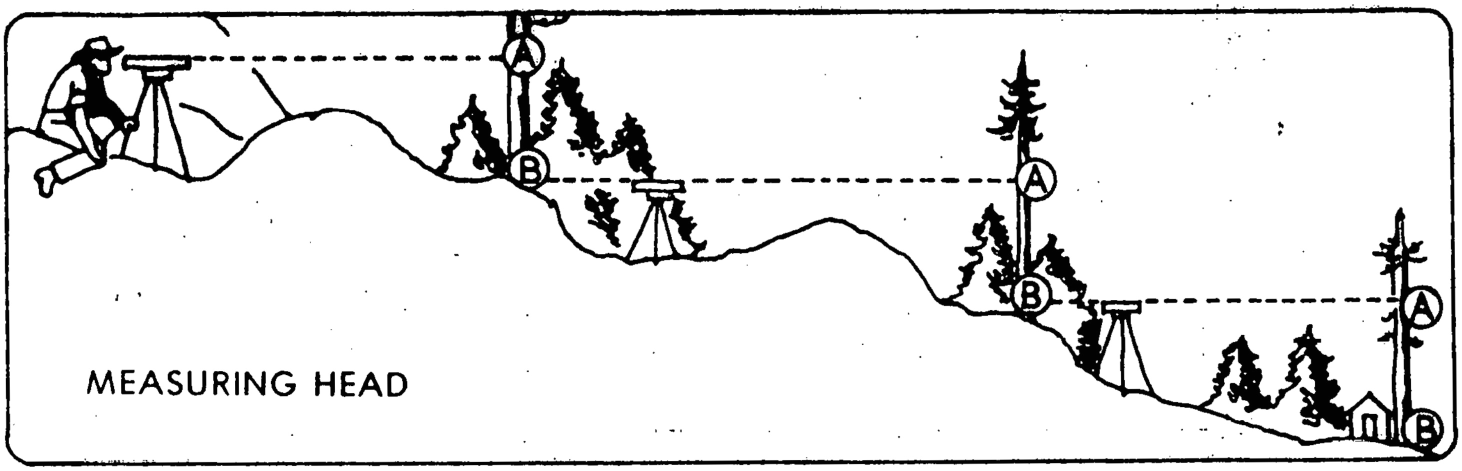


Figure 13-A-1

Remember:

- You are simply taking the sum of elevation differences from the water source to the turbine site.

- You need not be concerned with horizontal distances for head determination.

- You need not travel in a straight line.

- For heads of 25 feet or less you should be extremely accurate. In these cases, hiring a surveyor would be advisable.

FLOW. Flow is the quantity of water available at the source measured in cubic feet per minute. It must be noted that the flow measurements described below should be taken during the dry season. This precaution will help determine the minimum continuous output which can be expected from you hydroelectric system.

How To Determine Spring Flow

1. Temporarily dam up the spring and divert its flow through one opening.

2. Place a 5-gallon container beneath the opening and carefully time the seconds required to fill it completely.

3. To get flow in cubic feet per minute (CFM), divide the seconds required to fill the 5-gallon container into 40*--or,

$$\frac{40}{\text{seconds}} = \text{flow (CFM)}$$

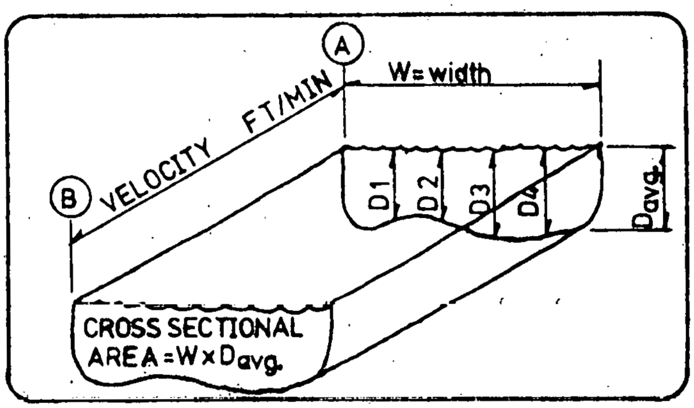
For example, if it took 10 seconds:

$$\frac{40}{10 \text{ sec.}} = 4\text{CFM}$$

4. Usable flow: due to the small amount of water involved it would be reasonable to use the total amount of flow without environmental damage.

How To Determine Stream Flow

Flow can be described as the volume of water which passes a given point on the stream in one minute. That is, the cross-sectional area of a stream moves a number of feet in one minute describing a quantity of water as illustrated below.



Stream Flow
13-A-2

* This number was derived from the unit conversion relationship:

$$5 \text{ gal.} \times \frac{1 \text{ cu. ft.}}{7.48 \text{ gal.}} \times \frac{60 \text{ sec.}}{1 \text{ min.}} = \frac{40 \text{ cu. ft. -sec.}}{\text{min.}}$$

This quantity of water which passes point A in one minute ending up at point B is the flow. The flow can be determined by performing four easy tasks.

1. AREA. Determine the cross-section area of the stream:

   - o Select a uniform, easily measured spot on the stream.
   - o Measure the width (w) of the stream in feet. (For purposes of example: let w = 10.2 ft.)
   - o Then, using a stick, measure the depth in feet at equal intervals along the cross-section of the stream. Record the depth at each interval and take the average.

Example: D1 = 1.0 ft.
D2 = 1.5 ft.
D3 = 1.7 ft.
D4 = 0.8 ft.
Total 5.0 ft.
Average D $\frac{5.0 \text{ ft.}}{4}$ = 1.25 ft.

   - o Multiply the width (2) by the average depth (D avg.) to get the cross-sectional area in square feet.

Example: Area D avg. x w
Area = 1.25 ft. x 10.2 ft. = 12.75 ft.^2

2. VELOCITY. Determine the stream velocity:

   - o Choose a stretch of water which is relatively straight and free of obstacles.
   - o Mark off two points 25 ft. apart along the stream and establish this distance with a stake at each end.
   - o Have another person drop a float (a cork, piece of bark, etc.) in the center of the stream at the upstream point as you carefully time the number of seconds requiring the float to pass the downstream point. This will give the time in seconds necessary for the cork to go 25 feet.

- o This figure can be changed into feet per minute by dividing seconds into 1500.**

Example: $\frac{1500}{8 \text{ secs.}}$ = 187.5 ft./min.

- o Multiply this number by o.65. This is done to average out the total stream flow by taking bed friction and channel roughness for a rough hill stream into account.

Example: 187.5 ft./min. x 0.65 = 121.9 ft./min.

- o This figure gives the stream velocity.

3. FLOW. Calculate the flow:

- o Multiply the average cross-sectional area (found in #1) times the stream velocity (found in #2).

Example: 12.75 sq. ft. x 121.9 ft./min. = 1554 cu. ft./min.

- o This number is the flow value for your entire stream.

4. USABLE FLOW. Determine the usable flow:

- o Because only a portion of the entire stream may be used for purposes of hydroelectric generation, the total flow must be converted to usable flow. Just how much of a year-round stream may be safely diverted depends upon the character of the individual stream itself. As a good working figure, we suggest that only 25% of the total flow during the dry season be temporarily diverted for energy development.

- o Multiply the total flow found in step 3 times 0.25 to give usable flow.

  Usable flow = total flow x 0.25

Example: Usable flow = 1554 CFM x 0.25
389 CFM

** This number was derived from the unit conversion relationship:

Vari. $\frac{25 \text{ ft.}}{\text{sec.}} \times \frac{60 \text{ sec.}}{\text{min.}}$ = 1500 ft./min. conversion to ft./min.

When measurement and calculations have been completed the power potential can be determined. The Delp Nomograph, shown as Figure 13-3 is a chart which gives the resultant power output from the combination of the determined head and flow values.

CHAPTER 14

LOW TEMPERATURE GEOTHERMAL SPACE HEATING

CHAPTER 14
LOW TEMPERATURE GEOTHERMAL SPACE HEATING

INTRODUCTION

The purpose of this chapter is to address the potential for low-temperature geothermal energy for home (space) heating in the small communities and remote villages within the State of Alaska. Energy is very expensive in remote Alaska. So, while only a few communities and villages have a geothermal resource nearby, an economical local energy source would nevertheless be very important to these locations.

Don Markle, a geothermal engineer from the Oregon Institute of Technology, assigned to the Division of Energy and Power Development, has compiled Alaskan geothermal data which includes site location, physical reservoir data, land tenure, attitude toward development, historical/ archeological significance, development status, institutional issues, environmental factors, population and transportation. This information is available in the recently published Geothermal Energy in Alaska: Site Data and Development Status.

HISTORY OF GEOTHERMAL SPACE HEATING

WORLD

Geothermal resources have been in use for centuries. Ancient Greek and Roman baths were well known, but geothermal baths were also being used as far away as the Andes Mountains by the Incas. Less sophisticated bathing and cooking was done by numerous groups throughout the world, including peoples in Alaska.

The use of geothermal chemicals probably predates use by Etruscan potters, artisans, miners and merchants in 500 B.C. in what is now Italy. The borates, sulfates, and sulfur from the springs were later used in the Middle Ages. Boric acid extraction led to the use of pressurized geothermal steam in a system invented by Francesco Larderal in 1827 in

Tuscany. In 1904, Prince Piero Ginori Conti set up an experimental geothermal generator, which was replaced by a 205 Kw system in 1913. By 1976, only the United States surpassed Italy's electrical generation from geothermal sources (about 400,000 Kw). Additionally, many Italian homes and a few greenhouses are heated with central system geothermal steam (Wehlage, 1976).

Geothermal water was first used for space heating in Iceland during the 13th century. Serious drilling for central use began in 1928 and expansion continues today (Wehlage, 1976). Geothermal resources now provide heating for half of the population of Iceland in addition to much of the country's electrical power (Lund, 1975).

The best example of a large scale geothermal heating system is Reykjavik, Iceland where 99 percent of the city of 88,000 is serviced. The city is divided into districts, each pumping from resources within the city or from Reykir approximately 15 km away. Input temperatures range from 80° to 119°C, lower than the 136°C temperature in the north at Myvatn. Plans are also being made to supply the 12,000 people of Akureyri from geothermal wells in Laugaland, 12 km south of the town (Lund, 1977). Both systems pump geothermal water from the wells to storage tanks, where it is held to meet demand and eventually circulated to the customer at 80°C (Lund, 1975).

Other countries use geothermal power as well. Hungary uses geothermal hot water for space heating and, notably, agricultural applications. New Zealand uses geothermal resources for space heating, electrical generation, and industrial purposes. The system at Wairakei reflashes the water, providing for greater utilization of the installed electrical generating capacity. Japan has a number of thermal areas and a variety of applications, including space heating, electrical generation, industrial power generation, horticulture, and raising of exotic fish and animals (Wehlage, 1976).

Table 14-1 shows the major users of geothermal water for space heating in 1975. This table does not include minor users such as Turkey (Tan in Howard, 1975) and the Philippines (Alcarez in Howard, 1975).

TABLE 14-1

PRESENT USES OF GEOTHERMAL WATER FOR SPACE HEATING

Country		Number of Locations and Estimated Usage	Estimated Average Annual Thermal Power Usage
Iceland		12 (101,000 people)	250 MW
USSR		8 (40,000 people)	100 MW
Japan		4 (20,000 people)	10 MW
Hungary		3 (3,000 people)	10 MW
USA		4 (3,000 people)	10 MW
New Zealand		3 (3,000 people)	20 MW
France		1 (10,000 people)	4 MW
	TOTAL	35 (180,000 people)	404 MW

The average usage is based on a utilization factor that varies from 10 percent to 53 percent (New Zealand and Iceland).

Source: John W. Lund, "Geothermal Space Heating;" Origianal source: Howard, 1975; Pearson, et al., 1975.

UNITED STATES

In North America, there has been a long history of geothermal baths and space heating of resorts. For instance, the development of the unusual dry steam field of California's Big Geyser has resulted in the world's largest geothermal electric power production area (Wehlage, 1976). However, the most successful U.S. space heating development has taken place in Klamath Falls, Oregon.

Residents of Klamath Falls have made use of the resource on a noncentralized basis since at least 1900. By 1974, there were approximately 400 hot water wells used for the space heating of about 500 structures (Lund, 1975). Used principally for space heating of residences, schools, and businesses, the geothermal water is also utilized to heat swimming pools, pasteurize milk, and melt snow from pavements (Lienau, ND).

Closed-loop, downhole heat exchangers have replaced the original use of natural hot springs as the principle means of utilization (Lund, 1975). Well depths range from 27 to 549 m, depending upon the required heat output. Residential wells are usually between 70 and 100 m, while commercial wells are commonly 300 to 400 m in depth. Temperatures vary from 40° to 110° C.

While the amount of heat in storage at Klamath Falls is not critical for present usage, water available to transfer the energy to the surface is limited. Three of the Klamath Falls schools help to conserve this water supply by operating systems that return the water to the reservoir after its use in heating (Lienau, ND).

Boise, Idaho has one of the oldest district heating systems. Built during the 1890's, it continues to serve about 200 houses and 10 to 12 businesses (Reistad in Howard, 1970).

ALASKA

Prehistoric use of Alaskan geothermal resources for bathing and cooking was probably quite common. Hot springs sometimes had religious significance to the inhabitants of the area. At times, structures were built for better utilization of the springs. Examples still in use are the wooden cribs constructed by the Tlingit Indians at Chief Shakes Hot Springs near Wrangell (Markle, 1979).

The Russians continued the in-situ, intermittent use of the hot springs where it was convenient. Most of the springs, however, were not near Russian settlements (Markle, 1979).

After Alaska's purchase by the United States, there was little further development until early entrepreneurs came north with the gold rush. Following the turn of the century, roadhouses and small settlements appeared at Sitka, Tenakee Springs, and Baranof in Southeast Alaska; Circle, Chena, and Manley Hotsprings near Fairbanks, and Pilgrim and Serpentine Hotsprings near Nome.

As the prospectors left Alaska, use of the hot springs declined. Some of the lodges survived on a marginal basis, but there was little change in the pattern of geothermal utilization until the last decade. Now, with the commercial growth of the State and the renewed interest in non-fossil fuel energy sources, geothermal resources have assumed a new importance.

Present usage and usage under consideration ranges from space and water heating to electrical generation, and agricultural to aquacultural application. Table 14-2 lists the utilization to date and the projected usage of the State's major geothermal springs. Figure 14-1 shows the location of these selected sites using a map of thermal springs by Gerald A. Waring (1965). When it is available, the chemical analysis of the spring water is provided in Table 14-3.

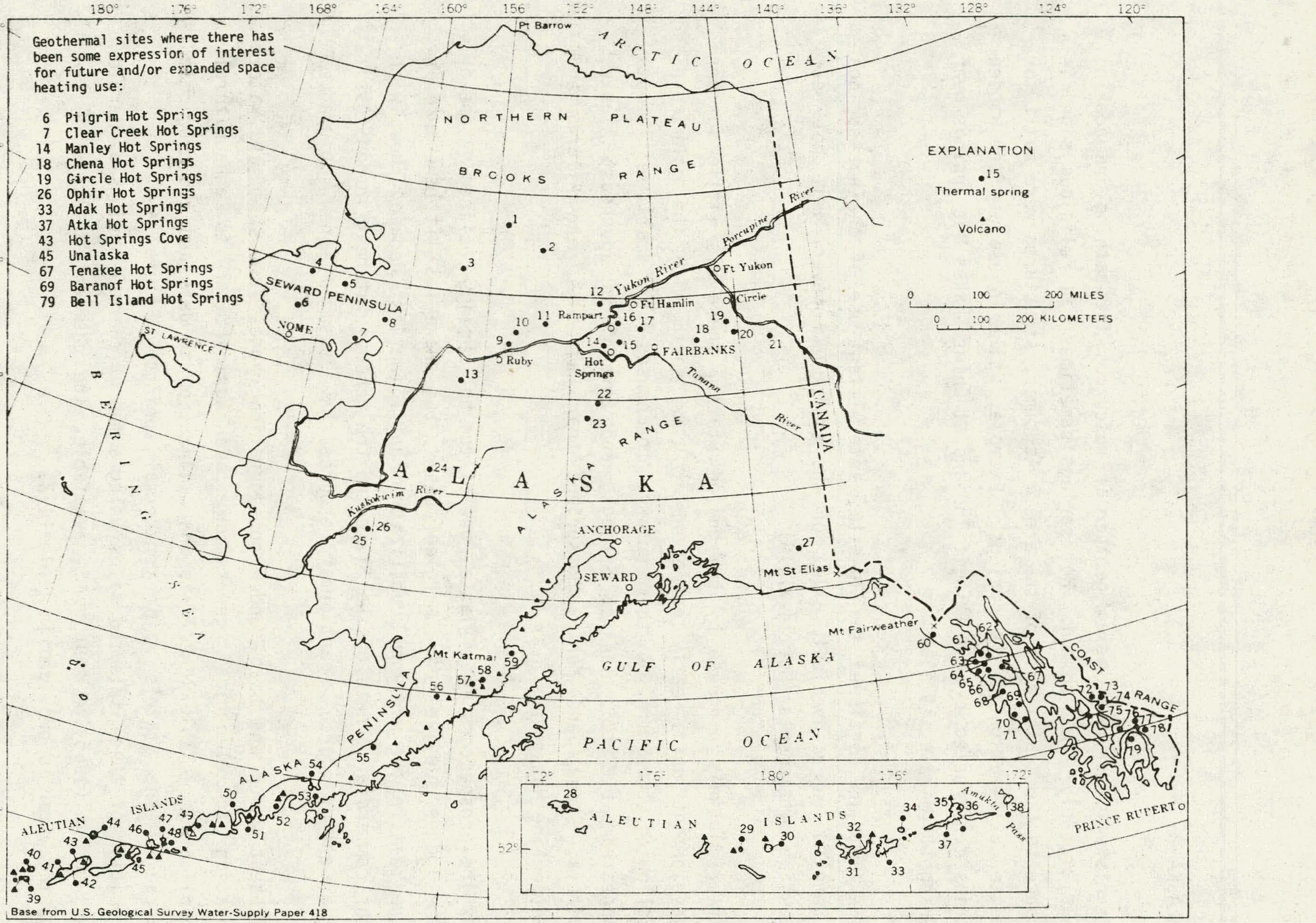


Figure 14-1

Thermal Springs and Volcanoes of Alaska

TAbLE 14-2

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

PILGRIM HOT SPRINGS

Location:	Northwest	Village:	Nome	Surface Temperature:	17°-45°C
	Latitude: 65° 06'N		Mary's Igloo	Water Flow Rate:	--
	Longitude: 164° 55'W				

Past	Formerly known as Kruzgamepa Hot Springs, the springs were used by Native Alaskans for bathing, years before the Russians arrived in Alaska. To accommodate visitors from Nome and other mining centers, a resort was built in about 1905. A fire in 1908 destroyed the roadhouse and saloon, and the property was donated to the Catholic Church. Dr. Frederick A. Ruppert S.J. and some 120 orphans who came to the church as a result of the Spanish influenza epidemic used the geothermal energy from 1919 to 1942 for space heating and gardening. Surplus vegetables were sold in Nome.
Present (1980)	The geothermal waters heat an area of perhaps 100 acres. This permits farming of vegetables such as potatoes and turnips (up to 17 lbs) and causes a micro-climate supporting a wide variety of unusual birds.
Future	Two exploratory wells have been drilled in the $245,000 geothermal project being conducted jointly by the State Division of Energy and Power Development and the Alaska Geological and Geophysical Survey. The deeper well of 150 feet encountered an artesican flow of 350 gallons with a surface temperature of 91°C. A third well will be drilled to a depth of at least 500 feet in the spring of 1980. The final phase of the demonstration project will be a local application of the resource, probably at least a greenhouse and additional soil or space heating. The geothermal potential already demonstrated could heat a combination of 200 homes and some commercial greenhouses. Mr. C. J. Phillips, the owner, is also interested in electrical power generation and possible aquaculture application.

Sources of Data:

C. J. Phillips, telecon July 20, 1978.

Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.

William Ogle, "Report of a Visit to a Number of Alaska Hot Springs to Aid in the Selection of a Site for the Possible Installation of a Small Binary Geothermal Electric Generating Plant," July 28, 1976.

McConkey, el. al., Alaska Regional Energy Resource Planning Project, Phase 1, Preliminary Report.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

CLEAR CREEK SPRINGS

Location: Northwest Latitude: 64° 51'N Longitude: 162° 18'W	Village: Elim (5 miles east) Moses' Point (15 miles south)	Surface Temperature: 67°C Water Flow Rate: 800 l/min

Past	Native bathing.
Present	Native bathing.
Future	No plans for expansion. Community Enterprises Development Corporation is involved with the Natives in fish processing (freezing) at Moses' Point, and represents a potential community user of geothermal energy. Calculations by Dr. Bill Ogle indicate that surface flow from the spring could produce 20 to 30 Kw of binary electrical power and space heat 30 homes.

Sources of Data:

Ed Rutledge, Community Enterprises Development Corp. Telecon to Greg Edblom, July 18, 1978.

Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.

McConkey, el. al., Alaska Regional Energy Resource Planning Project, Phase 1, Preliminary Report.

TABLE -2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

MANLEY HOT SPRINGS

Location: Interior
Latitude: 65° 00'N
Longitude: 150° 38'W

Village: Manley Hot Springs

Surface Temperature: 59°C
Water Flow Rate: 560-757 l/min

Past	Locating the springs in 1901, John Karshner joined with Frank Manley to build a geothermally-heated, 60-room hotel with a bar and bath. Before the hotel burned down and most of the people moved out in the late 1920's, swimming pools, stables, chicken coops, vegetable gardens and a hog sty made use of geothermal heat.
Present (1978)	Manley Hot Springs are being used in two large greenhouses, a bathhouse and space heating of the house of Mr. Charles Dart, the owner.
Future	Lee Leonard and Robert Forbes of the University of Alaska Geophysical Institute are working to establish a geothermal research station at the site, including a 2.5 kilowatt electrical generating unit. Assuming an efficiency of 30 percent and a 40°F temperature change, the spring could provide 1.05×10^9 Btu's for agricultural uses.

Sources of Data: Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Date Base Development Status, April 1979.
R. B. Forbes, communication to Greg Edblom, August 3, 1978.
McConkey, el. al, Alaska Regional Energy Resource Planning Project, Phase 1, Prelimary Report.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

CHENA HOT SPRINGS

Location: Interior
Latitude: 65° 03'N
Longitude: 146° 03'W

Village: Chena

Surface Temperature: 57°C
Water Flow Rate: 840 l/min

Past	In 1905, gold prospector Felix Pedro used the springs for recreational purposes. Later, George Wilson homesteaded the land, commercializing it as a health spa.
Present (1978)	Two 60-foot wells are being used to heat a lodge, residence, three cabins, and a swimming pool at the site.
Future	The owners have applied for a State loan for the expansion of the present lodge and construction of a second lodge and swimming pool, all to be heated geothermally. They are also interested in a greenhouse and electrical power generation. Proposed development calls for the annual utilization of 1.7 X 108 Btu's by 1984.

Sources of Data: Michael McCrackin (part owner), telecon July 20, 1978.
Don Markle, interview July 17, 1978, interview December 21, 1979, and _Geothermal Energy in Alaska: Site Data Base and Development Status_, April 1979.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

CIRCLE HOT SPRINGS

Location: Interior
Latitude: 65° 29'N
Longitude: 144° 39'W

Village: Circle Hot Springs

Surface Temperature: 59.5°C
Water Flow Rate: 1704 l/min

Past	Although the springs were in use much earlier, the resort area was homesteaded by Frank Leach in 1918.
Present (1978)	Owner Bill Hager now uses the water for gardening and to heat a 22-room hotel, 13 cabins, various outbuildings, and an Olympic-size swimming pool.
Future	No known plans.

Sources of Data: Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.
Michael McCrackin, telecon to DEPD, July 20, 1978.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

OPHIR HOT SPRINGS

Location: Southwest
Latitude: 61° 11'N
Longitude: 159° 51W

Village: Ophir

Surface Temperature: 63°
Water Flow Rate: 850 l/min

Past	Native bathing.
Present (1978)	Owner Harry Faulkner uses the spring to space heat his home. Since the warm water keeps the creek open year-round, he has also installed a low head, hydroelectric generator.
Future	No plans for expansion.

Sources of Data: Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

ADAK

Location: Aleutian Latitude: 51° 59'N Longitude: 176° 36'N	Village: Adak	Surface Temperature: 68° Water Flow Rate: --

Past	No known use.
Present (1979)	Under the direction of Carl Halsey, the United States Navy has drilled three exploratory wells, one demonstrating a bottom hole temperature of 66°C at 2000 feet (610 meters). Despite favorable resource and economic calculations, plans for a 4000 to 5000 foot (1219 to 1524m) exploratory well and a 4000 to 6000 foot (1219 to 1524m) production well have been blocked due to lack of funding.
Future	Space heating and electrical generation for the 5,000-person Naval installation will be pursued if the geothermal exploration proves encouraging. Plans call for the generation of 25 MW of electrical power and space heating capability of 3 X 10^{11} Btu's by 1985.

Sources of Data: Carl Halsey, telecon to DEPD, July 21, 1978.
Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

ATKA

Location: Aleutian
Latitude: 52° 11'N
Longitude: 174° 14'W

Village: Atka

Surface Temperature: --
Water Flow Rate: --

Past	Native bathing and cooking.
Present (1978)	Native bathing and cooking continue. The site is used as a subsistence camp.
Future	Although the Springs may have the potential for space heating the village some 25 miles away, the Aleutian-Pribilof Islands Association is currently more interested in the possibility of electrical power generation for the village and perhaps a fish processing plant. The electricity would allow the fish to be preserved by freezing rather than salting. Hydroponics is another possibility.

Sources of Date: Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.
Ralph Amovak, telecon to DEPD, July 21, 1978.

TABLE -2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

HOT SPRINGS COVE

Location: Aleutians
Latitude: 53° 14'N
Longitude: 168° 21'W

Village: Nikolski

Surface Temperature: 89°C
Water Flow Rate: 360 l/min

Past	The springs were once used for Native bathing and cooking.
Present (1978)	Native bathing and cooking continue as the site is used as a subsistence hunting and fishing camp.
Future	The Aleutian-Pribilof Island Association is interested in using the geothermal resources in hydroponics and electrical power generation for Nikolski, 40 miles away. Electricity would open the possibility of cold storage and processing of meat from their reindeer herd. Fifty megawatts of electrical power generation have been proposed for aluminum or manganese processing.

Sources of Data: Ralph Amovak, telecon to DEPD, July 21, 1978.
Don Markle, interview July 17, 1978, interview December 21, 1979, and _Geothermal Energy in Alaska: Site Data Base and Development Status_, April 1979.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

Numerous Springs Near Makushin Volcano

Location: Aleutians Latitude: 53° 50' N Longitude: 167° 40' W	Village: Unalaska	Surface Temperature: Approximately 40°C Water Flow Rate: --

Past	Native bathing and recreation.
Present (1980)	On September 13, 1979 the city council requested assistance from the State Department of Energy and Power Development to study the feasibility of tapping the local geothermal resource. Preliminary investigations by the State Division of Energy and Power Development, Oregon Institute of Technology, University of Utah Research Institute, and Energy Systems, Inc. have resulted in a formal proposal for additional studies.
Future	The State Division of Geological and Geophysical Surveys has proposed a resource assessment project in which Unalaska would be a major component. Working with NASA, infra-red radiometer, thermal scanner and radar imagery would be obtained for Unalaska and Umnak Islands; infra-red radiometer and thermal scanner imagery would be obtained for the other thirteen sites. Extensive geologic field mapping of Unalaska would be initiated by June 1, 1980 and a drilling operation would begin the following summer. With thirteen fish canneries and a seasonal population of 500 to 2000, Unalaska has a high potential for using a geothermal resource for space and water heating.

Source of Data: Neil Basescu, interview December 21, 1979.
Don Markle, interview December 21, 1979 and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

TENAKEE SPRINGS

Location: Southeast 50 mi. W. Juneau
Latitude: 58° 00'N
Longitude: 135° 55'W

Village: Tenakee Springs

Surface Temperature: 43°C
Water Flow Rate: 84 l/min

Past	In the early 1900's, the steamship Georgian made a weekly trip from Juneau to Tenakee Springs. The Springs were used for bathing because of their "medicinal" properties.
Present (1978)	There is now a city-owned bathhouse at the Springs.
Future	Unknown.

Source of Data: Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.
McConkey, el. al., Alaska Regional Energy Resource Planning Project, Phase 1, Preliminary Report.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

BARANOF HOT SPRINGS

Location: Southeast Latitude: 57° 05'N Longitude: 134° 50'W	Village: Baranof	Surface Temperature: 50°C Water Flow Rate: 113 l/min

Past	The Tlingit Incians used the springs for bathing before the Russians arrived. Later, the steamship servicing Sitka and Tenakee Hot Springs weekly from Juneau also stopped at the Baranof Hot Springs because of their "medicinal" properties. In the late teens and early 20's, the springs were used to heat a bathhouse built under the auspices of the Territory. At the same time, a bordello also used one of the springs for heating.
Present (1978)	The springs are being used for the space heating of one residence and to heat a bathing pool.
Future	The site has been selected for a fish hatchery. There is a possibility of expanding the geothermal utilization with a mineral water resort and perhaps wood drying.

Source of Data: Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.

TABLE 14-2 (cont.)

PAST, PRESENT AND FUTURE USE OF GEOTHERMAL WATERS IN ALASKA

BELL ISLAND

Location: 25 Min. North of Ketchikan by small boat
Latitude: 55° 56'N
Longitude: 131° 34'N

Village: Bell Island

Surface Temperature: 72°C

Water Flow Rate: 113 l/min.

Past	No known use.
Present (1978)	Mr. and Mrs. Jim Dykes run a small resort, using the Springs to heat the cabins and swimming pool.
Future	There has been some interest in the possibility of geothermally-heated aquaculture.

Source of Data: Don Markle, interview July 17, 1978, interview December 21, 1979, and Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.
McConkey, el. al., Alaska Regional Energy Resource Planning Project, Phase 1, Preliminary Report.

TABLE 14-3

HOT SPRINGS FLUID CHEMISTRY

(Parts per million)

	SiO_2	Al	Fe	Ca	Mg	Na	K	Li	NH_3	HCO_3	CO_3	SO_4	Cl	F	BR	B	pH	°C
Hot Springs Pilgrim	100	0.04	---	530	1.4	1450	61	4.0	30.1	---	30.1	---	21	3346	4.7	2.4	6.75	55
Clear	---	---	---	5.6	0.06	54	1.4	---	---	34	34	25	4.9	---	---	0.2	9.43	67
Manley	65	0.046	---	4.00	2.9	130	4.8	0.28	0.5	90.7	---	51	132	8.2	---	1.2	7.72	56
Chena	85	0.028	---	1.3	0.13	110	3.3	0.3	2.7	114.7	---	68	23.9	18.6	---	1.3	9.14	57
Circle	95	0.012	---	20.8	0.3	230	9.8	0.34	0.1	184.6	---	96	249	9.7	---	1.1	7.58	57
Ophir	30	0.02	0.06	2	0.1	97	1	---	0.04	---	---	240	---	1.4	---	0.1	9.4	---
Adak	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Atka	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Hot Springs Cove	99	---	---	153	3.3	153	27	2	---	69	---	86	1104	0.9	---	27	6.4	6.8
Unalaska	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Tenakee	60	0.05	---	28	0.76	190	3.3	0.08	---	54.8	---	322	95.4	5	---	4.4	9.0	---
Baranof	70	0.37	---	2.5	0.14	51	1.2	0.06	---	88.4	---	68	11	1.2	---	0.2	9.6	51
Bell Island	105.00	---	---	4.60	1.0	---	---	---	---	37.00	---	129.00	4.60	---	---	---	---	---

SOURCE: United States Geological Survey, "Geothermal Resources File," Anchorage, Alaska
Donald Markle, Geothermal Energy in Alaska: Site Data Base and Development Status, April 1979.

Worthy of special note are the Navy-funded exploratory drilling on Adak and the State funded project at Pilgrim Hot Springs in the Nome area. These projects are indicative of the increased interest in the State's geothermal resources. The recently published Geothermal Energy in Alaska: Site Data Base and Development States by Don Markle, funded by the United States Department of Energy through the Oregon Institute of Technology, provides an in-depth study of Alaska hot springs with an excellent collection of available background and technical data.

APPLICABILITY TO RURAL ALASKA

The demography of Alaska has an important influence on the energy usage in the State. Half to two-thirds of the 400,000 people live in the "Rail Belt" between Anchorage and Fairbanks. The rest are scattered across a region that would stretch from coast-to-coast of the Lower 48.

Because of these characteristics, transportation systems are quite limited. Most areas are accessible only by small plane, boat, dog sled, or foot. One of the unavoidable consequences of the size of the state is the extremely high cost of fuel. A barrel of fuel oil will cost over $100 in many towns (Ogle, 1974 and 1976).

Another result of people living in towns of under 300 is the restriction of financial resources. It is quite unlikely that a village will be doing much geothermal exploration and drilling solely for space heating energy. Therefore, with the exception of the U.S. Naval base at Adak and the State project at Pilgrim Hot Springs, current development of geothermal resources in Alaska is limited to simple development of natural hot springs (Ogle, 1974). There are nearly 80 located Alaskan hot springs (Waring, 1965), and an additional 22 reported thermal sites (Markle, 1979; Miller, 1973). See Figure 4-1.

With the low-temperature climate and relatively low temperature of the springs, geothermal resources are quite suitable for non-electrical applications. Utilization already includes recreational bathing, space and water heating, and agriculture (greenhouses and planting in areas heated by subsurface geothermal water). Expansion of these uses would reduce dependence on imported fuels and help provide a local source of foods that might not otherwise be available to the community (Leonard in Forbes, 1976).

Present interest also includes aquaculture and reindeer husbandry, along with drying and refrigeration facilities. Another possible use of geothermal resources is in the treatment of solid waste and sewage (Farquhar, 1977). Table 14-2 illustrates past utilization and present interest and plans for the space heating application of Alaska's major geothermal springs. Although high-temperature geothermal resources with vast economic potential are located in the Wrangell Mountains and the Aleutian Chain, development of these resources is a long-term possibility and is highly dependent upon marketing and technological factors.

Local Gradient Geothermal Energy

A 1977 study by Pacific-Sierra Research Corporation (Farquhar, 1977) investigated the direct-heat potential of using the geothermal gradient which exists at centers of population in Alaska rather than looking for high-gradient anomalies, which tend to occur too far from towns for piping of the hot water to be practical. The study analyzed various aspects of the economics of direct heat geothermal energy use such as population size, climate, local gradient and geology, drilling costs, remoteness of the particular site (which, of course, influenced many of the costs) and found that use of the earth's average geothermal gradient (30° per kilometer) could, under certain conditions, compete favorably with present heating costs. Before a project to heat a town such as Nome using the local geothermal gradient could be undertaken, though, more detailed geological information (such as would be obtained from test holes) is necessary, since this type of information is sparse in areas of Alaska other than those for which petroleum well information is available (Kirkwood, 1978).

An interesting suggestion is that the new capital site be examined for its local gradient geothermal potential as a possible source of heat for the new town. Using existing data, the Geoheat Utilization Center of the Oregon Institute of Technology is presently conducting an economic analysis of the geothermal potential at Willow. It has been proposed that 90 percent of the estimated 1.6 x 10^{12} Btu's to be needed for space heating by 1994 be provided by geothermal resources (Markle, 1978).

GEOTHERMAL SPACE HEATING TECHNOLOGY

Since geothermal space heating has a low annual operation cost, attention needs to be focused on capital costs. Unfortunately, geothermal space heating, whether used on an individual basis or in a heating district, has a high initial cost and is so capital-intensive that development is frequently precluded.

There is nothing complex about the concept of geothermal space heating, i.e., the movement of heat from a geothermal resource to, for example, a residence. The use of hot water systems using cast iron radiators has been around for decades. Geothermal waters require no fuel. However, the waters usually corrode plumbing materials at an accelerated rate due to their high salt content.

The cost of geothermal energy for direct heat application is predominantly a function of the initial cost of drilling and casing a well followed by the installation of heat exchangers, piping, valves and instrumentation.

GEOTHERMAL DRILLING IN ALASKA

A number of years ago at Pilgrim Hot Springs, it was necessary to elevate the geothermal hot water to a level of 15 to 18 feet above the surface of the ground so that the heat could be transferred into a nearby church. The church officials decided to merely hand-drill a pipe about 8 feet into the ground. With the temperature and pressure from the geothermal water, it was possible to obtain a flow from 8 feet beneath the surface of the water to the desired 15 to 20 feet above the level of the geothermal reservoir. This simple, yet appropriate, technology of tamping the pipe into the ground shows what a little ingenuity can do to develop an energy resource.

More recently, the engineers at Adak, Alaska on the Aleutian Chain have drilled three exploratory wells including one to a depth of 1,911 feet. The $245,000 State demonstration project at Pilgrim Hot Springs has completed two 150 foot exploratory wells and plans to drill a 500 foot well next spring. (See Table 14-2.)

While low- to moderate-temperature shallow-well technology is similar to that used for water wells, the drilling equipment that is used for a deep geothermal well is somewhat similar to the equipment that is used for an oil and gas well. Nevertheless, there is one major concern in geothermal drilling that is distinctive from that in oil and gas drilling. While drilling mud is acceptable for an oil and gas well, it can present a problem with a geothermal well in that it may cement the fractures and plug off the geothermal resource. Sometimes salt is used instead of mud to control the geothermal pressure. It is also important to carefully record temperature measurements at various depths, a less essential procedure in an oil and gas effort.

The drilling plans for the holes necessary for a demonstration space heating project are given in a report by R. C. Stoker (1975). Stoker indentifies the drilling materials for the (1) casing, (2) drill bits, (3) casing equipment, (4) drill tools, (5) drill rod, and (6) tubing.

GEOTHERMAL PIPING

Both at Chena Hot Springs, Alaska and Boise, Idaho, geothermal piping systems have used wood. A number of other materials (black steel, CPVC, PVC, cartina and asbestos cement) have been analyzed for costs by I.A. Engen (1978). See Figure 14-2. Also, an Alaska firm, Energy Systems, Inc., will soon publish general pipeline cost information.

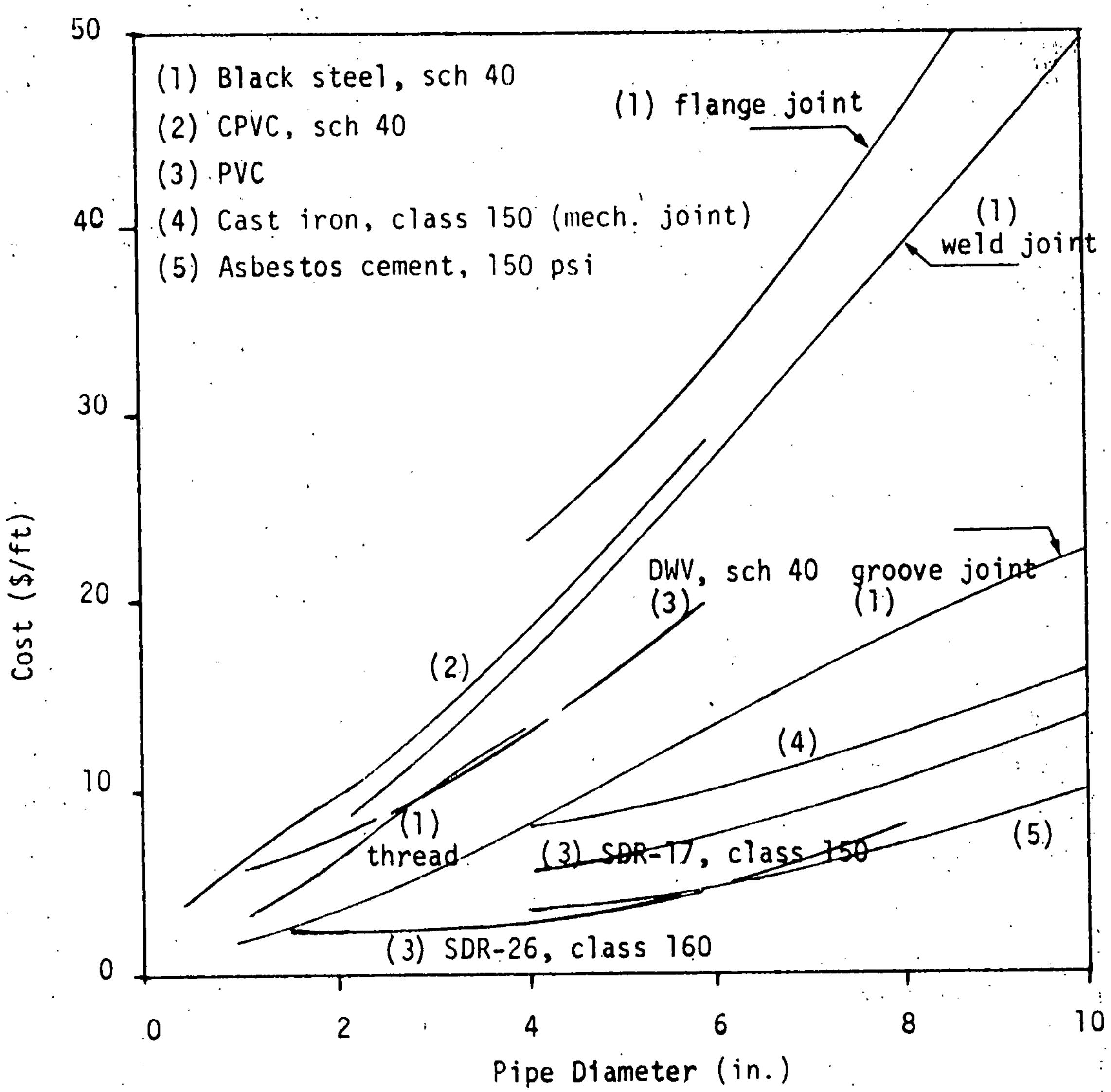


Figure 14-2

Pipe Installation Costs

(Add $3/yd^3 for burial service - trench and backfill.)

Source: I.A. Engen, "Residential Space Heating Costs: Geothermal vs Conventional Systems," 1978, p. 31.

There are several piping materials which can be used to transport geothermal waters. One is transite, a trade name for the asbestos cement manufactured by John Mansville and others. Another piping material is the standard carbon steel piping. Also, polyvinyl chloride, PVC piping, is used on waters up to about 120° F. It is generally available in stores such as Sears and Montgomery Wards. Above 120° F, the temperature and the pressure will be too great to permit the utilization of PVC material. CPVC pipe material is feasible for use in geothermal waters for temperatures up to 180° F.

Other geothermal piping includes steel and cast iron; however, experience has shown that some iron type piping materials are rapidly corroded as a result of electrolytic action. Another hazard is mineral deposits. Deposits can be minimized by using a closed loop system. A build-up of calcium carbonate, for example, can occur to such an extent that pipe may eventually become plugged. For projects requiring a considerable amount of piping, piping manufacturers such as Moller, Denmark; Permapipe, E.B. Kaiser and Pittsburgh Corning will actually design the system and provide cost estimates.

The flow from a well is a function of the inside diameter of the casing. The production flow rate versus well casing diameter is given in Figure 14-3.

HEAT EXCHANGERS

In order to transfer the geothermal heat into the air within a building it is not necessary to purchase sophisticated or expensive equipment. At Circle Hot Springs in Alaska, 30 foot coils of pipe are housed in a room about six by thirty feet. The geothermal water warms the pipe and the heated air is moved by fan to the areas of use.

Another type of heat exchanger is the well known cast iron radiator so familiar a few years ago. Today steel pipe heating elements with fins added to increase the transfer of heat to the air are in frequent use.

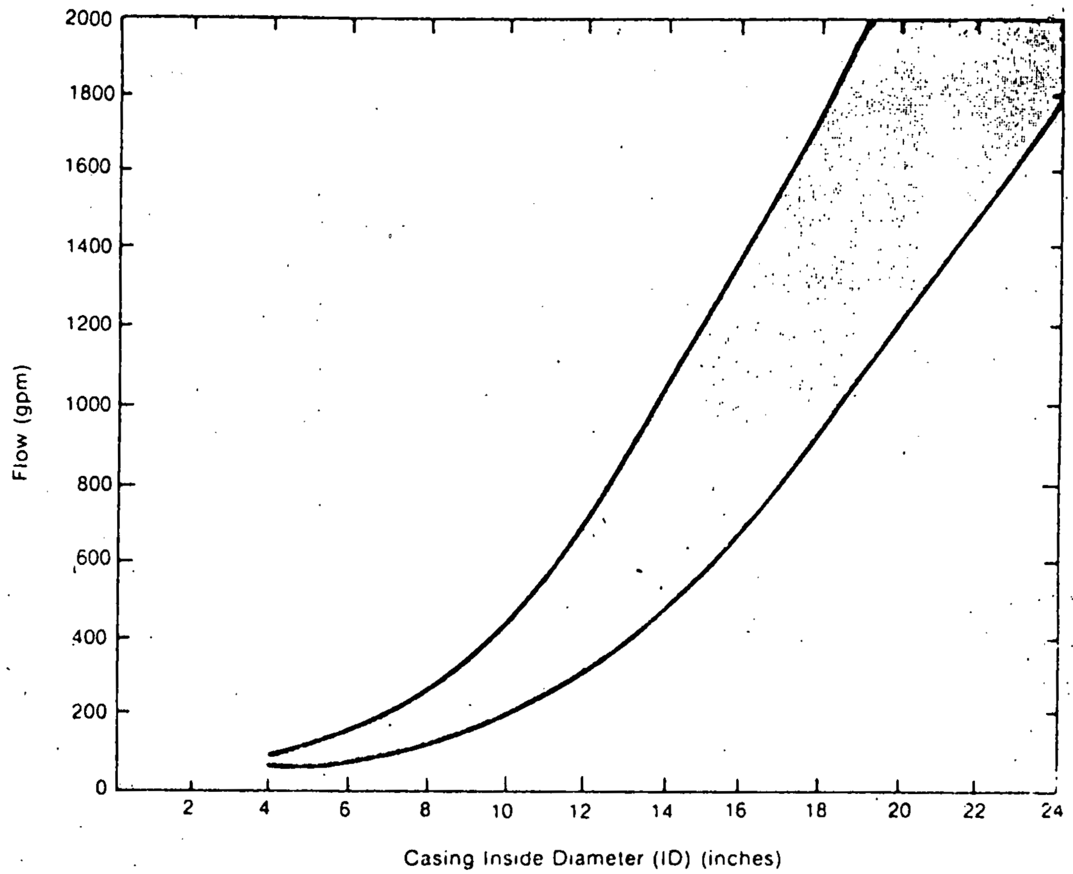


Figure 14-3

Production rate versus well casing diameter.

Source: I.A. Engen, "Residential Space Heating Costs: Geothermal vs Conventional Systems," 1978, p. 32.

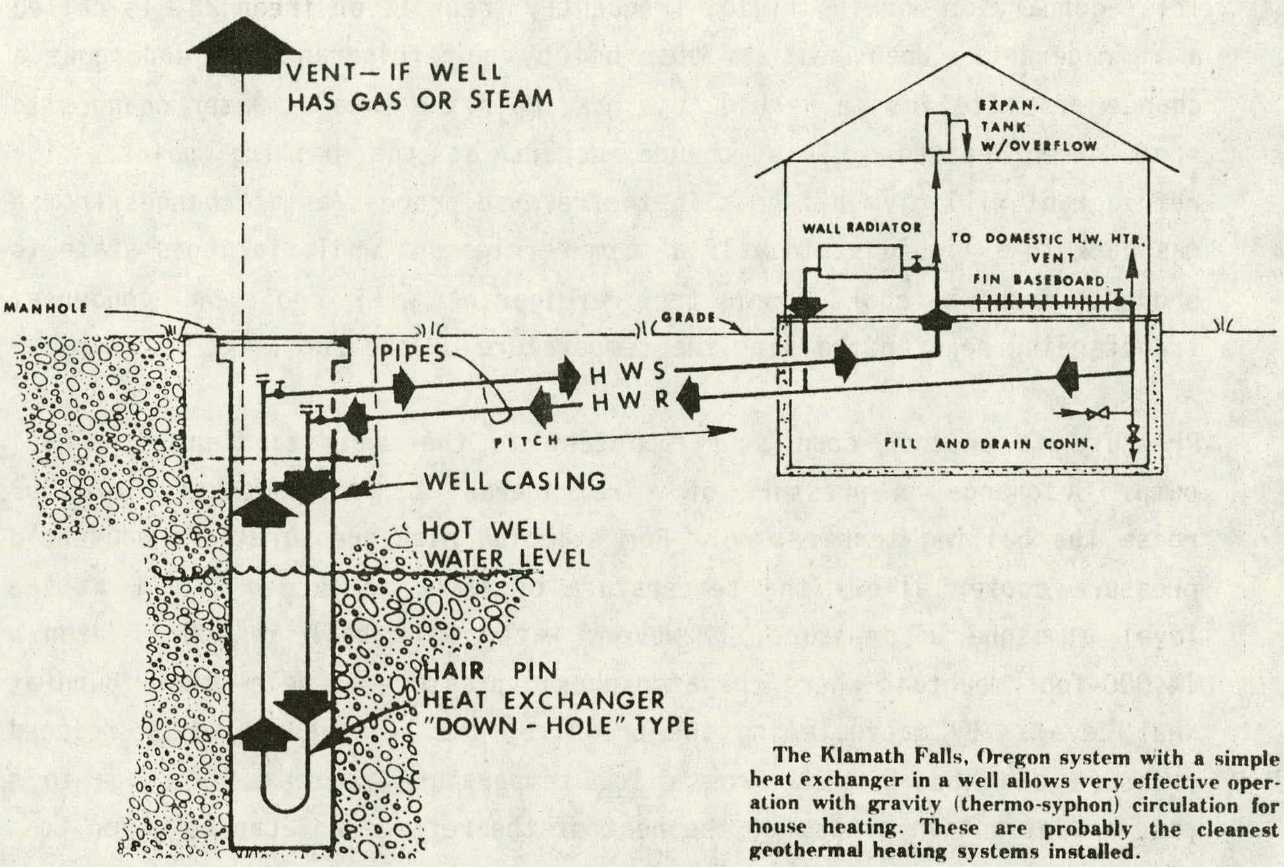
Heat exchangers may also be used down in the geothermal hole. These "down hole heat exchangers" prevent direct contact of geothermal waters with the plumbing system. This effectively eliminates the geothermal corrosion of the heating system.

The introduction of gas-bearing geothermal fluids directly into a home should be discouraged since the release of a noxious gas could be very harmful. The hairpin down hole heat exchangers used in Klamath Falls, Oregon (see Figure 14-4) provide an example of a closed system operation resulting in a very clean geothermal system.

THE HEAT PUMP*

In a residential forced air heating system, hot air in the temperature range of 100° F - 140° F is added to the room air to maintain the desired indoor temperature. Absorbing heat from a low temperature geothermal source of 60° F - 90° F and transferring heat to provide 100° F - 140° F air temperatures might seem impossible when the principle of heat flow from high to low temperature is considered. As implied by the name, heat pumps are to transfer or pump heat from a low temperature to a higher temperature medium. The principle is identical to the operation of a refrigerator; heat is removed (pumped) from the colder interior of the refrigerator and given off to the ambient air. A similar fluid is used inside the heat pump to absorb heat from the geothermal water and transfer this heat to a surrounding space. This secondary fluid is the key to the ability of a heat pump to transfer heat from low temperature sources.

*Slight modifications have been made to a part of an EG & G Idaho, Inc. report entitled "Heat Pumps Primer for Use with Low Temperature Geothermal Resources," by J. G. Keller, November 16, 1977.



The Klamath Falls, Oregon system with a simple heat exchanger in a well allows very effective operation with gravity (thermo-syphon) circulation for house heating. These are probably the cleanest geothermal heating systems installed.

Figure 14-4

The Klamath Falls Geothermal
Space Heating System

Source: Edward F. Wehlage, The Basics of Applied Geothermal Engineering, 1976, p. 164; Original Source: ISGE Transaction, Vol. 1, No. 1.

The secondary or working fluid, frequently freon 12 or freon 22, is called a refrigerant. When heat is absorbed by a refrigerant, it undergoes a change of state from a liquid to a gas, much the same as water changes to steam when heated. This change occurs at the boiling point. The refrigerant will give off heat in the reverse process as it changes from a gas back to a liquid state. If a warm refrigerant while in a gas state is brought into a cool room, the refrigerant will cool and condense, transferring heat and raising the temperature of the room.

Pressure is another condition important to the understanding of a heat pump. A change in pressure of a refrigerant can respectively lower or raise the boiling temperature. For example, high pressure in a household pressure cooker allows the temperature of water to exceed 212° F at sea level atmospheric pressure. However, water will boil at 198° F atop a 14,000-foot mountain where the atmospheric pressure is below that found at seal level. By manipulating the pressure, the refrigerant under reduced pressure can absorb heat from a low temperature source and change to a gas, and at a high pressure, the heat of the refrigerant can be given to a higher temperature substance while changing back to a liquid. Thus, a heat pump refrigerant can absorb heat and become vaporized from a low temperature geothermal source and transfer this heat to the higher temperature room air by condensing to a liquid. A schematic diagram illustrates these processes with the various stages numbered and described in Figure 14-5.

This process is continued as heat is removed from the low temperature geothermal water and transferred to the higher temperature room air. Return air ducts collect cool room air while supply air ducts provide the heated air to the room in much the same manner as a conventional forced air heating system except that in the heat pump case, the condenser coil replaces the fire box. Geothermal water from a spring or well is piped to the evaporator. The cooler geothermal water leaving the evaporator is then discharged. The heat pump schematic (Figure 14-5) is termed a water-to-air heat pump as it uses water as the heat source and air as the delivery medium. Some companies which manufacture water/air heat pumps are listed in Appendix 14-A.

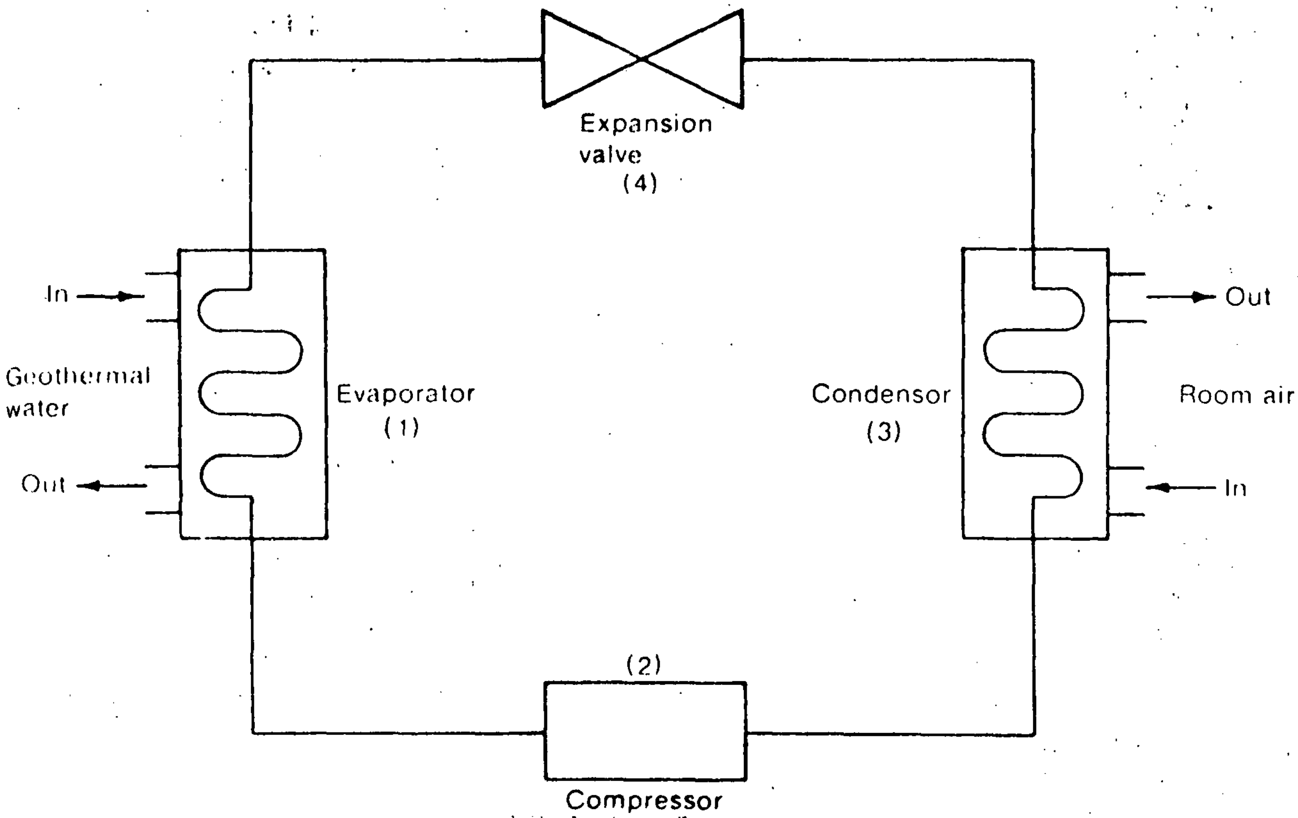


Figure 14-5

Heat Pump Schematic

1. The refrigerant enters the evaporator at low temperature and pressure as a liquid. In the evaporator, low temperature geothermal water transfers heat to the refrigerant which becomes vaporized. The refrigerant is capable of vaporizing at this low temperature because of the low pressure.

2. The refrigerant enters the compressor as a gas at low temperature and pressure. As a result of compression, the refrigerant leaves at high temperature and pressure.

3. The refrigerant enters the condensor as a gas at high temperature and pressure. Heat is given up to the room as the refrigerant condenses to a liquid at high pressure. The refrigerant is capable of condensing at high temperatures because of the high pressure.

4. The refrigerant enters the expansion valve as a liquid at high pressure and low temperature. As the pressure is reduced, its boiling point decreases and part of the refrigerant is vaporized cooling the remaining liquid.

Sources: J.G. Keller, "Heat Pumps: Primer for Use With Low Temperature Geothermal Resources," p. 5.

An energy requirement for heat pump is electricity which is used to circulate and compress the refrigerant. But for each electrical energy unit used, two, three, or more equivalent units of heat energy can be transferred from the source depending on the difference between the low and high temperatures. The efficiency of the heat pump is the ratio of these two energies and is called the coefficient of performance (COP). It is given by the formula:

$$COP = \frac{\text{quantity of heat energy delivered}}{\text{quantity of energy supplied to operate the device}}$$

Kunze and Forsgren (1978) have analyzed the economics of the heat pump as a device to assist in geothermal district space heating using 55° F, 80° F, 130° F and 180° F geothermal waters. Whether or not a system is economical depends upon a number of variables such as climate, Btu requirement and price of competing energy. Kunze and Forsgren concluded that pumping costs are less than 20% of the total costs for the particular cases they analyzed.

TECHNOLOGY SUMMARY DOCUMENTS

More detail on geothermal technology, including design procedures for house heating, hydraulics and pumping instrumentation and the mechanical/-electrical aspects of geothermal hardware, is given in a book entitled The Basics of Applied Geothermal by Edward F. Wehlage, published by Geothermal Information Services, 318 Cherrywood Street, West Covina, California 91791.

For a recent publication on technology, the 748-page transactions of the annual meeting of the Geothermal Resources Council held in Hilo, Hawaii of July 25-27, 1978, are available from P.O. Box 98, Davis, California 95616.

ENVIRONMENTAL IMPACTS OF GEOTHERMAL DEVELOPMENT

Space heating, the considered geothermal application for Alaskan hot springs, is an attractive and feasible use of this energy resource in both economic and environmental considerations. Air and water quality will unavoidably be impacted by wastewater disposal. However, with reasonable planning and adequate controls, small scale geothermal utilization would have a negligible impact on the environment and in some instances development would have beneficial consequences (Markle, 1978).

Use of geothermal waters located on State lands is regulated under the Geothermal Resources Act of 1971 as amended in 1974. This act provides for encouragement of the recovery of this resource, prospecting and leasing requirements, protection of the resource and preservation of the environment as shown in the following extract:

> (p) Conservation; prevention of waste and pollution. (1) All leases or permits under this section are subject to the condition that the lessee or permittee will, in conducting his exploration, development and production operations, use all reasonable precautions to protect the environment and to prevent pollution of the State's waters and waste of geothermal resources developed in the land leased or granted for prospecting under a permit.
>
> (2) With the approval of the commissioner, Department of Natural Resources a permittee or lessee may drill special wells, convert producing wells or reactivate and convert abandoned wells for the sole purpose of reinjecting geothermal resources of their residue.
>
> (3) The owner or operation of a geothermal well on land producing or reasonably presumed to contain geothermal resources shall properly construct the well in accordance with methods approved by the commissioner. The owner or operator shall make every reasonable effort to prevent damage to life, health, property and natural resources, to protect the geothermal resources deposits from damage or waste, to shut out detrimental substances from underground strata containing water suitable for irrigation or domestic purposes and from surface water suitable for these purposes, and to prevent the infiltration of deterimental substances into these strata and into surface water.
>
> (4) The commissioner shall require those tests or remedial work for the owner or operator of a geothermal well that in his judgment are necessary to prevent damage to life, health, property, and natural resources, to protect geothermal resources deposits from damage or waste, or to prevent the pollution of the state's waters by the infiltration of detrimental substances into underground or surface water suitable for irrigation or domestic purposes, for the best interest of the neighboring property owners and the public. To this end he may request the assistance of the Department of Environmental Conservation under AS 46.03. (Alaska Statute 38.05.181.)

All space heating uses of geothermal waters will require removal of the fluid from the spring, transfer of the hot waters to the point of use (for thermal extraction) and subsequent discharge of the spent fluid. Development proponents and environmental protection investigators agree that the likelihood of ecological degradation is slight; however, there are problems associated with the use of geothermal fluids that must be considered.

Initial construction activities would probably disrupt the site terrain and there would be a moderate level of alteration of the site vegetation. Establishment of a reservoir at the hot spring location would tend to reduce or eliminate the overflow mud area thus allowing the surrounding land to dry out. While this would destroy swamp flora, it would provide an area more conducive to growth of other terrestrial vegetation. Depending on the design of the reservoir wall, the construction could enhance the visual aesthetics of the site and provide better access to the spring (Markle, 1979).

Laying of pipes for transferring geothermal fluid would disrupt animal habitat along the transmission system as well as destroy certain plant forms. Careful routing, appropriate for local conditions, could alleviate some of the disruption but the site would still be altered. Construction of a wooden walkway over the pipeline would facilitate maintenance; this maintenance and routine pipe replacement would further serve to keep transmission paths open. More sophisticated delivery systems would improve the efficiency and extend the life of the operation but would require more extensive and expensive installation. These systems would, however, have the advantages of more extensive planning, improved materials, and more effective system controls which should provide additional environmental protection.

Pipes may have to be insulated for efficient transmission of hot water. This would reduce thermal exchange with the terrestrial environment. In permafrost areas, piping the hot water in uninsulated pipes could create environmental problems through ground subsidence or unusual thawing situations, especially where the pipes have been buried. Trenching is not recommended for laying the pipes. A board walkway covering above-ground installation of insulated pipe has been the method many small installations use. This is advantageous for maintenance operations as well as for environmental protection (Kirkwood, 1978). Wrapping the pipes will also decrease the possibility of exterior system corrosion, especially from electrolysis caused by the moving water in the pipe (Markle, 1978).

Alaska's hot springs are considered relatively clean in terms of corrosive precipitants, toxic substances and gaseous emissions. Nonetheless, actual levels must be analyzed at each potential use site. Generally, relative to other geothermal areas, Alaskan springs are high in silica and low in salt content. In some springs the water is potable; in others the brine levels are so high that the water is only useable in closed-loop piping systems. Table 14-4 shows an analysis of the content of Manley Hot Springs, a representational "clean" surface manifestation where the water is potable. Table 14-5 shows the Alaska Department of Environmental Conservation standards for drinking water, and provides a basis of comparison. The difference in water quality from site to site is marked. It should also be noted that potability often reflects the value of the water for other uses. In Japan, for instance, eels are raised for human consumption directly in the geothermal waters; in another Japanese site, an alligator farm uses only the heat from the waters and keeps the alligators carefully separated from the geothermal fluids (Ogle, 1978).

Care must be exercised in altering concentrations of potential pollutants in both the reservoir and the piping stages. Geothermal water is slightly acidic. When the water is impounded or concentrated in a reservoir, it is possible that the pH level will be changed and the water will become more acidic. This can seriously affect a point of discharge, as discussed below. Impoundment is not expected to increase the level of heavy metals, such as arsenic and mercury, or other toxic substances which are present in small concentrations in geothermal waters. The springs are also hosts for many organisms including coliform bacteria and algae. In a reservoir,

TABLE 14-4

CHEMICAL ANALYSIS OF WATER IN MANLEY HOT SPRINGS

GEOGRAPHIC LOCALITY

GEOTHERMAL FIELD-AREA..	MANLEY HOT SPRINGS (BAKER HOT SPRINGS)		
SAMPLE TYPE............	SURFACE		
COUNTRY CODE...........	US	COUNTRY NAME............	UNITED STATES
STATE/PROVINCE.........	ALASKA		
LATITUDE...............	65-00.00 N	LONGITUDE...............	150-38.00 W

SAMPLE INFORMATION

SOURCE TYPE...........	SPRING			
WATER SAMPLING TEMP.	56.0°C			
WATER FLOW RATE.......	9.33	LITERS/SECOND	560.0	LITER/MINUTE

WATER ANALYSIS W

PH 1)................. 7.72

14-36

SOLUTE ANALYSIS (WATER) PARTS PER MILLION

LI	NA	K	RB	CS	NA+K			
.28	130.00	4.50						
MG	CA	SR	BA	CA+MG				
1	4.00							
ZN	HG	B	HB02	AL	PB	AS	SB	U
		1.3						
F	CL	BR	I					
8.5	134.00							
NH4	N03	P04	SI02	S04	C03	HC03		
4.9			65.00	54.00		89.60		

References: White and Others, Assessment of Geothermal Resources of the U.S. - 1975, U.S.G.S. Circular 726.
Miller et. al. 1973.

Source: U.S.G.S., Geothermal Resources File, Revision 8, Record No. 0000231, Record Type B, February 1975.

TABLE 14-5

MAXIMUM CONTAMINANT CONCENTRATIONS FOR DRINKING WATER

(1) Inorganic Chemical Contaminants

Contaminant	Maximum Contaminant Concentration (mg/l)
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Fluoride	2.4
Iron[a]	0.3
Lead	0.05
Manganese[a]	0.05
Mercury	0.002
Nitrate (as Nitrogen)	10.
Selenium	0.01
Silver	0.05
Sodium[a]	250.

(2) Organic Chemical Contaminants

Contaminant	Maximum Contaminant Concentration (mg/l)
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP Silvex	0.01

(3) Physical Contaminants

Contaminant	Maximum Contaminant Concentration
Color	30[b] units
Turbidity	one[c] unit as a monthly average of samples required by the department

(4) Radioactive Contaminants

Contaminant	Maximum Contaminant Concentration (pCi/l)
Gross Alpha	15
Gross Beta	50
Strontium-90	8
Combined Radium-226 & 228	5
Tritium	20,000

(5) Maximum Total Coliform Bacteria Contaminant Concentration

Test Method	Maximum Contaminant Concentration
(A) Membrane Filter Techique	The coliform density may not exceed one per 100 milliliters in any routine sample.
(B) Fermentation Tube Method with 10 ml portions	Coliforms may not be present in more than one 10 milliliter portion in any routine sample.

Source: Drinking Water Standards, Environmental Conservation, Title 18 Alaska Administrative Code Chapter 80.050, January 1977.

Notes a, b & c: The State Department of Environmental Conservation has discretionary powers to allow higher maximum concentrations.

this may not be a problem, depending on water content, monitoring, and eventual use of the water. Brine build-up will occur around the reservoir and inside the pipes over an extended period of time. Careful handling of these materials and appropriate disposition of the used pipes will be necessary.

The low-level emissions of hydrogen sulfide and carbon dioxide will probably not be increased at the spring through the impoundment of spring water. Air pollution levels should be unaffected. However, use of open geothermal waters inside a house or other closed structure could expose residents to high levels of noxious gasses. Such use would require constant monitoring. It should also be mentioned that one noxious gas, H_2S, when combined with rain or moisture will form highly corrosive sulfurous acid.

Waste water from this type of utilization at most Alaskan sites is not expected to be detrimental to the environment. However, there are several problem areas related to water quality and appropriate disposition of spent thermal fluids. In the normal course of hot spring seepage or flow, the ground immediately surrounding the spring serves to filter out much of the brine and heavy metals. It also acts as a cooling area for the geothermal waters before they enter a stream system. Many proposed space heating installations will be closed-loop delivery systems, returning the water to the sources after heat extraction (Kirkwood, 1978). In these installations the discharge should not affect the ecosystem. In other instances the waste water may be pumped or drained into the same spring-stream system into which it would otherwise flow. The chemical composition of the spring water will not undergo substantial change during the piping and the decreased temperature of the used geothermal water should not affect the stream's aquatic biosystem (Forbes, 1976). In some instances, careful monitoring may be required. By piping the water away from the spring site, and then discharging it into the stream at a different point, the user may be in violation of the Environmental Protection Act. Depending upon the characteristics of the site and the extent of use, significant pollution could occur.

Table 14-6 lists the water quality criteria and maximum levels for pollutants for the State of Alaska. Category D, "Growth and propagation of fish and other aquatic life," is the section with the greatest sensitivity to change and, consequently, the most stringent restrictions on potential pollutants. If the numbers of coloform organisms at the spring site are at high levels, discharge of fluids into a stream may be prohibited. This would also be the case where the temperature of the main stream, after the discharge of used geothermal waters, is raised 4°F or to over 60°F, whichever is lower. This thermal increase could contribute to eutrophication of the stream as a build-up of algae and a concomitant decrease in available oxygen would destroy the fish habitat. Alternatively, and perhaps beneficially, a modest increase in temperature might improve the fish habitat. As noted above, the alteration of acidity could be very harmful to aquatic life. The pH must remain between 6.5 and 8.5, and the maximum pH change may not exceed 0.5 per hour. Table 14-5 shows other subjects to be considered when planning for disposition of the waste water. Significant levels of brine or heavy metals, at differing levels for different species, could destroy aquatic life--fish, fowl or fur bearers (Lamoreaux, 1978).

If other surface disposal is anticipated, the user must consider the fact that it may be in violation of the Environmental Protection Act. Allowing geothermal waters to mix with ground waters could cause pollution in the areas mentioned above as well as degrade the quality of the ground water. Use and discharge of any source of water requires the user to obtain a permit. One writer lists these basic considerations:

"1. Salinity: Salinity exceeding 330 ppm is undesirable, 1000 ppm [is] considered [the] tolerance limit for drinking water.

2. Temperature: Normal stream temperature plus a few degrees C is often considered the limit in a tightly-regulated environmental situation.

3. Gas content: H_2S, high CO_2, [or] low oxygen are unacceptable, depending on their levels of concentration.

4. Inadequate drainage capability." (Kunze, 1975)

TABLE 14-6

WATER QUALITY CRITERIA FOR WATERS OF THE STATE OF ALASKA

Water Quality Parameters / Water Uses	(1) Organisms of the Coliform Group (see note 1)	(2) Dissolved Oxygen mg/l or % Saturation	(3) pH	(4) Turbidity, measured in Jackson Turbidity Units (JTU)	(5) Temperature, as measured in degrees Fahrenheit (°F)	(6) Dissolved inorganic substances
A. Water supply, drinking, culinary and food processing without the need for treatment other than simple disinfection and simple removal of naturally present impurities.	Mean of 5 or more samples in any month less than 50 per 100 ml.	Greater than 75% saturation or 5 mg/l.	Between 6.5 and 8.5 (see note 3)	Less than 5 JTU	Below 60°F.	Total dissolved solids from all sources may not exceed 500 mg/l.
B. Water supply, drinking, culinary and food processing with the need for treatment equal to coagulation, sedimentation, filtration, disinfection, and any other treatment processes necessary to remove naturally present impurities.	Mean of 5 or more samples in any month less than 1000 per 100 ml, and not more than 20% of samples during one month may exceed 1000 per 100 ml.	Greater than 60% saturation or 5 mg/l.	Between 6.5 and 8.5 (see note 3)	Less than 5 JTU above natural conditions.	Below 60°F.	Numerical value is inapplicable.
C. Bathing, swimming, recreation.	Same as B 1	Greater than 5 mg/l.	Between 6.5 and 8.5 (see note 3)	Below 25 JTU except when natural conditions exceed this figure effluents may not increase the turbidity.	Numerical value is inapplicable.	Numerical value is inapplicable.
D. Growth and propagation of fish and other aquatic life, including waterfowl and furbearers.	Same as B 1 to protect associated recreational values.	Greater than 6 mg/l in salt water and greater than 7 mg/l in fresh water.	Between 7.5 and 8.5 for salt water. Between 6.5 and 8.5 for fresh water. Max. pH change per hour is 0.5. (see note 3)	Less than 25 JTU when attributable to solids which result from other than natural origin.	May not exceed natural temp. by more than 2°F for salt water. May not exceed natural temp. by more than 4°F for fresh water. No change shall be permitted for temp. over 60°F. Maximum rate of change permitted is 0.5°F per hour.	Within ranges to avoid chronic toxicity or significant ecological change.
E. Shellfish growth and propagation including natural and commercial growing areas.	Not to exceed limits specified in National Shellfish Sanitation Program Manual of Operations, Part I, USPHS. (see note 2)	Greater than 6 mg/l in the larval stage. Greater than 5 mg/l in the adult stage.	Between 7.5 and 8.5 (see note 3)	Less than 25 JTU of mineral origin.	Less than 68°F.	Within ranges to avoid chronic toxicity or significant ecological change.
F. Agricultural water supply, including irrigation, stock watering, and truck farming.	Mean of 5 or more samples less than 1,000 per 100 ml with 20% of samples not to exceed 2,400 per 100 ml for livestock watering, for irrigation of crops for human consumption, and for general farm use.	Greater than 3 mg/l.	Between 6.5 and 8.5 (see note 3)	Numerical values are inapplicable.	Between 60°F and 70°F for optimum growth to prevent physiological shock to plants.	Conductivity less than 1,500 micromhos at 25°C. Sodium adsorption ratio less than 2.5, sodium percentage less than 60%, residual carbonate less than 1.25 me/l, and boron less than 0.3 mg/l.
G. Industrial water supply (other than food processing).	Same as B 1 whenever worker contact is present.	Greater than 5 mg/l for surface water.	Between 6.5 and 8.5 (see note 3)	No imposed turbidity that may interfere with established levels of water supply treatment.	Less than 70°F.	No amounts above natural conditions which may cause undue corrosion, scaling, or process problems.

TABLE 14-6 (Cont.)

WATER QUALITY CRITERIA FOR WATERS OF THE STATE OF ALASKA

(7) Residues, including Oils, Floating Solids Sludge Deposits and Other Wastes	(8) Sediment	(9) Toxic or Other Deleterious Substances, Pesticides, and Related Organic and Inorganic Materials	(10) Color, as measured in color units	(11) Radioactivity	(12) Aesthetic considerations	(13) Water Quality Parameters / Water Uses
Same as B-7	Below normally detectable amounts.	Carbon chloroform extracts less than 0.1 mg/l and other chemical constituents may not exceed USPHS Drinking Water Standards. (see note 4)	True color less than 15 color units.	Conform with USPHS Drinking Water Standards. (see note 4)	May not be impaired by the presence of materials or their effects which are offensive to the sight, smell, taste, or touch.	A. Water supply, drinking, culinary and food processing without the need for treatment other than simple disinfection and simple removal of naturally present impurities.
Residues may not make the receiving water unfit or unsafe for the uses of this classification; nor cause a film or sheen upon, or discoloration of, the surface of the water or adjoining shoreline; nor cause a sludge or emulsion to be deposited beneath or upon the surface of the water, within the water column, on the bottom, or upon adjoining shorelines.	No imposed loads that will interfere with established levels of water supply treatment.	Chemical constituents shall conform to USPHS Drinking Water Standards. (see note 4)	Same as A-10	Conform with USPHS Drinking Water Standards. (see note 4)	Same as A-12	B. Water supply, drinking, culinary, and food processing with the need for treatment equal to coagulation, sedimentation, filtration, disinfection, and any other treatment processes necessary to remove naturally present impurities.
Same as B-7	No visible concentrations of sediment.	Below concentrations found to be of public health significance.	Same as A-10	Conform with USPHS Drinking Water Standards. (see note 4)	Same as A-12	C. Bathing, swimming, recreation.
Same as B-7	No deposition which adversely affects fish and other aquatic life reproduction and habitat.	None affecting public health or the ecological balance, and less than an amount that causes tainting of flesh.	True color less than 50 color units.	Conform to USPHS Drinking Water Standards except where concentration factors of aquatic flora and fauna exceed USPHS reduction factors; then maximum permissible concentrations of radionuclides shall be reduced below acute or chronic problem levels. (see note 4)	Same as A-12	D. Growth and propagation of fish and other aquatic life, including waterfowl and furbearers.
No visible evidence of residues. Less than acute or chronic problem levels as revealed by bioassay or other appropriate methods.	No deposition which adversely affects growth and propagation of shellfish.	Less than acute or chronic problem levels and below concentrations affecting the ecological balance. Less than an amount that causes tainting of flesh. Pesticides may not exceed 0.001 of the median lethal toxicity concentration for the most sensitive organism on 96-hour exposure.	True color less than 50 color units.	Concentrations shall be less than those resulting in radionuclide concentrations in shellfish meats which exceed the recommendations of the National Shellfish Sanitation Program, Manual of Operations, Part 1, USPHS. (see note 2)	Same as A-12	E. Shellfish growth and propagation including natural and commercial growing areas.
None in sufficient quantities to cause soil plugging and reduced yield of crops.	For sprinkler irrigation, water free of particles of 0.074 mm or coarser. For irrigation or water spreading, not to exceed 200 mg/l for an extended period of time.	Less than that shown to be deleterious to livestock or plants or their subsequent consumption by humans.	Inapplicable.	Conform with USPHS Drinking Water Standards.	Same as A-12	F. Agricultural water supply, including irrigation, stock watering, and truck farming.
No visible evidence of residues.	No imposed loads that will interfere with established levels of treatment.	Chemical constituents may not exceed concentrations found to be of public health significance.	True color less than 50 color units.	Conform with USPHS Drinking Water Standards. (see note 4)	Same as A-12	G. Industrial water supply (other than food processing).

TABLE 14-6 (Cont.)

Notes:

1. Organisms of the coliform group shall be determined by Most Probable Number or equivalent membrane filter technique.

2. Wherever cited in these standards, the *National Shellfish Sanitation Program, Manual of Operations, Part I*, means Sanitation of Shellfish Growing Areas, 1965 revision, U.S. Department of Health, Education and Welfare, Public Health Service Publication No. 33, Part 1, obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Price 45 cents), or in any Regional Office of the Department of Environmental Conservation, and which is on file in the office of the lieutenant governor.

3. Induced variation of pH conditions naturally outside this range may not exceed 0.5 pH unit and the pH change shall be only in the direction of this range. pH conditions naturally within this range shall be maintained within 0.5 pH unit of the natural pH.

4. Wherever cited in these standards, *USPHS Drinking Water Standards* means the Public Health Service Drinking Water Standards, 1962 revision, U.S. Department of Health, Education and Welfare, Public Health Service Publication No. 956, obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Price 30 cents) or from any Regional Office of the Department of Environmental Conservation, and which is on file in the office of the lieutenant governor.

5. Wherever cited in these standards, *National Bureau of Standards Handbook 69* means the handbook entitled "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure," U.S. Department of Commerce, National Bureau of Standards Handbook 69, June 5, 1959, obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, or in any regional office of the Department of Environmental Conservation, and which is on file in the office of the lieutenant governor.

6. Wherever cited in these standards, *Radiation Protection Guides* means the guidelines recommended by the former Federal Radiation Council and published in the May 18, 1960 Federal Register, and published in the September 26, 1961 Federal Register, obtainable from any Regional Office of the Department of Environmental Conservation and which are on file in the office of the lieutenant governor.

Source: State of Alaska, Environmental Conservation: Water Quality Standards. Administrative Code, Title 18, Chapter 70.020, October 1973.

Each site must be tested for concentration levels. Multipurpose use of the water, depends on the purity of the geothermal fluid being discharged.

It is possible that waste heat and noxious gas from the discharged water could cause air pollution in cold weather. With the atmosphere's susceptibility to fog formation over open water in cold periods, the discharged fluid could aggravate the problem and make a fog of concentrated, hazardous air pollutants. This condition may not occur during geothermal discharges, but the extent and persistence of "ice-fog" in northern communities makes this a hazard to consider.

Noise levels are not increased during the actual operation of the space heating system, although there might be considerable noise during construction, depending upon the extent of development activity.

Aesthetic considerations would be generally improved through development of this resource. Additionally, two disciplines may derive extensive and valuable information from careful development: biological studies of the thermal springs' ecosystems and archaeological exploration in the immediate vicinity of the geothermal sites.

> "Some concern has been voiced for thermal springs and the adjacent terrain as possible island ecosystem surrounded by a hostile arctic environment. It has been suggested, for example, that such ecosystems and the accompanying microenvironment (unless destroyed by man) may contain relic biological populations which have survived glacial episodes, dating back to Pliocene time. Although it remains to be proved, the reported presence of vigorous earthworms in the warm soil around Pilgrim Springs is of more than passing interest. . . even though the earthworms may have arrived via plants which were imported during the Nome gold rush." (Forbes, 1976.)

Many Alaskan springs have already been altered or developed. There has been no monitoring of the environmental impact of these utilizations for several reasons, including early development taking place before environmental regulations were established, remote location, and limited application having little impact. Future development of new sites on a similar scale or limited growth in the utilization of existing hot springs will require planning to provide for the maximum use of these resources while causing only minimal environmental degradation. Detailed monitoring of the impacts of these limited applications is not anticipated.

However, sites currently being investigated to determine potential for larger scale development are likely to be viewed differently. The proposed projects at Adak, Pilgrim Hot Springs and Unalaska will not only use greater quantities of water, but will involve the drilling of wells and the artificial surfacing of the hot water resource. All of these projects are in the proposal or assessment phase and which kinds of monitoring may be required has not been addressed.

RECOMMENDATIONS

The use of geothermal energy for space heating is site specific since the cost per mile of transporting the energy from its source to the point of use is great. Every rural community should inventory the natural energy resources nearby, including the geothermal resources, and a cost analysis should be done to determine the ranking of alternative energy options. The costs so obtained should be compared with present as well as projected fuel costs (usually imported diesel) and other factors so that plans can be made to shift to an alternative energy source at the appropriate time.

SUMMARY

Alaska has used geothermal energy for space heating in the past and the future expansion of such use is anticipated. A strong interest in geothermal energy is evidenced by the entrepeneurs who are investing their own funds for additional geothermal use, the federal government which is funding geothermal programs in Alaska, and the State government which has recently funded a significant effort at Pilgrim Hot Springs.

KEY CONTACTS

Ralph Amovak
Aleutian-Pribilof Island Association, Inc.
430 C Street
Anchorage, Alaska 99501
(907) 278-3567

Neil Basescu
Division of Energy and Power Development
State of Alaska
MacKay Building--7th Floor
338 Denali
Anchorage, Alaska 99501
(907) 276-0508

John Beebee
Energy Systems, Inc. (ESI)
4510 International Airport Road
Anchorage, Alaska 99502
(907) 243-1943

Robert Forbes
Route #1
Box 2114
Lopez, Washington 98261
(206) 468-2453

Carl Halsey
Code 2663
Naval Weapons Center
China Lake, California 99555
(714) 939-3819

Patricia Kirkwood
Energy Systems, Inc. (ESI)
4510 International Airport Road
Anchorage, Alaska 99502

Jay Kunze
Energy Services Division
Forsgren, Perkins and Associates, P.A.
Rexburg, Idaho 83440
(208) 356-9201

Lee Leonard
Geophysical Institute
University of Alaska, Fairbanks
Fairbanks, Alaska 99706
(907) 4797798

Don Markle
Division of Energy and Power Development
State of Alaska
MacKay Building--7th Floor
338 Denali
Anchorage, Alaska 99501
(907) 276-0508

Michael McCrackin
(Part Owner, Chena Hot Springs)
P.O. Box 808
Fairbanks, Alaska 99706
(907) 452-7867

William E. Ogle
Energy Systems, Inc.
4510 International Airport Road
Anchorage, Alaska 99502
(907) 243-1952

C. J. Phillips
(Owner, Pilgrim Hot Springs)
Nome, Alaska 99762
(907) 443-2560

James Whelan
Naval Weapons Center
China Lake, California 99555
(714) 939-3819

Jud Whitbeck
EG & G Idaho, Inc.
Idaho National Engineering Laboratory
Idaho Falls, Idaho 83401

REFERENCES

Alaska. Environmental Conservation: Drinking Water. Administrative Code (1978). Title 18, Chapter 80.

Alaska. Environmental Conservation. Revised Statutes. Sec. 46.03. (1976)

Alaska. Environmental Conservation: Water Quality Standards. Administrative Code (1973). Title 18, Chapter 70.020.

Alaska. Geothermal Resources Act. Revised Statutes. Sec. 38.05.181. (1974.)

Alaska, Division of Geological and Geophysical Surveys, Energy Resources Section (Klein, Robert M. and Kristina M. O'Connor). "Review of EIS 74-90, Section F (Energy Alternatives) and an Evaluation of Energy Alternatives." 1975.

Alaska Water Study Committee. Alaska Water Assessment, Problem Information. Juneau, Alaska. November 1976.

Basescu, Neil. Geothermal Specialist, Alaska Division of Energy and Power Development. Interview, December 21, 1979.

Bolan, Peter. "Heat Pumps and Fuel Cells." American Institute of Chemical Engineers. Paper #23d. United Technologies Corp., Power Systems Division, November 30, 1976.

Engen, I.A. "Residential Space Heating Costs: Geothermal vs Conventional Systems." TREE-1182. Idaho Falls, Idaho: EG & G Idaho, Inc., Idaho National Engineering Laboratory, February 1978.

Farquhar, John, Ramon Gritalva, and Patricia Kirkwood. Non-Electric Applications of Geothermal Energy in six Alaskan Towns: Final Report. Santa Monica, California: Pacific Sierra Research Corp., November 1977.

Forbes, Robert B., ed. Geothermal Energy and Wind Power. (Forbes) "Environmental Hazards and Protection." Anchorage, Alaska: University of Alaska Geophysical Institute and the Alaska Energy Office, Office of the Governor, April 1976.

Howard, J. H., ed. Present Status and Future Prospects for Non-Electric Uses of Geothermal Resources. Livermore, California: Lawrence Livermore Laboratory, University of California, October 15, 1975

Keller, J. G. "Heat Pumps: Primer for use with low temperature geothermal resources." Idaho Falls, Idaho: EG & G Idaho, Inc., November 16, 1977.

Kunze, Jay F., and Klane F. Forsgren (Energy Services Division, Forsgren, Perkins and Associates, P.A.) "The Economics of the Heat Pump as a Device to Assist in Geothermal District Space Heating," Geothermal Energy: A Novelty Becomes Resource." Transaction of the Geothermal Resources Council Annual Meeting, Hilo, Hawaii. Davis, California: Geothermal Resources Council, July 25-27, 1978, pp. 387-390.

Kunze, J. and W. Ogle, "Space Heating and Industrial Applications," Geothermal Energy and Wind Power. ed. Robert B. Forbes. Anchorage, Alaska: University of Alaska Geophysical Institute and the Alaska Energy Office, Office of the Governor, April 1976.

Lamoreaux, Bill. Sanitation Engineer, Environmental Protection Agency. Alaska Operations Office. Anchorage, Alaska. Interview. August 23, 1978.

Leonard, L., and R. B. Forbes. "Geothermal Resource Application," Geothermal Energy and Wind Power. ed. Robert B. Forbes. Anchorage, Alaska: University of Alaska Geophysical Institute and the Alaska Energy Office, Office of the Governor, April 1976.

Lienau, Paul J. and John Lund. "Utilization and Economics of Geothermal Space Heating in Klamath Falls, Oregon." A paper from the Geo-Heat Utilization Center, Oregon Institute of Technology. Klamath Falls, Oregon. Undated.

Lund, John W. "Geothermal Space Heating." A paper from the Geo-Heat Utilization Center, Oregon Institute of Technology. Klamath Falls, Oregon. Undated.

Lund, John W., Gene Culver and Paul J. Lienau. "Groundwater Characteristics and Corrosion Problems Associated with the Use of Geothermal Water." A paper from the Geo-Heat Utilization Center, Oregon Institute of Technology. Klamath Falls, Oregon. Undated.

Markle, Donald. Geothermal Energy in Alaska: Site Data Base and Development Status. Klamath Falls, Oregon: Oregon Institute of Technology Geo-Heat Utilization Center in cooperation with Alaska Division of Energy and Power Development for U.S. Department of Energy, April 1979.

_________. Interview with Alaska Division of Energy and Power Development. September 11, 1978 and December 21, 1979.

Merriam, Marshal F. Wind Energy for Human Needs. U.S. Energy Research and Development Administration. Lawrence Berkeley Laboratory. Berkeley, California, 1974.

Miller, Thomas P. "Distribution and Chemical Analyses of Thermal Springs in Alaska." Open File Map, 1973.

Ogle, William. "Geothermal Energy Possibilities in Alaska," Multi-purpose Use of Geothermal Energy. eds. Paul J. Lienau and John W. Lund. Proceedings of the International Conference on Geothermal Energy for Industrial Agricultural, and Commercial-Residential Uses. Klamath Falls, Oregon: Geo-Heat Utilization Center, Oregon Institute of Technology, October 7-9, 1974, pp. 201-208.

________. "Report of a Visit to a Number of Alaskan Hot Springs to aid in the Selection of a Site for the Possible Installation of a Small Binary Geothermal Electric Generating Plant," July 28, 1976; "Consideration on the Possible Application of Geothermal, Wind and Solar Energy to Minimize Consumption of Exhaustible Energy Resources at Certain Select Sites in the Alaskan Railbelt," September, 1976, in the possession of Energy Systems, Inc. (ESI), Anchorage, AK.

________. Energy Systems, Inc. (Anchorage, Alaska.) Presentation at Alaska Geothermal Meeting. August 1978.

Sacarto, Douglas M. State Policies for Geothermal Development. A project of the National Conference of State Legislatures. Denver, Colorado, 1976.

Stoker, R.C. "Drilling Plan Boise Slim (2 3/8 in. diameter) Holes Demonstration Space Heating Project, October 1975." ANCR-1261. Idaho Falls, Idaho: Aerojet Nuclear Company, Idaho National Engineering Laboratory, October 1975.

U.S. Congress. Senate. The Clean Water Act Showing Changes Made By The 1977 Amendments. Pub. L. 92-500 and Pub. L. 95-217. 95th Cong., 1st sess, 1977.

U.S. Department of the Interior. Bureau of Land Management. Alaska Outer Continental Shelf Office. Reference Papers #9 - Energy Alternatives. Anchorage, Alaska.

U.S. Environmental Protection Agency. Interim Primary Drinking Water Regulations. "Control of Organic Chemical Contaminants in Drinking Water." Federal Register, Vol. 43, No. 28. February 9, 1978. 6560-01.

U.S. Environmental Protection Agency. "National Pollutant Discharge Elimination System." Federal Register, Vol. 38, No. 98, May 22, 1973.

U.S. Geological Survey. Geothermal Resources File, Revision 8, Record No. 0000231, Record Type B, February 1975.

Waring, Gerald A., Revised by Reginald R. Blankenship and Ray Bentall. Thermal Springs of the United States and Other Countries of the World - A Summary. United States Geological Survey, Professional Paper 492. Washington: United States Government Printing Office, 1965.

Wehlage, Edward F. <u>The Basics of Applied Geothermal Engineering</u>. West Covina, California: Geothermal Information Services, 1976.

APPENDIX 14-A

WATER/AIR HEAT PUMP MANUFACTURERS

Trade Name	Company and Address	Telephone Number
Triton Heat Pump	York, Div. of Borg-Warner Corp. P. O. Box 1592 York, PA 17405	(717) 846-7890
Electro-Hydronic	Singer Co., Climate Control Div. 401 Randolph Street Red Bud, IL 62278	(314) 644-5200
Mammoth	Mammoth Div., Lear Siegler Inc. 13120-B County Rd. 6 Minneapolis, NM 55427 (James H. Langer)	(612) 544-2711
Friedrich (Climate Master Series)	Friedrich Air Conditioning & Refrigeration Company 4200 N. Pan Am Hwy. P. O. Box 1540 San Antonio, TX 78295	(512) 225-2000
Air Conditioning Corp.	Air Conditioning Corp. P. O. Box 6225 Greensboro, NC 27405	(919) 273-4472
Koldware	Heat Exchanger Inc. 8100 N. Monticello Ave. Skokie, IL 60076	(312) 267-8282
Vilter	Vilter Mfg. Corp. 2217 S. First Street Milwaukee, WI 53207	(414) 744-0111
Century/Comfort Aire	Heat Controller Inc. Losey at Wellworth Jackson, MI 49203	(517) 787-2100
Weatherking	Weatherking Inc. 4501 E. Colonial Drive Box 20434 Orlando, FL 32814	(305) 894-2891
McQuay Group Roofpak	McQuay Group, McQuay-Perfex Inc. 13600 Industrial Park Blvd. P. O. Box 1551 Minneapolis, MN 55440	(612) 559-2892
Whalen Co.	The Whalen Co. P. O. Box W Brock Bridge Rd. Laurel, MD 20810	(301) 776-4030

Trade Name	Company and Address	Telephone Number
Wilcox	Wilcox Mfg. Corp 13375 U.S. 19 North at 62nd Street P.O. Box 455 Pinellas Park, FL 33565	(813) 531-7141
McMillan	McMillan Heat Pump Inc. P.O. Box 5897 Jacksonville, FL 32207	(904) 733-7590
EnerCon	American Air Filter Co. 215 Central Ave. Louisville, KY 40201	(502) 637-0011
FHP Manufacturing	Florida Heat Pump Corporation 610 Southwest Twelfth Ave. Pampano Beach, FL 33060	(904) 733-3592
Command Aire	Command Aire Corp. P.O. Box 7916 Waco, TX 76710	(817) 753-3601
Addison	Addison Products Co. Their water/air system marketed under Weatherking name (Weatherking Inc.)	
Weathermaker	Carrier Air Condition, Div. of Carrier Corp. Carier Pkwy. Syracuse, NY 13201	(315) 463-8411
Aqua-Matic	Dunham-Bush, Inc. 175 South St. West Hartford, CT 06110	(203) 249-8671
Climatrol	Mueller Climatrol Corporation Woodbridge Ave. Edison, NJ 08817	(201) 981-0300
	Advanced Design Associates, Inc. Miami, FL	
	BudCo Bloomfield, CT	
	ElmBrook Refrigeration, Inc. Batter, WI	
	Lanco-Supreme, Inc. Torrance, CA	
Temlifier	Westinghouse	

APPENDIX B

UTILIZATION OF GEOTHERMAL SPRINGS IN SALMON HATCHERIES

From January 1977 to September 1977, seven sites were investigated by biologists from the Alaska Department of Fish and Game (ADF&G) and engineers contracted from Dames and Moore to determine the technical feasibility of the application of geothermal energy to hatchery production of salmon. Investigations consisted of identifying candidate thermal springs and evaluating the physical, chemical and biological characteristics of each site to determine its potential for salmon aquaculture.

Considerable information concerning the location, hydrological characteristics and geology of Alaskan thermal springs is contained in six reports: Miller (1973); Miller, et al. (1975); Miller and Barnes (1976); Rosenbruch and Bottge (1975); Waring (1883) and Waring (1917). These publications identify a total of 94 thermal springs in Alaska. Much of the existing information on flows, water temperature and water quality of these springs is sketchy; however, preliminary examination of tabulated information showed that as many as 30 of these thermal springs may have sufficient heat budgets to make them potentially valuable for aquaculture purposes.

A complete review of existing information on Alaskan thermal springs was conducted in an attempt to identify six candidates for hatchery sites. Limited funding precluded a survey of all geothermal sites. The location of candidate springs relative to existing common property fisheries, accessibility, land availability, logistical considerations,

---

Source: The material in this appendix has been extracted from the Dames and Moore report, An Investigation Of Selected Alaska Geothermal Spring Sources As Possible Salmon Hatchery Sites, prepared by R. O. Baker, R. C. Lebida, N. D. Pyle and R. P. Britch, for the State of Alaska, Division of Energy and Power Development under contract for the Energy Research and Development Administration, Division of Geothermal Energy, June 1978.

availability of construction material, management requirements, existence of adjacent non-thermal water supplies, and suitability of release areas are factors that were used to further evaluate the potential of candidate springs as hatchery sites. Seven sites were finally selected for evaluation. They are: (1) Akutan, in the Aleutian Islands; (2) False Pass, on the Alaska Peninsula; (3) Port Moller, on the Alaska Peninsula; (4) Mother Goose Lake, on the Alaska Peninsula; (5) Ophir Creek, in the Kilbuck Mountains northeast of Bethel; (6) Bailey, north of Ketchikan in Southeastern Alaska; and (7) Bell Island, north of Ketchikan in Southeastern Alaska.

The remoteness of geothermal springs in Alaska complicates their development as an energy source. Utilization will be dependent to a large degree on developing non-electrical applications which produce usable commodities at remote sites.

Alaska's salmon fisheries have historically been an extremely valuable resource, representing a major segment of the State's economy. In recent years (1961-1975) the annual value of salmon landings to commercial fishermen has varied from $26.2 to $67.9 million.

The total catch of salmon in Alaska has undergone drastic reduction. The reasons for this decline are complex but related mainly to past over-fishing, recent severe climatic conditions, and habitat alteration. This decline in salmon abundance has stimulated major efforts towards rehabilitation and enhancement of these fisheries by the State of Alaska.

Hatcheries and other artificial propagation techniques will play key roles in the restoration effort. Current plans call for the expenditure of upwards of $500 million of public and private funds through 1990 for hatchery construction in Alaska.

The rationale behind this expenditure is the greater overall survival rate of early freshwater life history stages of salmon in hatcheries as opposed to corresponding survival in the natural environment. Except for certain isolated land-locked populations of red or kokanee salmon (Oneorhynchus nerka), all five species of Pacific salmon are anadromous.

Alaska's harsh climate severely restricts survival of the early life history stages of salmon. Estimates of mortality from the egg to fry stage of development in the natural environment versus hatcheries are variable, but generally indicate that hatchery survival is 5-8 times greater than corresponding natural rates. This is the direct result of the ability to control the hatchery environment. Natural variables (freezing, predation, dewatering, flooding, siltation, low oxygen levels, etc.) are responsible for the mortality of salmon eggs. The higher survival rates of salmon in hatcheries necessitates fewer spawners and corresponding greater number of fish are available for commercial harvest.

The process of propagating salmon in hatcheries, releasing the fry to graze at sea, and harvesting either in an ocean fishery or upon return to their natal stream has been termed "ocean ranching." It is an efficient method of producing large amounts of high quality, low cost animal protein.

Artificial propagation has been instrumental in maintaining coho (O. kisutch) and king salmon (O. tshawythscha) populations in Washington and Oregon. Fisheries for these species have remained relatively stable, despite widespread destruction of freshwater habitat. These two species of salmon spend considerable time (1-2 years) in fresh water, growing to smolt size (10-15 cm) before migrating to the ocean. The most successful hatchery programs for these species have been based on smolt production. Hatched fry are fed and reared to smolt size before release into the natural environment.

Geothermal energy could play a major role in developing Alaska's hatchery program for coho and king salmon. Natural water temperatures in most of Alaska are too low during long winter periods to successfully operate hatcheries where overwinter rearing is required. Optimal growth and conversion efficiency occurs when water temperatures are in the 10-15 degree C range. Growth is negligible below 4.5 degrees C.

Hydrothermal spring water could be used to increase ambient fresh water temperatures by use of a heat exchange system or direct mixing. The warmed water will then be used as process water to improve egg survival and increase development rates of smolt. Increased egg survival are expected to reach 5-8 times nature's norm, and increased smolt growth rates should reach 250 percent, or reach maturity in 1/4 the normal time. The increased fish count available to commercial fisheries should more than offset the cost of heating the water.

Based on available data, the Bell Island appears to be the most satisfactory location for the construction of a demonstration hatchery utilizing geothermal energy. The Bailey site is considered the best alternate for a demonstration facility and superior to the Bell site for a full scale production hatchery. The major pros and cons of each site are summarized in Table 14-B-3. The potential for harvesting salmon produced by any facility should weight heavily in choosing a site for demonstration of full scale production.

Additional surveys and monitoring of critical parameters may be necessary at the most promising sites prior to initiation of the next project phase. If these studies indicate suitable sites exist for a demonstration facility and that Alaska geothermal resources have significant potential for hatchery production of salmon, then plans to design and construct a demonstration hatchery should be initiated.

TABLE 14-B-1
CHEMICAL ANALYSES OF SURFACE WATER SOURCES ASSOCIATED WITH GEOTHERMAL SPRINGS
IN SOUTHWEST AND SOUTHEAST ALASKA INVESTIGATED AS POTENTIAL FISH HATCHERY SITES, 1977.
RESULTS ARE REPORTED IN MILLIGRAMS PER LITER (MG/L) UNLESS OTHERWISE INDICATED

	Akutan Hot Springs	False Pass Hot Springs	Port Moller Hot Springs	MotherGoose L. Hot Springs	Ophir Creek Hot Springs	Bailey Bay Hot Springs	Bell Island Hot Springs
H_2S	0.02*	0.16*	0.16*	0.24*	0.02*	7*	0.02*
NH_3	0.04*	0.04*	1.6*	0.12*	0.04*	0.2*	0.14*
NO_3	0.3	0.2	0.2	0.7	0.4	0.2	0.6
Phosphate, Ortho	0.25	0.25	0.25	0.25	0.25	0.25	0.1
Alkalinity, Bicarbonate	122	27	17*	35	239	122	57
Alkalinity, Carbonate	0	0	0	0	0	11	0.4
CO_2	12*	0.2*	0.25*	5*	0.4*	0.2*	0.1
Chloride	140	45	1500*	455*	3.5	38*	174*
TDS	490*	300	3022	2298*	412*	280	700*
Hardness (Total)	60	60	480	1144	16	28	17
F	0.96*	0.25	1.9*	0.2	1.4*	2.0*	3.15*
SO_4	195*	580*	50	2000*	240*	330*	1175*
Se	0.008	0.002	0.005	0.002	0.002	0.002	0.01
Cu	0.010	0.004	0.008*	0.024*	0.005	0.007	0.008
Ca	8*	15*	61*	160*	2*	0.8*	6.0*
Na	150*	48	200*	195*	97*	93*	300*
K	10*	1	14*	40*	1	2.0	7.2*
Ag	0.00015	0.0002	0.00015	0.0008	0.00015	0.0002	0.0002
Pb	0.006	0.007	0.3*	0.002	0.003	0.002	0.004
Cd	0.0003	0.001	0.003	0.0003	0.0003	0.0003	0.0003
Cr	0.0012	0.002	0.0012	0.0012	0.0012	0.0025	0.0012
SiO_2	40	22	8	80	30	54	55
Al	0.01	0.05*	0.19*	0.47*	0.02*	0.01	0.01
As	0.04	0.04	0.032	0.038	0.02	0.005	0.02
B	3.2	1.0	2.8	1.0	0.1	0.3	0.01
Fe	0.05	0.7	0.94	0.05	0.06	0.05	0.47
Mg	1.0	0.1	1.0	130	0.1	0.1	0.2
Mn	0.004	0.004	0.008	0.009	0.003	0.003	0.005
Ni	0.005	0.004	0.1	0.035	0.012	0.007	0.025
Sb	0.05	0.02	0.025	0.054	0.06	0.005	0.01
Zn	0.07*	0.001	0.002	0.001	0.001	0.001	0.001
Hg	0.001	0.001	0.001	0.001	0.001	0.001	0.001
V	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Conductance (umhos/cm)	600	250	3750	2000	400	350	800
Temperature** (°C)	24	24	25	25	24	26	25
pH	7.2	8.3*	8.1*	7.1	9.4*	8.8*	8.9*
Date	5-20-77	5-21-77	5-22-77	6-2-77	6-3-77	6-7-77	6-8-77

* Exceeds ADF&G water quality criteria for salmon aquaculture
** Temperature at which chemical analysis was accomplished

TABLE 14-B-2
CHEMICAL ANALYSES OF SURFACE WATER SOURCES ASSOCIATED WITH GEOTHERMAL SPRINGS IN SOUTHWEST AND SOUTHEAST ALASKA INVESTIGATED AS POTENTIAL FISH HATCHERY SITES, 1977. RESULTS ARE REPORTED IN MILLIGRAMS PER LITER (MG/L) UNLESS OTHERWISE INDICATED.

	Akutan Hot Springs Creek	False Pass Hot Springs Creek	Needle Lake	Volcano Creek	Ophir Creek	Spring Creek	Bell Island Creek
H_2S	0.03*	0.02*	0.02*	0.02*	0.02*	0.02*	0.02*
NH_3	0.04*	0.04*	0.04*	0.07*	0.04*	0.04*	0.06*
NO_3	0.2	0.2	0.4	0.6	0.6	0.2	0.5
Phosphate, Ortho	0.25	0.25	0.25	0.1	0.25	0.25	0.1
Alkalinity, Bicarbonate	7	8	70	42	24	43	4
Alkalinity, Carbonate	0	0	0	0	0	0	0
CO_2	0.9*	0.4*	13*	--	7.5*	60*	2.3*
Chloride	15*	5.6*	0.3*	106*	0.35*	0.3	0.4
TDS	290	86	95	1513*	122	9	33
Hardness (Total)	40	35	95	--	24	20	1.0
F	0.05	0.02	0.09	0.40	0.09	0.02	0.1
SO_4	64*	110*	22	170*	3.5	30	60*
Se	0.002	0.002	0.002	--	0.004	0.002	0.002
Cu	0.003	0.01*	0.005	--	0.002	0.003	0.007*
Ca	8	4	7	--	6	0.7	0.9
Na	15	7	2	--	1	0.1	2.5
K	1	1	1	--	1	0.1	0.25
Ag	0.002	0.00015	0.00015	--	0.0002	0.00015	0.0002
Pb	0.007	0.002	0.003	--	0.004*	0.002	0.002
Cd	0.0015*	0.0003	0.0003	--	0.0003	0.003*	0.0003
Cr	0.0012	0.0012	0.0012	--	0.0012	0.01*	0.005
SiO_2	7	5	2	--	2*	0.2	0.1
Al	0.01	0.04*	0.1	--	0.09*	0.01	0.01
As	0.04	0.005	0.003	--	0.004	0.004	0.004
B	0.2	0.01	0.01	--	0.01	0.01	0.01
Fe	0.6*	0.05	0.9*	--	0.7	0.05	0.05
Mg	1.0	1	1	--	1*	0.1	0.01
Mn	0.008	0.008	0.008	--	0.005	0.004	0.004
Ni	0.001	0.001	0.001	--	0.001	0.001	0.001
Sb	0.005	0.008	0.005	--	0.005	0.005	0.005
Zn	0.001	0.001	0.001	--	0.1	0.001	0.001
Hg	0.001	0.001	0.001	--	0.001	0.001	0.001
V	0.01	0.01	0.01	--	0.01	0.01	0.01
Conductance (umohs/cm)	120	80	22	500	45	6.5	12.5
Temperature** (^oC)	23	24	24	20	23	26	24
pH	7.2	7.6	7.0	6.6	6.8	5.6*	6.5
Tannin/Lignin	--	--	--	--	--	--	0.8
Date	5-20-77	5-21-77	6-2-77	6-2-77	6-3-77	6-7-77	6-8-77

* Exceeds ADF&G water quality standards for salmon aquaculture.
** Temperature at which chemical analysis was accomplished.

TABLE 14-B-3
SUMMARY OF SELECTED ALASKA GEOTHERMAL SOURCES
INVESTIGATED AS POSSIBLE SALMON HATCHERY SITES, 1977.

	Akutan	False Pass	Port Moller	Mother Goose	Ophir	Bailey	Bell
Land Status	?	?	?	?	+	+	+
Water Quantity	?	?	-	-	+	+	+
Water Quality	o	o	o	o	o	o	o
Microbiology	+	_	*	o	o	o	o
Brood Stock	-	+	-	-	-	-	-
Ecology	+	+	-	-	+	+	+
Existing Fishery	-	+	+	+	+	+	+
Building Site	?	+	-	-	+	+	+
Construction Costs	-	-	+	-	-	-	+
Logistical Support	-	+	+	-	-	+	+
Harvest Potential	?	+	?	+	+	+	+

+ = Satisfactory
- = Unsatisfactory
o = Satisfactory with treatment
? = Questionable status
* = Surface water not tested

The Alaska Division of Energy and Power Development is keenly interested in conservation of the State's natural resources, specifically energy resources to supplement or replace fossil fuels. This commitment has led to this study and similar studies for waste heat utilization projects. In any demonstration projects using heated water, certain energy requirements will have to be met. It is DEPD's goal to meet them with alternate forms of energy whenever possible.

CHAPTER 15

WIND

CHAPTER 15
WIND

INTRODUCTION

Multivane fan waterpumping windmills, the type of wind machine most widely used in the world today, were developed in the United States midwestern plains region in the middle of the 19th century by artisans, mechanics, farmers, manufacturers and others who had little contact with the world of scientific analysis. The combination of product improvement and cost reduction through factory production brought these wind machines into large scale application.

Electricity producing wind machines are not mass produced on a large scale at this time. Nevertheless, research in use of wind energy conversion systems (WECS) in power grids as a supplement to diesel fuel is currently under way in Alaska. Hopefully, the engineering talent and interest of organizations such as Grumman Corporation coupled with the determination and talent of the homesteader and the native Alaskan mechanic will help control the enormous cost of electricity in the sparcely populated regions of our State.

HISTORY

Wind has been a source of energy for millennia. In ancient times, seafaring countries used the wind to move boats and ships, agrarian nations captured the power of the wind to lift water and to grind grain, and in oriental societies kites were developed as toys, scientific instruments and as an art form. Some authorities cite China and Japan as early users of windmills, possibly as early as 2000 B.C. (Tetra Tech, 1976). M. F. Merriam in Wind Energy For Human Needs (1974) notes that several authors give Persia credit for the invention of the windmill at some uncertain date in the remote past. It is believed that large vertical axis machines were first used to pump water. They were also used to mill flours and grind meal. Merriam lists two sources which give Hammurabi credit for planning to use windmills in an irrigation project in

17th Century (B.C.) Babylon. Merriam also mentions that Hindu writing from 400 B.C. is cited by H. Wulf in Traditional Crafts of Persia as the first written document to make reference to windmills. There is general agreement that Persia, during the first thousand years A.D., was the only nation making extensive use of windmills. References to wind power began appearing in literature in western Europe, notably France and England, during the twelfth century A.D.

In the next seven hundred years, wind power continued to be developed and utilized in areas where wind capture was feasible. Horizontal axis machines were in widespread use in Europe, with large numbers of windmills being used in Great Britain, the Netherlands, North Germany and Denmark. (For a description of vertical and horizontal axis designs, see Alaska's Energy Resources, Vol. I.) The famous Dutch windmills were used for grinding grain and were also the instrument for reclaiming land from the sea.

As the steam engine became important for industrial power production in the 19th century, the number of wind power installations declined. Then, the development of the internal combustion engine and the extensive use of petroleum fuels continued making wind machines economically obsolete.

In Askov, Denmark, in 1891, Paul La Cour was experimenting with the generation of electricity from windmills. His successful efforts were later utilized to provide power for Askov. This design was used until 1960 when it was superceded by hydroelectric power.

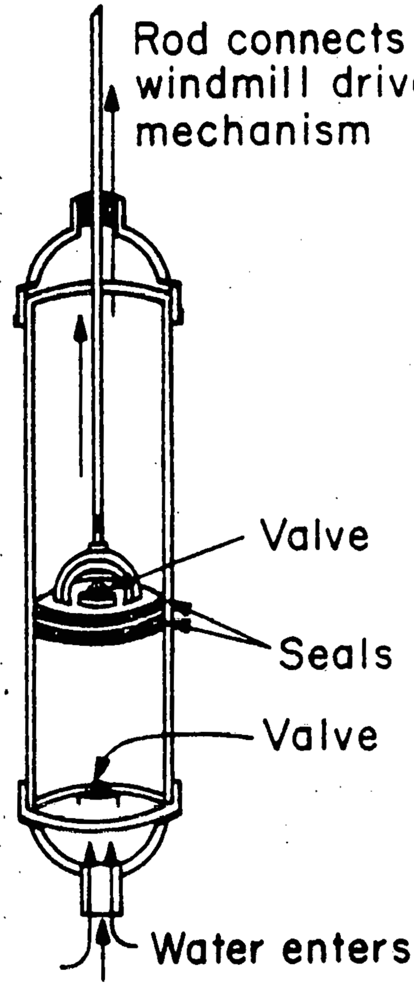
Three years after La Cour began his experiments, Fridtjof Nansen was ice-bound in the course of an Arctic expedition. He set up a windmill and connected it to a dynamo which provided electricity to charge batteries. The historical irony is particularly significant for Alaskan readers: at a time when houses of metropolitan centers were still lighted by kerosene and gas, electric lights were glowing in the vicinity of the North Pole (DeKorre, 1974).

George and Wallace Manikowski in turn-of-the-century North Dakota have been given the credit for founding the first United States commercial production of wind electric plants. By 1911, the Manikowski family farm was electrified with 110V DC wind-originated current; Wallace had written the first government bulletin on the wind electric generator by 1913; George had applied for his first patent in 1914 and the Wind Electric Corporation of Wyndmere, North Dakota was formed in 1918 to produce and market a 14-1/2-foot diameter, belt-drive wind generator (Killam, 1978).

In the 20th century, wind machines were still being utilized to generate electricity in Europe and in North America. The 1920's and 1930's were perhaps the apex for the early wind generator industry. Hundreds of thousands of high speed, two or three thin-blade propeller, small diameter wind generators were sold in the United States for use on farms and homes that were not connected to the central-station electric power systems (Merriam, 1974). Fossil fuel technology became more sophisticated, as did electrical generation and transmission equipment, and in the 1950's the central power grid was extended to provide electricity to the majority of households and farmsteads in the United States.

Although some are still operating in rural areas to pump water (Figure 15-1) or generate electricity for individual farm houses, windmills have not been commonplace since about 1950. It has been suggested that the specific units available to the farmers were largely responsible for the decline in windmill useage. Had the towers been higher, the windmills might have been able to take advantage of greater wind velocities (McConkey, 1977). Other factors of this decline included the lack of flexibility of the equipment, the unreliability of the wind and the increasing energy demand of the consumer. Wind availability is critical and not always dependable; electricity storage and transmission is expensive and the 1930's technology was not oriented to improving wind generation equipment. The generators available to users in the 1930's, rated at a few hundred watts, were inadequate to meet growing household energy demands.

Figure 15-1



Used with American multivane fan windmills for lifting water, the piston moves up and down in the cylinder, driven by the reciprocating push rod which is driven by the windmill. There is a one-way valve in the piston and also in the bottom of the cylinder. Water enters through the lower valve when the piston is rising, then passes through the valve in the piston when the piston is moving downward. The lower valve is closed when the piston is moving downward, and the upper valve is closed when the piston is moving upward.

Source: Marshal T. Merriam, "Wind Energy for Human Needs," November 1974, pp. 77 and 91.

Wind power use did continue in many areas, however. Ten thousand water pumping windmills were in operation on the Island of Crete in 1954. In the City of Gedsen, Denmark, a 200 Kw windmill was operational from 1957 to 1969 (Wetink, 1973).

An early macro Wind Energy Conversion System (WECS) was the Smith-Putnam unit constructed at Grandpa's Knob, Vermont. Rated at 1250 Kw in a 30-mile per hour wind, on October 19, 1941, it became the first wind-powered unit to feed synchronously into a utility power grid. After 1100 hours of experimental operation over a four and one-half year period, the project experienced a mechanical failure and the propeller blade was thrown. The project was then discontinued, primarily for economic reasons (Tetra Tech, 1976).

In recent years, local and world wide interest in wind power has been revived as the limits to our fossil fuels have become more apparent. With many remote communities experiencing higher fossil fuel costs, having no access to interconnecting power grids, and possessing impressive wind resources, wind technology has become an important alternative.

In the Soviet Union, numerous small farms and villages in northern regions are not connected to their national electricity supply grid. Planners are developing several programs to utilize wind power to meet these communities' energy demands. Additionally, Soviet planners are putting together a program to develop a country-wide energy grid that would be powered by large scale wind turbines, with back-up power provided by conventional thermal power stations. Construction has already begun on the first section of the grid; by 1980, plans call for 4,500 turbines to be installed. By 1990 there may be as many as 150,000 units in operation with a total grid capacity of 4,500 million watts (Wind Power Digest, 1978).

Alaskan communities in the first third of the twentieth century were using windmills to pump water and generate small quantities of electricity. Growth of the popularity of wind power was parallel to that in the rest of the United States. A compilation of windmill sites and an inventory of wind machine use has not yet been written, but field surveys and literature searches are revealing evidence of windmill use over most of the State. Dr. Tunis Wentink, of the University of Alaska, Geophysical Institute, writing in the Winter 1973 issue of the Northern Engineer stated, "Small windmills were used in various parts of Alaska for years until oil, though often expensive, replaced wind" as an energy source. He added that the problems were related to the size of the equipment and the resulting lack of generating capacity as well as the "inability to control the charge of the storage batteries."

Around the State, windmill towers or skeletal remains hint at the widespread application of wind technology. Six miles west of the Canadian border, at the mouth of Mission Creek, is the city of Eagle. This supply camp for the Forty Mile River Gold Rush in the late 1880's was also the site of Fort Egbert. An old windmill, apparently used for drawing water, still stands beside the water pump, a reminder of the luxuries at this early Alaskan spring (Figure 15-2). A wooden tower with skeletal blades stands at Kruzgamepa (now Pilgrim Hot Springs), forty-five miles north of Nome (Figure 15-3). There are also remains of a battery bank storage system at Hope where an attempt was made to use wind power to generate electricity for the school house. A photograph of the old Paxon Lodge in the late 1940's or early 50's shows a two-bladed windmill in the background (Figure 15-4).

John Beck, an archaeologist for the Bureau of Land Management, has noted evidence of windmill use at a road house shelter in the Rainy Pass area on the Iditarod Trail. There are tower remnants still standing approximately fifteen feet above the cabin, with insulated wire running down the structure. He has also observed what might have been a windmill tower platform at Rennies Landing, northwest of McGrath.

In engineering reports, histories and surveys, there are occasional references to windmill use. Some have mentioned Nome, Barrow and Kodiak as areas where people found use for wind machines. Flip Todd (1977) writes that "windmills were used extensively four decades ago in Alaska's coastal villages which are subject to consistent strong winds coming off the ocean."

Eighty miles north of Bethel, on the Yukon River in the Yukon-Kuskokwim Delta, lies the Yupik Eskimo village of Marshall (Fortuna Ledge). Gold was discovered near Marshall on Wilson Creek in 1913 and a placer mining camp was established. In the late 1920's the Fortuna Ledge Mining Company installed a wind generator to supply power for the Company's store and some of the local homes. Current residents say the generator was in operation for over twenty years; it apparently failed in the 1950's because of lack of maintenance. The forty-five foot angle-iron tower is still standing (Figure 15-5) and Marshall residents are evaluating the site and the tower for the feasibility of renovation and installation of a new wind turbine (Duffy, 1978).

Contemporary applications of wind power in the state are primarily remote sites such as cabins or fish camps, and at mountain top communication installations, in small household hobby applications and at villages in test or demonstration projects (McConkey, 1977). Several small Wind Energy Conversion Systems (WECS) are available to the consumer, but only a few of these have been tested in Alaska (Forbes, 1975). There are about fifty windmills presently in use in the State, including several larger commercial models. The home size models have been installed in several Southeastern communities, in the Interior and Southwest regions and extensively for Southcentral residences and recreation sites.

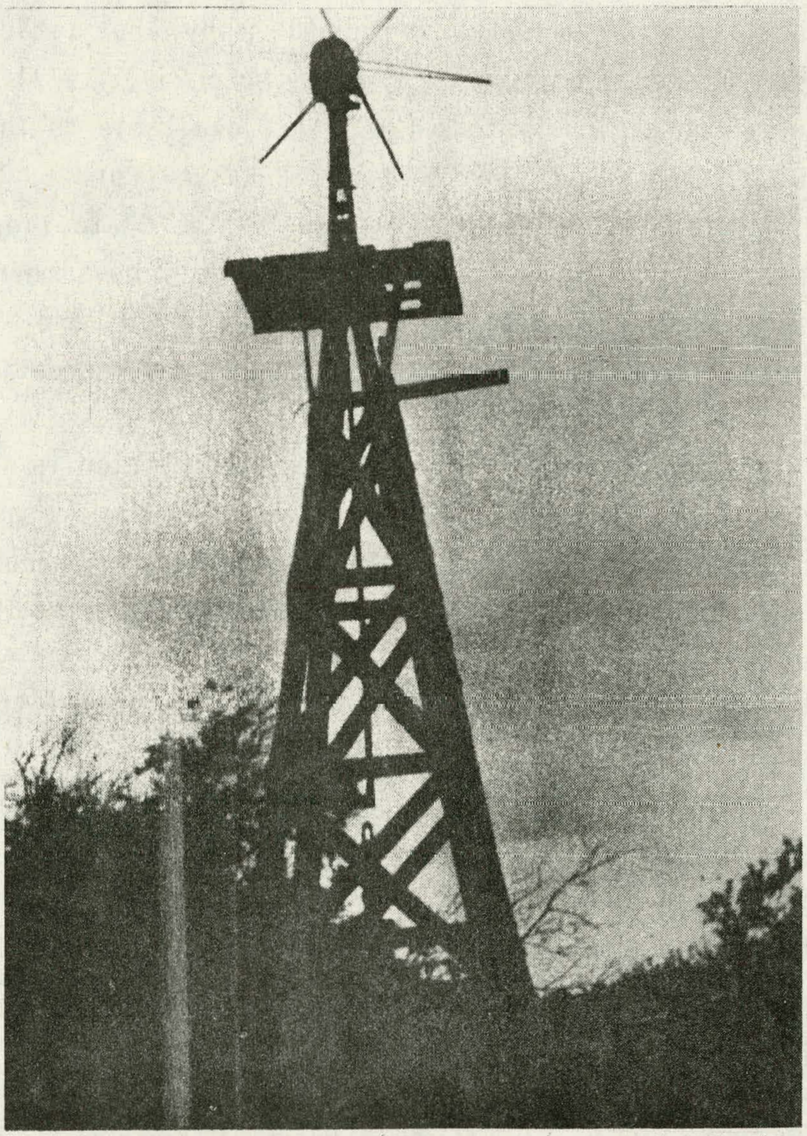
Wasilla High School started a WECS installation in 1977, as did a business on Unalaska in the Aleutians. The high school installation is a demonstration project using a 12-foot diameter Sencenbaugh windmill and is funded by a federal grant. The Unalaska Dunlite WECS will be used by a commercial sheep herd owner to generate electricity for a three kilowatt system. Electricity will be stored in 15-eight volt batteries.

In Unalakleet, a musk-ox cooperative has installed a WECS to provide lighting for a farmhouse and electricity for small power tools. There is a 10.5-foot diameter windmill installation to power the television relay station between King Salmon Air Force Station and Dillingham. The North Slope Borough has installed two 3 Kw Dunlite WECS to provide electricity for the homes at Point Lay (Todd, 1977).

Staff, Alaska Division of Parks

Figure 15-2. Multivane fan windmill at Fort Egbert, Eagle, Alaska, identified as an Aermotor manufactured in Chicago. This may have pumped water (the most efficient use of multivane fans) and also generated small quantities of electricity for the telegraph system. Date of in-stallation unknown.

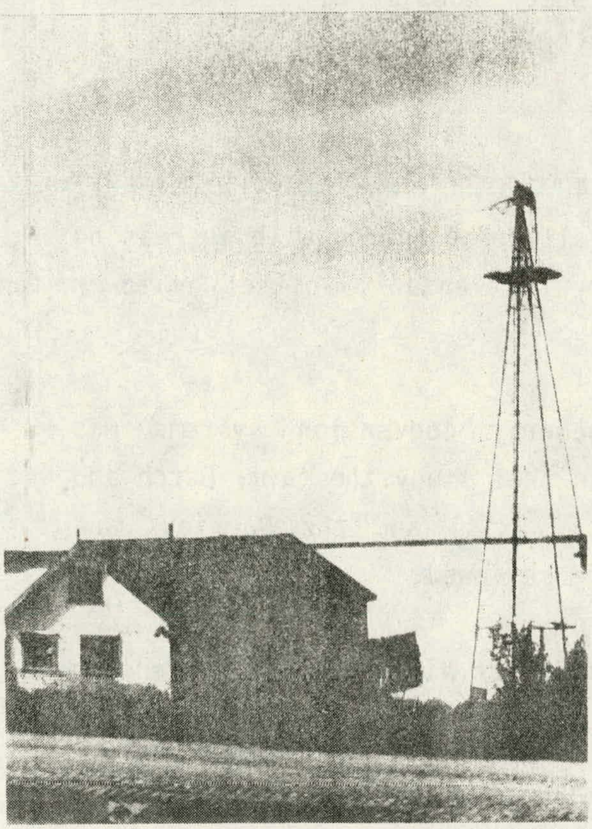
Figure 15-3. Wooden tower and skeletal remains of blade at Kruzgamepa (Pilgrim Hot Springs). Apparently used for pumping water. Installation date unknown.



Sy Neeley, Glenallen

Staff, Alaska Division of Parks

Figure 15-4. The two bladed wind mill located behind Paxon Lodge, in the upper right section of the photograph, appears to be an electricity generating unit. The lodge and surrounding structures were destroyed by fire in the early 1970's. Although this picture is undated, it corresponds to other photographs of this site taken in the late 1940's or early 1950's.



James Duffy, Bethel

Figure 15-5. Tower at Marshall, installed by Fortuna Ledge Mining Company in 1920's. May have supported generation system as large as 20KW.

Four other major installations have served as demonstration projects for wind power applications in Alaska: Kotzebue, Ugashik, McHugh Creek and Nelson Lagoon. These were described in Alaska's Energy Resources, Vol. I.

WIND ENERGY CONVERSION SYSTEMS TECHNOLOGY

The power obtained from a wind energy machine is a function of the density of the air and of the cube of the velocity of the wind. The maximum power which can be extracted is 59.2 percent of the power originally in the moving air. William Ogle stated:

> "For convenience sake, the power per square meter that may be recovered by a 35% efficient machine at sea level is given roughly by the following equations:
>
> $$\text{Power (watts)} = 0.031\ V^3\ \text{(knots)}$$
>
> or
>
> $$\text{Power (watts)}\ \ 0.02\ V^3\ \text{(mph)}$$
>
> For example, a 20-knot wind should produce 248 watts/meter^2 and a 20-mile per hour wind should produce 160 watts/meter^2" (Ogle, 1976).

At 10.4 knots, the minimum mean wind speed considered desirable for satisfactory windmill performance, the recoverable energy is 35 watts/meter^2.

For small windmills, tower heights of 40 to 60 feet are recommended Although higher wind velocities are generally encountered with increasing heights, the additional energy production is eventually offset by tower costs (Wentink in Forbes, 1976).

The technology associated with wind energy conversion systems was addressed in Volume 1 (McConkey, 1977). In that study the farm, Dutch and modern propeller concepts (all horizontal axis) and the Darrieus and S-Rotary concepts (both vertical axis) were reviewed.

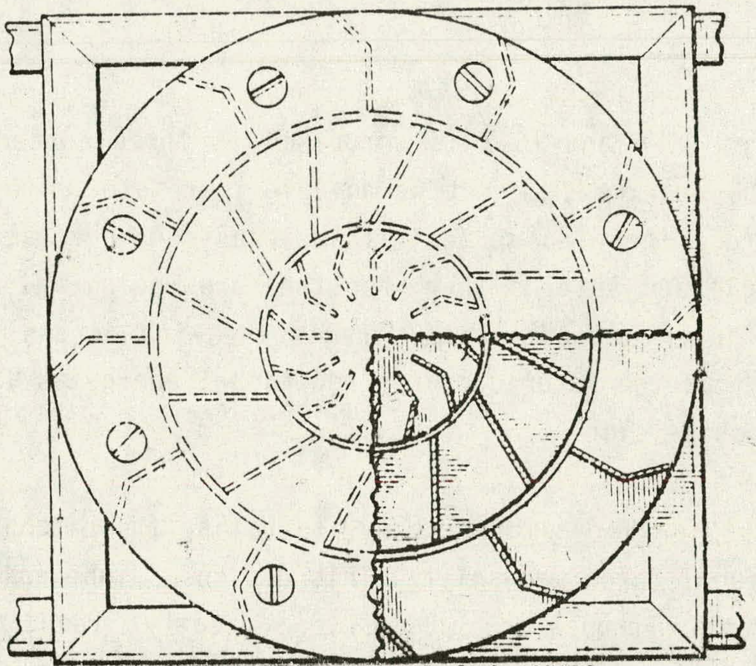
Another vertical-axis concept designed by Robert Nisle deserves attention because of possible future applicability in Alaska. The wind turbine, as shown in Figures 15-6 and 15-7 is comprised of three concentric sets of blades, only the intermediate set being able to rotate. The outer set is arranged to direct the wind so that it impinges on the rotating blades at a favorable angle and shields them when they are moving against the wind. The stationary inner set of blades directs the wind across the center of the machine so that the rotor captures additional energy as the wind exits through the opposite side.

The turbine will feather automatically, adjusting the pitch of the blades using a centrifugal force mechanism. This design is inherently more rigid than conventional propeller windmills, greatly reducing vibration problems. The rotary blades are mounted on a shaft that can be connected by belts or gears to equipment such as a pump or electric generators.

A small 200-watt "Wincharger", a battery charger, is somewhat popular in Alaska. The two Anchorage vendors report combined sales of about two per month at about $525 to $550 each. Both the 12 volt and 24 volt units are kept in stock (Alaska Industrial Hardware, Inc. and Alaska Marine and Equipment, Inc., 1978). The charging rates go from 2 1/2 amperes at 350 revolution per minute to 14 amperes at 900 revolutions per minute in a 23 mile per hour wind. The unit starts charging at 7 miles per hour and when the wind velocity exceed 23 miles per hour, a governor flaps open automatically and spreads the wind away from the propeller (Table 151). The governor also acts as a flywheel to maintain constant propeller speed and eliminate vibrations in gusty winds.

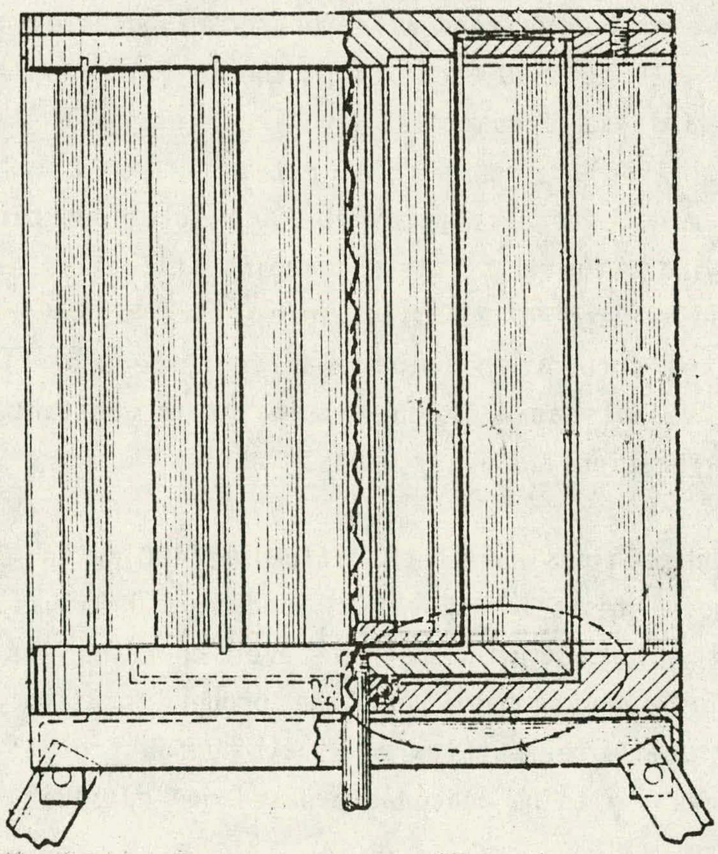
Large scale wind machines have been defined as 100 Kw to 1250 Kw. The 100 Kw unit undergoing tests by NASA near Sandusky, Ohio has had engineering problems and the largest wind machine ever operated was destroyed in a high wind. Alaska is probably not the proper location for large scale wind machines until reliability has been demonstrated and maintenance costs have been shown to be reasonable based on "outside" testing.

Medium scale wind machines, 2 to 100 Kw power range, are of interest to Alaska. However, both the 2 Kw Dunlite at Kotzebue and the 20 Kw Grumman



Non-Directional Vertical Axis WECS
Top View

Figure 15-7



Non-Directional Vertical Axis WECS
Side View

Source: Robert Nisle, correspondence to Gene Rutledge, 1978.

at Nelson Lagoon (Table 15-1) are still considered in the research and development stage for Alaskan conditions rather than off-the-shelf hardware ready for remote communities. Experience gained in Alaska is likely to have widespead application in WECS design.

Of special interest to potential wind users would be the detailed description of wind energy conversion systems and lists of manufacturers, distributors, subsystem components and suppliers found in A Guide to Commercially Available Wind Machines (Rockwell International, 1978).

ENVIRONMENTAL IMPACT

Ecological disturbances are not generally associated with the operation of wind turbines; however, there are some potentially adverse effects in both the construction and the operational phases of Wind Energy Conversion Systems (WECS). Several relatively minor areas of concern have been discussed by wind power proponents and researchers. Some negative impacts may be realized in the initial conversion of the site and questions have been posed concerning the safety of the hardware during operation.

Construction activity will produce some environmental changes. Tower platforms will have special requirements because of ground conditions (freezing and thawing, solifluction processes), vibrations developed during operation, and structural stresses experienced in adverse climatic conditions. Pathways will have to be opened for access, transmission lines or buried cables. There will be destruction of some vegetation and a small amount of change in wildlife habitat. In permafrost regions, construction activity damage will be more extensive. Other than that produced during the construction period, there will be no atmospheric emissions of smoke or noxious gases.

Some researchers have raised the question of climatic disturbances, especially when large equipment or several towers in a windmill farm configuration are being used. Weather modification, however, is not expected to be a serious problem. In those Alaskan locations where several windmills may be used in series for electrical generation (assuming that

TABLE 15-1

WIND SPEEDS AND ELECTRICAL OUTPUTS FOR SELECTED WIND TURBINES

Wind Machine	Wind Speed Range for Equipment Operation	Electrical Output
Grumman-Windstream 25	8 mph	Trickle Charge
	26 mph	15 Kw
	29 mph	20 Kw (maximum)
Dunlite-Brushless Generator	6-8 mph	Trickle Charge
	25 mph	2 Kw (maximum)
Winco-Wincharger Model No. 1222 H Wind Electric battery charger	7 mph	Trickle Charge
	23 mph	200 watt (maximum)

Source: Sales brochures prepared by Grumman Energy Systems, A Division of Grumman Corp., 4175 Veterans Memorial Highway, Ron Kon Koma, New York 11779; Dunlite Electrical Co. Pty. Ltd., 2127 Frome Street, Adelaid S.A. Australia; and Winco, Division of Dyna Technology, Inc., Minneapolis, Minnesota 55420.

the technological problems of voltage control, energy storage and equipment interconnection can be solved), the machines can be sited at a reasonable distance from each other. Alteration of the downstream wind should not occur because "atmospheric horizontal mixing and energy replenishment from the upper layers should quickly smooth out any [wind] energy unbalance" (Wentink, 1976). Less than half the kinetic energy of the wind can be used by the windmills and the area of the wind that is blocked by the blades is exceptionally small. The decrease in air flow "would be less than what we tolerate routinely in the vicinity of buildings." (Merriam, 1974)

Perhaps the most significant wind power intrusion into wildlife habitat is the potential death of birds if the fly into the moving blades. The possibility of bird kills is considered remote except during migratory periods. Since these flights are seasonal occurrences and somewhat predictable, it has been suggested that these periods be used for system shutdown to perform routine checks and seasonal maintenance (Wentink, 1976).

There will be some construction noise, but operational noise should be minimal, depending upon the equipment used. Multivane fans, because of their poor aerodynamic efficiency, would produce some noise. There is no noise associated with high speed propeller-type wind generators, though other components in the generation system will contribute to overall operational sound levels.

Radio wave interference can be caused by all-metal blades and also by wooden blades coated with metallic paint. This can occur through reflection or diversion of the waves by the routine movement of the blades, and through oscillation in response to the wind direction (Wentink, 1976). Windmill towers, in general, should not be sited near airports, runway approaches or repeater stations; however, certain communications installations may use WECS for electricity generation if siting conditions or appropriate equipment are able to eliminate interference.

Navigable airspace is protected by the Federal Aviation regulations. Tower construction must comply with siting (and height) prohibitions as well as marking and lighting requirements. WECS installations should not be located near airports, runways, and approach, landing or takeoff paths.

Occasional structural failures indicate that there are mechanical problems and safety hazards which require attention in the planning and site selection stages. The following examples show some dangers associated with the windmill blades. "The Smith-Putnam windmill (Vermont, 1948) threw a sixty-five foot, eight-ton metal blade 750 feet. . . it landed in one piece on its tip" (Wentink, 1976). In 1975, the Ugashik, Alaska windmill experienced a safety system failure during high winds and was destroyed. The eight-foot wooden blades were thrown and fragments were found as far away as a quarter of a mile. In 1977, the top portion of the Nelson Lagoon, Alaska windmill tower buckled. At some point in the breakage, the blades severed the guy wires and the two blades were displaced. No personal or property damage (other than to the windmills) was caused by these mechanical failures, but future installations must take these problems into account.

When we think about windmills as they are portrayed in the landscape paintings of English, Dutch and the American mid-west countrysides, it is difficult to imagine visual aesthetics being degraded by the construction of windmill towers. However, it is true that poor siting of the towers, overbearing transmission lines or large numbers of wind turbines clustered in a windmill farm could be objectionable visual intrusions, and certainly these should be factors in planning for wind power generation systems.

"However, visual appearance alone . . .does not interfere with local or global ecological relationships" (Merriam, 1974). Aesthetic considerations for wind power are overwhelmingly favorable, particularly when taking into account the additional environmental benefits of fuel conservation and the absence of water degradation, two major ecological considerations.

APPLICABILITY OF WIND RESOURCES TO RURAL ALASKA

It has been estimated that in the first 1100 meters of air above Alaska there are 3.4 x 10^6 megawatts of kinetic energy available annually (Wentink in Forbes, 1975). In many parts of the State, especially along the north coast, west coast, and Aleutian Chain, this energy reaches an intensity suitable for wind energy conversion systems (Wise, 1978). People usually choose a sheltered area in which to settle, but even a village protected from the wind is sometimes near a mountain pass, ridgetop, or some other path of prevailing winds.

Based on Alaskan bush energy habits and wind patterns, it may be assumed that a significant portion, perhaps half, of the energy generated by a windmill will be unuseable. Losses may occur when wind-derived voltages are less than the battery bank voltage, batteries are fully charged and unable to accept surplus generation, or windmills are shut down for safety during high winds (Wentink in Forbes, 1975).

Tunis Wentink calculated the cost of a 6 Kw windpower installation at Ugashik, Alaska in 1976. "Assuming fee labor and no interest payments, the installation cost would be about $1,670/Kw." (Wentink in Forbes, 1975) However, remote communities are already paying extremely high diesel fuel prices, and these costs can only be expected to rise as fossil fuel reserves are depleted. Through savings on fuel costs alone, suitable areas could recover the capital costs of a wind plant in four to six years.

The Alaska State Legislature recently established a loan fund for the purchase, construction, and installation of alternative power devices. As an alternative system, a WECS is eligible for a loan of up to $10,000, to be repaid in up to 20 years at not more than eight percent annual interest. These loans can be used to finance as much as 80 percent of a project. The fund is intended to encourage the utilization of energy sources other than non-renewable fossil or nuclear fuels.

There are a number of wind energy conversion systems available with ratings of 20 Kw or less. Although many of these have not yet been tested in Alaska, experience to date has demonstrated greater success with the smaller systems. Larger systems have required more technical expertise, costly repair and maintenance, and significant down time.

In Alaska, special attention needs to be given to tower foundation construction because of freezing and thawing conditions. Icing of the blades can result in excessive vibration which can be destructive to the main bearings and tower. Icing is dependent on local conditions; in contrast to the difficulties realized in the Australian mountains, WECS in Barrow and Antarctica have encountered few problems with blade icing.

For single households and bush communities, use of DC output may be preferable despite the movement toward controlled frequency AC in modern windmill systems. Incandescent lights, motors, and heaters work well on DC and avoid the necessity of DC-AC inverters, which increase the capital investment in wind-powered systems by 30 to 70 percent (Wentink in Forbes, 1975).

The appendices contain lists of known average mean wind velocities around the State. Also, in Chapter 17 of this report, there is a chart showing communities and their likelihood of possessing a useable wind energy potential. An average annual mean wind speed of 10.4 knots was selected as the minimum criterion, although there are windmills generating in areas of the State with less wind. Also, it should be kept in mind that readings were probably taken at airports or other somewhat protected sites not likely to be selected for windmills. The charts simply provide a general guide; each site must be individually studied to determine its suitability. See Wegley, 1978 for additional siting information.

RECOMMENDATIONS

(1) Additional wind measurements should be made at potential WECS sites rather than just sheltered villages and airport locations. The energy from the wind is very site and height dependent.

(2) Wind energy conversion systems mechanical failures should be evaluated as function of unit size, wind velocity and weather conditions. Although it is recognized that other variables are involved in the functioning of WECS, such a study would provide valuable guidelines in determining boundary conditions for economical operation in Alaska.

SUMMARY

Like the rest of the nation, Alaska is suffering from a lack of experience with modern wind energy conversion systems. Although both State and Federal agencies have become involved, only a small number of community-oriented windmills have been tested and these have been in operation over a relatively short period of time. Individuals have erected small windmills, but there has been no assessment of their combined success. Perhaps, the recently established State loan fund for alternative energy development will not only provide an incentive for small wind projects, but will also generate additional information on which to base further evaluation. A very important deficiency is the absence of wind data for much of the State.

Nonetheless, Alaska has a high potential for use of wind energy. This is not only because of the strong winds in some areas, but also because of the remote character of many small communities and homesteads. This potential becomes more attractive as the cost of fossil fuels rises. Despite some experimental problems, there is still a growing interest in wind systems in the State. The use of wind resources may be an appropriate means of providing increasing energy independence.

KEY CONTACTS

Alaska Industrial Hardware, Inc.
2192 Viking Drive
Anchorage, Alaska 99501
(907) 276-7201

Alaska Marine & Equipment, Inc.
1200 W. International Airport Road
Box 6208
Anchorage, Alaska
(907) 276-1540

John Beck
Anchorage District Office
Bureau of Land Management
4700 E. 72nd Avenue
Anchorage, Alaska 99507
(907) 344-9661

Grant Petersen
Energy/Public Relations Specialist
Division of Energy and Power Development
State of Alaska
MacKay Building, 7th Floor
338 Denali
Anchorage, Alaska 99501
(907) 272-0527

Robert Swanson
S & S Electric, Inc.
P. O. Box 4-2439
Anchorage, Alaska 99509
(907) 344-0022

Tunis Wentink, Jr.
Professor of Physics
Geophysical Institute
Universtity of Alaska
Fairbanks, Alaska 99701
(907) 479-7607

James L. Wise
Climatologist
Arctic Environmental Information and Data Center
University of Alaska
707 'A' Street
Anchorage, Alaska 99501
(907) 279-4523

REFERENCES

Alaska, Division of Geological and Geophysical Surveys, Energy Resources Section (Klein, Robert M. and Kristina M. O'Connor). "Review of EIS 74-90, Section F (Energy Alternatives) and an Evaluation of Energy Alternatives." 1975.

Alaska Industrial Hardware, Inc. Private communication to Alaska Division of Energy and Power Development (DEPD), July 28, 1978.

Alaska Marine and Equipment, Inc., Private Communication to Alaska Divison of Energy and Power Development, July 31, 1978.

Beck, John. Telecon to Kyle Weaver (DEPD), October 9, 1978.

DeKorre, James B. "The Answer is Blowin' in the Wind," The Mother Earth News Handbook of Homemade Power. May 1974.

Duffy, James. Association of Village Council Presidents Housing Authority. Correspondence, September 11, 1978.

Forbes, Robert B., ed. Geothermal Energy and Wind Power. Proceedings of the Alaska Geothermal and Wind Resources Planning Conference. Anchorage, Alaska: Geophysical Institute of the University of Alaska and the Alaska Energy Office, July 8-9, 1978.

Fowler, John M. and Katheryn Mervine, "Wind Power," National Science Teachers' Association FACT SHEET U.S. Department of Energy, Technical Information Center, Oak Ridge, TN.

Killam, John. "Looking Back," Wind Power Digest. Spring 1978.

Hawaii. Alternate Energy Sources for Hawaii. Report of the Committee on Alternate Energy Sources for Hawaii. Sponsored by University of Hawaii and State of Hawaii. Department of Planning and Economic Development. Undated.

McConkey, W., D. Lane, M. Rahm, and G. Rutledge. Alaska Regional Energy Resources: Planning Project - Phase I. Vol. I. Anchorage: Prepared by Alaska Division of Energy and Power Development for U.S. Energy Research and Development Administration, 1977.

Merriam, Marshal F. Wind Energy for Human Needs. UCID-3724. Berkeley, California: Lawrence Berkeley Laboratory, University of California, November 1974.

Nisle, Robert. Conversation with Dr. Gene Rutledge (DEPD).

Ogle, William E. "Consideration on the Possible Application of Geothermal, Wind and Solar Energy to Minimize Consumption of Exhaustible Energy Resources at Certain Select Sites in the Alaska Railbelt," September 1976.

Rockwell International. The Wind Systems Program, Rocky Flats Plant. A Guide to Commercially Available Wind Machines. RFP-2836. Prepared with the assistance of the American Wind Energy Association for the U.S. Department of Energy, Federal Wind Energy Program. April 3, 1978.

"Soviet Wind Program," Wind Power Digest. Spring/Summer 1978.

Tetra Tech, Inc. Energy Fact Book - 1976, Arlington, Virginia: Tetra Tech, Inc., February 1976.

Todd, Flip. "Having to Look at Coal, Tides, Steam, Wind," Alaska Industry. June 1977.

U.S. Department of the Interior. Bureau of Land Management. Alaska Outer Continental Shelf Office. Reference Papers #9 - Energy Alternatives. Anchorage, Alaska.

Wegley, Harry L., Montie M. Orgill and Ron L. Drake. A Sitting Handbook for Small Wind Energy Conversion Systems. Prepared by Battelle Pacific Northwest Laboratories for the U.S. Department of Energy. May 1978.

Wentink, Tunis. "Wind Power for Alaska--An Impossible Dream?" Northern Engineer. Winter 1973-74.

_____. "Power and Energy Productivity of Small Windmills in Alaska," "Wind Power Potential of Alaska," and "Wind Power Applications." In Geothermal Energy and Wind Power, ed. Robert B. Forbes. Anchorage, Alaska: University of Alaska Geophysical Institute and the Alaska Energy Office, Office of the Governor, April 1976.

Wise, James L. Interview with DEPD, July 28, 1978.

APPENDIX 15-A

USING WIND CLIMATOLOGICAL SUMMARIES FOR SITING SMALL WIND ENERGY CONVERSION SYSTEMS

WIND CLIMATOLOGY SUMMARIES

The summaries include wind speed frequencies by direction, graphs of wind speed versus duration of speed, height and location of the wind sensor, the average wind speed, the available wind power, and descriptions of the site and the surrounding terrain. (See Table 15-A-1 and the following appendices.)

Other possible sources of wind data are: the United States Soil Conservation Service, the Agricultural Extension Service, United States and State Forest Services, some public utilities, airlines, industrial plants, and agricultural and meteorological departments at local colleges and universities.

USES OF WIND SUMMARIES

Wind summaries for a potential WECS site are extremely useful. In complex terrain, such as hilly or mountainous areas, they are particularly valuable for developing good siting strategy and estimating power output. Wind summaries from nearby weather stations can be used for flat terrain.

Source: Harry L. Wegley, Montie M. Orgill and Ron L. Drake, A Siting Handbook for Small Wind Energy Conversion Systems, Produced for the U.S. Department of Energy by Battelle Pacific Northwest Laboratory, May 1978.

TABLE 15-A-1

MODEL SAMPLE WIND SUMMARY--PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED: WINDSPEED INTERVALS (MILES PER HOUR)

Direction	0-3	4-7	8-12	13-18	19-24	25-31	32-38	Total	Average Speed
N	1	1						2	5.5
NNE	1	2	1					4	5.8
NE	3	8	3					14	5.9
ENE	1	5	2					8	6.3
E	1	2						3	5.5
ESE	1	2						3	5.7
SE	1	3	2					6	7.1
SSE		3	2	1				6	7.8
S	1	3	3	1				8	8.3
SSW	1	3	5	5	1			15	11.5
SW	1	4	5	5	2			17	11.7
WSW	2	2	1					5	10.4
W	1	1						2	7.7
WNW	1	1						2	7.5
NW		1						1	5.9
NNW	1							1	6.1
Calm	3								
Total	20	41	24	12	3	0	0	100	8.1

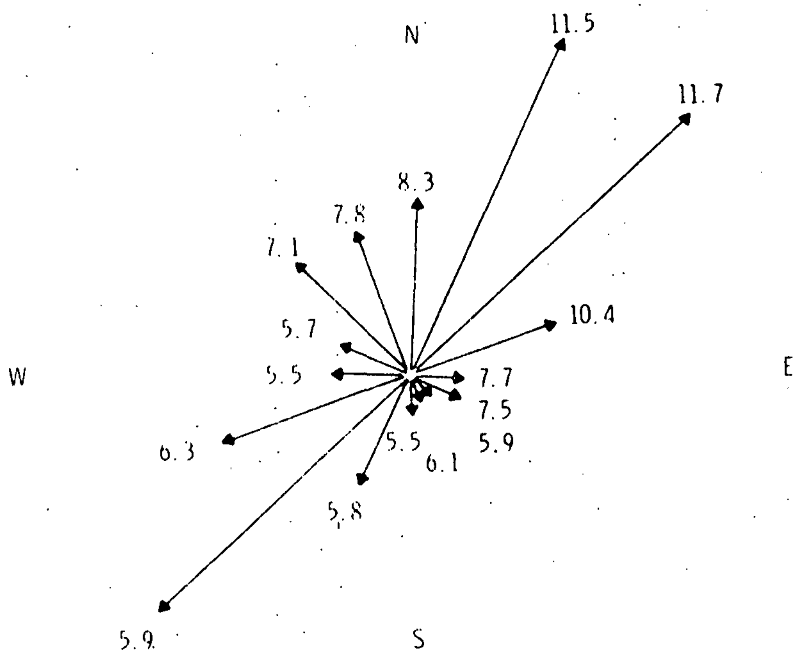


FIGURE 15-A-1

Sample Wind Rose (constructed from Table 15-A-1). Each arrow shaft is proportional in length to the percentage of time that the <u>wind blows along the arrow</u>. Number at the head of each arrow indicates the average wind speed for that direction .

Wind roses (Figure 15-A-1) show the percentage of time that the wind blows from certain directions and the mean wind speed from those directions. The user can construct a crude wind energy rose from a wind summary table by first cubing the average wind speed for each direction, then multiplying the cubed speeds by the percentage frequency of occurrence for each wind direction. An example of this technique is given in Figure 15-A-2, where Table 15-A-1 has been used to construct the wind energy rose. The derived numbers are roughly proportional to the energy contained in winds blowing from each direction.

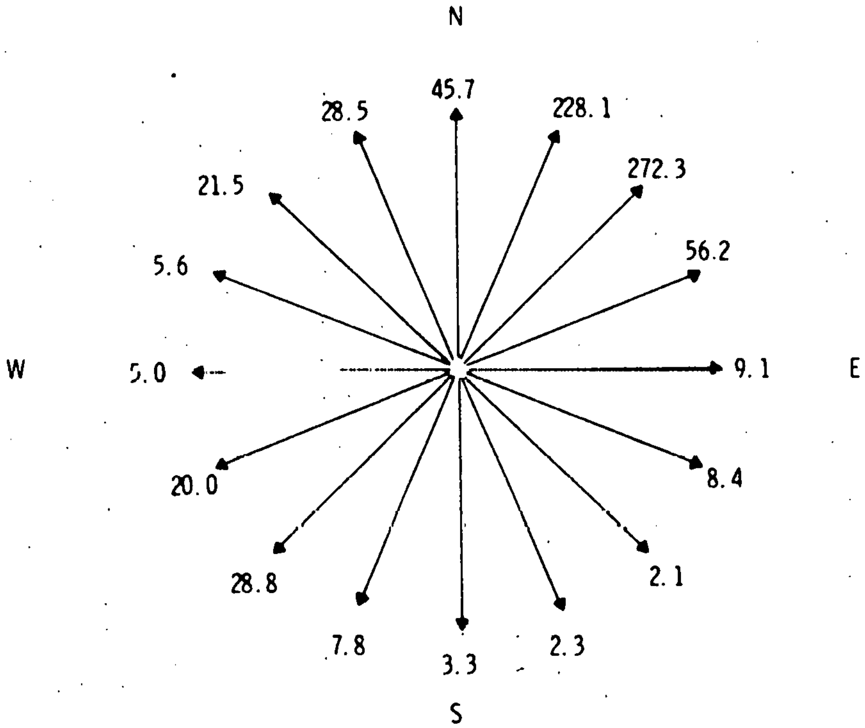


FIGURE 15-A-2

SAMPLE WIND ENERGY ROSE
(Constructed from Table 15-A-1)

SAMPLE CALCULATION: In Table 15-A-1 wind from the north blows 2% (0.02) of the time and averages 5.5 mph.

5.5x5.5x5.5x0.02 = 3.3
(Which is plotted at the head of the arrow shaft coming from a northerly direction)

In Figure 15-A-2 most of the wind power is associated with winds blowing from the southwest, the <u>prevailing power direction</u>. The user should determine the prevailing power direction for his siting area and any other direction with which significant wind power is associated. To minimize the adverse effects of barriers, he should locate the WECS so that there are no barriers upwind, along any of these directions.

APPENDIX 15-B
WIND SPEED DATA

Three tables of wind data obtained at Alaskan locations are included in this appendix. They originally appeared in Tunis Wentink's "Wind Power Potential of Alaska," a section of Geothermal Energy and Wind Power, edited by Robert B. Forbes, sponsored by the Alaska Energy Office, Office of The Governor and The Geophysical Institute, University of Alaska, April 1976. The narrative on "Ranking Sites" is also by Dr. Wentink.

TABLE 15-B-1

NEAR-SURFACE YEARLY MEAN WIND SPEEDS AT VARIOUS ALASKAN LOCATIONS

General Area	Station	Yearly Mean Speed* (knots)	Data Period	Anemometer Height (feet)**
Aleutian Islands	Shemya	16.2	1950-72	184-20
	Amchitka	18.3	1943-50	?
	Adak	13.1 (sh)	1942-65	75-15
	Atka	10.9 (sh)	1942-45	?
	Nikolski[a]	14.0	1959-69	30-13
	Ft. Glenn[a]	13.6	1942-48	?
	Driftwood Bay[b]	8.3 (sh)	1959-69	?
	Dutch Harbor[b]	9.6 (sh)	1946-54	33
	Cape Sarichef	13.7	1952-56	?
	St. Paul[c]	16.0	1962-71	42
Alaska Peninsula	Cold Bay	14.9	1956-72	88-21
	Port Moller	8.9 (sh)	1959-59	30-20
	Port Heiden	12.8	1942-67	29
	Ugashik	Under measurement by us		
	King Salmon	9.6	1956-72	38-20
Alaska "Panhandle" and Gulf of Alaska	Annette Island	9.5	1942-70	53-20
	Juneau	7.4 (sh)	1948-70	32-37
	Yakutat	7.0	1941-70	59-20
	Cordova	4.4 (sh)	1946-70	36-20
	Middleton Isl.	11.9	1945-63	30-20
	Kodiak	8.9 (sh)	1946-69	60-16
Kuskokwim and Yukon Rivers and Deltas	Cape Newenham	9.8	1953-70	30-13
	Cape Romanzof	11.7	1953-70	15-11
	Bethel	11.2	1958-72	69-20
	McGrath[d]	4.3	1949-73	26
Norton and Kotzebue Sounds, Seward Peninsula	Koyuk	9.5	1944-45	?
	Moses Point	10.6	1945-67	?
	Nome	9.5	1955-73	75-21
	Northeast Cape[e]	11.0	1952-69	30-13
	Tin City	14.9	1953-70	?
	Kotzebue	11.1	1945-70	31
Northwestern and Northern coasts	Cape Thompson	17.4	1960-61	?
	Pt. Hope	10.7	1945-48	?
	Cape Lisburne	10.5	1953-70	13
	Barrow	10.6	1945-68	39-31
	Kaktovik[f]	11.2	1945-70	27-20
Fairbanks (Interior)	Fairbanks	4.3		

* (sh): Pronounced topographic shielding effects may be involved.
** Last value is usually the most recent height. Large horizontal shifts may also have occurred.

a: Umnak Island
b: Unalaska Island
c: Pribilof Island
d: Interior location
e: St. Lawrence Island
f: Barter Island

RANKING OF WIND POWER SITES

In Table 15-B-2, 67 Alaskan sites have been ranked on the basis of measured mean yearly wind speeds and/or the yearly average potential wind power. These stations are representative of more than 100 Alaskan sites. The means are taken from data acquired during our literature survey, and the wind power figures are from the excellent compilation by Reed (1975). Readers who refer to this table should realize that:

1. None of the data involve optimization of wind instrument location for wind power surveys.
2. No attempt has been made to correct for the changes in anemometer location (vertically or horizontally) over extended observation periods.
3. Close agreement should not be expected when average powers derived from our $\bar{V}$ mean wind speed) are compared to Reed's watts/m^2, because:
   a. In some cases the recording periods for the two sets of data are different; and
   b. Reed's power fluxes are means for long time periods derived by averaging monthly power fluxes (Reed, 1975).
4. The wind power fluxes are high in terms of what can be extracted by presently available windmills. The theoretical Betz (1966) extraction limit of 59.3% for unshrouded windmills is not included, and neither are the normal mechanical and electrical efficiencies taken into account. Also, the cut-in speed and the power limiting at higher velocities (25 knots or 12.9 m/s), as plannned for present windmill design, are not included.

Nevertheless, simple conversions may be applied to Reed's results in order to estimate the actual power obtained from a particular windmill at a specific location. For example, the "Elektro WVG-50G" 6KW machine (disc area 19.9m^2) gives a factor f=0.59 (Betz limit x 10^{-3}KW/w x 19.9m^2 = 1.17 x 10^{-2}/w). An empirical factor K (0.39) seems to express the machine versus wind speed characteristics when coupled with the speed duration curves. It may be considered a composite "shape factor;" it includes variables such as cut-in speed, practical efficiencies, and calms. Then, for this particular windmill, fk = 4.5 x 10^3 KW-m^2/w. As shown in Table 15-B-3, fk, when multiplied by Reed's values, leads to useful estimates of the yearly mean power which compare well in most cases with our results, derived from computed power productivity curves.

TABLE 15-B-2

RANKING OF ALASKAN WIND POWER SITES

RANK	[1]Average yearly wind Velocity ($\bar{V}$)	$\bar{V}$ yearly, meters/ sec.	Site	[2]Wind Power watts/m^2	Remarks
1	18.3	9.41	Amchitka Is.	1025	Uninhabited
2	17.4	8.95	Cape Thompson		Uninhabited
3	16.2	8.33	Shemya Island	633	Restricted area
4	14.9	7.66	Cold Bay	574	Prime test site
5	14.9	7.66	Tin City	549	
6	16.0	8.23	St. Paul Island	547	
7	13.7	7.05	Cape Sarichef (Unimak Island)		
8	13.6	7.00	Cape AFB (Umnak Island)	498	
9	14.0	7.20	Nikolski (Umnak Island)	482	
10	12.8	6.58	Port Heiden	430	
11	13.1	6.74	Adak Island	405	
12	11.7	6.02	Cape Romanzof	381	
13	11.9	6.12	Middleton Island	377	
14	11.3	5.81	Attu Island	369	Site probably shielded; $\bar{V}$ low should rank near #3.
15	11.2	5.76	Kaktovik (Barter Is.)	341	
16	11.0	5.66	Northeast Cape (St. Lawrence Is.)	329	
17	10.9	5.61	Atka Island		$\bar{V}$ probably lower limit
18	10.7	5.50	Point Hope		
19	10.5	5.40	Cape Lisburne	315	
20	11.1	5.71	Kotzebue	292	
21	11.4	5.86	Unalakleet	265	
22	9.8	5.04	Cape Newenham	242	
23	10.6	5.45	Moses Point	241	
24	NA*	---	Golovin	241	
25	9.6	4.9	Dutch Harbor (Unalaska Is.)	233	Shielded instrument site (?)
26	9.5	4.9	Nome	218	
27	8.1	4.2	Big Delta	216	
28	9.5	4.9	Koyuk		
29	9.5	4.9	Annette Island	199	
30	10.6	5.45	Point Barrow	193	
31	9.6	4.9	King Salmon	191	
32	8.9	4.6	Kodiak	189	
33	8.9	4.6	Port Moller	172	
34	11.2	5.76	Bethel	172	
35	NA*	---	Flat	172	
36	7.9	4.1	Haines	147	
37	8.3	4.3	Driftwood Bay (Unalaska Is.)		

TABLE 15-B-2 (CONTINUED)

RANKING OF ALASKAN WIND POWER SITES

RANK	[1]Average yearly wind Velocity (V̄)	V̄yearly, meters/ sec.	Site	[2]Wind power watts/m2	Remarks
38	NA*	---	Craig	129	
39	7.4	3.8	Juneau	116	
40	7.0	3.6	Yakutat	115	
41	5.7	2.9	Gulkana	81	
42	NA*	---	Ruby	79	
43	6.0	3.1	Umiat	76	
44	6.6	3.4	Kenai	75	
45	5.6	2.9	Tanana	73	
46	5.4	2.8	Indian Mountain	70	
47	5.6	2.9	Fort Yukon	65	
48	4.7	2.4	Sparrevohn	64	
49	NA*	---	Manley Hot Springs	63	
50			Anchorage (International Airport)	61	
51	6.4	3.3	Galena	59	
52	NA*	---	Ketchikan	58	
53	NA*	---	Kaltag	57	
54	6.6	3.4	Valdez	53	
55	5.8	3.0	Bettles	49	
56	5.6	2.9	Homer		
57	5.0	2.6	Nenana	42	
58	4.6	2.4	Anchorage (Merrill Field)	38	
59	4.4	2.3	Cordova (Mile 13 Apt.)	37	Shielded instrument site (?)
60	5.7	2.9	Anchorage (Elmendorf AFB)	36	
61	6.6	3.4	Sitka	33	
62	7.9	7.9	Petersburg	33	
63	4.3	2.2	Tatalina	31	
64	4.2	2.2	Northway	29	
65	4.3	2.2	McGrath	28	
66	4.3	2.2	Fairbanks (International Airport)	27	
67	3.8	2.0	Wiseman	24	

* Not yet available.

1. Taken from Wentink (1976).

2. As taken from Reed (1975); these values are the averages of the 12 mean monthly wind powers calculated from unsmoothed duration curves.

TABLE 15-B-3

YEARLY MEAN POWER* FOR SPECIFIC ALASKAN SITES AND WIND MACHINE "X"

Site	Annual average wind velocity ($\bar{V}$) mph	Annual average wind velocity ($\bar{V}$), m/s	watts/m^2 (Reed)	Mean Power ($\bar{P}$) in Kw Reed x fk 1/	Mean power ($\bar{P}$) in Kw Wentink 2/
Amchitka Island	21.1	9.43	1025	4.7	3.27
Cold Bay	17.4	7.78	574	2.64	2.70
St. Paul Island	17.1	7.64	548	2.52	2.59
Umnak Island	15.6	6.97	498	2.29	2.25
Middleton island	13.7	6.12	377	1.73	1.79
Cape Romanzof	13.4	5.99	381	1.76	1.90
Kotzebue	13.2	5.90	292	1.34	1.63
Cape Lisburne	12.1	5.41	315	1.45	1.62

* Not optimum power, which also depends on site selection and machine height.

1/ f = 1.17 x 10^{-2} Kw m^2/w; k = 0.39 (empirical).

2/ From machine power versus windspeed characteristics and actual mean yearly speed duration curve.

APPENDIX 15-C

TABLE 15-C-1

MEAN ANNUAL WIND SPEED DATA FOR ALASKAN SITES FROM THE AIR WEATHER SERVICE

Location	Mean Annual Wind Speed (Knots)	Location	Mean Annual Wind Speed (Knots)
Adak	11.97	Juneau	7.4
Anchorage	5.6	Kenai	6.6
Amchitka	18.3	King Salmon/Naknek	9.1
Aniak	5.6	Kodiak	8.5
Annette Island	8.9	Kotzebue	11.1
Attu	11.3	McGrath	4.2
Barrow	10.6	Middleton Island	11.8
Barter Island	14.6	Moses Point	12.1
Bethel	11.3	Nenana	5.0
Bettles	6.1 (mph)	Nikolski	14.2
Big Delta	8.1	Nome	9.6
Cape Lisburne	10.5	Northeast Cape	11.2
Cape Newenham	9.8	Northway	3.8
Cape Romanzof	11.7	Palmer Ag. Ex. Station	3.8 (mph)
Cape Sarichef	13.7	Port Hedien	12.9
Cold Bay	15.7	Port Moller	8.9
Cordova	4.4	St. Paul Island	14.9
Driftwood Bay	7.8	Shemya	17.3
Dutch Harbor	9.6	Sitka	7.3
Eielson	2.7	Sparrevohn	4.7
Elmendorf	4.4	Talkeetna	6.2
Fairbanks	4.3	Tanana	8.3
Fort Yukon	6.6	Tatalina	4.3
Galena	3.9	Tin City	14.9
Gulkana	5.7	Umiat	6.0
Gustavus	4.5 (mph)	Umnak	15.8
Haines	9.1 (mph)	Unalakleet	10.5
Indian Mountain	5.9	Valdez	6.6
		Yakutat	7.0

Source: This material was obtained from the files of James L. Wise, Climatologist for the University of Alaska, Arctic Environmental Information and Data Center, 707 'A' Street, Anchorage, Alaska. The data was originally obtained by the Data Processing Division, USAF/ETAC, Air Weather Service (MAC).

APPENDIX 15-D
WIND SPEED DATA FOR ALASKAN COASTAL COMMUNITIES

The following data was taken from W. A. Brower, et al., Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska, Volumes I, II, and III, prepared by the University of Alaska, Arctic Environmental Information and Data Center and the National Climatic Center, Asheville, NC for the Bureau of Land Management and OCSEAP, 1977. Other climatological data is listed in this Atlas for these and other coast communities and would be of value to anyone planning to undertake implementation of a Wind Energy Conversion System.

TABLE 15-D-1

Monthly Mean Wind Speed in Knots

Site	Ja	F	Ma	A	My	Jn	Jy	Au	S	O	N	D	Annual
Point Lay	11.6	11.3	11.2	11.1	10.3	8.8	8.8	8.9	10.0	10.1	13.1	11.6	10.6
Wainwright	9.8	8.2	8.4	8.8	8.9	8.5	7.9	8.0	8.8	8.6	10.9	8.5	8.8
Lonely	9.1	7.8	8.1	7.9	8.0	8.2	7.8	8.4	9.5	9.6	10.7	8.3	8.6
Oliktok	11.4	9.9	10.2	9.4	9.2	9.3	9.0	9.6	10.9	10.5	11.7	10.4	10.1
Gambell	19.8	18.7	17.4	15.8	14.1	10.7	12.1	12.3	14.8	17.2	19.1	19.6	16.0
St. Paul	18.1	18.7	16.7	16.3	14.1	11.9	11.1	12.5	13.9	16.5	17.8	17.9	15.4
Homer	5.7	6.2	6.4	6.6	6.7	6.3	5.6	5.4	5.4	6.0	6.1	6.1	6.0
Yakataga	6.7	7.0	7.4	7.8	8.0	6.9	6.7	6.3	7.3	8.0	7.7	7.7	7.3

APPENDIX 15-E

INDEX OF SUMMARIZED WIND DATA (FOR ALASKAN LOCATIONS)

This material is extracted from M. J. Changery, W. T. Hodge and J. V. Ramsdell, Index--Summarized Wind Data, prepared for the Energy Research and Development Administration by Battelle Pacific Northwest Laboratories, September 1977.

The Appendix consists of three sections:

This index is intended to be a guide to available summaries. It does not present the actual summaries or original wind data, but lists the locations and periods for which summaries can be obtained from the National Climatic Center. Additional sources of wind data, presenting only monthly mean speed, are available but not listed in this document. The majority of summaries present the frequency or percentage of observations of the wind speed in various speed classes (1-3 mph, 4-7 mph, etc.) for each of 8, 16, or 36 compass points. Data for a given number of years are presented on a monthly and/or seasonal and/or annual basis. In addition, the mean speed for each direction and for all directions is usually given. A few of the summary types were developed for wind data only. In most summaries, however, wind is only one of a number of elements available. For this index, only the wind portion is presented. Since various agencies in the past have been involved in the production of these summaries, the speed class intervals have varied and data may be in knots rather than miles per hour.

Information on locations without summaries but with digitized records can be obtained from the Center.

Copies of summaries listed can be obtained for the cost of reproduction by contacting the Director, National Climatic Center, Federal Building, Asheville, NC 28801.

TABLE 15-E-1

ALASKAN LOCATIONS AND THE AVAILABLE SUMMARIES

STATE: ALASKA

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAB#/REMARKS
ADAK	DAVIS AFB	AK	25701		51 53N	176 39W	0004	11 42 - 06 50	ABC	MA	
ADAK	NS	AK	25704	70454	51 53N	176 39W	0004	10 42 - 04 45	SOMAR	MA	
ADAK	NS	AK	25704	70454	51 53N	176 39W	0004	10 42 - 02 65	A-F	MA	1.2
ADAK	NS	AK	25704	70454	51 53N	176 38W	0005	01 46 - 12 55	QMC	M	161
ADAK	NS	AK	25704	70454	51 53N	176 39W	0004	03 49 - 02 63	SMAR	MA	
ADAK	NS	AK	25704	70454	51 53N	176 39W	0004	01 50 - 12 60	SMOS	MA	2
ADAK	AAF	AK	25707		51 50N	176 38W	0004	02 44 - 12 44	ABC	MA	
AKULURUK		AK	26610		62 30N	164 25W	0010	05 44 - 08 44	AB	MA	45
ALATNA		AK			66 34N	152 44W	0102	12 36 - 04 41	11390	MA	
ALEXAI POINT	AFS ATTU ISLAND	AK	45701		52 50N	173 10E	0000	06 43 - 08 45	AB	MA	45
AMAK ISLAND	AFS	AK	25609		55 24N	163 08W	0005	04 44 - 09 44	AB	MA	45
AMCHITKA ISLAND	AFB	AK	45702	70439	51 24N	179 16E	0063	02 43 - 12 46	AB	MA	45
AMCHITKA ISLAND	AFB	AK	45702	70439	51 24N	179 16E	0063	02 43 - 11 50	A-F	MA	1.2
AMCHITKA ISLAND	AFB	AK	45702	70439	51 24N	179 16E	0063	02 43 - 08 48	ABC	MA	
AMCHITKA ISLAND	AFB	AK	45702	70439	51 24N	179 16E	0063	06 45 - 05 50	CVSBY	MA	T10115
AMERICAN RIVER	AAF	AK	26611		65 27N	165 40W	0036	06 44 - 08 45	AB	MA	45
ANCHORAGE	ELMENDORF AFB	AK	26401	70272	61 15N	149 48W	0065	03 41 - 10 68	A-F	MA	1.2
ANCHORAGE	ELMENDORF AFB	AK	26401	70272	61 15N	149 48W	0065	03 41 - 12 63	ABC	MA	
ANCHORAGE	ELMENDORF AFB	AK	26401	70272	61 15N	149 48W	0065	01 46 - 12 55	QMC	M	161
ANCHORAGE	ELMENDORF AFB	AK	26401	70272	61 15N	149 48W	0054	01 51 - 12 70	STAR	MA	T15332.3
ANCHORAGE	MERRILL FIELD LAWRS	AK	26409		61 13N	149 50W	0041	01 35 - 04 41	11390	MA	
ANCHORAGE	MERRILL FIELD LAWRS	AK	26409		61 13N	149 50W	0041	11 48 - 10 53	WND TAB	MA	T2095
ANCHORAGE	INTERNATIONAL APT WBAS	AK	26451	70273	61 10N	149 59W	0040	11 53 - 05 58	WND TAB	MA	T2095
ANCHORAGE	INTERNATIONAL APT WBAS	AK	26451	70273	61 10N	149 59W	0040	11 53 - 06 65	A-F	MA	2
ANCHORAGE	INTERNATIONAL APT WBAS	AK	26451	70273	61 10N	149 27W	0031	01 56 - 12 60	SHO	MA	
ANCHORAGE	INTERNATIONAL APT WBAS	AK	26451	70273	61 10N	149 50W	0040	01 56 - 12 60	SHO	MA	
ANCHORAGE	INTERNATIONAL APT WBAS	AK	26451	70273	61 10N	150 01W	0048	01 65 - 12 73	WND TAB	SA	T14085
ANCHORAGE	INTERNATIONAL APT WBAS	AK	26451	70273	61 10N	150 01W	0048	01 65 - 12 73	CVSBY	A	T14085
ANCHORAGE	INTERNATIONAL APT WBAS	AK	26451	70273	61 10N	150 01W	0048	01 65 - 12 69	STAR	MA	T13853
ANCHORAGE	ELMENDORF AFB	AK	26452	70272	61 15N	149 48W	0063	11 53 - 02 55	ABC	MA	
ANIAK		AK	26516	70232	61 35N	159 32W	0026	11 39 - 04 41	11390	A	
ANIAK	CAA	AK	26516	70232	61 35N	159 32W	0028	01 43 - 06 54	ABC	MA	
ANIAK	CAA	AK	26516	70232	61 35N	159 32W	0026	01 45 - 12 55	QMC	M	161
ANIAK	FAA	AK	26516	70232	61 35N	159 32W	0028	07 48 - 07 70	A-F	MA	2
ANNETTE ISLAND	AAF	AK	25301		55 02N	131 35W	0035	10 41 - 12 46	AB	MA	
ANNETTE ISLAND	WBAS	AK	25308	70398	55 02N	131 34W	0034	01 42 - 12 70	A-F	MA	2
ANNETTE ISLAND	WBAS	AK	25308	70398	55 02N	131 34W	0034	01 46 - 12 55	QMC	M	161
ANNEX CREEK		AK	25311		58 18N	134 06W	0007	04 37 - 04 41	11390	A	1
ATKA	AAF	AK	25708		52 13N	174 12W	0011	04 44 - 10 45	AB	MA	45
ATKA		AK	25715		52 12N	174 20W	0003	11 36 - 01 41	11390	A	1
ATTU	NAU	AK	45709	70409	52 50N	173 11E	0028	09 43 - 04 45	SOMAR	MA	
ATTU	NAU	AK	45709	70409	52 50N	173 11E	0028	05 45 - 09 48	ABC	MA	
ATTU	NAU	AK	45709	70409	52 50N	173 11E	0028	05 45 - 07 55	SMAR	MA	
ATTU	NAU	AK	45709	70409	52 50N	173 11E	0028	01 47 - 06 58	A-F	MA	1.2
BARROW	ROGERS-POST MEM APT WBAS	AK	27502	70026	71 18N	156 47W	0008	01 45 - 07 54	ABC	MA	
BARROW	ROGERS-POST MEM APT WBAS	AK	27502	70026	71 18N	156 47W	0009	01 45 - 12 60	A-F	MA	2
BARROW	ROGERS-POST MEM APT WBAS	AK	27502	70026	71 18N	156 47W	0008	01 45 - 03 61	SMAR	MA	
BARROW	ROGERS-POST MEM APT WBAS	AK	27502	70027	71 18N	156 47W	0008	01 45 - 12 55	QMC	M	161
BARROW	ROGERS-POST MEM APT WBAS	AK	27502	70026	71 18N	156 47W	0009	01 50 - 12 54	WND TAB	M	T6010
BARTER ISLAND	WBAS	AK	27401	70086	70 08N	143 38W	0006	01 47 - 12 55	QMC	M	161
BARTER ISLAND	WBAS	AK	27401	70086	70 08N	143 36W	0015	10 47 - 12 63	ABC	MA	
BARTER ISLAND	WBAS	AK	27401	70086	70 08N	143 36W	0015	10 47 - 07 70	A-F	MA	2
BARTER ISLAND	WBAS	AK	27401	70086	70 08N	143 38W	0009	11 47 - 12 53	WND TAB	M	TCL4021
BARTER ISLAND	WBAS	AK	27401	70086	70 08N	143 36W	0009	01 50 - 12 54	WND TAB	M	T6010
BEAVER FALLS		AK	25313		55 23N	131 28W	0011	05 40 - 04 41	11390	A	
BETHEL	WBAS	AK	26615	70219	60 00N	161 45W	0011	12 32 - 04 41	11390	MA	
BETHEL	WBAS	AK	26615	70219	60 48N	161 43W	0004	01 45 - 04 65	A-F	MA	1.2
BETHEL	WBAS	AK	26615	70219	60 47N	161 43W	0004	01 45 - 04 54	ABC	MA	1.9
BETTLES	WBAS	AK	26533	70174	66 55N	151 31W	0189	01 68 - 12 72	WND TAB	MA	T50108
BIG DELTA	FORT GREELY FAA	AK	26406	70267	63 59N	145 43W	0392	01 46 - 12 55	QMC	M	161
BIG DELTA	CAA	AK	26415	70267	64 00N	145 44W	0388	10 35 - 04 41	11390	A	
BIG DELTA	FAA	AK	26415	70267	64 00N	145 44W	0388	07 44 - 06 55	ABC	MA	
BIG DELTA	FAA	AK	26415	70267	64 00N	145 44W	0388	01 49 - 03 69	A-F	MA	2
BIG DELTA	FAA	AK	26415	70267	64 00N	145 44W	0389	01 60 - 12 64	STAR	SA	T14063
BIG DELTA	FAA	AK	26415	70267	64 00N	145 44W	0389	01 67 - 12 71	STAR	SA	T14063
BROAD PASS		AK			63 22N	149 02W	0648	10 38 - 04 41	11390	A	
BULDIR ISLAND	AAF	AK	45706		52 22N	175 58E	0015	05 44 - 08 45	AB	MA	45
CANDLE		AK	26619		65 56N	161 55W	0003	02 38 - 04 41	11390	A	
CAPE DECISION	COAST GUARD	AK	25315	70388	56 00N	134 08W	0015	11 39 - 04 41	11390	A	
CAPE LISBURNE	AFS	AK	26631	70104	68 52N	166 08W	0016	09 52 - 12 70	A-F	MA	2

TABLE 15-E-1 (Cont.)

STATE: ALASKA

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAB*/REMARKS
CAPE LISBURNE	AFS	AK	26631	70104	68 52N	166 08W	0016	10 52 - 03 62	ABC	MA	
CAPE LISBURNE	AFS	AK	26631	70104	68 52N	166 08W	0016	01 54 - 12 61	CVSBY	MA	TCL7062
CAPE NEWENHAM	AFS	AK	25623	70305	58 40N	162 10W	0169	07 53 - 05 70	A-F	MA	2
CAPE NEWENHAM	AFS	AK	25623	70305	58 40N	162 10W	0169	08 53 - 07 53	ABC	MA	
CAPE NEWENHAM	AFS	AK	25623	70305	58 40N	162 10W	0169	01 54 - 12 61	CVSBY	MA	TCL7062
CAPE ROMANZOFF	AFS	AK	26633	70212	61 47N	165 52W	0135	04 53 - 03 63	ABC	MA	
CAPE ROMANZOFF	AFS	AK	26633	70212	61 47N	165 52W	0135	04 53 - 05 70	A-F	MA	2
CAPE ROMANZOFF	AFS	AK	26633	70212	61 47N	165 52W	0135	01 54 - 12 61	CVSBY	MA	TCL7062
CAPE SARICHEF	COAST GUARD	AK	25622		54 36N	164 56W	0053	02 40 - 04 41	11390	A	
CAPE SPENCER	COAST GUARD	AK	25316	70365	58 12N	136 38W	0026	08 38 - 04 41	11390	A	1
CAPE ST ELIAS	COAST GUARD	AK	25401	70380	59 48N	144 36W	0016	03 38 - 04 41	11390	A	
CENTRAL		AK	26418		65 35N	144 48W	0265	02 40 - 02 41	11390	A	
CHICKEN		AK			64 04N	141 55W	0609	10 35 - 05 40	11390	A	
CHINCHINBROOK	COAST GUARD	AK	26417	70279	60 14N	146 39W	0056	01 40 - 04 41	11390	A	
CHIRIKOF ISL	NAS	AK	25505		55 55N	155 35W	0036	11 43 - 10 45	N	MS	158
CHITINA		AK			61 32N	144 27W	0174	06 39 - 04 41	11390	A	
CHUGINADAK ISL	AAF	AK	25601		52 50N	169 50W	0024	07 43 - 06 44	AB	MA	45
CIRCLE		AK	26447		65 48N	144 04W	0213	04 31 - 04 41	11390	A	
CIRCLE HOT SPGS		AK	26419		65 29N	144 36W	0285	07 35 - 04 41	11390	A	
COAL CREEK		AK			65 16N	143 16W	0320	05 38 - 10 40	11390	A	
COLD BAY	THORNBROUGH AFB	AK	25603		55 12N	162 42W	0028	03 42 - 12 53	ABC	MA	1
COLD BAY	THORNBROUGH AFB	AK	25603		55 12N	162 42W	0028	07 52 - 06 53	CVSBY	MA	TCL7062
COLD BAY	THORNBROUGH AFB	AK	25603		55 12N	152 42W	0028	01 54 - 06 54	CVSBY	MA	TCL7062
COLD BAY	WBAS	AK	25624	70316	55 12N	162 43W	0029	06 42 - 07 64	A-F	M	1,9,92
COLD BAY	WBAS	AK	25624	70318	55 12N	162 43W	0029	06 42 - 03 68	A-F	MA	1,2
COLD BAY	WBAS	AK	25624	70316	55 12N	162 43W	0029	06 42 - 11 64	A-F	M	1,0,80
COLD BAY	WBAS	AK	25624	70316	55 12N	162 43W	0029	07 55 - 12 61	CVSBY	MA	TCL7062
COLD BAY	WBAS	AK	25624	70316	55 12N	162 43W	0028	01 56 - 12 63	SHB	MA	
COLD BAY	WBAS	AK	25824	70316	55 12N	162 43W	0028	01 69 - 12 73	WND TAB	MA	T51263
COPPER CENTER		AK			61 58N	145 19W	0318	11 38 - 04 41	11390	A	
CORDOVA	AAF	AK	26402		60 29N	145 30W	0013	06 42 - 08 45	AB	MA	45
CORDOVA	MILE 13 APT FAA	AK	26410	70296	60 30N	145 30W	0013	02 31 - 04 44	11390	A	
CORDOVA	MILE 13 APT FAA	AK	26410	70298	60 30N	145 30W	0015	01 46 - 12 55	OMC	M	161
CORDOVA	MILE 13 APT FAA	AK	26410	70296	60 30N	145 30W	0013	01 46 - 07 70	A-F	MA	2
CORDOVA	MILE 13 APT FAA	AK	26410	70296	60 30N	145 30W	0013	01 59 - 12 62	STAR	SA	T50320
COUNCIL		AK			64 53N	163 41W	0029	05 36 - 04 41	11390	A	1
CRAIG		AK	25317	70392	55 20N	133 09W	0003	09 30 - 04 41	11390	A	1
CRAIG		AK	25317	70392	55 20N	133 09W	0003	01 59 - 12 68	WND TAB	MA	T11208
CROOKED CREEK		AK	26518		61 52N	158 15W	0045	03 30 - 04 41	11390	A	1
DEERING		AK			66 04N	162 45W	0004	11 36 - 04 41	11390	A	
DILLINGHAM		AK	25513	70321	58 01N	158 31W	0025	08 39 - 04 41	11390	A	
DRIFTWOOD BAY	AFS	AK	25515		53 58N	166 51W	0010	06 59 - 05 69	A-F	MA	2
DRIFTWOOD BAY	AFS	AK	25515		58 50N	166 51W	0010	06 59 - 05 63	ABC	MA	
DUTCH HARBOR	NS	AK	25611	70480	53 53N	166 32W	0008	06 33 - 04 45	SOMAR	MA	
DUTCH HARBOR	NS	AK	25611	70489	53 53N	166 32W	0008	01 45 - 12 54	OMC	M	161
DUTCH HARBOR	NS	AK	25611	70489	53 53N	165 32W	0008	05 45 - 12 53	SMAR	MA	
DUTCH HARBOR	NS	AK	25616	70488	53 53N	166 32W	0004	07 36 - 04 41	11390	A	
DUTCH HARBOR	NF	AK	25616	70489	53 53N	166 32W	0004	07 36 - 04 41	11390	MA	
DUTCH HARBOR	SAWR	AK	25616	70489	53 53N	165 32W	0004	01 46 - 07 54	A-F	MA	1,2
DUTCH HARBOR	AFS	AK	25620	70488	53 54N	166 32W	0007	12 50 - 12 51	ABC	MA	
EAGLE		AK	26422		64 46N	141 12W	0255	09 30 - 04 41	11390	A	1
ELDRED ROCK	COAST GUARD	AK	25310	70364	58 58N	135 13W	0016	03 39 - 03 41	11390	A	
ELIM		AK			64 37N	162 14W	0009	10 37 - 06 39	11390	A	
FAIRBANKS	LADD AFB	AK	26403		64 51N	147 35W	0141	02 41 - 01 55	ABC	MA	
FAIRBANKS	LADD AFB	AK	26403		64 51N	147 35W	0141	02 42 - 10 60	A-F	MA	2
FAIRBANKS	LADD AFB	AK	26403		64 51N	147 35W	0141	01 46 - 12 55	OMC	M	161
FAIRBANKS	EIELSON AFB	AK	26407	70265	64 39N	147 04W	0172	11 44 - 10 68	A-F	MA	1,2
FAIRBANKS	EIELSON AFB	AK	26407	70265	64 39N	147 04W	0166	11 44 - 12 63	ABC	MA	
FAIRBANKS	EIELSON AFB	AK	26407	70265	64 39N	147 04W	0166	01 61 - 12 70	STAR	SA	T14703
FAIRBANKS	INTERNATIONAL APT WBAS	AK	26411	70261	64 49N	147 52W	0133	07 49 - 07 70	A-F	MA	2
FAIRBANKS	INTERNATIONAL APT WBAS	AK	26411	70261	64 49N	147 52W	0133	01 56 - 12 60	SHB	MA	
FAIRBANKS	INTERNATIONAL APT WBAS	AK	26411	70261	64 49N	147 52W	0134	01 61 - 12 70	STAR	SA	T14703
FAIRBANKS	INTERNATIONAL APT WBAS	AK	26411	70261	64 49N	147 52W	0133	01 67 - 12 67	WND TAB	M	TCL0673
FIVE FINGER LT	COAST GUARD	AK	25310	70385	57 16N	133 37W	0009	03 39 - 04 41	11390	A	

STATE: ALASKA

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAB#/REMARKS
FLAT		AK	26520		62 27N	158 00W	0002	09 31 - 04 41	11390	MA	1
FORT YUKON	MUNICIPAL APT	AK	26413	70194	66 35N	145 18W	0124	09 30 - 04 41	11390	A	
FORT YUKON	MUNICIPAL APT CAA	AK	26413	70194	66 35N	145 18W	0128	12 37 - 07 54	ABC	MA	
FORT YUKON	MUNICIPAL APT FAA	AK	26413	70194	66 35N	145 18W	0128	07 48 - 09 63	A-F	MA	2
FT GLENN	UMNAK ISL	AK	25602		53 23N	167 54W	0030	03 42 - 12 46	AB	MA	45
GALENA	AFS	AK	26501	70222	64 43N	156 54W	0030	09 42 - 09 45	AB	MA	45
GALENA	AFS	AK	26501	70222	64 43N	156 54W	0038	09 42 - 05 70	A-F	MA	1,2
GALENA	AFS	AK	26501	70222	64 43N	156 54W	0038	10 42 - 12 63	ABC	MA	
GALENA	WBAS	AK	26509	70222	64 43N	156 54W	0037	01 40 - 12 55	QMC	M	161
GAMBELL		AK	26703	70204	63 46N	171 45W	0008	08 35 - 03 40	11390	A	
GAMBELL		AK	26703	70204	63 46N	171 45W	0008	11 42 - 06 48	N	MS	158
GOLOVIN		AK	26628		64 33N	163 01W	0006	02 30 - 04 41	11390	MA	1
GOODPASTOR		AK			64 20N	144 05W	0762	11 39 - 04 41	11390	A	
GUARD ISLAND	COAST GUARD	AK	25320	70383	55 27N	131 53W	0006	02 40 - 02 41	11390	A	
GULKANA	CAA	AK	26425	70271	62 09N	145 27W	0480	01 45 - 12 70	A-F	MA	2
GULKANA	CAA	AK	26425	70271	62 09N	145 27W	0480	01 45 - 11 58	ABC	MA	
GULKANA	INTERMEDIATE FIELD	AK	26425	70271	62 09N	145 27W	0481	01 67 - 12 71	STAR	SA	T14063
GUSTAVUS		AK	25322	70367	58 25N	135 42W	0006	08 39 - 02 41	11390	A	
HAINES		AK	25323		59 14N	135 27W	0078	07 30 - 04 41	11390	MA	
HEALY	HEALEY FORK	AK	26447		63 51N	148 58W	0411	10 38 - 04 41	11390	A	
HOLTZ BAY	AAF ATTU ISLAND	AK	45704		52 55N	173 10E	0013	02 43 - 09 45	AB	MA	
HOLY CROSS		AK	26521		62 10N	159 45W	0046	06 40 - 04 41	11390	A	
HOMER	MUNICIPAL APT	AK	25507	70341	59 38N	151 30W	0022	01 65 - 12 75	WND TAB	SA	T52360
HUGHES	MUNICIPAL APT	AK	26522		66 04N	154 14W	0166	10 39 - 04 41	11390	A	
ILIAMNA		AK	25506	70340	59 45N	154 55W	0046	03 39 - 04 41	11390	A	
IMURUK LAKE	AFS	AK	26813		65 35N	163 50W	0170	04 45 - 09 45	AB	MA	45
JACKWADE		AK			64 07N	141 35W	0548	05 40 - 04 41	11390	A	1
JUNEAU	MUNICIPAL APT WBAS	AK	25309	70381	58 22N	134 35W	0007	01 45 - 12 55	QMC	M	161
JUNEAU	MUNICIPAL APT WBAS	AK	25309	70381	58 22N	134 35W	0006	07 40 - 12 70	A-F	MA	2
JUNEAU	WBO	AK	25324	70381	58 18N	134 24W	0040	12 30 - 04 41	11390	MA	
JUNEAU	WBO	AK	25324	70381	58 18N	134 24W	0040	04 35 - 04 41	11390	MA	
KALSKAG		AK			61 27N	160 48W	0027	03 39 - 04 41	11390	A	
KALTAG	AAF	AK	26502		64 18N	158 43W	0048	07 43 - 09 45	AB	MA	45
KALTAG		AK			64 20N	158 45W	0020	06 31 - 04 41	11390	MA	1
KASILOF		AK			60 18N	151 16W	0018	01 39 - 04 41	11390	A	
KENAI	MUNICIPAL APT FAA	AK	26523	70259	60 34N	151 15W	0027	08 48 - 07 67	A-F	MA	2
KENAI	MUNICIPAL APT CAA	AK	26523	70259	60 34N	151 15W	0027	01 48 - 12 58	STAR	MA	T15332,3
KENAI	MUNICIPAL APT CAA	AK	26523	70259	60 34N	151 15W	0027	01 59 - 12 63	WND TAB	MA	T6783
KENAI	MUNICIPAL APT FAA	AK	26523	70259	60 34N	151 15W	0032	01 66 - 12 70	STAR	SA	T13873
KETCHIKAN	WBO	AK	25325	70395	55 21N	131 38W	0005	00 30 - 04 41	11390	MA	
KISKA ISLAND	AAF	AK	45703		51 58N	177 34E	0090	09 43 - 10 45	AB	MA	45
KISKA ISLAND	NS	AK	45710		51 58N	177 33W	0022	02 42 - 07 44	SOMAR	M	
KODIAK	NAF	AK	25501	70350	57 45N	152 20W	0034	12 41 - 04 45	SOMAR	M	
KODIAK	NAF	AK	25501	70350	57 45N	152 20W	0034	01 45 - 12 55	QMC	M	161
KODIAK	NAF	AK	25501	70350	57 45N	152 20W	0034	05 45 - 12 59	SMAR	MA	
KODIAK	NAF	AK	25501	70350	57 45N	152 20W	0034	05 45 - 09 54	ABC	MA	
KODIAK	NAF	AK	25501	70350	57 45N	152 20W	0034	01 46 - 12 69	SMOS	MA	2
KODIAK	NAF	AK	25501	70350	57 45N	152 20W	0034	01 49 - 12 64	SMAR	MA	
KODIAK		AK	25509		57 48N	152 24W	0046	08 36 - 04 41	11390	A	
KOKRINES	AAF	AK	26503		64 54N	154 40W	0056	07 43 - 08 45	AB	MA	45
KOTZEBUE		AK	26616	70133	66 52N	162 38W	0003	09 30 - 04 41	11390	MA	
KOTZEBUE	WBAS	AK	26616	70133	66 52N	162 38W	0005	01 45 - 12 55	QMC	M	161
KOTZEBUE	WBAS	AK	26616	70133	66 52N	162 38W	0006	01 45 - 09 55	ABC	MA	
KOTZEBUE	WBAS	AK	26616	70133	66 52N	162 38W	0006	01 45 - 12 70	A-F	MA	2
KOYUK	AAF	AK	26602		64 52N	161 06W	0012	05 43 - 08 45	AB	MA	45
LIVENGOOD		AK	26428		65 35N	148 29W	0228	02 31 - 04 41	11390	A	
MANLEY HOT SPGS		AK	26505	70178	65 00N	150 38W	0080	09 30 - 04 41	11390	MA	
MANLEY HOT SPGS		AK	26505	70178	65 00N	150 38W	0080	12 43 - 09 45	AB	MA	45
MARY ISLAND	COAST GUARD	AK			55 06N	131 11W	0011	02 40 - 02 41	11390	A	
MCGRATH	CAA	AK	26510	70231	62 58N	155 37W	0101	02 31 - 04 41	11390	A	

TABLE 15-E-1 (Cont.)

STATE: ALASKA

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAB#/REMARKS
MCGRATH	WBAS	AK	26510	70231	62 58N	155 37W	0104	01 38 - 06 48	ABC	MA	
MCGRATH	WBAS	AK	26510	70231	62 58N	155 37W	0104	07 48 - 07 70	A-F	MA	2
MIDDLETON ISL	CAA	AK	25402	70343	59 20N	146 10W	0013	01 45 - 04 54	ABC	MA	
MIDDLETON ISL	CAA	AK	25402	70343	59 28N	146 19W	0013	11 53 - 10 58	CVSBY	MA	TCL7062
MIDDLETON ISL	AFS	AK	25403	70343	59 20N	146 19W	0013	01 45 - 06 63	A-F	MA	1,2
MIDDLETON ISL	AFS	AK	25403	70343	59 28N	146 19W	0013	06 51 - 07 60	ABC	MA	
MIDDLETON ISL	AFS	AK	25403	70343	59 20N	146 19W	0013	01 50 - 12 62	STAR	SA	T50320
MIDDLETON ISL	AFS	AK	25403	70343	59 28N	146 10W	0013	01 59 - 12 61	CVSBY	MA	TCL7062
MOSES POINT	AAF	AK	26603		64 43N	162 05W	0006	06 43 - 09 45	ABC	MA	45
MOSES POINT	CAA	AK	26620	70203	64 12N	162 03W	0006	11 45 - 07 67	A-F	MA	2
MOSES POINT	CAA	AK	26620	70203	64 12N	162 03W	0006	11 45 - 10 55	ABC	MA	
MOUNTAIN VILL		AK	26635		62 07N	163 45W	0151	10 44 - 09 45	AB	MA	45
NAKNEK	AFB	AK	25503	70326	58 41N	155 39W	0014	01 42 - 12 46	AB	MA	45
NAKNEK	AFB	AK	25503	70326	58 41N	155 39W	0014	01 42 - 06 48	ABC	MA	
NAKNEK	AFB KING SALMON APT WBAS	AK	25503	70326	58 41N	156 30W	0014	01 42 - 08 64	ABC	MA	
NAKNEK	KING SALMON APT WBAS	AK	25503	70326	58 41N	156 38W	0014	05 42 - 12 70	A-F	MA	2
NAKNEK	AFB KING SALMON APT WBAS	AK	25503	70326	58 41N	156 39W	0014	06 42 - 07 64	A-F	M	1,8,92
NAKNEK	AFB KING SALMON APT WBAS	AK	25503	70326	58 41N	156 39W	0014	06 42 - 11 64	A-F	M	1,9,80
NAKNEK	AFB	AK	25503	70326	58 41N	155 39W	0014	02 45 - 03 55	WND TAB	S	TCL4550,13
NAKNEK	KING SALMON APT WBAS	AK	25503	70326	58 41N	155 39W	0014	01 46 - 12 55	OMC	M	161
NAKNEK	AFB KING SALMON APT WBAS	AK	25503	70326	58 41N	155 39W	0014	01 54 - 12 61	CVSBY	MA	TCL7062
NAKNEK	KING SALMON APT WBAS	AK	25503	70326	58 41N	155 39W	0014	01 56 - 12 60	SHD	MA	
NAKNEK		AK	25510		58 42N	155 44W	0015	07 35 - 03 41	11390	A	1
NENANA	MUNICIPAL APT CAA	AK	26435	70260	64 33N	149 05W	0110	08 30 - 04 41	11390	A	
NENANA	MUNICIPAL APT CAA	AK	26435	70260	64 33N	149 05W	0110	07 43 - 06 49	ABC	MA	45
NENANA	MUNICIPAL APT CAA	AK	26435	70260	64 33N	149 05W	0110	01 49 - 12 67	A-F	MA	2
NIKOLSKI	AFS	AK	25605		52 55N	168 58W	0096	03 43 - 08 45	AB	MA	45
NIKOLSKI	AFS	AK	25626		52 55N	168 47W	0214	06 59 - 05 67	A-F	MA	2
NIKOLSKI	AFS	AK	25626		52 55N	168 47W	0214	07 59 - 12 63	AB	MA	
NO GRUB		AK			64 30N	145 45W	0397	02 39 - 11 39	11390	A	
NOME	AFB	AK	26604		64 31N	165 26W	0005	09 42 - 03 46	ABC	MA	45
NOME	WBO	AK	26617	70200	64 30N	165 26W	0005	06 35 - 04 41	11390	MA	
NOME	WBAS	AK	26617	70200	64 30N	165 26W	0007	01 45 - 12 55	OMC	M	161
NOME	WBAS	AK	26617	70200	64 30N	165 26W	0005	01 45 - 11 58	ABC	MA	·
NOME	WBAS	AK	26617	70200	64 30N	165 26W	0005	01 45 - 07 70	A-F	MA	1,2
NOME	WBAS	AK	26617	70200	64 30N	165 26W	0005	03 50 - 02 55	CVSBY	A	T1241
NOME	WBAS	AK	26617	70200	64 30N	165 26W	0005	01 54 - 12 61	CVSBY	MA	TCL7062
NOME	WBAS	AK	26617	70200	64 30N	165 26W	0005	01 55 - 12 56	WND TAB	MA	T2579
NORTHEAST CAPE	AFS	AK	26632	70206	63 19N	168 56W	0010	07 52 - 08 69	A-F	MA	1,2
NORTHEAST CAPE	AFS	AK	26632	70206	63 19N	168 56W	0011	12 52 - 11 62	ABC	MA	
NORTHEAST CAPE	AFS	AK	26632	70206	63 19N	168 56W	0010	01 54 - 12 61	CVSBY	MA	T7062
NORTHWAY	WBAS	AK	26412	70291	62 57N	141 56W	0523	06 42 - 05 48	AB	MA	45
NORTHWAY	FAA	AK	26412	70291	62 57N	141 56W	0523	01 45 - 05 64	AB	MA	
NORTHWAY	FAA	AK	26412	70291	62 57N	141 56W	0523	01 45 - 12 70	A-F	MA	1,2
NULATO		AK			64 43N	158 04W	0064	02 31 - 04 41	11390	A	19
NUNIVAK ISLAND		AK	26605		60 12N	166 05W	0015	01 44 - 06 45	AB	MA	45
OGLIUGA	AAF	AK	25702		51 33N	178 48W	0015	03 43 - 08 44	AB	MA	45
OHOGAMUTE		AK			61 38N	161 54W	0013	01 37 - 06 38	11390	A	
OPHIR		AK			63 10N	158 33W	0121	10 39 - 04 41	11390	A	
PETERSBURG		AK	25329	70306	56 49N	132 57W	0015	04 32 - 04 41	11390	MA	19
PETERSBURG		AK	25329	70306	56 49N	132 57W	0015	01 45 - 12 55	OMC	M	161
PIGOT BAY		AK			60 49N	148 20W	0085	08 39 - 12 39	11390	A	
PILG???M SP????GS		AK			65 05N	164 5???	0?15	10 37 - 04 41	113???	A	
?IL??/ ??INT		A?	2?5?4		?? ????	1?? 3?W	00?5	1? 3??- 04 41	113???	A	1
PLATINUM	AAF	AK	25604		59 01N	161 47W	0006	10 42 - 09 45	AB	MA	45
PLATINUM		AK	25613		59 01N	161 47W	0006	04 39 - 03 41	11390	A	1
POINT HOPE	AAF	AK	26601		68 21N	166 47W	0005	05 44 - 09 45	AB	MA	45
POINT HOPE		AK	26623		68 20N	166 49W	0004	10 43 - 08 48	WND TAB	S	TCL4550,12
POINT HOPE		AK	26623		68 20N	166 49W	0004	11 45 - 06 48	WND TAB	M	T6010
POINT SPENCER		AK	26612		65 15N	166 21W	0003	01 44 - 09 45	AB	MA	45
POINT SPENCER	AAF	AK	26612		65 15N	166 21W	0003	01 44 - 09 45	ABC	MA	
PORT HEIDEN	FORT MORROW AAF	AK	25504	70333	56 57N	158 33W	0025	02 43 - 09 45	AB	MA	45
PORT HEIDEN	CAA	AK	25508	70333	56 57N	159 37W	0031	08 42 - 06 51	A-F	MA	1,2
PORT HEIDEN	CAA	AK	25508	70333	56 57N	158 37W	0031	06 43 - 11 50	A-F	M	1,8,80
PORT HEIDEN	CAA	AK	25508	70333	56 57N	158 37W	0031	06 43 - 07 50	A-F	M	1,9,92
PORT MOLLER	AFS	AK	25625		56 00N	160 31W	031L	07 59 - 06 63	ABC	MA	
PORT MOLLER	AFS	AK	25625		56 00N	160 31W	031E	06 65 - 05 68	A-F	MA	2
PORTAGE		AK	26437		60 51N	148 59W	0010	10 35 - 04 41	11390	A	1

TABLE 15-E-1 (Cont.)

STATE: ALASKA

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAB#/REMARKS
PROSPECT CREEK	ALYESKA PIPELINE SERVICE	AK			66 48N	150 40W	0335	10 70 - 03 73	WND TAB	MA	T14063.16
PRUDHOE BAY	SAWR	AK			70 15N	148 20W	0013	06 67 - 10 72	WND TAB	MA	T14063
RADIOVILLE		AK	25332		57 36N	136 08W	0004	09 35 - 04 41	11390	A	
RAPIDS		AK			63 32N	145 51W	0648	10 35 - 04 41	11390	A	
REINDEER PASS	AAF	AK	25606		53 31N	167 55W	0022	00 43 - 08 44	AB	MA	45
RICHARDSON		AK			64 17N	146 21W	0268	10 35 - 04 41	11390	A	
RUBY		AK			64 44N	155 26W	0053	03 31 - 04 41	11390	MA	17
SAVOONGA		AK	26704		63 41N	170 26W	0010	11 30 - 10 35	11390	A	1
SCOTCH CAP		AK	25618		54 24N	164 45W	0018	05 38 - 04 41	11390	A	
SEGUAM	AAF	AK	25703		52 23N	172 25W	0018	04 43 - 09 45	AB	MA	45
SEMISOPOCHNOI I		AK	45707		51 55N	179 35E	0030	03 44 - 08 44	AB	MA	45
SENTINAL ISLAND	COAST GUARD	AK			58 33N	134 55W	0018	03 40 - 04 41	11390	A	
SEWARD		AK	26438	70277	60 07N	149 27W	0020	12 30 - 04 41	11380	A	18
SHEMYA ISLAND	AFB	AK	45708	70414	52 43N	174 06E	0040	07 43 - 07 53	ABC	MA	
SHEMYA ISLAND	AFB	AK	45708	70414	52 43N	174 06E	0040	01 46 - 12 59	SMAR	MA	
SHEMYA ISLAND	SAWR	AK	45715	70414	52 43N	174 06W	0028	07 43 - 03 68	A-F	MA	1.2
SHISHMAREFF		AK	26625		66 14N	166 07W	0004	05 37 - 04 41	11390	A	
SHUNGNAK		AK	26513		66 54N	157 02W	0043	10 43 - 06 48	N	MS	158
SITKA	NAS	AK	25307		57 02N	135 21W	0030	09 38 - 06 44	SOMAR	M	
SITKA	CAA	AK	25333	70371	57 04N	135 21W	0020	08 30 - 04 41	11390	MA	1
SITKA	FAA	AK	25333	70371	57 04N	135 21W	0020	04 57 - 05 61	CVSBY	MA	T4311
SKAGWAY	AAF	AK	25303		59 27N	135 18W	0006	10 43 - 04 45	AB	MA	45
SKAGWAY		AK	25335	70362	59 27N	135 18W	0003	07 31 - 04 41	11390	A	1
SKWENTNA		AK	26514	70255	61 57N	151 10W	0060	05 39 - 04 41	11390	A	
SOLDOTNA	SAWR	AK			60 28N	151 02W	0035	03 62 - 12 64	WND TAB	MA	T8418
SOLOMON		AK	26620		64 35N	164 24W	0004	01 31 - 04 41	11390	MA	1
SPARREVOHN	AFS	AK	26534	70235	61 06N	155 34W	0527	08 51 - 12 70	A-F	MA	1.2
SPARREVOHN	AFS	AK	26534	70235	61 06N	155 34W	0527	07 52 - 06 62	ABC	MA	
SPARREVOHN	AFS	AK	26534	70235	61 06N	155 34W	0527	01 54 - 12 61	CVSBY	MA	TCL7062
ST. MATTHEW ISL	AAF	AK	26701		60 28N	172 42W	0028	10 42 - 10 45	AB	MA	45
ST. PAUL ISLAND	AAF	AK	25705		57 08N	170 16W	0028	11 43 - 10 45	AB	MA	45
ST. PAUL ISLAND	NS	AK	25712		57 07N	170 16W	0005	06 33 - 05 34	SOMAR	MA	
ST. PAUL ISLAND		AK	25713	70308	57 09N	170 13W	0008	08 36 - 04 41	11390	A	
ST. PAUL ISLAND	WBAS	AK	25713	70308	57 09N	170 13W	0008	11 43 - 07 70	A-F	MA	1.2
ST. PAUL ISLAND	WBAS	AK	25713	70308	57 09N	170 13W	0008	01 45 - 12 55	QMC	M	161
ST. PAUL ISLAND	WBAS	AK	25713	70308	57 09N	170 13W	0008	10 45 - 04 61	SMAR	MA	
STAMPEDE	SAWR	AK			63 44N	150 22W	0762	01 38 - 04 41	11390	A	
STEVENS VILLAGE		AK	26448		66 01N	149 05W	0106	05 40 - 04 41	11390	A	
STONY RIVER		AK	26527	70234	61 46N	156 38W	0067	03 40 - 04 41	11390	A	
STUYAHUK		AK			62 10N	161 50W	0457	06 38 - 05 40	11390	A	
SUMMIT	CAA	AK	26414	70264	63 20N	149 08W	0733	05 40 - 04 41	11390	A	
TALKEETNA	CAA	AK	26528	70251	62 18N	150 06W	0109	06 40 - 04 41	11390	A	
TANACROSS	AAF	AK	26405		63 24N	143 18W	0473	05 44 - 09 45	AB	MA	45
TANALIAN POINT		AK	26501		60 19N	154 22W	0085	05 38 - 04 41	11380	A	
TANANA	AFS	AK	26504		65 12N	152 12W	0070	06 43 - 09 45	AB	MA	45
TANANA	CAA	AK	26529	70178	65 10N	152 06W	0067	08 30 - 04 41	11390	MA	
TATALINA	AFB	AK	26536		62 54N	155 57W	0286	04 52 - 12 70	A-F	MA	1.2
TATALINA	AFB	AK	26536		62 54N	155 58W	0286	07 52 - 06 62	ABC	MA	
TATALINA	AFB	AK	26536		62 54N	155 58W	0286	01 54 - 12 61	CVSBY	MA	TCL7062
TATALINA	AFB	AK	26536		62 54N	155 57W	0286	01 67 - 12 67	WND TAB	M	TCL9673
TELLER		AK	26607		65 18N	166 55W	0003	08 43 - 09 43	AB	MA	45
TELLER	AAF	AK	26628	70118	65 16N	166 21W	0003	07 37 - 04 41	11390	A	
TENAKEE		AK	25336		57 47N	135 47W	0006	02 40 - 04 41	11390	A	
TIN CITY	CAPE PRINCE OF WALES AFS	AK	26634	70117	65 34N	167 55W	0082	05 53 - 12 70	A-F	MA	2
TIN CITY	CAPE PRINCE OF WALES AFS	AK	26634	70117	65 34N	167 55W	0082	05 53 - 04 63	ABC	MA	
TIN CITY	CAPE PRINCE OF WALES AFS	AK	26634	70117	65 34N	167 55W	0082	01 54 - 12 61	CVSBY	MA	TCL7062

TABLE 15-E-1 (Cont.)

STATE: ALASKA

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAB#/REMARKS
TREE POINT	COAST GUARD	AK	25337		54 48N	130 56W	0011	02 40 - 04 41	11390	A	
UMIAT	SAWR	AK	26500	70162	69 22N	152 00W	0102	01 46 - 02 55	A-F	MA	1,2
UMIAT	AFS	AK	26537		69 22N	152 00W	0103	05 45 - 07 54	ABC	MA	
UMNAK ISLAND	CAPE AFB	AK	25602		53 23N	167 54W	0039	03 42 - 06 48	ABC	MA	
UMNAK ISLAND	NORTH SHORE	AK	25610		53 32N	167 47W	0020	09 44 - 12 45	AB	MA	45
UNALAKLEET	AAF	AK	26608		63 54N	160 47W	0006	08 43 - 09 45	ABC	MA	45
UNALAKLEET		AK	26627	70207	63 53N	160 48W	0009	12 30 - 04 41	11390	A	1
UNALAKLEET	CAA	AK	26627	70207	63 53N	160 48W	0006	11 45 - 10 55	ABC	MA	
UNALAKLEET	FAA	AK	26627	70207	63 53N	160 48W	0006	07 48 - 12 70	A-F	MA	1,2
UNALAKLEET	FAA	AK	26627	70207	63 53N	160 48W	0006	12 53 - 12 61	CVSBY	MA	TCL7062,14
UTOPIA CREEK	INDIAN MTN AFS	AK	26535	70173	66 03N	153 45W	0327	08 51 - 07 70	A-F	MA	2
UTOPIA CREEK	INDIAN MOUNTAIN AFS	AK	26535	70173	66 03N	153 45W	0327	08 51 - 12 63	ABC	MA	
UTOPIA CREEK	INDIAN MOUNTAIN AFS	AK	26535	70173	66 03N	153 45W	0327	01 54 - 12 61	CVSBY	MA	TCL7062
UTOPIA CREEK	INDIAN MOUNTAIN AFS	AK	26535	70173	66 03N	153 45W	0327	01 67 - 12 67	WND TAB	MA	TCL9573
VALDEZ		AK	26442	70275	61 07N	146 16W	0003	08 31 - 04 41	11390	A	
VALDEZ		AK	26442	70275	61 08N	146 15W	0022	01 63 - 12 67	WND TAB	MA	T10709
WALES	AAF	AK	26603		65 37N	168 03W	0005	07 43 - 09 45	AB	MA	45
WALES	WBAS	AK	26618	70116	65 37N	168 03W	0009	10 37 - 04 41	11390	A	15
WALES	WBAS	AK	26618	70118	65 37N	168 03W	0005	01 46 - 12 52	DMC	M	161
WISEMAN		AK	26511		67 26N	150 13W	0393	02 31 - 04 41	11390	MA	1
WISEMAN		AK	26511		67 26N	150 13W	0393	01 38 - 12 48	DMC	M	161
WRANGELL		AK	25338	70387	56 28N	132 23W	0005	08 30 - 04 41	11390	A	1
YAKATAGA	INTERMEDIATE FIELD	AK	26445	70298	60 05N	142 30W	0008	03 43 - 12 47	N	MS	158
YAKUTAT	AAF	AK	25302	70361	59 31N	139 40W	0009	08 41 - 12 45	AB	MA	45
YAKUTAT	AAF	AK	25302	70361	59 31N	139 40W	0009	09 41 - 06 48	ABC	MA	
YAKUTAT	STATE APT CAA	AK	25339	70361	59 31N	139 40W	0009	08 36 - 04 41	11390	A	1
YAKUTAT	STATE APT CAA	AK	25339	70361	59 31N	139 40W	0009	05 41 - 07 71	A-F	MA	1,2
YAKUTAT	STATE APT CAA	AK	25339	70361	59 31N	139 40W	0009	01 46 - 12 55	DMC	M	161

EXPLANATION OF ENTRIES

CITY is the city or town name for the location at which the original observations were taken. It may also be the name of a military installation.

NAME-TYPE is usually the airport or field name and/or service which operated the station. If these had changed during the period summarized, the name and/or service valid for the longest portion of the summary is used. A few stations may have no identifying information.

Under NAME, commonly used abbreviations are:

APT -	Airport	INL -	International
ATL -	Air Terminal	MAP -	Municipal Airport
BD -	Building	MEM -	Memorial
CAP -	County Airport	METRO-	Metropolitan
CO -	County	MN -	Municipal
FLD -	Field	RGL -	Regional
GEN -	General	TERM -	Terminal
GTR -	Greater		

Under TYPE, commonly used abbreviations are:

AAB -	Army Air Base	MCAF -	Marine Corps Air Facility
AAF -	Army Air Field	MCAS -	Marine Corps Air Station
AAFB -	Auxiliary Air Force Base	NAAF -	Naval Auxiliary Air Facility
AEPG -	Army Energy Proving Ground	NAAS -	Naval Auxiliary Air Station
		NAF -	Naval Air Facility
AF -	Air Force	NAS -	Naval Air Station
AFB -	Air Force Base	NAU -	Naval Air Unit
AFS -	Air Force Station	NF -	Naval Facility
ANGB -	Air National Guard Base	NS -	Naval Station
ASC -	Army Signal Corp	PG -	Proving Ground
CAA -	Civil Aeronautics Administration	SAWR -	Supplementary Airways Weather Reporting (Station)
FAA -	Federal Aviation Administration	WBAS -	Weather Bureau Airport Station
FSS -	Flight Service Station	WBO -	Weather Bureau Office
LAWR -	Limited Airways Weather Reporting (Station)		

ST is a two-letter code identifying each of the fifty states.

WBAN # refers to the five-digit number identifying stations operated by United States Weather Services (civilian and military) currently or in the past. A few stations have had no number assigned.

WMO # refers to the five-digit block and station numbers assigned to U.S. stations as authorized by the World Meteorological Organization. Many stations with a WBAN number will have no corresponding WMO number.

LAT, LONG are the latitude and longitude of the station in degrees and minutes. If the station changed coordinates during the period summarized, the location reflects the site with the longest record.

ELEV is the elevation (above sea level) of the station in meters. Reported station elevation was used if the barometric height above sea level was not available. If an elevation change occurred during the period summarized, the elevation reflects the station height for the longest period of record.

PERIOD OF RECORD is the first and last month-year of the summarized period. As an example, 01 38 - 12 44 is read as January 1938 through December 1944.

SUMMARY TYPE identifies each summary according to its format.

SUMM FREQ is the summary frequency or the time period in which the summarized data are presented. Abbreviations used are:

- M - Monthly. Data for each calendar month combined and presented on a monthly basis.
- S - Seasonal. Data for the months December through February of the period of record are combined into a winter season, summarized and presented on a seasonal basis. The months March-May, June-August, and September-November are similarly summarized.
- A - Annual. All data for the period summarized together.
- MA - Monthly and Annual.
- SA - Seasonal and Annual.
- MS - Monthly and Seasonal.
- MSA - Monthly, Seasonal and Annual.
- IYM - Individual Year-Month. Data are presented for individual months of record.
- SP - Special Period. The special period presented is described further in the given summary's Tab #/Remarks column.

27. September-December only.
28. By hourly groups.
29. For 0900-1600 and 1700-0800 LST.
30. Period 01/37-03/38 for Indio (Stn #03105).
31. Precipitation-wind tabulation for April-October.
32. By day and night hours on microfilm.
33. Periods: July 15-31, August 1-15 for 1000 and 1400 LST.
34. No data for 27 months.
35. See Edwards AFB.
36. Some data from Paso Robles (Stn #23231).
37. All observations by various stability classes.
38. See Moffett Field.
39. Also contains a contact wind rose.
40. Eight directions and calm.
41. Includes a percentage graph.
42. 1200 LST observations only.
43. Some missing data.
44. Contains all weather, precipitation, and visibility $>$ 6 miles, wind tabulations for day and night hours.
45. Also called 94A.
46. See Farallon Island SE.
47A. 0100-0400 LST.
47B. 0700-1000 LST.
47C. 1300-1600 LST.
47D. 1900-2200 LST.
47E. 0600-2200 LST.
47F. 0700 LST.
47G. 1600 LST.
47H. 0600-0900 LST.
47I. 1600-1800 LST.
47J. 0700-0900 LST.
47K. 1900-0600 LST.
47L. 1000-1500 LST.
47M. 1200-2000 LST.
47N. 0800-2100 LST.
47P. 1100-1300 LST.
48. Also contains bimonthly summaries.
49. Located in city file.
50. Three speed groups.
51. June, July, August--daylight hours only.
52. Special tables.
53. Pre-1944 data from Bolling AAF (Stn #13710).
54. Also known as Chantilly, VA, FAA (pre-Dulles).
55. See Andrews AFB, MD.
56. Data for 01/74 from Herndon APT (Stn #12841).
57. See also Cape Kennedy AFB.
58. Tower data--8 levels (3-150 m).
59. June-August only.
60. Data for 09/42-09/45 from Carlsbad AAF (Stn #23006).
61. Data after 07/53 from Key West NAS (Stn #12850).
62. Data through 1945 from Marianna AAF (Stn #13851).

TAB #/REMARKS column contains additional identifying or explanatory information. Many of the summaries produced by the National Climatic Center and Air Weather Service for a specific project are identified by a tabulation number. A "T" followed by a 4- or 5-digit number identifies a summary produced by the NCC. Similarly, a "TCL" with a number indicates an AWS summary. Not all summaries can be so identified. This number is provided as an aid in requesting a specific tabulation.

Numbers following or in place of a tabulation number refer to remarks. These remarks are provided if additional information describing a summary is necessary. Examples are summaries with data for hourly or 3-hour periods, specified hours only, combined stations, etc.

REMARKS. This is a list of descriptive remarks coded by number in the Tab #/Remarks column of the index. Numbers missing were not used.

1. Broken period.
2. 3-hourly groups.
3. Day-night.
4. 0600-1800 LST only.
5. 10-12 observations per day, all daylight hours.
6. By hours 00, 03, 06, 09, 12, 15, 18, 21 LST.
7. See microfilm for broken periods and format.
8. Includes flying weather conditions.
9. Part "C" only.
10. Hours 0600-1200 LST only.
11. May-November only.
12. Broken period--pre-11/45 data from Point Hope (Stn #26601).
13. Broken period by hourly groups.
14. Less 12/59.
15. Pre-1939 data from Tin City (Stn #26634).
16. Less 12/70.
17. 0500-1600 LST only.
18. 2-13 observations daily.
19. 0700-1900 LST only.
20. Combined data for Douglas AAF (Stn #23001) for 11/42-11/45 and Douglas APT (Stn #93026) for 11/48-12/54.
21. Part "A" only by hourly groups--combined data for Kingman CAA (Stn #93167) for 01/34-12/41 and Kingman AAF (Stn #23108) for 03/43-06/45.
22. For hours 0800, 1400, 1700 LST only.
23. Direction and speed by visibility, relative humidity $\geq$ 90 percent and/or precipitation, and relative humidity $\geq$ 90 percent and no precipitation--August, October, and December only.
24. Part "A" only.
25. By 2-hourly groups.
26. Daylight hours only.

63. Contains 14 months of data from Morrison Field (Stn #12865).
64. Contains graphical wind rose.
65. Tabulated by temperature and relative humidity intervals.
66. Seasonal by day and night hours.
67. Closed and instrument weather conditions only.
68. Less 01/49.
69. 24 observations daily.
70. 8 observations daily.
71. 1 of 3 parts.
72. Tabulation by day and night hours for May 1-September 30 and October 1-April 30.
73. Tabulated for December-March and April-November.
74. Data prior to 10/42 and after 10/45 from Sioux City APT (Stn #14943).
75. For day--clear and cloudy, and night--clear and cloudy conditions.
76. Also contains a ceiling-visibility tabulation
77. 0700-1900 LST only.
78. All weather and 2 relative humidity classes.
79. Summer season only--1957 missing.
80. May, August-November only.
81. Includes separate wind rose for WSO.
82. Four speed categories.
83. Monthly tabulation for 0400 and 1400 LST, seasonal tabulation for all observations.
84. Some data from Presque Isle AFB (Stn #14604).
85. Four observations per day.
86. Semi-monthly periods.
87. 1935 data from Boston WBAS (Stn #14739).
88. VFR, IFR, closed conditions.
89. Pre-03/52 data from Paso Robles (Stn #23231).
90. August 1-15 only for hours 1000 and 1400 LST.
91. Partial SMOS.
92. June, July only for hours 2200L--0200L.
93. April through December only.
94. Less April 1958 and 1960.
95. January, April, July, and October only.
96. Winter season only.
97. Part "C" and "E" only.
98. 36 compass points.
99. Less October-December 1945 for a 2-hour period after sunrise.
100. November 1951 substituted for November 1955.
102. For hour groups 07-09, 10-15, 16-18, and 19-06 LST and all hours combined.
103. For hours 0100, 0700, 1300, and 1900 LST (individual and all hours combined).
104. Day and night hours, clear and cloudy conditions.
106. Pre-02/33 data from Albuquerque WBO (Stn #23073).
108. Precipitation wind rose tabulation.
109. All observations by 6 hourly groups.

110. For ceiling less than 600 feet and/or visibility less than 1-1/2 miles--also an annual hourly summary.
111. Also summarized by month-hour for hours 0200 and 1400 LST.
112. Summarized by days 1-15 and 16 to end of month for day and night hours.
115A. 1300 LST.
115B. 0400 LST.
115C. 1000 LST.
115D. 1600 LST.
115E. 2200 LST.
115F. 0700 LST.
115G. 0100 LST.
115H. 1900 LST.
117. See Covington, Kentucky.
118. Pre-04/32 data from Oklahoma City WBO (Stn #93954).
119. May to October only.
120. Monthly for 1961-63, individual months 1-4/64.
121. Also contains day and night summaries.
124. Summary titled Scranton.
125. See Wilkes-Barre.
126. December-February for 0730 and 1930 LST only.
128. Pre-12/44 data from Galveston AAF (Stn #12905).
129. Data for 10/62-12/63 for Greenville-Spartanburg APT (Stn #03870).
132. February-April and June-September only.
133. Pre-03/43 data from English Field (Stn #23047).
134. Post-10/66 data from Fort Wolters.
135. Less 6/68.
136. Four hours 00-23 and 07-22 LST.
140. Also contains annual ceiling/visibility tabulation.
141. Less 0000 and 0300 LST.
142. See Killeen.
143. See Dugway PG.
144. Data for 1943-49 for Wendover AFB (Stn #24111).
145. 0400-1800 LST.
146. See Washington, D.C.--Dulles International APT WBAS.
147. See Washington, D.C.--National APT WBAS.
149. 0700-1200 LST.
150. Tower data, year-month-level, month-level and month-level-hour.
151. Pre-11/41 data from Paine Field CAA (Stn #24222).
152. 10 observations per day--closed on weekends.
153. 10 observations per day--wind speed estimated.
155. By 5°F temperature intervals--with and without thunderstorms.
157. One speed group--greater than 14 knots.
158. Speed classes in Beaufort Force--mean speed by direction in mph.
159. Hourly groups for 0600-1600 LST.
160. Post-05/55 data from Forest Sherman (Stn #03855).
161. By speed classes and 5°F temperature classes.
162. For all hours combined and for hours 0030 and 1230 individually.

TABLE 15-E-2
(AB) (ABC)

"A," "B," AND "C" SUMMARIES

These standard summaries were prepared in the past by the Air Weather Service from digitized data. The "A&B" summaries contain direction vs. speed tables derived from hourly data. Most but not all locations also have a "C" summary prepared with separate distributions for Closed, Instrument, and Contact conditions. The earliest summaries of this type were known as 94A. For some stations a separate page lists the monthly maximum wind and peak gust.

AIR WEATHER SERVICE
DATA CONTROL UNIT

SURFACE WINDS

PERCENTAGE FREQUENCY OF OCCURRENCE
DIRECTIONS BY SPEED GROUPS

CLAYTON NEW MEXICO (STATION NAME) — JAN (PERIOD)

STATION	YEAR	MONTH	CODE	SPEED / DIR	1-3 MPH	4-12 MPH	13-24 MPH	25-31 MPH	32-46 MPH	47 MPH AND OVER	TOTAL 4 MPH AND OVER	TOTAL NO. OF OBSERVATIONS %	TOTAL NO. OF OBSERVATIONS OBS	SUM OF SPEED	MEAN WIND SPEED MPH
23051		01	11	N	.1	1.3	1.9	1.3	.4	.1	5.0	5.1	148	2971	20.1
			12	NNE	.2	1.8	3.3	.7	.1		5.9	6.1	179	2857	16.0
			22	NE	.2	2.3	2.4	.5			5.2	5.4	156	2229	14.3
			32	ENE	.1	1.2	1.1				2.3	2.3	68	824	12.1
			33	E	.1	1.4	.8				2.2	2.3	67	784	11.7
			34	ESE		.5	.3				.8	.9	25	292	11.7
			44	SE	.1	1.4	.3				1.6	1.7	50	471	9.4
			54	SSE		1.3	1.0	.1			2.4	2.4	71	935	13.2
			55	S		2.6	3.0	.1	.3		6.0	6.0	176	2524	14.3
			56	SSW	.1	4.3	5.9	1.7	1.1		13.0	13.1	382	6637	17.4
			66	SW		2.9	6.8	1.3	1.0	.1	12.1	12.2	355	6663	18.8
			76	WSW		2.1	6.3	1.3	.7		10.4	10.4	304	5670	18.7
			77	W		4.0	12.9	.9	.5		18.4	18.4	536	8850	16.5
			78	WNW		1.4	2.2	.2			3.8	3.8	110	1604	14.6
			88	NW	.2	2.0	2.7	.3	.2		5.2	5.4	157	2410	15.4
			18	NNW		.9	1.3	.3	.3		2.8	2.9	84	1567	18.7
			00	CALM								1.6	46		
TOTALS →				1.6	1.2	31.3	52.2	8.8	4.7	.2	97.2	100.0	2914	47288	16.2

TABLE 15-E-3

(A-F)

REVISED "A" THROUGH "F" SUMMARIES

This summary prepared from digitized data by the Air Weather Service is similar to the Navy SMOS. The data summarized supplements that presented in the "A&B" and "C" summaries. This summary also presents data monthly (eight 3-hour periods and all hours combined) and annually. For many stations a separate page lists the peak gust for each year-month of record. A separate table also is included showing the distribution under IFR conditions.

DATA PROCESSING DIVISION
ETAC/USAF
AIR WEATHER SERVICE/MAC

SURFACE WINDS

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED
(FROM HOURLY OBSERVATIONS)

26411 (STATION) FAIRBANKS ALASKA IAP (STATION NAME) 48-70 (YEARS) ALL (MONTH)

ALL WEATHER (CLASS) ALL (HOURS (L.S.T.))

(CONDITION)

SPEED (KNTS) DIR.	1 - 3	4 - 6	7 - 10	11 - 16	17 - 21	22 - 27	28 - 33	34 - 40	41 - 47	48 - 55	≥ 56	%	MEAN WIND SPEED
N	3.9	5.5	2.9	.6	.0	.0						12.7	5.2
NNE	2.4	3.8	1.4	.4	.0	.0						8.1	5.2
NE	2.7	3.2	1.1	.4	.0	.0	.0					7.4	5.1
ENE	1.4	1.5	1.0	.4	.0	.0	.0					4.6	5.6
E	1.7	1.6	.7	.2	.0	.0						4.2	5.0
ESE	1.0	.8	.4	.1	.0	.0						2.3	4.9
SE	1.1	.8	.3	.1	.0	.0						2.2	4.4
SSE	.8	.9	.2	.0	.0							2.0	4.4
S	1.6	1.8	.6	.1	.0		.0					4.1	4.5
SSW	1.1	1.9	1.4	.3	.0	.0	.0					4.7	6.1
SW	1.4	2.1	2.1	.9	.1	.0	.0					6.7	6.9
WSW	.9	1.2	1.5	.9	.1	.0	.0	.0				4.7	7.8
W	1.2	1.1	1.1	.5	.1	.0						3.9	6.5
WNW	.9	.8	.5	.2	.0	.0						2.3	5.3
NW	1.5	1.0	.4	.1	.0	.0						2.9	4.3
NNW	1.9	2.1	1.7	.2	.0	.0						6.0	5.4
VARBL													
CALM												21.1	
	25.6	30.2	17.3	5.3	.5	.1	.0	.0				100.0	4.3

TOTAL NUMBER OF OBSERVATIONS 160817

TABLE 15-E-4

(ASWR)

AIRPORT STUDY WIND ROSE

This standard annual summary was prepared by the Weather Bureau for airport design. Three separate summaries were prepared (all hours combined):

I. Ceiling 0-400 feet and/or visibility 0-1 mile
II. Ceiling 0-500 feet and/or visibility 0-1.5 mile
III. Any ceiling or visibility condition

U S WEATHER BUREAU

SURFACE WIND SUMMARY

STATION: Cody, Wyo   MONTH: Annual   PERIOD OF RECORD: Dec [illegible] thru Dec [illegible]

STA. NO.	MO.	DIR. CODE	VEL. / DIR.	0-3 M.P.H. OBS.	%	4-15 OBS.	%	16-31 OBS.	%	32-47 OBS.	%	OVER 47 OBS.	%	TOTAL ALL OBS.	%	TOTAL VEL.	AV. VEL.	TOT. 4 M.P.H. & OVER OBS.	%
[illegible]	[illegible]	10	N	1	3.3	4	13.4							5	16.7	32	6.4	4	13.4
		11	NNE			2	6.7							2	6.7	12	6.0	2	6.7
		12	NE	1	3.4	1	3.3							2	6.7	10	5.0	1	3.3
		13	ENE																
		14	E	1	3.3									1	3.3	1	1.0		
		15	ESE																
		16	SE	1	3.3									1	3.3	1	1.0		
		17	SSE																
		18	S																
		19	SSW	2	6.7									2	6.7	5	2.5		
		20	SW	1	3.4	1	3.3							2	6.7	8	4.0	1	3.3
		21	WSW			1	3.3							1	3.3	6	6.0	1	3.3
		22	W	1	3.3									1	3.3	2	2.0		
		23	WNW					1	3.3					1	3.3	16	16.0	1	3.3
		24	NW			1	3.3	2	6.7	1	3.3			4	13.3	78	19.5	4	13.3
		25	NNW			2	6.7	1	3.3					3	10.0	44	14.7	3	10.0
		[illegible]	CALM	5	16.7									5	16.7				
		TOTAL		13		12		4		1				30	100	215	7.2	17	
		%			43.4		40.0		13.3		3.3								56.6

● INDICATES LESS THAN 1/2 of 1/10%

Code 51
Surface wind summary with ceiling 0-400 feet and/or visibility 0-1 miles.

TABLE 15-E-5

(CVSBY)

CEILING-VISIBILITY WIND TABULATION

This summary was formerly prepared by the National Climatic Center in accordance with particular project specifications. The tabulation presented a distribution of ceiling, visibility, and wind speed by direction and was generally derived from digitized data. It was usually prepared on an annual basis only with 17 parts - one for each direction and calm. More recent tabulations follow the format listed as (WND TAB) whenever special ceiling-visibility classes are required.

STA	DIR	CEILING GROUPS IN FEET	VEL GROUPS MILES	VISIBILITY GROUPS IN MILES 0-1/4	5/16-1/2	5/8-3/4	1	1 1/4-1 1/2	1 3/4-2 1/2	3+	TOT OBS	
14751	N	1000+	1-4					1	7	227	235	
14751	N	1000+	5-9			1		3	9	764	777	
14751	N	1000+	10-14				2			286	288	
14751	N	1000+	15-29				1		2	98	01	
14751	N	1000+	30+									
14751	N	1000+	TOT			1	3	4	18	1365	1391	
14751	N	600-900	1-4			2	1	1	1	3	8	
14751	N	600-900	5-9			3	1	3	3	8	18	
14751	N	600-900	10-14		3	1				1	5	
14751	N	600-900	15-29		3	1					4	
14751	N	600-900	30+									
14751	N	600-900	TOT		6	7	2	4	4	12	35	
14751	N	500	1-4						1		1	
14751	N	500	5-9	2			2			1	5	
14751	N	500	10-14		1						1	
14751	N	500	15-29									
14751	N	500	30+									
14751	N	500	TOT	2	1		2		1	1	7	
14751	N	400	1-4				1	1	1		3	
14751	N	400	5-9		1	1			1	2	5	
14751	N	400	10-14									
14751	N	400	15-29	1	1						2	
14751	N	400	30+									
14751	N	400	TOT	1	2	1	1	1	2	2	10	
14751	N	300	1-4		1		1				2	
14751	N	300	5-9	1		1	1				3	
14751	N	300	10-14				1	1			2	
14751	N	300	15-29									
14751	N	300	30+									
14751	N	300	TOT	1	1	1	3	1			7	
14751	N	200	1-4	2	1		1				4	
14751	N	200	5-9	1		1					2	
14751	N	200	10-14									
14751	N	200	15-29									
14751	N	200	30+									
14751	N	200	TOT	3	1	1	1				6	
14751	N	0-100	1-4	3							3	
14751	N	0-100	5-9	1							1	
14751	N	0-100	10-14									
14751	N	0-100	15-29									
14751	N	0-100	30+									
14751	N	0-100	TOT	4							4	
14251	N	TOT VIS		11	11	11	12	10	25	1380	1460	
14751	N	TOT VEL			256	811	290	97			1460	
14751	N	% VEL			17.5	55.5	20.3	6.6			100.0	
14751	N	% DIR									3.3	43847

TABLE 15-E-6

(N)

N-TYPE SURFACE SUMMARY

This standard surface summary is prepared by the Air Weather Service from digitized records. Wind data are usually presented on a monthly, seasonal, and annual basis. Many of the earlier "N" summaries presented wind speed classes in Beaufort Force. The majority of "N" summaries are for locations outside the U. S. and are based on less than 24 obs/day.

Air Weather Service
Data Control Division
Grove Arcade Bldg.
Asheville, N. C.

PERCENTAGE FREQUENCY OF SURFACE WINDS

PONCE PUERTO RICO LOSEY FIELD (STATION NAME) — SPRING (SEASON) — 11607 (STATION NO) — 2• (SUMMARY NO)

N 18° 01' W 66° 30' — APR 1941-DEC 1945 (PERIOD)

DIR.	FORCE	1	2	3	4	5	6	7	8	9	≥10	TOTAL %	TOTAL OBS	MEAN WIND SPEED M.P.H.
32	N	7.2	1.1	.1								8.3	132	5.1
02	NNE	3.9	.8	.2								4.9	78	6.1
04	NE	11.2	3.8	.1								15.1	240	6.2
06	ENE	7.0	4.5	.1								11.7	185	7.4
08	E	5.2	6.7									11.9	188	8.8
10	ESE	2.6	7.5	.6								10.7	169	10.5
12	SE	2.0	15.6	2.6								20.2	320	13.4
14	SSE	.5	2.5	.1								3.0	48	11.0
16	S	.8	.6									1.5	23	7.0
18	SSW	.2	.4									.6	10	9.3
20	SW	.2	.2									.4	6	6.7
22	WSW													
24	W	.3										.3	5	4.0
26	WNW	.2										.2	3	4.3
28	NW	2.0	.1									2.1	33	4.7
30	NNW	4.1	.8									4.9	77	5.2
40	CALM											4.3	68	
	TOTALS	47.3	44.7	3.7								100.0	1585	8.3

• SUMMARY 1 - DETAILED SUMMARY - BEAUFORT SCALE
SUMMARY 2 - CONDENSED SUMMARY - BEAUFORT SCALE

MAXIMUM WIND DIR. 12 M.P.H. 26.0

AWS(CL) FORM 301 REVISED 16 AUG 55

TABLE 15-E-7

(QMC)

QUARTERMASTER CORPS

This standard monthly summary was prepared from digitized data by the Air Weather Service for the Army Quartermaster Corps. Part 13 of the summary presents the frequency and percentage of wind speed by 5°F temperature classes.

	TEMP	SIG	TEMP	FREQ AND PERCENTAGE FREQ OF WIND SPEED																SIG	
STA NO	RANGE	TEMP	%	CALM		1-3		4-7		8-12		13-18		19-24		GTR24		GTR46		OBS	
34041 05	025/029	2	.1	2	.1															2	.1
	030 034	7	.2	6	.2			1												7	.2
	035 039	46	1.2	18	.5	6	.2	8	.2	11	.3	3	.1							46	1.2
	040 044	222	5.9	48	1.3	33	.9	72	1.9	47	1.2	20	.5	2	.1					222	5.9
	045 049	607	16.1	117	3.1	88	2.3	201	5.3	154	4.1	45	1.2	1		1		1		607	16.1
	050 054	812	21.6	136	3.6	119	3.2	300	8.0	182	4.8	65	1.7	8	.2	2	.1			812	21.6
	055 059	766	20.3	111	2.9	110	2.9	292	7.8	180	4.8	60	1.6	9	.2	4	.1			766	20.3
	060 064	568	15.1	43	1.1	54	1.4	216	5.7	169	4.5	70	1.9	11	.3	5	.1			568	15.1
	065 069	360	9.6	19	.5	26	.7	139	3.7	120	3.2	47	1.2	9	.2					360	9.6
	070 074	239	6.3	14	.4	22	.6	78	2.1	81	2.2	31	.8	11	.3	2	.1			239	6.3
	075 079	112	3.0	3	.1	15	.4	40	1.1	30	.8	19	.5	5	.1					112	3.0
	080 084	23	.6	3	.1	1		9	.2	8	.2	1		1						23	.6
	TOTAL	3764	100.0	520	13.8	474	12.6	1356	36.0	982	26.1	361	9.6	57	1.5	14	.4	1		3764	100.0

TABLE 15-E-8

(SHO)

SUMMARY OF HOURLY OBSERVATIONS

This standard summary was prepared by the Weather Bureau for about 130 of the principal airport stations. They were prepared monthly for 1949-1954 or monthly and annually for either 1951-1960 or 1956-1960. Some give frequencies (as shown), while later tables give percentages.

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR)									AV. SPEED
	0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	25 - 31	32 - 38	39 - 46	47 OVER	TOTAL	
N	2	35	50	31	9	7	4	1		139	12.4
NNE	2	44	72	39	6					163	10.3
NE	15	64	149	109	12	3				352	10.8
ENE	25	25	41	40	22	2				155	11.3
E	21	46	28	17		1				113	7.7
ESE	12	51	27	8	1					99	7.1
SE	12	9	9	5						35	6.2
SSE	11	27	19	13		2				72	8.5
S	26	38	24	5	2	1	2			98	7.1
SSW	13	46	50	22	5	1				137	8.9
SW	33	115	85	34	8	6				281	8.4
WSW	18	75	122	56	10	1				282	9.8
W	13	43	66	39	9	10				180	10.9
WNW	6	36	101	108	27	8	1			287	12.9
NW	9	46	131	216	106	53	14	1		576	16.0
NNW	2	24	94	137	76	27	7			367	15.9
CALM	48									48	.0
TOTAL	268	724	1068	879	293	122	28	2		3384	11.5

TABLE 15-E-9

(SMAR)

SUMMARY OF MONTHLY AEROLOGICAL RECORDS

This summary was prepared in the past from Navy Aerological Records on magnetic tape subsequent to 1945. It is no longer prepared, having been replaced by the SMOS. The SMAR is a monthly and annual summary presented in both frequency and percentage form. In addition to the standard direction vs. speed summary, a separate page (not presented) lists the six highest hourly wind speeds and six highest peak gusts for each month for the period examined.

SMAR (REV) 1

CHIEF OF NAVAL OPERATIONS
NAVAL WEATHER SERVICE DIVISION

JANUARY
MONTH

SUMMARY OF MONTHLY AEROLOGICAL RECORDS

PAGE 1

BRUNSWICK MAINE/NAS (STATION) 24.1M (ELEVATION) 043/53N (LATITUDE) 69/56W (LONGITUDE) DECEMBER 1951 THRU OCTOBER 1962 (PERIOD OF RECORD)

DIR CODE	FREQUENCY OF WIND SPEED GROUPS (KNOTS) 3-7	8-12	13-20	21-30	31-40	> 40	CALM	TOTAL
11	366	330	243	52				991
12	375	333	300	31	1			1040
22	346	223	146	14				729
32	73	15	24	1				113
33	32	6	4	1				43
34	18	9	6					33
44	23	10	3					36
54	28	13	33	6	1			81
55	64	34	25	17	1			141
56	97	81	86	21				285
66	204	222	140	8				574
76	148	122	36	2				308
77	133	88	28	3				252
78	90	99	65	7				261
88	170	263	231	41				705
18	226	392	350	65	4			1037
00							1492	1492
	2393	2260	1720	269	7		1492	8121
	29.5	27.8	21.2	3.3	.1	.0	18.4	100.0

DIR CODE	FREQUENCY OF TOTAL CLOUD AMOUNTS IN TENTHS 0	1	2	3	4	5	6	7	8	9	10	TOTAL	WIND DIR
11	266	50	42	49	26	16	31	30	49	38	394	991	N
12	103	22	26	18	17	13	18	26	47	24	726	1040	NNE
22	38	12	14	11	17	12	18	18	31	22	536	729	NE
32	2	1	3	2	4	1	3	2	9	12	74	113	ENE
33	1	1	1		1		1	1	2	3	32	43	E
34		1	1	1				1	1		28	33	ESE
44	3		2	1			1	3			26	36	SE
54	2	1			1		1		3	2	71	81	SSE
55	11	3	3	4	2	3		5	4	5	101	141	S
56	23	7	13	5	7	8	8	6	15	9	184	285	SSW
66	81	29	22	18	16	18	16	24	36	31	283	574	SW
76	97	15	24	12	11	11	6	13	23	17	79	308	WSW
77	89	10	21	21	13	4	13	13	16	7	45	252	W
78	126	12	18	19	18	8	6	12	7	10	25	261	WNW
88	263	56	43	36	37	19	32	29	41	26	123	705	NW
18	401	72	65	64	40	30	26	37	57	50	195	1037	NNW
00	385	57	85	66	46	34	45	54	87	61	572	1492	CALM
	1891	349	383	327	256	177	225	274	428	317	3494	8121	TOTAL
	23.3	4.3	4.7	4.0	3.1	2.2	2.8	3.4	5.3	3.9	43.0	100.0	% OF TOT

DIR CODE	FREQUENCY OF WEATHER RAIN	RAIN SHOWERS	DRIZZLE	FR RN & FR DZ	SNOW	HAIL	THUNDER	NO WEATHER
11	29	9	14	24	115			809
12	91	2	45	63	281			569
22	73		35	59	167			408
32	22		6	1	13			72
33	7		1		8			27
34	9		1		6			17
44	7				2			27
54	35			2	10			38
55	44		2		13			85
56	41		3	1	22			224
66	22	2	1		28			521
76	5		2		4			298
77	1				8			243
78	3				2			256
88	3			4	18			682
18	4		4	5	43			983
00	15	1	18	14	81			1363
	411	14	132	173	821			6622
	5.1	.2	1.6	2.1	10.1	.0	.0	81.6

DIR CODE	FREQUENCY OF CEILINGS (FEET) 0-150	151-350	351-550	551-1050	1051-2050	2051-3050	3051-10500	10501-20500	20501-30500	> 30500 AND UNLIM	< 6/10 CLOUDS	TOTAL	WIND DIR
11	8	32	37	56	80	79	129	39	6	21	504	991	N
12	39	74	130	171	140	49	132	51	2	9	243	1040	NNE
22	18	53	79	129	47	48	137	41	8	24	145	729	NE
32	3	5	9	23	6	3	25	11	3	2	23	113	ENE
33		5	1	9	3	1	14	1	1	2	6	43	E
34	1	4	8	4	3	1	3	4			5	33	ESE
44	1	2	1	3	4	6	6	2		1	10	36	SE
54	6	13	7	9	10	8	10	6	2		10	81	SSE
55	6	22	13	19	12	6	18	11	1	3	30	141	S
56	34	26	17	23	15	13	46	20	1	14	76	285	SSW
66	30	23	18	25	28	29	125	37		36	223	574	SW
76		3	5	13	12	15	58	10	1	11	180	308	WSW
77	1	2		6	3	7	33	14	1	9	176	252	W
78	1			2	4	8	33	4	1	2	206	261	WNW
88			3	9	18	26	117	23	3	16	490	705	NW
18	4	4	10	17	26	38	161	33	6	14	724	1037	NNW
00	46	29	19	48	52	65	260	102	9	65	797	1492	CALM
	198	297	357	566	463	402	1307	409	45	229	3848	8121	TOTAL
	2.4	3.7	4.4	7.0	5.7	4.9	16.1	5.0	.6	2.8	47.4	100.0	% OF TOT

TABLE 15-E-10

(SOMAR)

SUMMARY OF MONTHLY AEROLOGICAL RECORDS

This summary was prepared from Navy records prior to 1945. It was replaced by the SMAR.

CHIEF OF NAVAL OPERATIONS

AEROLOGICAL SECTION

SUMMARY OF MONTHLY AEROLOGICAL RECORDS

9. Frequencies of Surface Winds, by Directions and Velocity Groups*

STATION: MIAMI FLA — LATITUDE: 25 58 N — LONGITUDE: 80 17 W — MONTH: Dec — YEARS: 1941 Thru 1944

STATION NO	WD CODE	DIR CODE	DIRECTION	1-3 No. of obs.	1-3 %	4-10 No. of obs.	4-10 %	11-21 No. of obs.	11-21 %	22-27 No. of obs.	22-27 %	28-40 No. of obs.	28-40 %	Over 40 No. of obs.	Over 40 %	Total over 3 No. of obs.	Total over 3 %	Total by directions No. of obs.	Total by directions %	Total velocity	Ave. velocity
[illegible]		32	N	7	1.0	67	9.4	55	7.7	3	0.3					124	17.4	131	18.4	1314	10.0
		02	NNE	1	0.1	13	1.8	1	0.2							14	2.0	15	2.1	111	7.4
		04	NE	7	1.0	42	5.9	29	4.1	5	0.7	1	0.1			77	10.8	84	11.8	901	10.7
		06	ENE	1	0.1	11	1.5	9	1.3							20	2.8	21	2.9	198	9.4
		08	E	12	1.7	67	9.4	31	4.4	3	0.4					101	14.2	113	15.9	99[illegible]	8.8
		10	ESE			13	1.8	9	1.3							22	3.1	22	3.1	229	10.4
		12	SE	3	0.4	51	7.2	26	3.6	2	0.3					79	11.1	82	11.5	797	9.7
		14	SSE	4	0.6	3	0.4	3	0.4							6	0.8	10	1.4	76	7.6
		16	S	9	1.2	26	3.7	8	1.1							34	4.8	43	6.0	305	7.1
		18	SSW	1	0.1	4	0.6	1	0.1							5	0.7	6	0.8	41	6.8
		20	SW	3	0.4	25	3.5	8	1.1							33	4.6	36	5.0	320	8.9
		22	WSW	2	0.3	2	0.3									2	0.3	4	0.6	21	5.2
		24	W	3	0.4	12	1.7	5	0.7							17	2.4	20	2.8	162	8.1
		26	WNW	1	0.1	2	0.3	4	0.5							6	0.8	7	1.0	65	9.3
		28	NW	2	0.3	45	6.3	39	5.5	1	0.1					85	11.9	87	12.2	944	10.9
		30	NNW			13	1.8	14	2.0							27	3.8	27	3.8	306	11.3
		00	CALM	XXXX	XXX	XXXX	XXX	XXXX	XXX	XXXX	XXX	XXXX	XXX	XXX	XXX	XXXX	XXX	5	0.7	XXXXXX	XXXX
			TOTALS BY VEL. GROUPS	56	7.8	396	55.6	242	34.0	13	1.8	1	0.1			653	91.5	713	100.0	6702	9.5

≠ LESS THAN 0.05%

* OBSERVATIONS AT: 4, 8, 12 A. M. AND 4, 8, 12 P. M. LOCAL STANDARD TIME

NOTE: THE INFORMATION ON THIS FORM WAS COMPILED BY THE STATISTICS DIVISION, U. S. WEATHER BUREAU, UPON REQUEST OF THE CHIEF OF NAVAL OPERATIONS. ANY REQUEST FOR ADDITIONAL INFORMATION SHOULD BE MADE TO THE CHIEF OF NAVAL OPERATIONS. 1403

TABLE 15-E-11

(SMOS)

SUMMARY OF METEOROLOGICAL OBSERVATIONS - SURFACE

This summary is prepared from Navy Meteorological Records on magnetic tape and is routinely updated when five additional years of record become available. Various parameters are summarized with winds presented monthly (eight 3-hour periods and all hours combined) and annually. For many stations a separate page lists the peak gust for each year-month of record.

SURFACE WINDS

PERCENTAGE FREQUENCY OF WIND DIRECTION AND SPEED (FROM HOURLY OBSERVATIONS)

13721 (STATION) PATUXENT RIVER, MARYLAND NWSED (STATION NAME) 46-70 (YEARS) JAN (MONTH)

ALL WEATHER (CLASS) ALL (HOURS (L.S.T.))

CONDITION

SPEED (KNTS) DIR	1 - 3	4 - 6	7 - 10	11 - 16	17 - 21	22 - 27	28 - 33	34 - 40	41 - 47	48 - 55	≥ 56	%	MEAN WIND SPEED
N	.7	2.0	2.3	1.7	.6	.2	.0					7.5	9.3
NNE	.4	1.2	1.4	1.3	.4	.1	.0					4.7	9.8
NE	.4	1.3	1.4	.6	.2	.0	.0					3.9	8.1
ENE	.3	.7	.4	.3	.0	.0						1.7	6.8
E	.4	.7	.3	.1	.1	.0	.0					1.7	6.5
ESE	.4	.3	.3	.1	.0							1.7	5.6
SE	.7	1.3	1.2	.4	.1	.0						3.9	6.7
SSE	.6	1.7	1.2	.4	.1							4.0	6.8
S	.9	2.1	2.0	.7	.2	.0						5.9	7.3
SSW	.4	1.6	2.4	1.6	.2	.0						6.3	8.9
SW	.5	1.5	2.3	3.0	1.2	.2						8.3	11.0
WSW	.3	.9	1.1	1.0	.3	.0						3.6	9.6
W	.6	1.5	1.4	1.2	.4	.1	.0	.0				5.3	9.0
WNW	.6	1.7	1.5	1.9	1.1	.5	.1	.0				7.6	11.3
NW	.8	2.5	3.0	3.6	2.2	1.4	.4	.1				14.0	12.8
NNW	.6	2.2	2.6	2.5	1.3	.5	.1	.0				10.0	11.0
VARBL													
CALM												9.8	
	8.6	24.1	25.3	20.4	8.1	3.0	.6	.1				100.0	8.8

TOTAL NUMBER OF OBSERVATIONS 20074

5702 SURFACE WINDS JAN 68

TABLE 15-E-12

(STAR)

STABILITY ROSE

This summary has been processed from digitized records using the Pasquill Stability Classification explained in the February 1964 issue of the Journal of Applied Meteorology. A wind direction vs. speed table is prepared for each of five or six stability classes and usually for all classes together. This summary may be presented on a monthly and/or seasonal and/or annual basis.

SEA. JJA — FREQUENCY DISTRIBUTION — STATION =13962 ABILENE, TX OBS 1972-73

DIRECTION	SPEED(KTS) 1 - 3	4 - 6	7 - 10	11-16	17-21	GREATER THAN 21	AVG SPD	TOTAL
N	0	5	6	5	1	0	10.1	17
NNE	0	0	2	6	0	0	12.4	8
NE	0	0	8	2	0	0	10.0	10
ENE	0	3	3	3	0	0	8.8	9
E	0	0	5	2	0	0	10.4	7
ESE	0	0	6	4	0	2	13.2	12
SE	0	1	19	8	0	0	9.8	28
SSE	0	1	10	24	5	0	12.9	40
S	0	4	30	108	16	1	12.6	159
SSW	0	0	7	35	13	0	13.8	55
SW	0	1	3	12	4	0	13.5	20
WSW	0	0	2	4	1	0	12.1	7
W	0	0	1	1	0	0	9.5	2
WNW	0	0	0	0	0	0	0.0	0
NW	0	2	3	0	0	0	7.0	5
NNW	0	0	0	0	0	0	0.0	0
AVG	0.0	5.3	9.0	13.1	18.0	25.3	12.2	
TOTAL	0	17	105	214	40	3		

NUMBER OF OCCURRENCES OF D STABILITY = 379

NUMBER OF CALMS WITH D STABILITY = 0

TABLE 15-E-13

(WND TAB)

WIND TABULATION

This summary is prepared by the National Climatic Center and Air Weather Service in accordance with particular project specifications. Accordingly, the format may vary from the sample presented. Data for a portion of these have been extracted manually from original records.

STA	MO	DIR	0-10 KNOTS	11-20 KNOTS	21-29 KNOTS	30-43 KNOTS	44+ KNOTS	TOTAL NO OF OBSERVATIONS %	OBS	SUM OF SPEED	MEAN WIND SPEED KNOTS
23195	01	N	1190	313	18			17.1	1521	12295	8.1
23195	01	NNE	1130	93				13.7	1223	7790	6.4
23195	01	NE	608	25	1			7.1	634	3611	5.7
23195	01	ENE	224	11				2.6	235	1292	5.5
23195	01	E	227	3				2.6	230	1013	4.4
23195	01	ESE	162	8				1.9	170	866	5.1
23195	01	SE	295	72	2			4.1	369	2845	7.7
23195	01	SSE	266	57	1			3.6	324	2346	7.2
23195	01	S	263	31				3.3	294	1892	6.4
23195	01	SSW	148	14	1			1.8	163	921	5.7
23195	01	SW	158	10				1.9	168	855	5.1
23195	01	WSW	155	10				1.9	165	935	5.7
23195	01	W	303	51	9	1		4.1	364	2680	7.4
23195	01	WNW	349	65	7			4.7	421	3120	7.4
23195	01	NW	512	66	4			6.5	582	4108	7.1
23195	01	NNW	691	230	16			10.5	937	8020	8.6
23195	01	CLM	1115					12.5	1115		
23195	01	TOT	7796	1059	59	1		99.9	8915	54589	6.1

(1139 C)

COMBINED PERIOD SUMMARY OF SURFACE WIND BY VELOCITY GROUPS

This standard monthly summary was prepared by the Weather Bureau from hourly observations. Entries are frequency of observations taken on or near the half hour; thus, Hour 1 is 0130, Hour 2 is 0230, etc. The period of record usually covers the early to mid portion of the 1930's. These earlier tabulations often reflect an 8-point directional bias.

FORM 1139-C-AER.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU

COMBINED PERIOD SUMMARY OF SURFACE WIND BY VELOCITY GROUPS

STATION Mobile, Ala. ELEVATION ______ MONTH January PERIOD 1931-1935

DIR.	HOUR M.P.H.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	NO.	%	NO. / %
	CALM	27	20	21	33	17	23	41	28	16	20	15	7	15	9	4	13	11	21	39	12	20	30	30	19	511	16.	511 / 13
N	4-18	22	23	26	36	21	22	32	12	13	23	9	15	31	12	17	12	12	16	33	15	15	30	28	23	525	26	582
	19-31	2		1	1	2	2	1	1	2	2	4	2	4	4	4	3	3	1	4	2	2	3	1		57	11	
	32-47																											
	OVER 47																											14
NNE	4-18	3	6	2	11	11	7	13	11	14	15	14	17	10	11	7	13		6	2	5	7	6	2	2	212	12.	223
	19-31		1		1	2			1			1						1			1	1		1	1	11	3	
	32-47																											
	OVER 47																											5
NE	4-18	12	7	21	15	7	17	27	20	12	27	11	11	20	10	7	16	13	11	22	7	10	13	20	11	351	12.	364
	19-31					1	1	2			1			2										2		7	2	
	32-47																											
	OVER 47																											9
ENE	4-18	3	2	2	3	4	4	2	7	13	3	16	7	11	11	7	3	4	3	3	1	2	2	1	2	130	9.2	132
	19-31										1							1								2	2	
	32-47																											
	OVER 47																											3
E	4-18	9	3	20	10	5	6	20	7	11	21	11	11	12	11	11	10	11	7	12	5	3	6	13	3	251	9.7	258
	19-31			1							2			1			1	1							1	7	3	
	32-47																											
	OVER 47																											6
ESE	4-18	9	6	1	5	8	2	5	3	5	9	10	6	11	3	8	5	4	6	2	2	9	5	2	11	132	9.3	142
	19-31		1		1				1	1	1					1	2	1		1						10	7	
	32-47																											
	OVER 47																											3
SE	4-18	13	11	9	7	3	1	13	10	15	17	11	16	14	17	11	25	15	12	23	17	17	20	22	11	341	21	423
	19-31	4			3	1	3	5	3	4	6	4	8	10	3	5	2	1	7	6	1	1	3	2	3	81	17	
	32-47																1									1	8	
	OVER 47																											10
SSE	4-18	7		11	7	5	4	3	5	4	7	11	13	12	12	16	17	17	13	8	4	2	6	9	7	212	13	254
	19-31		2		1	2			2	1	3	3	3	6	3	1	4	3	2	2				2		42	11	
	32-47																											
	OVER 47																											6
S	4-18	17	7	17	8	4	5	8	3	2	2	8	5	13	12	18	28	13	16	24	12	13	20	20	10	283	98	288
	19-31													1	1	1	1						1			5	2	
	32-47																											
	OVER 47																											7
SSW	4-18	2	4	2		2	2	3	1	1	1	3	1	6	3	1	4	6	4	3	1	1	2	1	2	63	88	72
	19-31										1				1	2	2	1		1	1					9	12	
	32-47																											
	OVER 47																											2
SW	4-18	6	7	7	3	3	7	10	4	3	3	2	2	3	2	4	4	2	6	12	4	7	7	8	7	123	21.	143
	19-31	1			1	1	1	1	1		2	2	1	2	1	2	1			1			1			20	15	
	32-47																											
	OVER 47																											4
WSW	4-18	1	2	2	3		3	1	3	4	3	2	2	2	2	3	1	4	2	2				2		47	33	61
	19-31			1				1			1	1	1	2			1	1	1			1				13	22	
	32-47																											
	OVER 47																											2
W	4-18	12	4	6	11	6	3	7	4	3	7	7	4	4	1	3	5	7	4	14	5	7	11	6	4	138	88	154
	19-31		1		1			1	1	3	1	1		3		2		2			1			1		13	12	
	32-47																											
	OVER 47																											4
WNW	4-18	1	3	3	1	1	4	6	2	3	4	4	3	4	3	4	1	6	2	2		1			1	65	77	90
	19-31			2								2	1	2	4	1	3	1	2				1			17	21	
	32-47																			1		1				2	2	
	OVER 47																											2
NW	4-18	9	11	22	11	7	3	23	2	5	11	6	8	13	8	9	28	11	4	11	7	6	9	11	6	267	84	250
	19-31	4			1	1	1	3	2	2	2	1	1	3	1	3	1	1	1	1			3	1	1	38	15	
	32-47				1	1																		1		3	1	
	OVER 47																											6
NNW	4-18		6	3	4	6	5	11	5	2	7	6	7	1	4	8	10	2	3	2	5	6	3	5	4	143	20	178
	19-31		2		1		2	2	1			1	1	3		4	3	4	2		2	1	2		1	35	20	
	32-47																											
	OVER 47																											4
NO.		136	124	136	136	124	124	248	155	155	217	155	155	217	155	186	217	155	155	248	123	124	186	186	123	4126	11.	4126 / 100
%																												

TABLE 15-E-15

(1139 D)

MONTHLY WIND SUMMARY

This monthly and annual summary was prepared for the same period as the 1139 C. The format is similar except the data are not presented for individual hours. Many stations have only an annual summary and a few report wind direction to only 8 compass points.

1139 D

PERIOD SUMMARY BY COMBINED VELOCITY GROUPS

STATION MONTEAGLE, TENN. MONTH DECEMBER PERIOD 1934-1938

DIR. / MPH.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOT. OBS.	%
4-15	141	32	33	13	19	31	504	454	206	60	83	56	110	149	578	288	2757	74
16-31	2						42	68			8	2	2	5	23	16	168	5
32-47																		
OVER 47																		
CALM																	790	21
TOT. OBS.	143	32	33	13	19	31	546	522	206	60	91	58	112	154	601	304	3715	
%	4	1	1	#	1	1	15	14	5	2	2	2	3	4	16	8	CALM 21	100

(1139 E)

SURFACE WINDS

This monthly and annual summary was prepared by the Weather Bureau generally for 1938-1942. The format is similar to the 1139 D with the average speed by direction added. The 8-point bias is also evident in this summary.

WEATHER BUREAU

SURFACE WINDS

Period Summary By Velocity Groups

POINT MONTARA, CALIFORNIA (Station) — ANNUAL (Month) — FEB. 1936 Thru NOV. 1941 (Year)

	code	VEL / DIR	0-3 m.p.h.	4-15	16-31	32-47	over 47	TOTAL all obs.	TOTAL VEL.	AV. VEL.	TOTAL obs. 4mph. & over	%
492	16	N	12	141	22			175	1739	99	163	2
492	1	NNE	6	13	6			25	266	106	19	#
492	2	NE	24	77	21	3		125	1118	89	101	1
492	3	ENE	4	30	8	1		43	449	104	39	#
492	4	E	48	250	19			317	2466	7.8	269	2
492	5	ESE	15	85	1			101	784	7.2	86	1
492	6	SE	104	566	107	12		789	7993	101	685	6
492	7	SSE	30	226	77	11		344	4209	122	314	3
492	8	S	89	768	125	12		994	10385	104	905	8
492	9	SSW	21	143	15	4		183	1777	97	162	2
492	10	SW	99	341	29	3		472	3653	77	373	3
492	11	WSW	19	68	11	1		93	798	86	74	1
492	12	W	80	502	62	4		648	6064	9.4	568	5
492	13	WNW	30	277	53	5		365	4070	11.2	335	3
492	14	NW	245	2765	454	38		3502	37779	108	3257	30
492	15	NNW	17	837	37	2		893	3245	111	276	3
492	20	Calm	2360					2360				(1) 30
	TOTAL		3203	6483	1047	94		10829	86735	80	7626	X
	%		(1) 30	60	9	1		X	X	X	X	100

X INDICATES LESS THAN ½ OF 1%

APPENDIX 15-F

TABLE 15-F-1

WIND SPEED DATA FROM SELECTED ARMY SITES (1945)

The following mean annual wind speed data was obtained by the U.S. Army Air Corps, 11th Weather Region in 1945 under wartime conditions. It serves as an indicator for these sites, but the information should be verified through more recent and more extensive data collection.

Site	Mean Annual Wind Speed (MPH)
Alexai Point	12.0
Buildir	10.3
Kiska	18.3
Atka	14.3
Sequam	16.2
Umnak	14.7
Platinum	14.3
Nunivak	15.8
St. Matthew	14.0
Skagway	10.0

Source: This material was obtained from the files of James L. Wise, Climatologist for the University of Alaska, Arctic Environmental Information and Data Center, 707 "A" Street, Anchorage, Alaska.

APPENDIX 15-G

TABLE 15-G-1

MONTHLY METEOROLOGICAL DATA TABULATED FOR SELECTED ALASKAN COMMUNITIES

Community	Table Number	Community	Table Number
Aniak	H-1	Indian Mountain	H-17
Annette Island	H-2	Juneau	H-18
Anchorage	H-3	Kenai	H-19
Barrow	H-4	King Salmon	H-20
Barter Island	H-5	Kodiak	H-21
Bethel	H-6	Kotzebue	H-22
Big Delta	H-7	McGrath	H-23
Cape Lisburne	H-8	Nenana	H-24
Cape Newenham	H-9	Nome	H-25
Cape Romanzof	H-10	Northway	H-26
Cordova	H-11	Seward	H-27
Fairbanks	H-12	Sparrevohn	H-28
Fort Yukon	H-13	Summit	H-29
Galena	H-14	Tin City	H-30
Gustavus	H-15	Unalakleet	H-31
Homer	H-16	Yakutat	H-32

Source: Feasibility Study for an Airborne High Sensitivity Gamma Ray Survey of Alaska Phase II Report, 1976-1979 Program. By Texas Instruments Services Group, Grand Junction, Colo. GJO 1646, 1975.

CHAPTER 16

FUEL CELLS

CHAPTER 16

FUEL CELLS

INTRODUCTION

Fuel cell research and development has recently attracted considerable national funding (U.S. Department of Energy). The potential benefits are (1) minimum impact on the environment, especially air, (2) quiet operation, (3) modular size options, and (4) requirement of less fuel per Kwh produced. Alaska is especially interested in the fuel cell because (a) the energy savings have been estimated to be 30 to 48 percent depending upon the system. This could be significant in remote communities where the cost of fuel, including transportation, is extremely expensive. (b) The net requirement for cooling water is zero--water is very costly in Arctic Alaska. (c) The size of one unit under development (40 Kw) is small enough to meet the requirements of rural communities and additional modules can be added as demand increases.

The fuel cell power plant is a device for generating electricity, often from common fuels such as kerosene, gasoline, or natural gas. However, the manner in which electricity is generated in the fuel cell is substantially different from the diesel powered internal combustion generator set or the gas turbine, which use similar fuels. In these systems, the heat is derived from combustion of the fuels to provide a driving force to create mechanical energy, i.e., a "spinning wheel" which is the rotary part of an electric generator. A "spinning wheel" is also common in plants using coal or uranium. Wind power systems and hydroelectric power plants also use the "spinning wheel," although combustion is not involved. In contrast, fuel cells involve neither combustion nor the "spinning wheel."

The fuel cell energy conversion process is unique. Electricity is generated by converting the chemical energy of the fuel into direct current by an electrochemical process. A fuel cell is somewhat like a battery that is being fueled and used continuously. However, unlike a fuel cell, in a battery the electrodes are "consumed."

The basic parts of a fuel cell are (1) a fuel electrode (anode), (2) an oxidant electrode (cathode) and (3) an ionic conductor between the two electrodes called an "electrolyte," or a membrane or diaphragm that will permit the passage of ions, but not electrons.

HISTORY OF FUEL CELL USE

The first device incorporating the essential features of what is now called a fuel cell was created by Sir William R. Grove in 1839. His experiments generated electricity by supplying hydrogen and oxygen to two separate electrodes immersed in sulphuric acid (Liebhafsky, 1968). Essentially, he was reversing the process of electrolysis of water by recombining the hydrogen and oxygen (Tetra Tech, 1972).

Attempts to make a fuel cell which consumes carbon directly began over a century ago: notably Becquerel (1855), W. W. Jacques (1896), and E. Baur (1910) (Liebhafsky, 1968) Although their efforts furthered the development of fuel cells, they fell short of producing an economically viable, functioning unit. This is evidenced by the continuing research on "second generation" fuel cells. E. W. Junger, in 1908, was probably the first to use a redox (reduction-oxidation reaction) cell. Later, in 1912, W. Nernst made a similar cell which operated at 40-60° C instead of 200° C. E. N. Rideal and U. R. Evans experimented with regenerable metal electrodes and also fused, glass-like electrolytes in 1921 and 1922 (Williams, 1966).

There was considerable interest in the potentialities of fuel cells, but major breakthroughs were not soon in coming. Interestingly, attempts to replace expensive platinum electrodes with cheaper nickel resulted in the founding of a large nickel industry (Tetra Tech, 1972). Still, most of the potential fuel cells systems had been approached at least in theory by 1930.

In 1932, Francis Bacon began his work aimed at developing a useful power source based on a simple hydrogen-oxygen cell. This contrasted with earlier and contemporary studies which emphasized the electrochemical aspects of fuel cells, usually attempting to burn conventional fuels (Williams, 1966). In 1959, he demonstrated a 6 Kw unit (Tetra Tech, 1972).

Practical application of the fuel cell did not come until the 1960's with the Gemini and Apollo space programs. General Electric supplied the fuel cells for the Gemini program. The Apollo fuel cells were developed by United Technologies Corporation (UTC) in its Pratt & Whitney Aircraft Division. The (UTC) work is now being conducted by its Power Systems Division created in 1974.

Although somewhat primitive by today's standards, United Technologies' fuel cell power plants were used successfully on numerous space missions, including the Gemini missions, Biosatellite missions, Apollo lunar landings, Skylab, and the Apollo-Soyuz linkup. On a typical Apollo flight, three 1.5 Kw units were used to produce all of the electricity needed in the command module. On 17 missions, the Apollo fuel cells accumulated some 11,000 hours of space operation without a failure (Villers, ND).

TARGET (Team to Advance Research for Gas Energy Transformation) is jointly sponsored by United Technologies and over thirty gas and combination gas-electric utilities in the U.S., Canada, and Japan. Between 1971 and 1973, 65 12.5 kilowatt fuel cells (PC11) were used in 35 store, bank, condominium, apartment, home and light industrial plant locations delivering one million Kwh of electrical power during 205,000 hours of operation (Podolny, 1971 and Lueckel, ND).

Columbia Gas System's fuel cell experience dates back to the early 1960's when it installed an experimental 500-watt Pratt & Whitney unit to power instrumentation at a compressor station in Stanton, Kentucky. A 3.75-kilowatt unit was later used to power home appliances at its Columbus, Ohio research center and in 1968 a methane-air unit was installed in a home (Villers, ND).

Another aspect of the TARGET program was to identify power plant specification requirements as they related to on-site market needs. For on-site commercial and multi-unit residential power plants, it was concluded that 40 Kw was the appropriate rating for initial market entry. The resulting unit, designated PC18, was the largest hydrocarbon-air fuel cell power plant ever tested, exhibiting 40 percent overall electrical efficiency (Lueckel, ND). With heat recovery, efficiency jumps to 60-80 percent. Fifty to seventy units are expected to be field tested over a two-year period beginning in mid-1980 to mid-1981 (Fiore, 1978).

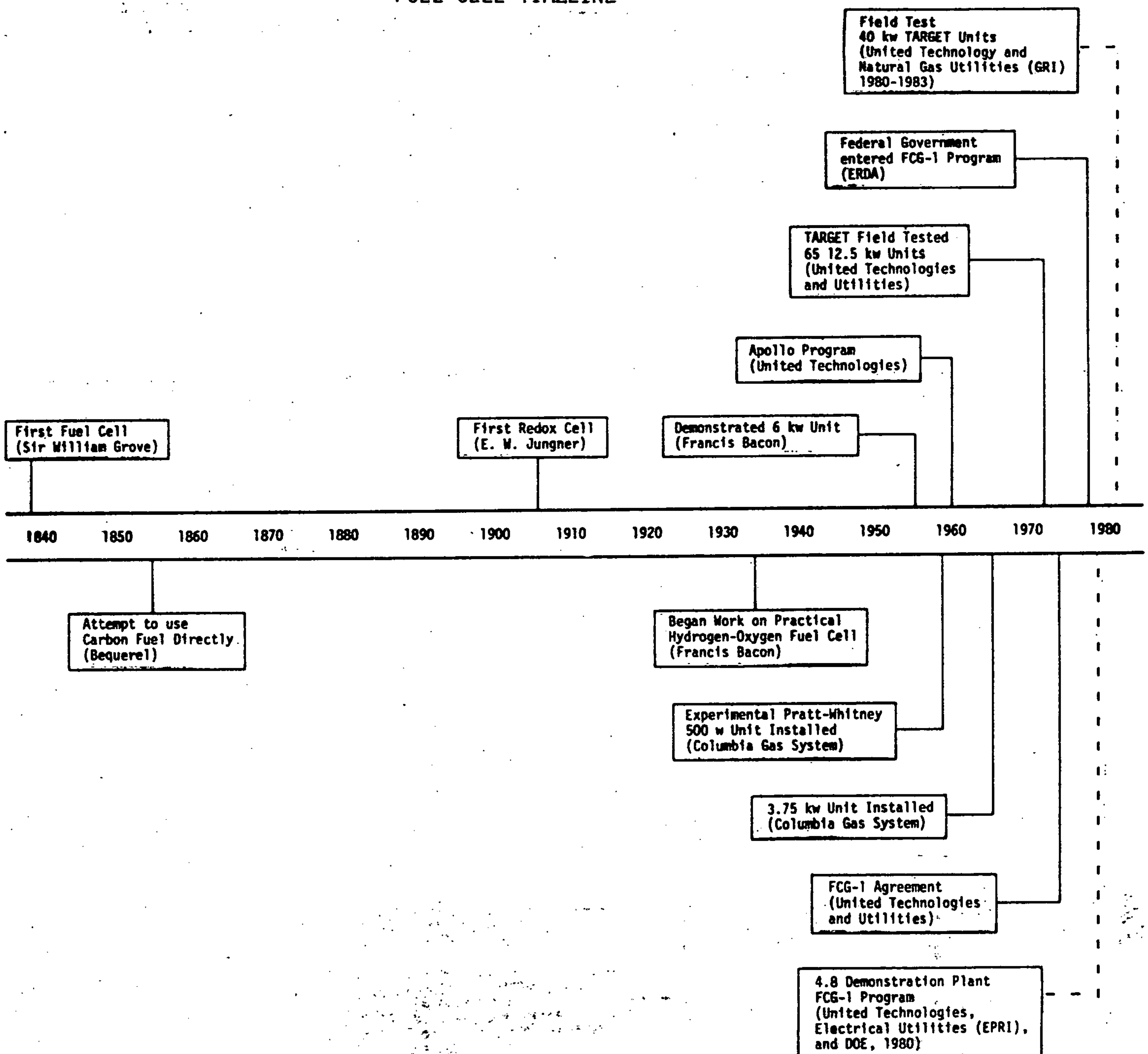
Entering into agreements with nine electric utilities in 1972, United Technologies began work on the FCG-1 power plant. The program involves scaling-up in four steps: (1) a 1-MW pilot plant (testing completed 1978), (2) a 4.8-MW demonstration plant, to begin on site testing in 1980, (3) 10 to 30 MW demonstration plants using 4.8 MW modules (Fickett, 1978), and (4) commercial production of the 10 to 36 MW FCG-1 power plants. The 1-MW pilot plant was to be fueled with naphtha (the fraction of petroleum that boils between gasoline and kerosene) and was designed to deliver 13.8 KV to a utility line.

Funded jointly by the Electric Power Research Institute and United Technologies, the EPRI RP114 Program is directed toward the development of second-generation fuel-cell power plants. Investigating a number of cell technologies differing from the acid cells used in the first generation systems, they hope to provide a reduction in costs. It is felt that future systems with heat ratings of 7,500 Btu/Kwh can be achieved. The second area of emphasis is the expansion of the range of useable fossil fuels, considering fuel-conditioning methods for heavy hydrocarbon fuels, coal and oil gasification products, and methanol (Lueckel, ND).

Despite a major commitment by the utility industry, federal support of fuel cell development did not come until 1976, when the Energy Research & Development Administration (ERDA) became involved with the 4.8-MW and 26-MW units of the FCG-1 program (Fickett, 1976).

Figure 16-1

FUEL CELL TIMELINE



Division of Energy and Power Development, State of Alaska

FUEL CELL TECHNOLOGY

Although the concept of the fuel cell remains the same, the specific characteristics vary significantly with the options available for the primary parts of the cells: the anode, cathode, and the electrolyte matrix. As studies continue, alternative systems will certainly continue to appear. Wishing simply to provide the reader with a basic understanding of the operation of a fuel cell, this overview will present only a portion of the numerous possibilities.

ENERGY MECHANISMS

An atom is composed of a nucleus containing neutrons and protons with electrons in a shell(s) surrounding the nucleus. In a nuclear fission power plant, the nucleus of the atom is split, resulting in two or more particles which weigh in total less than the nucleus prior to the split. This difference in weight is converted to energy (heat) via Einstein's equation, i.e. energy equals mass times the velocity of light squared, $E=MC^2$. The heat increases the water temperature in a pressurized water reactor and forms steam that impinges upon the blades of a turbine causing a "magnetic wheel" (the rotor) to spin within the stator (wire coils) of a generator, thereby causing electrons to flow in a wire (electricity).

Atoms can be combined to form molecules and there is a "bonding" energy from atom to atom holding the molecules together. Combustion of a molecule releases energy from these bonds by rearranging the molecular structures and forming different molecules during a chemical reaction. For example, in a gas turbine, natural gas (CH_4) reacts with oxygen releasing energy which heats air which turns the turbine to generate electricity.

The fuel cell does not make use of a magnetic wheel to generate electricity. In a fuel cell, the electrons (e-) are electro-chemically "separated" from an atom, e.g., hydrogen. The electromotive force created causes the electrons to flow through wire. This flow of electrons, electricity, can be used to perform a variety of work along the route of the wire. In summary, a fuel cell converts chemical energy directly into electrical energy.

FUEL CELL TYPES

The Basic Hydrogen-Oxygen Fuel Cell

Shown in Figure 16-2 are two platinum foil electrodes immersed in a conductive acid electrolyte. Bubbled around one electrode is hydrogen, while oxygen is similarly supplied to the other. A diaphragm separating the electrodes in the solution prevents the direct contact of the hydrogen and the oxygen, but permits the passage of hydrogen ions through the diaphragm.

The fuel, hydrogen, is fed to the negative electrode, the anode. Because of the catalytic properties of the anode surface, each hydrogen molecule contacting the surface is dissociated into two hydrogen ions which enter the electrolyte solution. The remaining two electrons pass through the external electrical circuit.

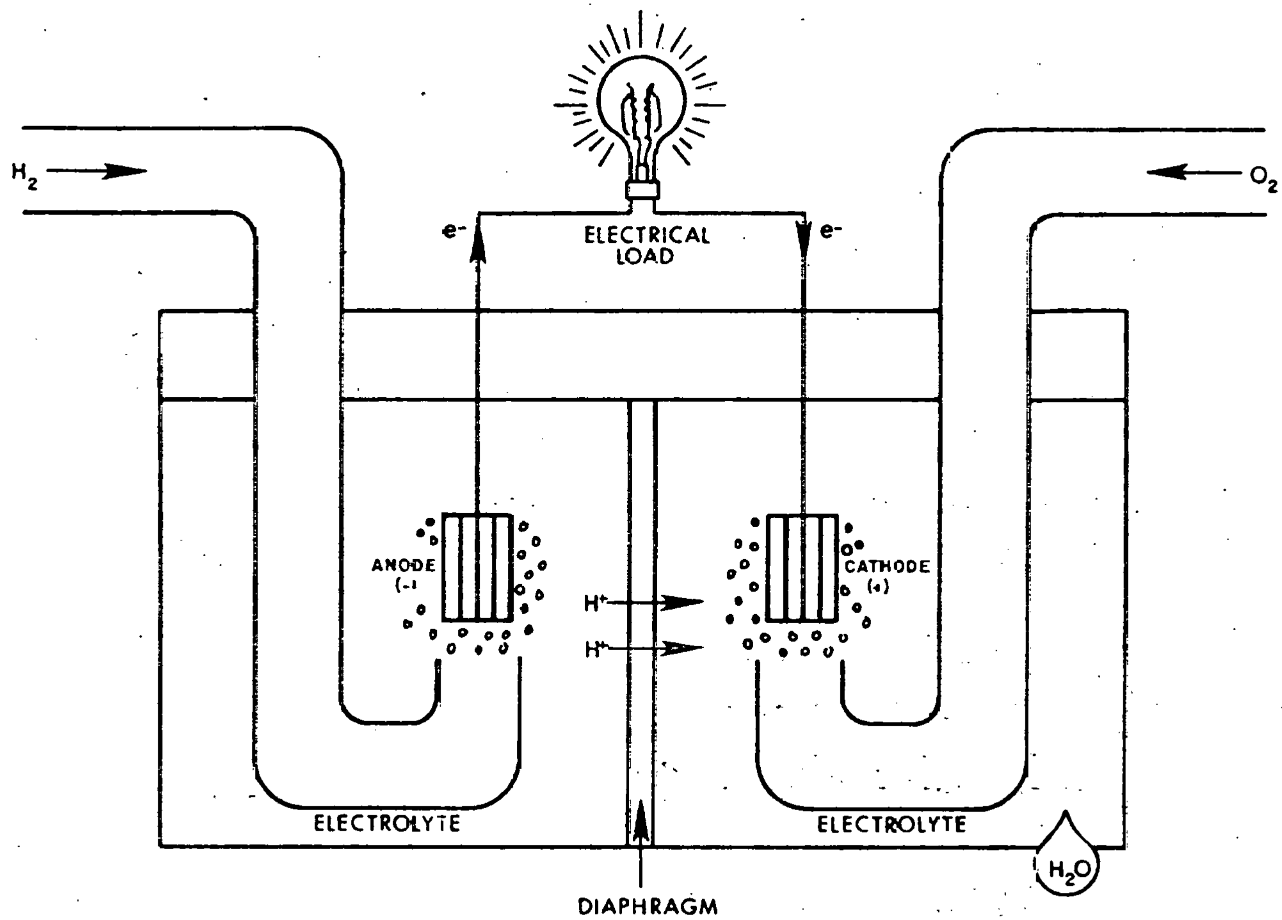
$$2H \longrightarrow 2H^{+} + 2e^{-}$$

At the positive electrode, the cathode, oxidation is taking place. The bubbling oxygen combines with the free hydrogen ions passing through the diaphragm and the electrons from the cathode to form water.

$$1/2\ O_2 + 2H^{+} + 2e^{-} \longrightarrow H_2O$$

The normal combustion process of a hydrogen-oxygen flame has been replaced by two separate electrochemical reactions.

A single fuel cell will generate roughly 100-200 watts of electricity at approximately 1 volt DC for each square foot of electrode. The fuel cell power section connects a number of single cells in series, permitting the



Anode:	$H_2 \rightarrow 2H^+_{anode} + 2e_{anode}$
Electrolyte:	$2H^+_{anode} \rightarrow 2H^+_{cathode}$
External circuit:	$2e_{anode} \rightarrow 2e_{cathode}$
Cathode:	$\frac{1}{2}O_2 + 2H^+_{cathode} + 2e_{cathode} \rightarrow H_2O$
Net reaction:	$\frac{1}{2}O_2 + H_2 \rightarrow H_2O$

Figure 16-2

SIMPLE HYDROGEN-OXYGEN FUEL CELL

Division of Energy and Power Development, State of Alaska generation of thousands of volts if desired. Connecting a number of modules permits power levels in the multi-megawatt range (Podolny, 1971).

Direct Type Fuel Cell

A direct type fuel cell is shown in Figure 16-3. Again, the reactions take place directly on the surfaces of the electrodes, which are made of porous conductors. The gases are carefully pressurized to provide a balance that avoids either a flooding or drying of the electrode pores, which would lower reaction rate and current flow. A typical alkaline electrolyte would be a 20 to 40 percent solution of potassium hydroxide (KOH), resulting in the following reactions:

Cathode:

$$O_2 + 2H_2O + 4e^- \rightarrow 4(OH)^-$$

Anode:

$$2H_2 + 4(OH)^- \rightarrow 4H_2 + 4e^-$$

Overall:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Ion-Exchange Membrane Cell

The ion-exchange membrane fuel cell uses a quasi-solid state membrane to perform the function of an acid electrolyte. Hydrogen ions can pass through the membrane, but neutral atoms and other ions cannot. Serving as electrodes and as an electrocatalyst, each side of the membrane is coated with platinum or palladium. Ion-exchange membrane fuel cells produce 100 to 200 amperes per square foot at 0.7 volt (Tetra Tech, 1976).

High Temperature Cell

Hydrogen and carbon monoxide can usually be obtained from hydrocarbon fuels. However, the CO reacts less readily than the H_2. To avoid the resulting problems with acid and alkaline electrolytes, high temperature

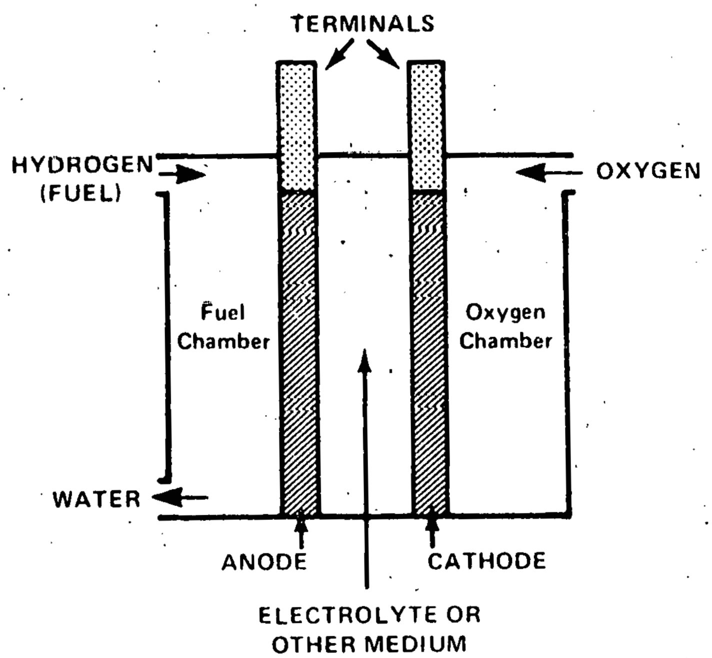


Figure 16-3

Direct Type Fuel Cell

Source: Tetra Tech, Inc., Energy Fact Book 1976, p. XIII-2.

fuel cells have been specially developed. Current densities typically range from 20-100 amperes per square foot at 0.7 volt.

Cathode:

$$O_2 + 2CO_2 + 4e^- \rightarrow 2CO_3^{--}$$

Anode:

$$H_2 + CO_3^{--} \rightarrow H_2O + CO_2 + 2e^-$$
$$CO + CO_3^{--} \rightarrow 2CO_2 + 2e^-$$

Union Carbide Cell

Not all fuel cells require high temperatures to operate. The Union Carbide Cell is of the direct alkaline electrolyte type and operating at room temperature produces a current density of about 100 amperes per square foot of electrode at 0.7 volt.

Redox Cell

Unlike normal fuel cells, where reactions take place directly at the electrodes, the Redox Cell (Figure 16-4) uses the fuel and oxidant to regenerate the two electrolytic fluids. Dividing the cell is a diaphragm which allows free passage of H^+ ions. An example would be General Electric Company's now abandoned fuel cell using H_2 and O_2:

Anode Reaction:

$$2Ti^{+++} + 2H_2O \rightarrow 2TiO^{++} + 4H^+ + 2e^-$$

Anode regeneration:

$$2TiO^{++} + 2H^+ + H_2 \rightarrow 2Ti^{+++} + 2H_2O$$

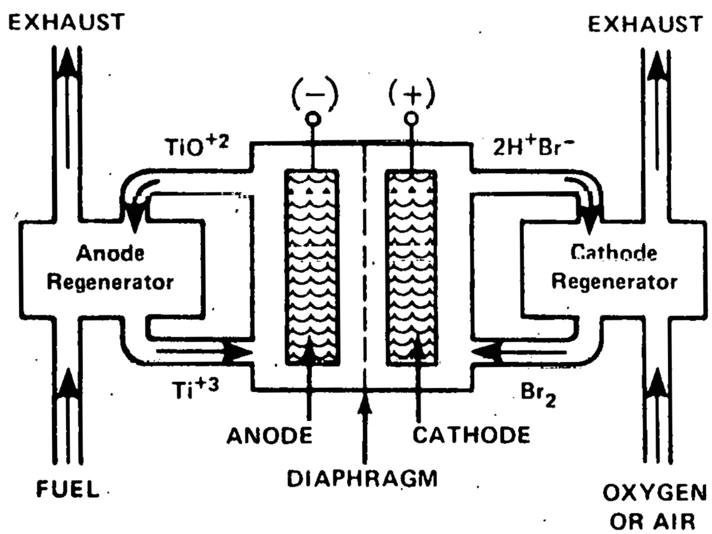


Figure 16-4

Redox Cell Schematic

Source: Tetra Tech, Inc., Energy Fact Book 1976, p. XIII-5; Original Source: S.S.L. Chang, Energy Conversion, Englewood Cliffs: Prentice-Hall, 1963.

Overall reaction on anode side:

$$H_2 \rightarrow 2H^+ + 2e^-$$

Cathode reaction:

$$Br_2 + 2e^- \rightarrow 2Br^-$$

Cathode regeneration:

$$2H^+ + 2Br^- + \tfrac{1}{2}O_2 \rightarrow Br_2 + H_2O$$

Overall reaction on cathode side:

$$\tfrac{1}{2}O_2 + 2e^- + 2H^+ \rightarrow H_2O$$

Hydrazine Fuel Cells

Although hydrazine is a very expensive fuel, it has several important advantages. Because of its high energy density with respect to volume and weight, it is often preferred for certain military applications. It does not require the use of noble metals as anode catalysts and the electrolyte is not contaminated by its reaction products (Tetra Tech, 1972).

FUELS

Hydrogen: Although hydrogen will continue as the dominant fuel, where the mission can justify the high expense, e.g., space and military programs, it is presently too expensive for common use in fuel cells. Therefore, fuel cells using a variety of other fuels are being developed.

Current Commercial Fuels

Natural Gas: Natural gas, which is chiefly methane (CH_4), is one of the most promising fuels for use in commercial fuel cells. It is easy to desulfurize, readily available in many areas, a distribution system is already in existence, and gas utilities are willing to finance part of the necessary research and development. Both the 40 Kw and 4.8 MW modules discussed in this chapter will be able to use natural gas. Methane's calorific value is a very high 13,256 kilocalories/kilogram gross (23,861 Btu's/lb.).

<u>Naphtha</u>: Naphtha is a group of liquid petroleum fuels with a calorific value ranging from 11,122 to 11,177 kilocalories/kilogram gross (20,020 to 20,120 Btu's/lb.). The liquid nature of naphtha facilitates its shipping and storage. Again, either the 40 Kw or the 4.8 MW fuel cell power plants will be able to use this fuel.

<u>Propane</u>: Propane ($C_3.H_8.$) is sold commercially as a hydrocarbon mixture with a calorific value of 11,977 kilocalories/kilogram gross (21,560 Btu's/lb.). The 40 Kw fuel cell generator is designed to be able to use it as a fuel.

Electrolyte-Soluble Fuels

The kind of fuel and oxidant largely determines the design of low-temperature, low-pressure fuel cells. When gaseous fuels are used, the electrochemical reactions take place at gas/liquid/solid interfaces within a relatively expensive porous electrode. If, however, the fuel is soluble in the electrolyte, electrodes consisting of a thin conducting sheet, which is catalytically active if necessary, is essentially all that is needed. In addition, liquid fuels generally have the advantage of greater ease of transport and storage, elimination of heavy gas cylinders, and higher energy/weight and energy/volume ratios than gaseous fuels.

Ideally, a liquid fuel would have the following properties:

1) inexpensive
2) readily available
3) liquid over a wide range of temperature
4) chemically stable and soluble in, but inert toward strong acids or bases

5) low viscosity
6) high flash point
7) high calorific value
8) inoffensive, preferably gaseous, waste products
9) rapid ionization at the anode with a minimum of overvoltage
10) inert at the cathode

Best meeting these criteria are methanol, ammonia, and hydrazine.

Methanol: Methanol studies have had limited success. The process is self-poisoning due to material adsorbed on the electrode, allowing methanol fuel cells to perform only at low efficiencies. With improved electrocatalysts, methanol fuel cells would probably become practical propositions (Liebhafsky, 1968).

Ammonia: Apparently ammonia has not been used as a direct fuel in well-developed fuel cells. However, there are plans to crack ammonia into nitrogen and hydrogen for use in various fuel cells, including a 200-Kw submarine (Andrew and Glayebrook in Williams, 1966).

Hydrazine: (N_2H_4 and $N_2H_4H_2O$) Hydrazine is becoming increasingly popular as a fuel because it has an anodic reactivity approaching that of hydrogen. Unfortunately, high cost and low voltage efficiency discourage its use as a fuel except in special applications such as military uses where fuel transportation costs are high (Liebhafsky, 1968).

The chemical reactions and the ideal efficiency of several common fuels are shown in Table 16-1.

REFERENCE ELECTRODES

While there are a number of materials used for electrodes, their suitability is usually measured against reference electrodes which have accurately known potentials on the standard hydrogen scale. The calomel electrode is used in fuel cell studies over a wide range of temperatures. The hydrogen electrode is useful over a wide range of pH and temperature. The mercury-mercuric oxide electrode is used as a reference electrode in

TABLE 16-1

IDEAL EFFICIENCY VALUES FOR H_2, N_2H_4 AND SOME COMMON HYDROCARBON FUELS

REACTANT Half-Cell Reaction Complete-Cell Reaction	$\Delta F^\circ_r/\Delta H^\circ_r$, Ideal Efficiency (percent)
HYDROGEN $H_2 \rightleftarrows 2H^+ + 2e^-$ $H_2 + \frac{1}{2} O_2 \rightleftarrows H_2O$	83.0
METHANE $CH_4 + 2H_2O \rightleftarrows CO_2 + 8H^+ + 8e^-$ $CH_4 + 2O_2 \rightleftarrows CO_2 + 2H_2O$	91.9
METHANOL (aq) CH_3OH (aq) $+ H_2O \rightleftarrows CO_2 + 6H^+ + 6e^-$ CH_3OH (aq) $+ 1\frac{1}{2} O_2 \rightleftarrows CO_2 + 2H_2O$	97.1
CARBON MONOXIDE $CO + H_2O \rightleftarrows CO_2 + 2H^+ + 2e^-$ $CO + \frac{1}{2} O_2 \rightleftarrows CO_2$	90.9
ETHANE $C_2H_6 + 4H_2O \rightleftarrows 2CO_2 + 14H^+ + 14e^-$ $C_2H_6 + 3\frac{1}{2} O_2 \rightleftarrows 2CO_2 + 3H_2O$	94.1
ETHANOL (aq) C_2H_5OH (aq) $+ 3H_2O \rightleftarrows 2CO_2 + 12H^+ + 12e^-$ C_2H_5OH (aq) $+ 3O_2 \rightleftarrows 2CO_2 + 3H_2O$	97.5
ETHYLENE $C_2H_4 + 4H_2O \rightleftarrows 2CO_2 + 12H^+ + 12e^-$ $C_2H_4 + 3O_2 \rightleftarrows 2CO_2 + 2H_2O$	94.3
ACETYLENE $C_2H_2 + 4H_2O \rightleftarrows 2CO_2 + 10H^+ + 10e^-$ $C_2H_2 + 2\frac{1}{2} O_2 \rightleftarrows 2CO_2 + H_2O$	95.0
PROPANE $C_3H_8 + 6H_2O \rightleftarrows 3CO_2 + 20H^+ + 20e^-$ $C_3H_8 + 5O_2 \rightleftarrows 3CO_2 + 4H_2O$	95.0
PROPYLENE $C_3H_6 + 6H_2O \rightleftarrows 3CO_2 + 18H^+ + 18e^-$ $C_3H_6 + 4\frac{1}{2} O_2 \rightleftarrows 3CO_2 + 3H_2O$	95.1
BENZENE $C_6H_6 + 12H_2O \rightleftarrows 6CO_2 + 30H^+ + 30e^-$ $C_6H_6 + 7\frac{1}{2} O_2 \rightleftarrows 6CO_2 + 3H_2O$	97.2
HYDRAZINE (aq) N_2H_4 (aq) $+ 4OH^- \rightleftarrows N_2 + 4H_2O + 4e^-$ N_2H_4 (aq) $+ O_2 \rightleftarrows N_2 + 2H_2O$	99.4

The symbols used in the table are:
ΔF°_r Standard-state free energy of reaction at 25°C.
ΔH°_r Standard-state heat of reaction at 25°C.

The ideal efficiency is defined as the ratio of the maximum amount of electrochemical energy (ΔF) that can be obtained from a chemical reaction to the heat energy of the reaction (ΔH).

Source: Tetra Tech, Inc., Energy Fact Book 1976, p. XIII-7; Original Source: Carl Berger (ed.), Handbook of Fuel Cell Technology, Englewood Cliffs, New Jersey: Prentice-Hall, 1968.

alkaline solutions (Andrew and Jones in Williams, 1966). In molten carbonate cells, a number of electrode materials have been studied, a selection being difficult because of the corrosion of the electrodes caused by the electrolyte at the high operating temperatures.

Electrodes must possess the following properties:

1) chemical stability towards the electrolyte, fuel, and air
2) physical stability at the operating temperature
3) high catalytic activity
4) good mass transfer (Jones in Williams, 1966)

Platinum metals have been shown to serve as highly effective electrodes for a wide range of fuels, including hydrocarbons. Unfortunately, widespread application of such fuel cells is discouraged by the high cost. And, cost aside, world platinum supplies are insufficient for use in millions of fuel cells (Williams, 1966). On the brighter side, developments during the last ten years have resulted in a dramatic decrease from requirements as high as 2000 grams of platinum per kilowatt to 10 grams now (Gorman, 1977).

ELECTROLYTES

An electrolyte is a substance which in solution or as a liquid is able to conduct electricity by the movement of its ions to the electrodes. A large number of electrolytes are used, depending largely upon the specifics of the fuel cell under consideration. Two of the more important distinguishing characteristics are the state of the matter and the pH. Discussed briefly below are some of the more common electrolyte concepts.

Liquid electrolytes are the oldest and, in many ways, still the most important. In all cells employing aqueous electrolytes, hydrogen or hydroxyl ions are important in both the electrode processes and the current transport through the electrolyte. The first fuel cells used acid electrolytes with higher conductivity (Smith in Williams, 1966). Typically, sulphuric acid is used in acid fuel cells intended to operate below 80° C and phosphoric acid is used for higher temperatures. Alkaline electrolytes such as potassium hydroxide may be used. Strongly alkaline electrolytes are generally restricted to hydrogen, hydrazine (N_2H_4), and ammonia (NH_3) as fuels because they do not contain carbon. Strong buffer solutions, commonly potassium carbonate, may be used. Finally, low electrical conductivity and poor performance of oxygen electrodes in such electrolytes has discouraged the use of acid buffer solutions except in some biochemical fuel cells which use live bacteria or enzymes to catalyze electrode reactions (Williams, 1966).

Phosphoric acid is used with platinum electrodes for hydrocarbon fuels in the 150-200° C temperature range. Unfortunately, phosphoric acid is extremely corrosive at these temperatures (Smith in Williams, 1966). The development of suitably resistant construction materials has significantly reduced the problem of corrosion (Fickett, 1978). Higher operating temperatures increase efficiency, but may reduce cell life and reliability (Gorman, 1977). Phosphoric acid will be used in both the 40 Kw and 4.8 MW units described in this chapter.

Both acid and alkaline aqueous electrolytes need not necessarily be mobile. Electrolytes can be immobilized in matrices or gel form using agents such as finely divided silica, asbestos fibers or plaster of Paris.

In high temperature fuel cells operating at 500° C or higher, two types of non-aqueous electrolytes are generally used. Fused alkali metal carbonates have higher electrical conductivity and permit lower operating temperatures. Unlike the fused carbonates, solid ionically conducting oxides do not require the addition of carbon dioxide to the gas supplied to the cathode (Williams, 1966).

SUPPORT SYSTEM

Fuel cells require clean fuels to operate efficiently. The reformer (conditioner or processor) converts natural and synthetic fuels, either liquid or gas, to a more readily usable gaseous mixture. The most common method currently in use is steam-reforming (Williams, 1966), in which fossil fuel and steam are catalytically reacted under heated conditions to produce a hydrogen-rich gas stream for use in the fuel cell. Carbon dioxide and a small amount of SO_2 are also produced in the process (Lueckel, ND). Typical of other hydrocarbons, the basic steam reforming of methane and the following water gas shift reaction can be shown as (Smith in Williams, 1966):

$$CH_4 + H_2O \quad CO + H_2$$
$$CO + H_2O \quad CO_2 + H_2$$

Although second generation fuel cells can use a much wider range of fuels, contaminants such as SO_x remain a problem, reducing the life and efficiency of the power unit (Fickett, 1976).

While the vast majority of our electrical machinery is designed for alternating current, fuel cells generate direct current. Therefore, to be useful, the direct current must often be converted to alternating current, or at least pulsating current, by an inverter. Direct current can be converted to alternating current by either a motor-generator or a solid state inverter, both of which are capable of 80 to 90 percent efficiencies (Tetra Tech, 1976). Earlier rotary or mercury-arc systems are giving way to solid state inverters. Efficiencies of 95 percent and significant decreases in cost and size have resulted from continuing advances in solid state technology (Lueckel, ND).

ADVANTAGES OVER EXISTING ELECTRIC GENERATING SYSTEMS

Numerous aspects of the fuel cell make it attractive when compared to other methods of generating electricity.

First, fuel cells convert chemical energy directly into electrical energy. In contrast, electrical generators frequently convert chemical energy to heat, heat to mechanical energy, and then mechanical energy to electricity. This multiple conversion results in a loss of efficiency.

Hydro and wind generators produce electricity in only one step: mechanical to electric energy. However, it should be noted that the direct current coming from the fuel cells must be converted to alternating current before it can be used for most practical applications.

Many energy systems accept heat from a high-temperature source, produce work and reject heat to a low-temperature sink (Bolan, 1976). Recoverable work is limited by the difference in the two temperatures as described by Carnot: $(T_1 - T_2)/T_1$ (Williams, 1976). Fuel cells, however, are not heat machines and are not restricted by the Carnot-cycle limitation. The fuel cell's electro-chemical nature enables it to maintain a high efficiency over a wide range of sizes and loads. Heat may be recovered without affecting the electrical conversion efficiency.

Power plant systems require reserves on line either at idle or part power to respond rapidly to demand changes. Up to a 15-percent reduction in overall utility system fossil fuel consumption could result from the use of fuel cells to provide this "spinning reserve." The fuel cells automatically adjust almost instantaneously to changes in demand, the reaction stopping when the load is removed (Lueckel, ND).

Perhaps the most exciting characteristic of the fuel cell is its minimal environmental impact. The common waste products are carbon dioxide, water, and heat. In the Apollo spacecraft, using hydrogen as fuel for the fuel cell, the astronauts used the waste water for drinking (Villers, ND). NO_x, SO_2, smoke, and particulate emissions from fuel cells are only 1/10th to 1/50,000th of those from conventional central power stations. Also, the fuel cell system is quiet. Virtually the only noises involved are those of any fans or pumps used in the system, and these can be insulated for noise.

Unlike conventional systems, fuel cells perform with high efficiency over a wide range of loads, their efficiency remaining fairly constant from 25 percent to 125 percent of rated power (Figure 16-5). Based on the higher heating value of input fuel and AC power output, first-generation power plant efficiency will exceed 38 percent and that of second-generation plants is expected to be greater than 45 percent (Figure 16-6).

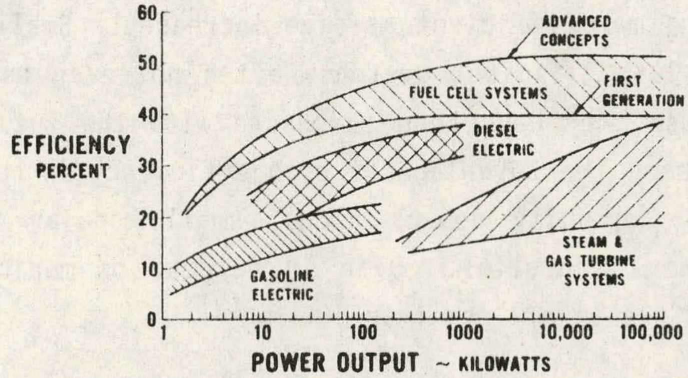


Figure 16-5
Power System Efficiency Comparison

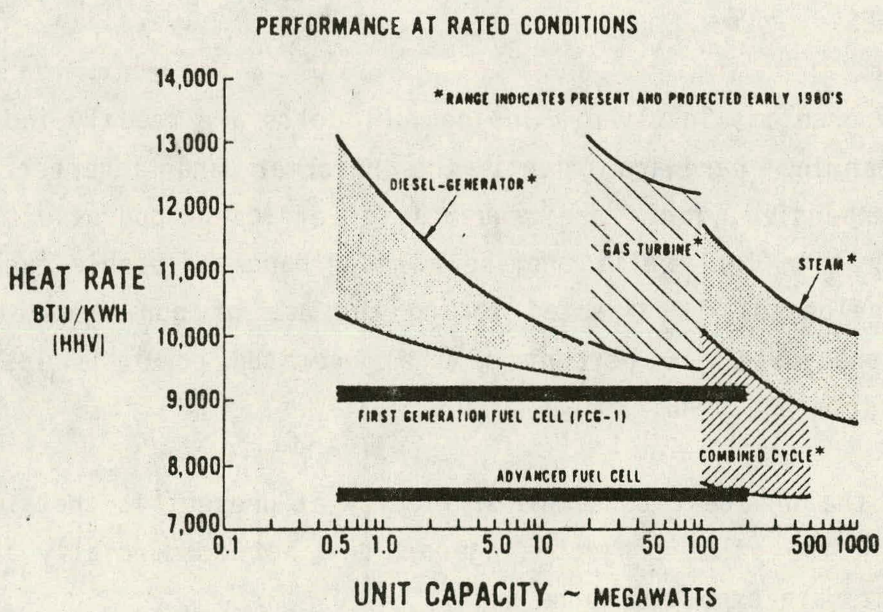


Figure 16-6
Heat Rate of Various Powerplant Types

Source: William J. Lueckel, Jr. and James R. Casserly, "Fuel Cells for Utility Service," pp. 3 and 5.

In conventional systems, efficiency is largely a function of power demand, the systems becoming more efficient as size increases. Small communities are forced to use less efficient systems, often not even using these to full capacity because they have been purchased with the future growth in mind. Fuel cells have the advantage of high efficiency in both small and large systems. As community demand grows, small modular units can be added to the system in parallel. Over 40 percent of municipal utility capacity comes from plants of less than 100 MW.

Energy losses of 3 to 6 percent often occur in conventional power transmission. On-site or near-site fuel cell power plants provide an attractive alternative. Because of their environmental and modular characteristics, site selection is much more flexible (Lueckel, ND).

The heat resulting from the chemical reactions that is not captured for use can be dispersed into the surrounding air. Cooling does not require an external water supply (Villers, ND).

DISADVANTAGES

Two primary problems involved in using fuel cells are readily indicated by the accompanying hardware, i.e., the reformer and inverter. Clean, sometimes expensive, fuels are required for efficient operation, although second-generation fuel cells promise a wider range of usable fuels. Most current development is directed toward the use of non-renewable fossil fuels. Approximately 5 percent of the generated power is lost in the conversion from DC to AC.

Of course, the greatest consumer difficulty at present is that fuel cells are still in the pilot project stage and are not commercially available. Initial costs are expected to be high.

Finally, at the present time, some of the fuel cell system components are expected to have a shorter life than those of conventional power sources (Tetra Tech, 1976).

THE REFERENCE UNIT

There are no off-the-shelf fuel cells with a history of reliable service available for rural communities today (1978). However, national research and development funding has now begun on two different units--a 4.5-MW generator and a 40-Kw generator capable of integrating its waste heat into useable energy.

THE 4.5-MW POWER PLANT

In 1977, Consolidated Edison Co. of New York, Inc., was selected as the host utility for a prototype 4.5-MW fuel cell power plant. This major demonstration project was initiated in 1976 as a joint effort by United Technologies Corp. (UTC), Department of Energy (DOE), and Electric Power Research Institute (EPRI). The funding contributions are $5 million by EPRI, $25 million by DOE and $12 million by UTC (R & D Status, 1978).

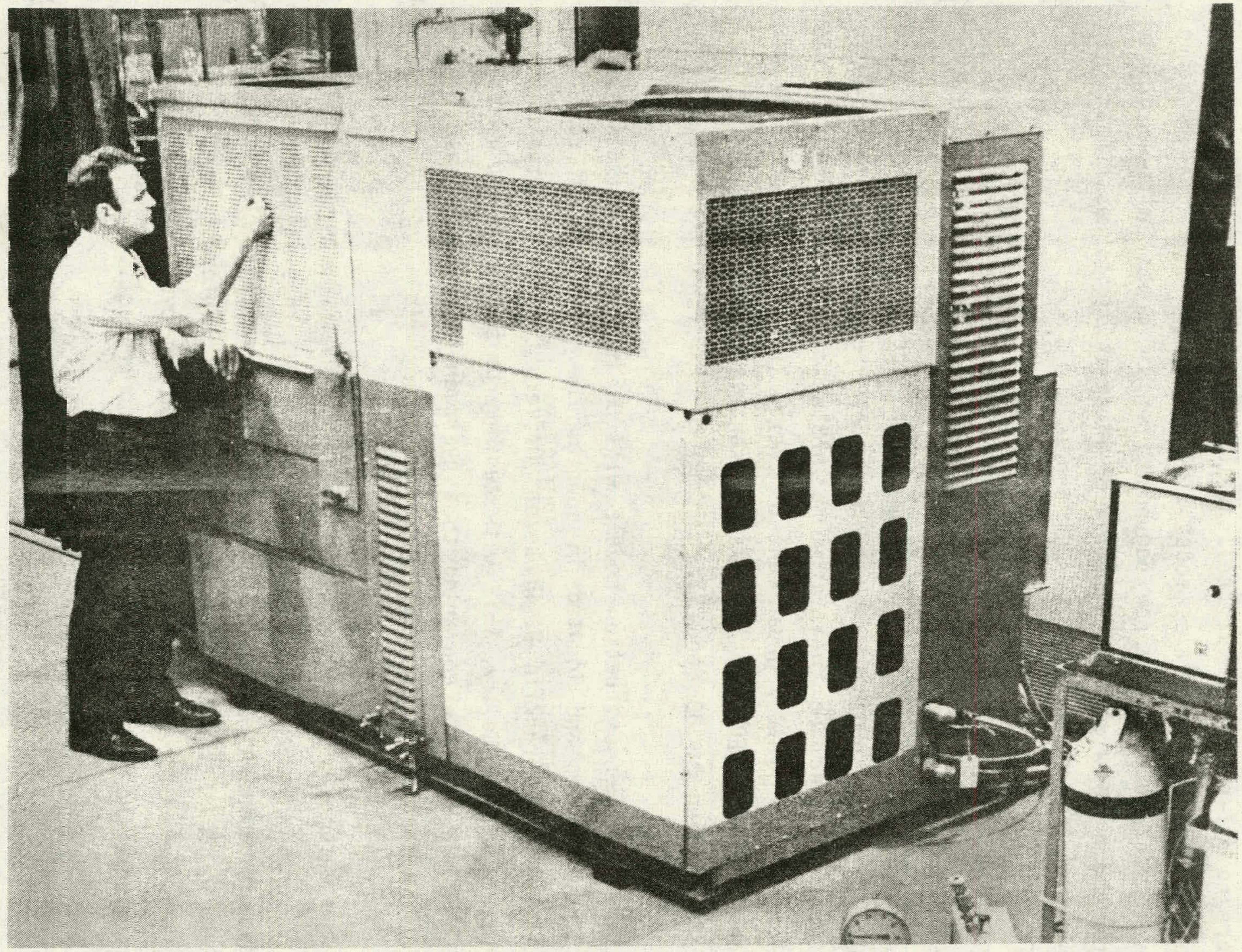
The 4.5-MW FCG-1 demonstration module will be installed on the Consolidated Edison system and located in downtown New York City at East Fifteenth Street and Franklin D. Roosevelt Drive. Delivery of the unit is estimated to be about July, 1979 with testing to begin in 1980 (Fickett, 1978). Naphtha will be converted to a hydrogen-rich gas for use in the fuel cell in the fuel processing substation.

While the Anchorage demand for electrical energy is such that a 4.5-MW unit or even six 4.5-MW modules would be practical, this unit is presently too large for rural and remote Alaska. Therefore, attention is focused on the 40-Kw unit. Nevertheless, Alaska has a strong interest in the 4.5-MW and/or 9-MW generators that are to be operated from pyrolysed urban waste, biomass gases, and especially coal gasification products.

THE 40-KW UNIT

A 40-Kilowatt power plant designed for on-site power generation in buildings and at industrial locations is under development. This size

Figure 16-7



Pilot 40-Kilowatt Fuel Cell Powerplant

Source: Peter Bolan, "Heat Pump and Fuel Cells", P.2.

unit is of special interest in rural Alaska. The development of this 40-Kw plant is being supported by a group of gas utility companies and the U.S. Department of Energy. A photograph of prototype 40-Kw unit is shown in Figure 16-7. Note that the size is such that transportation and housing of the unit should be of no major concern. The goals of the 40-Kw power plant development program include:

Rating	40 Kw
Efficiency (LHV)	40 percent (part-load)
Operating Range	0-40 Kw
Power Output	3 Phase
Water Required	None
Startup	Automatic or Semi-Automatic
Fuel	Pipeline Gas/Naphtha/Propane

The 40-Kw size was chosen to meet the energy requirements of a 16-unit apartment. The energy requirements for the building were determined by using techniques of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) and by developing the electric load profile using data correlations and load analysis techniques. In order to provide the most realistic analysis, a specific location was selected for the 16-unit apartment: Hartford, Connecticut. This area, with 6200 heating degree days, is representative of much of the northern part of the Lower 48. The major building characteristics and weather parameters are presented in Table 16-2.

TARGET (Team to Advance Research for Gas Energy Transformation, Inc.) is composed of approximately thirty gas distribution and transmission companies that contracted with United Aircraft Corporation for the research, development, and testing of natural gas fuel cells for powering total energy systems or other power generation purposes (Smith, 1977).

The results of the joint efforts of TARGET and United Technologies Corporation, the development of a 40-Kw fuel cell powerplant, is fairly well along. The present plans call for some modification of the 40-Kw unit, leading to the manufacture of 50 to 70 of the modified fuel cell units. The fuel cells would be used for a field test program starting in mid-1980.

TABLE 16-2

CHARACTERISTICS OF 16-UNIT APARTMENT LOCATED
IN HARTFORD, CONNECTICUT

BUILDING DESIGN

2 STORY BUILDING	BRICK VENEER
16 APARTMENT UNITS	725 FT 2/UNIT
INTERNAL HEAT GENERATION	44,000 BTU/HR
HEATING LOAD	516,000 BTU/HR
ELECTRICAL BASELOAD DEMAND	18 KW
PEAK ELECTRICAL DEMAND	39 KW

WEATHER DATA

HEATING DESIGN TEMPERATURE	0°F
COOLING DESIGN TEMPERATURE	90°F
HEATING DEGREE DAYS	6200

Source: Bolan, Peter, "Heat Pumps and Fuel Cells, "American Institute of Chemical Engineers, Sixty-Ninth Annual Meeting, Paper Number 23 d, Nov. 30, 1976.

The research and development activities of TARGET have been transferred to the newly-formed Gas Research Institute. The fuel cell activities will be funded by and continue under the joint auspices of the Gas Research Institute and the Department of Energy.

A Program Opportunity Notice (PON) will be announced in 1979 by DOE for those interested in using one of these first fuel cells, but the cost to the user is expected to be about $300,000 for a two-year period even though there will be no charge for the fuel cell. This cost will be for instrumentation, testing, and data analysis for the demonstration (Lawrence, 1978).

In summary, the 40-Kw fuel cell unit has been selected as the reference unit for potential applicability to rural communities in Alaska. It uses natural gas, naphtha or propane as fuel, phosphoric acid as the electrolyte and carbon with some platinum at the electrodes.

ENVIRONMENTAL IMPACT

As manufacturing costs are reduced and the technology becomes available, rural Alaska may find numerous applications for small 40-kilowatt fuel cells. Extremely efficient in the production of electricity, the fuel cell has the potential for exceptional versatility and is purportedly nearly free of adverse environmental effects in the installation and operational phases. Sophisticated research is developing an energy generation system that does not use or degrade water, is quiet and clean, and can be located at the point of power use. Because of its efficiency, the fuel cell can also contribute to fuel conservation.

Although relatively minor, some aspects of fuel cell power generation do contribute to environmental pollution (Reitze, 1974). There are some atmospheric emissions. However, the exhaust products from experimental fuel cells are measured at less than one tenth of the Environmental Protection Agency standards for acceptable levels of atmospheric pollutants. A comparison of these emissions from fuel cells and other large scale electric generation plants is shown on Table 16-3 and Figure 16-8.

There are barely measurable discharges of particular matter, smoke is negligible and NO_x emissions are very low. SO_x emission levels depend on fuel input; when natural gas is used, SO_x emission is also very low.

There is no noise generated by the basic process in the fuel cell. Air fans and transformer hum do create some noise and other system components, reformers and inverters, increase the sound levels. These levels have been compared to those produced in a household furnace, freezer or small motors (Fiori, 1978), though noise levels would vary depending on the size of the fuel cell generation equipment. The system can be sound-proofed in several ways, including acoustical baffling. These modifications would, of course, increase the already high front-end costs.

A fuel cell is self-contained. It requires no water for input nor for cooling and it produces no chemical discharges that would require flushing or washing. The water produced during the chemical transformations is used in later stages of power production.

These factors along with the small physical size of the cell result in simplified installation requirements. Initial construction activities could be compared to pouring a concrete platform for a patio with electrical wiring hookups (Fiori, 1978). The generation equipment can be placed in or near user facilities, thus reducing or eliminating transmission equipment and structures. This would conserve fuel and improve efficiency by reducing power loss during transmission. It would also decrease down-time for system maintenance or emergency repairs (Villers, ND). When these features are reviewed, another advantageous environmental consequence appears: fuel efficiency and conservation. Through capture of generated heat using heat exchangers and heat pumps, the energy value of the fuel used could be as high as 70-90 percent (Bolan, 1976). These encouraging figures come from experimental installations. However, practical on-site utilization is expected to approach these efficiency percentages. The conservation savings on scarce and expensive fuels would be enormous. Additionally, developers believe that fuel cells in the future may operate as efficiently by utilizing synthetic liquid or gaseous fuels derived from oil shale or coal, or from hydrogen derived from use of solar energy (Villers, ND).

POTENTIAL APPLICABILITY TO RURAL COMMUNITIES

The characteristics of the fuel cell have already been described in the preceding section. However, a review of those qualities of particular relevance to isolated communities is in order. It should be noted that many of the characteristics discussed are based upon laboratory test data and still await extensive field tests.

DURABILITY

Although various components of the fuel cell are expected to have a shorter life than diesel generators (the electric power system most likely to be replaced in rural Alaska), replacements and repairs can be made by local personnel. The simplicity of the fuel cell design minimizes the need for technically-skilled operators and service persons.

OPERATION

Fuel cells are expected to provide quiet, reliable, unattended operation (King, ND). Since there are few moving parts, maintenance will primarily involve infrequent replacement of filters, requiring only simple tools and modest skills (Lueckel, ND).

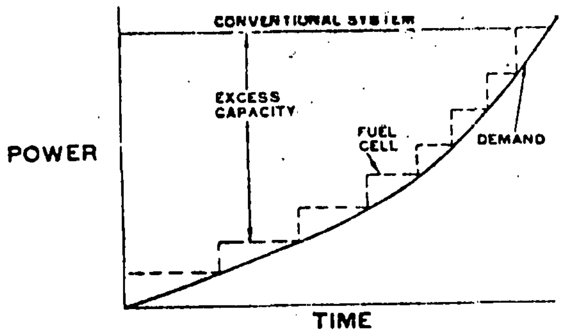
COSTS

Although fuel cell power plants are not yet commercially available, it is anticipated that the cost of the units will become competitive in the near future. One of the primary thrusts of current development is to reduce equipment costs and take advantage of the higher efficiencies fuel cells offer.

Most obvious is the saving of expensive fuel in remote areas where transportation is a major part of the cost. Just using the electricity from the 40-Kw unit results in a 40 percent efficiency (output Btu/input Btu) as shown in Figure 16-5. Adding heat (a very useful product in Alaska) recovery brings efficiencies to 60-80 percent (Fiore, 1978). High fuel cell efficiences are achieved over a broad load range. This is especially important in rural Alaskan communities which often have a low load factor, the ratio of average load to peak load.

The modular construction approach is important to the economics of the fuel cell. In contrast with conventional generator sets, capacity can be added in small increments as demand grows. A large investment in excess capacity can be avoided in this manner. Modular design also reduces field assembly requirements (King, ND).

Figure 16-8



Matching Installed Capacity with load demand (King, ND)

Fuel cells would be of special interest to those areas which have a local fuel supply, i.e., natural gas: Barrow, Prudhoe Bay, North Pole and Cook Inlet. However, most remote and rural areas of Alaska presently use diesel powered electrical generators. Thus, transportation and storage facilities for a fuel such a naphtha already exist.

In the foreseeable future, only the 40 Kw and 4.5 MW units will become commercially available. Except near population centers, the larger unit would be of impractical size. One or more of the 40-Kw modules might be used in villages having populations of perhaps 100 or more. The figure of 100 is a very rough guideline, as residential and commercial electrical consumption varies widely at different sites throughout the State.

In summary, durability, reliability, ease of repair, ease of shipment, ease of use, time for training, and cost of equipment will not be known in Alaska until field testing is done in Alaska. Field testing in the Lower 48 will help but will not substitute for Alaska field testing. Also, the benefits of the fuel cell have been addressed by ERDA (Burnett, ND) and there is lack of concensus in certain areas; for example, estimates of the 1985 oil savings impact of first generation fuel cells varies widely, at least by a factor of three.

RECOMMENDATIONS

The fuel cell could become a significant producer of electrical energy in the rural and remote communities in Alaska in the future. Diesel oil is now the fuel that is used to the greatest extent to produce electricity; however, since the efficiency of the fuel cell is much greater, naphtha (a fuel cell liquid fuel) might produce cheaper electricity even if the naphtha is more expensive.

While a 40-Kw fuel cell is currently being tested, it is not available as off-the-shelf hardware at this time. Extensive field testing is planned for the 40-Kw unit under the sponsorship of the Gas Research Institute and DOE.

(1) Alaska needs to evaluate the benefits associated with participation in the field testing currently planned for a number of 40-Kw units throughout the nation. It has been estimated that the cost of such a participation would be about $300,000. If the cost/benefit ratio is satisfactory, a number of sources for funding should be considered: State of Alaska, boroughs, utilities and energy industries.

(2) A study needs to be done to determine the future possibilty of using resources found near the rural communities to power the fuel cells. For example, the peat resources in Alaska are greater than all of the Lower 48 states combined. If gas obtained from the peat could serve

as the fuel, the economic impact on a rural community might be very favorable. In about 40 villages, the 1977 cost of electricity was 372 mills per Kw hour.

(3) Fuel cells can use natural gas as a fuel, thereby providing an opportunity for more efficient utilization of our remaining reserves. A study should be made on the potential for energy (natural gas) conservation for Barrow, Anchorage, Kenai, Prudhoe Bay and North Pole using fuel cells in the near future for a period of 20 to 30 years.

SUMMARY

Since the invention of fuel cells in 1839, there have been significant technological advances. Experimentation has included a wide variety of fuels, electrodes, electrolytes and cell designs with varying degrees of success. Still, despite field testing and limited military and space application, the fuel cell has yet to become a commercial reality.

Theoretically at least, fuel cells have much to offer: more efficient use of fuel, low environmental impact, modular size, and avoidance of over-capacity. One is hopeful that the new round of field testing to begin in 1980 will be successful.

As costs will undoubtedly be the guiding factor in determining the applicability of fuel cells to rural Alaska, the results of the field tests will be of great importance. It still remains to be determined whether the high equipment costs can be offset by more efficient use of high cost fuel and lower maintenance expenses at these remote sites.

KEY CONTACTS

Arnold P. Fickett
Program Manager
Fuel Cells and Chemical Energy
Conversion Technology
Electric Power Research Institute
3412 Hillview Avenue
P. O. Box 10412
Palo Alto, California 94303
(415) 855-2000

Vince Fiore
Gas Research Institute
3424 South State Street
Chicago, Illinois 60616
(312) 567-6608

Kent Grinage
Utility Manager
North Slope Borough
P. O. Box 69
Barrow, Alaska 99723

Lloyd M. Hodson
Alaska Village Electric
Cooperative, Inc.
999 E. Tudor Road
Anchorage, Alaska 99503
(907) 277-6632

Mike Kelly
Golden Valley Electric
Association, Inc.
Box 1249
Fairbanks, Alaska 99707
(907) 452-1151

L. R. Lawrence, Jr.
Gas Research Institute
3424 South State Street
Chicago, Illinois 60616
(312) 567-6608

Lawrence D. Markley
Manager of Environmental
Systems
Chugach Electric Association, Inc.
731 Gambell
Anchorage, Alaska 99501
(907) 276-3500

William H. Podolny
General Manager
Fuel Cells Operations
United Technologies
P. O. Box 109
South Winsor, Connecticut 06074

Jack Ross
Carlson Sales, Inc.
(Manufacturer's Representative
for Electric Industry)
P. O. Box 99097
Seattle, Washington 98199
(206) 284-4630

L. J. Schultz
General Manager
Chugach Electric Association, Inc.
731 Gambell
Anchorage, Alaska 99501
(907) 276-3500

Walter H. Smith
Vice President
Intermountain Gas Company
555 South Cole Road
P. O. Box 7608
Boise, Idaho 83707
(208) 377-6000

REFERENCES

Alaska, Division of Geological and Geophysical Surveys, Energy Resources Section (Klein, Robert M. and Kristina M. O'Connor). "Review of EIS 74-90, Section F (Energy Alternatives) and an Evaluation of Energy Alternatives." 1975.

Bolan, Peter (United Technologies Corporation). "Heat Pumps and Fuel Cells." Presented at Annual Meeting of American Institute of Chemical Engineers, November 30, 1976.

Burnett, William M. (U.S. Energy Research and Development Administration). "Fuel Cell Benefits--The Program Management Office Viewpoint." Washington, D.C.

Fickett, Arnold. "Fuel Cells: Versatile Power Generators," EPRI Journal. April, 1976.

________. Telecon to DEPD, July 15, 1978.

Fiore, Vincent. Telecon to DEPD, July 5, 1978.

Gorman, Robert. "On the Way, Power for Electric Grids from Fuel Cells," Popular Science. March, 1977.

Hawaii. Alternate Energy Sources for Hawaii. Report of the Committee on Alternate Energy Sources for Hawaii. Sponsored by University of Hawaii and State of Hawaii. Department of Planning and Economic Development. Undated.

King, Jr., Joseph M. and Sigurd H. Folstad (Pratt & Whitney Aircraft Division). "Electricity for Developing Areas Via Fuel Cell Powerplants." Undated.

Lawrence, L.R. Telecon to DEPD, July 5, 1978.

Liebhafsky, Herman A. and Elton J. Cairns. Fuel Cells and Fuel Batteries. New York: John Wiley & Sons, Inc., 1968.

Lueckel, W.J. (Pratt & Whitney Aircraft Division, United Aircraft Corporation), L.G. Edklund (Pratt & Whitney Aircraft Division) and S.H. Law (Northeast Utilities, Hartford, Conn.). "Fuel Cells for Dispersed Power Generation." Undated.

Lueckel, William J., Jr. and James R. Casserly (United Technologies Corporation). "Fuel Cells for Utility Service." Undated.

Podolny, William H. (Pratt & Whitney Aircraft Division). "Fuel Cell Powerplants for Rural Electrification." December, 1971.

"R & D Status Report--Fossil Fuel and Advanced Systems Division: Fuel Cells," EPRI Journal, III, June, 1978.

Reitze, Arnold W., Jr. Environmental Planning: Law of Land and Resources. Washington, D.C.: North American International. 1974.

Smith, Walter (Intermountain Gas, Boise, Idaho). Letter to Gene Rutledge, DEPD, May, 1977.

Tetra Tech, Inc. Energy Fact Book--1976. Chapter XIII. TT-A-642-76-211. Arlington, Virginia: February, 1976.

Villers, Ralph. "Energy and the Fuel Cell." Undated.

Williams, Keith R., ed. An Introduction to Fuel Cells. Amsterdam: Elsevier Publishing Company, 1966.

APPENDIX 16-A

1978 FUEL CELL PROGRAM OVERVIEW

The National Fuel Cell Seminar was held July 11-13, 1978 in San Francisco, California. At this seminar, representatives from the Department of Energy, Electric Power Research Institute, Gas Research Institute, Department of Defense, National Aeronautics and Space Administration, and the Environmental Protection Agency presented program overviews of fuel cell work underway in their organizations. Their remarks, as documented in the published abstracts, are given in this appendix.

DOE FUEL CELL PROGRAM OVERVIEW

Gary E. Voelker
Division of Power Systems
U.S. Department of Energy
Washington, D.C. 20545

One of the primary objectives of the National Energy Plan is to shift our national energy consumption profile away from scarce resources and toward more plentiful fossil resources in the near-term and eventually to inexhaustible resources. Accomplishing this objective requires the development and introduction of more energy efficient equipments in the near-term. These equipments must also allow for a transition from petroleum and natural gas to alternate fuel sources in the longer term. In order to achieve the above objective, the nation must have new powerplants as prime movers which are highly efficient over a wide load range, environmentally acceptable, fuel flexible and with their waste heat in a readily useable form. The fuel cell is a device that converts fuel to electrical energy in a highly efficient and environmentally acceptable manner regardless of the unit size. Because of their unique features, fuel cell powerplants can be located close to the point of electricity demand, reducing energy losses associated with transmission and distribution and permitting effective use of waste heat. Fuel cell systems evolving within the next five to ten years are strongly viable in the following applications:

(a) Industrial cogeneration where advantage is taken of the high electrical and thermal efficiencies (including utilization of waste fuel streams):

(b) Integrated energy systems for community systems and district heating; and operating from waste and coal derived fuels

(c) Electric Generation including peaking and intermediate cycling loads, spinning reserve, small utilities, replacement of old inefficient units and base load from coal.

(d) Transportation applications including product petroleum pipeline pumping, gas pipeline compression, and electric hybrid vehicles.

In addition to the above foreseeable energy saving applications, the foreign market potential for phosphoric acid fuel cells is quite large. It fits into four markets:

(1) Developed countries where environmental considerations are important, (2) developing nations because of the small unit size and ability to run without operating personnel, (3) oil and gas-rich countries where

the low capital cost, efficiency, and ability to operate without trained personnel make fuel cells attractive, (4) and countries that are shifting to an alcohol fuel based economy because of the higher conversion efficiency.

The objective of the DOE Fuel Cell Program is to establish the commercial feasibility of fuel cell powerplants for electric utility applications, industrial cogeneration and building total energy systems in the near term and to develop advanced, higher efficiency, economically competitive, fuel cell technologies for all end use applications in the longer term. Due to the initiatives taken by a coordinated national fuel cell program, the nation can experience, over the next three to six years, the development of a fuel cell industry with its significant associated national benefits.

In order to achieve the overall DOE Fuel Cell Program objectives, the program is divided into four project areas. Each of these areas has a specific objective as follows:

<u>4.8 MW Electric Utility Powerplant Development</u>

Test on a utility grid, the operational feasibility of electric utility fuel cells which are nearing readiness for commercialization

<u>Phosphoric Acid Systems Development</u>

Development fuel cell systems for non-electric utility applications and provide technology to lower cost and increase reliability of first generation fuel cell systems.

<u>Molten Carbonate Fuel Cell Systems Development</u>

Advance the state-of-the-art of molten carbonate fuel cells in order to achieve the earliest possible commercialization of coal fueled powerplants in electric utility base load and industrial cogeneration applications.

<u>Fuel Cell Applied Research</u>

Support emerging systems with a sufficient technology base, examine advanced fuel cell systems and broaden the spectrum of acceptable fuels.

The status of each of these project areas is summarized below:

<u>4.8 MW Electric Utility Powerplant Development</u>

Accomplishments to date include execution of contracts for construction of the 4.8 MW fuel cell powerplant and the spare parts required for validation and supplemental testing in a host utility. The design and design confirmation phases of the program have been completed and projected performance, meeting specification goals, has been substantiated through sub-component testing and modeling. Another contractual action, selection of a host for integration of the powerplant in a utility grid, has been completed. Site preparation will be initiated shortly. It is expected that the program will closely meet scheduled milestones. This will result in completion of hardware construction during FY 78 and completion of the utility testing during FY 80. Implementation of a plan for a commercial feasibility program will be initiated in FY 79 when projected performance has been achieved through utility demonstration. The commercial feasibility program will involve the improved technology development, the correction of performance deficiencies discovered during the operational test and the initiation of a manufacturing methods development program.

Phosphoric Acid Systems Development

In the on-site/integrated energy systems area, emphasis is on the development of kilo-watt size powerplants. Of these, the 40 kw modification and development program is in the most advanced stage. The 40 kw powerplant is in the engineering and development phase.

The 40 kw pilot powerplant, was originally developed under gas utility and United Technologies sponsorship and was the starting point for this development effort. This pilot powerplant has operated for over 10,000 hours. The current program is directed toward cost, reliability, endurance and performance improvements of the pilot powerplant design in order to develop a viable proper functioning 40 kw field test powerplant.

Two major potential powerplant cost reduction tasks have been initiated in FY 1978. The first, platinum catalyst activity enhancement represent an alternate to higher temperature and pressure of increasing performance. The activity will focus primarily on the cathode. The success of this task will have an important impact upon phosphoric acid fuel cells systems being developed for OS/IES applications. The second activity involves the development of a low cost integral cell stack concept. It is anticipated that the development effort for this latter activity will allow it's incorporation into the 40 kw powerplants under development for field testing.

Several systems studies are underway that will be completed during the year identifying market & regulatory restraints, capital requirements, quantifying benefits and associated costs. In addition a study of the feasibility of a fuel cell integrated with an urban, industrial or agricultural waste conversion system is underway and will be completed during the year. This study will compare the economics of several fuel cell/waste conversion system configurations with a conventional system coupled with a waste conversion system and establish a developmental plan for fuel cell systems in this application. An industrial cogeneration solicitation for proposals (RFP) utilizing fuel cells will also be let. This, RFP will result in a number of site specific studies from which an initial field demonstration will be selected.

The fuel cell technology development for transportation applications program was initiated late in FY 1977. Present activities involve refinement of the program plan in order to emphasize cost reductions, mass fabrication, fuel selection and technology requirements specific to this application. All of these items require certain development work, and, although the benefits appear large - particularly, efficiency, environmental pollution and petroleum dependency reduction - this is the first formalized attempt at developing fuel cells for this application.

Molten Carbonate Systems Development

In order to meet the requirements of an electric utility baseload system, the goals established for the molten carbonate fuel cell stacks are:

. life of 40,000 hours to meet low maintenance requirements,

. current density of 150 A/ft^2 at 0.85 V, and a

. first cost (stack only) of \$60/kW at the current density and endurance design points.

Successful achievement of these goals will allow for a system design of 50% overall conversion efficiency at a competitive capital cost.

Cell performance is rapidly approaching the goal specification, and may well exceed that level before other goals are met. The present current density at 0.85 V is 110 mA/cm^2. This specification must be met under system operating conditions of temperature (~923 K), Pressure (~10 atm), CO_2 recycle (currently by burner) and in-cell fuel utilization (currently ~85%).

The best cell life to date is 13,500 hours. Obviously, the cell was built with what is now two year old technology. Since then, apparently satisfactory solutions to the wet seal corrosion problem which was the apparent cause of failure) have been devised. The next hurdle appears to be electrolyte management, and several approaches to this problem are under study.

Fuel Cell Applied Research

Technology development efforts have been initiated to investigate the areas of electrocatalysis, cell materials behavior, electrode polarization, alternate acid electrolytes, and fuel process modeling. Advanced concepts currently being evaluated include solid oxide fuel cells, direct coal fuel cells, direct methanol and methane fuel cells, alkaline fuel cells, and advanced fuels utilization concepts such as partial oxidation, autothermal reforming and advanced steam reforming.

EPRI FUEL CELL PROGRAM

A. P. Fickett
Electric Power Research Institute
Palo Alto, CA 94303

The objective of the EPRI Fuel Cell Program is "to develop and assist the commercial introduction of a fuel cell power plant technology that will provide the electric utility industry with a power generating option that is highly efficient, environmentally acceptable, and compatible with available utility fuels while fully realizing the economic and operating advantages of an essentially modular power generator".

To accomplish this objective, EPRI's fuel cell projects address both first-generation (FCG-1) and advanced technologies. The first-generation efforts concentrate on the early demonstration and commercialization of the FCG-1 power plant. The advanced technology efforts focus, in the near-term, on molten carbonate power plants for dispersed applications with increased efficiency and operational flexibility. In the intermediate term, the efforts focus on expanding the molten carbonate technology to develop and commercialize a central station fuel cell power plant integrated with a coal gasifier. The specific targets of fuel cell development are shown in Table I on the next page.

Figure 1 depicts the projected time line for the EPRI fuel cell activities.

To achieve these targets, EPRI supports a variety of projects ranging from fundamental research to major power plant demonstrations. The specific projects supported in the 1977-1978 time period are tabulated in Table II.

The annual EPRI fuel cell budget is approximately $10 million and will likely remain at this level over the next few years. About sixty percent of the funds are allocated to the first generation related activities with forty percent available for advanced technology efforts.

TABLE I

FUEL CELL DEVELOPMENT TARGETS

	FCG-1 Phosphoric Acid	ADVANCED Molten Carbonate	
	Dispersed	Dispersed	Central Station
Commercial Introduction	1983	1988	1992
Fuel Options	Naphtha Natural Gas Clean Coal Fuels	FCG-1 Fuels plus Distillate	Coal
Capital Cost ($/kW)	350	350	800
Fixed O&M $/kWyr	0.3	0.3	1.0
Variable O&M (mills/kWh)	3.0	3.0	3.0
Heat Rate (Btu/kWh) Full Load/(Part Load)	9300(9000)	7500(7300)	7500(7500)
Life Years	20	20	20

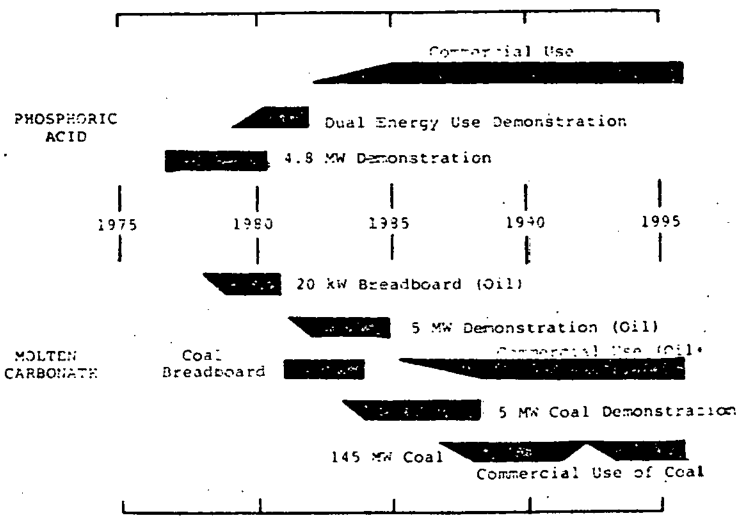


Figure 1. Fuel Cell Program Time Line

TABLE II

EPRI PROJECTS (1977-1978)

Project	Purpose	Contractor
RP114	Develop advanced power plant technology	UTC
RP239	Define cost/efficiency of molten carbonate fuel cell integrated with Texaco coal gasifier	Fluor
RP371	Research molten carbonate anode sintering	Northwestern University
RP583	Research phosphoric acid cathode sintering	Exxon
RP634	Research phosphoric acid cathode performance	Case Western
RP842-1*	Design and fabricate 4.8 MW demonstrator	UTC
RP842-2*	Install and test 4.5 MW demo on utility system	Con. Edison
RP842-3	Provide automatic data and recording equipment for 4.5 MW test	UTC
RP842-4	Improve phosphoric acid technology	UTC
RP918	Assess role of fuel cells in small utilities	Burns & McDonnell
RP919	Assess No. 2 fuel processing concepts	Catalytica
RP1041-1	Assess advanced steam reforming processes	KTI
RP1041-2	Develop data on autothermal reforming	JPL
RP1041-3	Evaluate heat exchanger materials	Lockheed
RP1042	Assess cost and availability of fuel cell fuels	ADL
RP1085-1	Provide molten carbonate power plant system requirements (oil and coal)	GE
RP1085-2	Research molten carbonate fuel cells	IGT
RP1135	Assess dual energy use fuel cells	Mathtech
RP1200-1	Evaluate phosphoric acid cathode technology	ERC
RP1200-2	Research phosphoric acid (cathode) carbon substrates	Stonehart
RP1200-3	Research kocite as a phosphoric acid cathode substrate	UOP
RP1273	Test a 20 kW molten carbonate stack	UTC

* Joint EPRI-DOE efforts

OVERVIEW OF ON-SITE FUEL CELL POWER PLANTS

Vincent B. Fiore
Gas Research Institute
10 W. 35th Street
Chicago, Illinois 60616

Over the last sixteen years, the gas industry has been supporting fuel cell technology. In 1977, the Department of Energy placed heavy emphasis on developing fuel cell technology. Within the next five to seven years, commercial on-site fuel cell systems should be a reality, largely due to the efforts of the gas industry and the U. S. Government.

In the mid-1960's, the gas industry's interest in fuel cells was to develop a piece of hardware that would be one answer to the all-electric threat. It would also provide the industry with a new product that would be more efficient and require less maintenance than total energy systems that were being sold. In the early 1970's, a major field test was conducted with the cooperation of many gas utilities throughout the United States. This test proved that the fuel cell was a viable concept and could provide a host of added advantages not thought of initially. The low pollution characteristics and the fact that the fuel cell could provide, in addition to the electrical needs, hot water and space heating through heat recovery, were two such advantages. These added features made the fuel cell a product that could significantly conserve natural gas.

In addition to this test, several business configurations were evaluated. For the gas utilities, equipment ownership, leasing and/or maintenance were all part of this evaluation. On-site fuel cell energy service through the utilities seemed to offer the greatest advantages to the end user, both from an economical and practical standpoint.

Today's efforts are concentrating on developing a 40 kW on-site fuel cell, which seems to be the right size and building block for commercial applications. Emphasis is being placed on making this power plant economically feasible. All three components, the reformer, the cells, and the inverter, are being worked on and modified to reach this objective.

For the immediate future, the Department of Energy and the Gas Research Institute plan to field test fifty 40 kW power plants. This two-year field evaluation will provide the necessary technical inputs for improving the unit's performance, and will document the actual conservation benefits that could be realized. This type of information will in turn establish the basis for proceeding with commercialization.

U.S. ARMY (DOD) FUEL CELL PROGRAM OVERVIEW

James R. Huff
U.S. Army Mobility Equipment Research and Development Command
Fort Belvoir, VA 22060

Major emphasis of the current Army program is focussed on the application of phosphoric acid technology to satisfy the Army requirement for a family of silent, lightweight electric energy plants (SLEEP). This family is to encompass the size range from 0.5 to 5.0 KW, with the 1.5 KW member targeted for initial development. It is desirable for these power plants to have a multifuel capability; however, the technology for production of a hydrogen rich fuel stream from logistic fuels lags the rest of the system. Therefore, the selected approach for entry into engineering development is based on the steam reforming of methanol. At the same time, efforts are continuing to develop other processes for converting the more complex logistic fuels (JP-4, diesel, and gasoline) into an acceptable fuel stream for phosphoric acid fuel cell systems. These investigations are aimed at developing a stable catalyst configuration for thermocatalytic cracking of logistic fuels and at achieving high temperature steam reforming of diesel fuel. Cost effectiveness of both the methanol and logistic fuel systems is presently being evaluated and, if the results are favorable for either, they will be fielded on a one-for-one basis to replace present gasoline engine driven generator sets in the 0.5 to 5.0 KW power range. The contractual programs in support of the planned entry into engineering development will be discussed. Two of these are the subject of separate presentations and therefore will be covered only briefly.

A secondary area of emphasis for military application is in the range of 1 to 100 watts. This addresses the need for smaller, high energy density power sources to power tactical surveillance or communications equipment. The system under investigation is based upon two developments. First, a hydrogen generator has been developed which utilizes calcium hydride and water to produce hydrogen to demand via diffusion control principles. Secondly, a hydrogen/air fuel cell using a solid polymer electrolyte (SPE) was found to operate well at low temperatures. In-house and contractual efforts on systems combining these components will be discussed.

Technology base efforts are designed to provide an evaluation of other fuel cell components and/or materials to assess their role in various military applications and to provide for evolutionary development of these components/materials for incorporation into future fuel cell systems. The major alternate electrolyte technologies are those based on solid polymers and advanced organic acids. The former is being characterized under conditions representative of those to be expected in SLEEP family applications. The latter is a continuing investigation of electrolytes capable of sustaining faster reaction rates with more complex fuel streams and an improved understanding of what leads to these favorable kinetics. Emphasis on basic elements of general applicability lies in the continued reduction of noble metal catalyst loadings, the further optimization of electrode structure to improve catalyst activity and stability, and the search for satisfactory non-noble catalysts. Portions of these efforts will be covered in separate presentations. An area of interest, not being fully explored in this program, is new concepts and/or materials for matrices and a better understanding of their role in system performance.

This presentation is intended to convey an understanding of Army needs and current problem areas and our efforts at satisfying them, as well as eliciting new ideas or approaches from the participants and others associated with the fuel cell community.

NASA FUEL CELL PROGRAM

Lawrence H. Thaller
NASA-Lewis Research Center
Cleveland, Ohio 44135

Fuel cell systems have supplied on-board electrical power during a number of NASA missions. Current and future missions will also employ them as part of the on-board electrical supply system. For the Gemini flights of the mid-sixties, an early variant of the solid polymer electrolyte (SPE) or acid membrane technology was used. These were followed by improved membranes used in the Biosatellite flights of the late sixties. The Apollo flights from the late sixties through the mid-seventies used fuel cells with trapped alkaline electrolytes of approximately 85% potassium hydroxide. Finally the Space Shuttle will use trapped alkaline electrolyte fuel cells of somewhat lower concentrations (about 35% KOH). Over the past 20 years both the acid membrane technology as produced by the General Electric Company and the trapped alkaline electrolyte technology as produced by United Technologies, Inc. have experienced significant gains in their performance and reliability. In terms of hardware parameters, these improvements are related to increased current densities, reduced hardware weights and longer operating times within specified performance limits. New catalyst formulations, new materials of construction, increased operating temperatures and improved basic understanding of the various decay modes have all contributed to the advances achieved in these two technologies. The basic objectives of these technology programs have been to:

1. Maintain the technology readiness of the trapped alkaline and acid membrane fuel cell concepts.

2. Explore possible improvements in these technologies and verify these improvements via life tests.

3. Explore system modifications that might be necessary to meet projected future mission requirements of the agency.

Besides maintaining technology programs, the agency must of course fund the flight hardware procurements as missions become realities. The Shuttle Orbiter is the next major program that will be using fuel cells for on-board power requirements. Unpowered Orbiter flights with on-board fuel cells have been going on for about a year. Actual powered flights to and from near earth orbit will not take place until early 1979. Thus, the newest fuel cells in space will represent a five-year-old technology.

Numerous space missions that could be carried out with a space transportation system based on the Shuttle have been envisioned and some have reached the advanced system studies stage. These studies have pointed up several somewhat divergent mission types for fuel cells. Although the names of these potential missions may change from year to year, the requirements tend to form two quite separate groupings.

The mission type which currently appears likely to find acceptance is what is referred to as a space base. This would be a rather large facility buildup in low earth orbit with power requirements in the 100-500 kW range for duration of up to five years between refurbishments. These long mission times suggest the use of solar arrays coupled with energy storage (for dark-time periods) as the most suitable combination. An energy storage system concept using water electrolysis cells/gas storage/fuel cells is currently viewed as the most weight effective. In a recent study for a 100 kW power system, a weight saving of ~65% or 80,000 pounds was estimated for the fuel cell/electrolyser combination compared to a more conventional, large nickel cadmium battery system. For this application the major technical requirement would of course be fuel cell system life. Low system weight would be a factor, but only if mutually consistent with extended lifetime.

The other type of mission which has faded somewhat with the emphasis on near earth orbital activity has been referred to as the Space Tug and more recently as the Oribtal Transfer Vehicle. This involves a reuseable vehicle for excursions between the Shuttle in near earth orbit and synchronous orbits for the placement and repair or retrieval of satellites in mainly geostationary positions. The fuel cell projected for this type of application would be one that would stress minimum weight. Since only a small number of total missions would be required of any one vehicle, long fuel cell life would not be required. High current density operation using lightweight components and propellant grade hydrogen and oxygen would be best suited for this application.

Within the past few years the strong points and weak points of the acid membrane and the trapped alkaline fuel cell technologies have become more fully understood. Technology improvement programs have been ongoing at the General Electric Company and United Technologies, respectively, supported by NASA. At the risk of oversimplification, the trapped alkaline technology has exhibited good cell performance and the emphasis has been on extending the times during which the cells operate at an acceptable performance level. The acid membrane technology on the other hand has consistently exhibited very long lifetimes and the emphasis has been on improvements of the electrical performance. Figures 1 and 2 illustrate the typical evolution over the past 5-8 years for the acid and alkaline

technologies, respectively. Endurance has not yet been verified at the higher temperature and current densities for SPE, nor have full powerplants yet been constructed for either technologies at the improved levels of performance.

The current thrust of the NASA fuel cell effort is to draw from the technology bases that have been generated over the years and use them to produce subscale and preliminary full size hardware that are optimized for the most probable future NASA missions. Life testing of hardware items plus concurrent decay modeling and failure analysis will help determine the relative suitability of these two competing technologies prior to the selection of the actual hardware supplier for specific mission use.

The NASA program in fuel cells is directed by NASA Headquarters and carried out by the Lewis Research Center, Johnson Spacecraft Center and Marshall Space Flight Center. At Lewis the emphasis is on technology and at the other centers the emphasis is on systems integration and mission application. There is, however, some overlap.

The current thrust of the Lewis effort is in the trapped alkaline technology area. This work is investigating new and improved materials that would further extend operating times at higher operating temperatures and current density. The life testing at these more stressful conditions represents a form of accelerated testing of the new materials of construction. The specific goals of this technology effort is to produce cell hardware that will have a capability of 40,000 hours at 100 amps per square foot for long endurance applications and a capability of 3,000 hours at 1000 amps per square foot maintaining a cell voltage of 0.90 volts for the high current density applications.

The Johnson Center is planning to test a complete trapped alkaline fuel cell system. In this test the hardware would closely resemble that actually to be used in Shuttle flights but would test the system over a broader range of conditions not normally expected in Shuttle operations.

The Marshall Center is demonstrating the technology readiness of a lighter weight alkaline technology (20 lbs/kW as compared to 40 lbs/kW developed for Shuttle). This new lightweight technology was developed to the single cell level previously by Lewis.

The Johnson Center is funding a technology readiness program on the acid membrane type hardware to bring together a number of improvements that would enhance overall performance. In addition Johnson and Lewis are now formulating a joint program to develop technology for a low earth orbit energy storage system based on the fuel cell/electrolyzer concept.

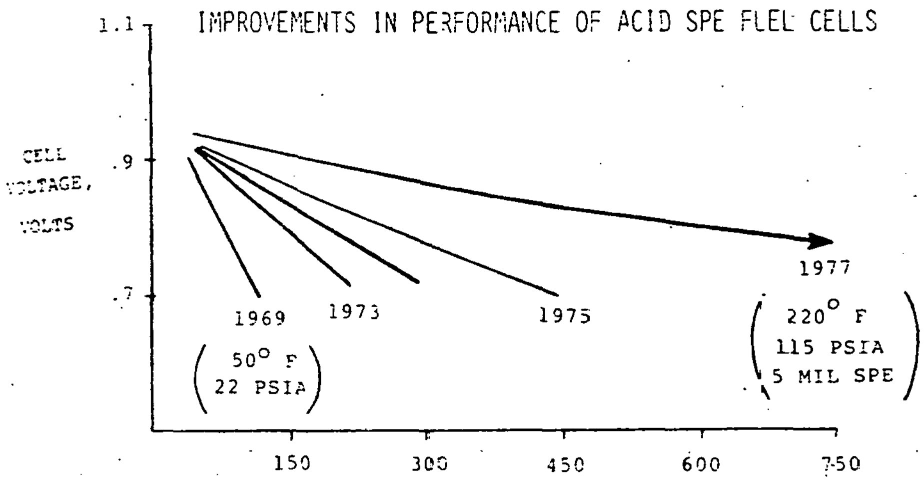


FIGURE 1

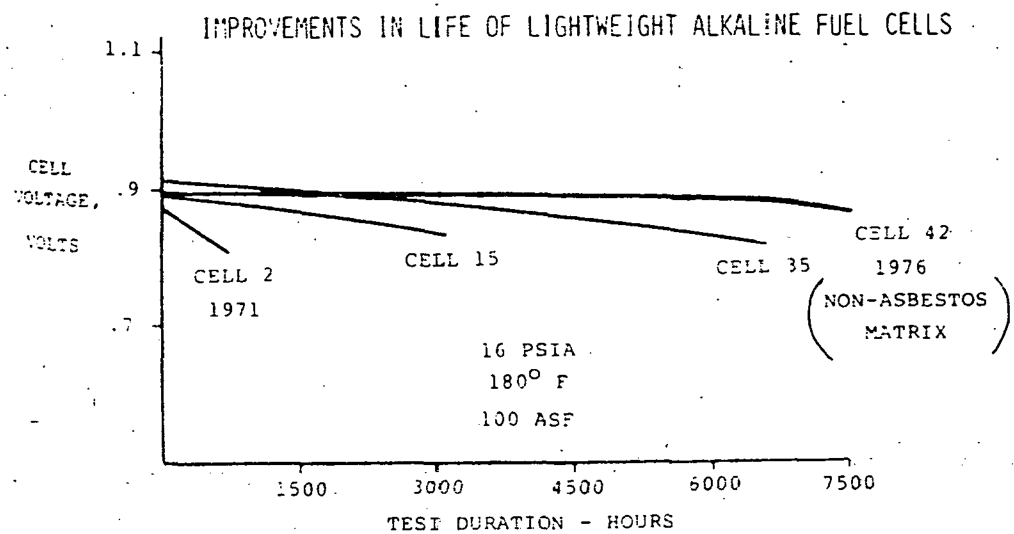


FIGURE 2

EPA FUEL CELL PROGRAM OVERVIEW

Gary L. Johnson
U.S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina 27711

The Environmental Protection Agency's research and development activities pertaining to fuel cells originated with EPA's mission to promote the development of environmentally clean energy systems. During the years preceding the creation of the Energy Research and Development Administration (ERDA) and now the Department of Energy (DOE), a significant portion of Federal-supported fuel cell research was sponsored by EPA. Much of this research effort was dedicated to basic research in electrolytes, fuel availability, systems design, etc. With the emergence of the ERDA/DOE fuel cell programs, EPA's role in fuel cell R&D has declined as many programs funded originally by EPA have since been transferred to DOE, and no new programs are forthcoming. During Session II of this National Fuel Cell Seminar, a report will be made on EPA's last active fuel cell project -- the Environmental Assessment of Residential Energy Supply Systems Using Fuel Cells. With the completion of this project, EPA's active fuel cell R&D program will come to an end. This EPA Fuel Cell Program Overview, then, will be a gentle remembrance of projects past, and a challenge to those who will carry on with the work.

EPA's fuel cell R&D interests encompassed both basic and applied research. The early work by SRI International in the direct use of coal in a fuel cell was sponsored by EPA. A feasibility study of the use of coal anode and air cathode in a molten-carbonate electrolyte cell was completed by SRI International in 1975. Work is continuing in this area, as will be reported in a later Session, under another sponsor. Other EPA-sponsored projects included a study of fuel cell technology by Burns & Roe, an investigation of the potential use of mixed oxide electrolytes in fuel cells by the National Bureau of Standards, and an evaluation of 3.0 kW fuel cell power plant using a steam-methyl alcohol reformer and a phosphoric acid electrolyte by the U.S. Army (MERADCOM).

EPA made extensive use of fuel cell technology in the EPA-Van, a research unit designed and constructed for EPA by Engelhard Industries. The EPA-Van was designed to optimize energy conserving features and minimize pollutant emissions. Accordingly, the EPA-Van utilizes solar energy collector panels, a heat pump, catalytic appliances, and two fuel cells. The fuel cells used are Engelhard Model 750 units mounted in parallel. Each unit produces 800 W nominal at 28V. The hydrogen fuel is produced from anhydrous ammonia. The EPA-Van has been used and displayed throughout the country since its completion is 1976.

As demonstrated by these fuel cell projects, EPA believes that fuel cells hold great promise as pollution-free energy generation systems, and EPA will continue to advise researchers on the environmental implications of future fuel cell energy systems.

CHAPTER 17

SITING CRITERIA AND PRELIMINARY SCREENING OF COMMUNITIES FOR ALTERNATE ENERGY USE

CHAPTER 17

SITING CRITERIA AND PRELIMINARY SCREENING OF COMMUNITIES FOR ALTERNATE ENERGY USE

INTRODUCTION

The summaries below discuss some of the siting factors useful in interpreting Table 17-1 at the end of the Chapter. Chapters 13 through 16 provide addition information which should be considered in actual site selection.

Three of the four alternate energy technologies discussed in this chapter are dependent on local sources of renewable energy for siting: wind having an average annual speed of 10.4 knots (about 12 miles per hour) for wind energy conversion systems; water with an adequate flow and head from lakes, streams or springs for very small hydroelectric generators; and geothermal springs having temperatures up to 150° C for low temperature geothermal home space heating units. Fuel cells, capable of using a variety of fuels (predominantly nonrenewable hydrocarbons), are not necessarily dependent on local energy sources and could be located effectively almost anywhere as long as the electric demand is adequate to use the energy produced by the 40 Kw unit. Communities with populations of 100 or more are considered the possible candidates for fuel cell electric power development. Fuel cells probably won't be available "off-the-shelf" until 1986 or later.

SITING WIND ENERGY CONVERSION SYSTEMS (WECS)

To date, average yearly wind speeds are known to have been measured in 59 Alaskan communities of the 365 listed in Table 17-1. Measurements were made predominantly for airport-related needs. Not enough is known about the wind resource in 306 of the places listed to determine whether a wind machine would have enough wind to reliably produce electricity. In order to develop Alaska's wind resources, the wind needs to be measured with an anemometer over a period of time (at least a year, possibly longer) by communities considering the use of wind as an alternative energy source.

Local disfiguration of vegetation may also prove useful in estimating average annual wind speeds.

When possible, most Alaskan communities are situated in such a manner that the houses and other permanent structures are protected from the wind because living in a windy area is considered undesirable. However, many places may have a local wind energy source a short distance from the area of settlement. A minimum average annual wind speed of 10.4 knots (12 mph) can serve as one general indication of site suitability. However, systems designed for lower average wind speeds may be feasible in areas with less wind if the cost of energy from existing sources is high. Table 17-2 shows the wind speeds and electrical outputs for three selected wind turbines. All three begin to charge at 6 to 8 mph and reach maximum electrical outputs at 23 to 29 mph.

Of course, average yearly wind speeds are only one consideration in determining whether the wind in a given location is adequate for a certain wind machine. The entire wind regime, including the speed by percent of total time the wind blows, and the seasonality of the wind, determines the extractable wind energy. Some of the smaller wind generators have minimum speeds below which the amount of electricity produced is unacceptable.

The wind speed generally increases with height. The widely applied rule-of-thumb for selecting a tower height is that the tower be 15 to 25 feet above obstructions within a 300- to 500-foot radius.

The wind resources should generally be within two miles of use for larger systems (serving several families) for the required power transmission lines to be cost effective. Small (one or two family) systems should probably be no further than about one-quarter of a mile, from the point of use. A longer distance would require a transmission system which would probably be too costly to be feasible.

Wind resources adequate to justify siting a wind energy conversion system may often be found along ridges; on the tops of isolated hills, on cliffs, buttes and mountains; in valleys, basins and canyons; and along islands and unsheltered points along the coastline. Presently only 26 communities of a total of 365 are known to have average yearly wind speeds of 10.4 knots or more. All are thought to be likely candidates for alternate wind energy use. The Arctic, Northwest and Southeast Regions seem to have the most wind resources. Not one Interior Region community appears to have adequate wind energy resources although wind turbines are known to have been installed in Interior communities (Figure 15-2 of the wind machine at Eagle). The major cause for dissatisfaction with wind machines by users has been found to be the lack of adequate wind resources. This problem can sometimes be corrected by siting the WECS at a different location where an adequate source of wind is available. Corrective measures cannot be made when there is not adequate wind.

A helpful source of WECS siting information is A Siting Handbook for Small Wind Energy Conversion Systems by Harry L. Wegley, Montie M. Orgill and Ron L. Drake prepared for Battelle Pacific Northwest Laboratory at Richland, Washington and published in May, 1978. Unfortunately, coastal sites are not discussed in detail in the handbook.

SITING VERY SMALL HYDROPOWER GENERATORS

Although numerous studies on Alaska's larger hydropower sites have been prepared by federal agencies over the past seventy years or so, no inventories have been made of the smaller potential hydro sites. (See Appendix 8-A, Alaska's Hydroelectric Resources Inventory, Preliminary Report.) Whereas the larger waterways can be assessed initially by using topographic maps, aerial photos and other office engineering techniques, even preliminary studies of sites under 1.5 MW need to be evaluated in the field at the point of planned power generation.

Of course, a small amount of water can be harnessed from Alaska's larger water courses to produce relatively small amounts of electricity by very small hydroelectric generators for individual community use. But, the suitability (reliable volume of water and head) of small creeks, lakes and springs for year round use is largely unknown and unrecorded and will probably only be measured on an "as needed" basis. William Delp suggests that, with the DC to AC approach, power transmission will be cost effective for distances of up to three miles.

The preliminary evaluation of Alaskan communities for the applicability of very small hydropower development is based on the assumption that most communities in Alaska are located near waterways. It is also assumed that in the Southern part of Alaska there is enough precipitation and a mild enough climate to assure a year-round source of water for very small hydroelectric power applications. For this first cut and preliminary evaluation, the study team's "best guess" approach revealed that very small hydro applications are considered likely in about one third, or 115 sites, of the 365 identified Alaska Settlements shown in Table 17-1. Most of the likely communities are located in the Southcentral and Southeast Regions and are within a mile of a fairly large source of inland water. Due to the scarcity of fluid water during winter months, no potential year round sites within approximately a mile of Arctic and Northwest Region settlements are thought to exist. More information is needed to identify and evaluate potential sites in the Interior and Southwest Regions which may have potential for development.

SITING LOW TEMPERATURE GEOTHERMAL SPACE HEATING SYSTEMS

Of the alternate energy technologies discussed which are entirely dependent on local sources, the one having the most limited application in Alaska is low temperature geothermal. This is due to the limited availability of thermal springs near Alaskan settlements. Presently only about 100 geothermal springs are known in Alaska and only 39 of these appear to be close enough to areas of settlement (within 30 miles) to be useable for space heating purposes. More field information may add as many as 29 additional communities to that list. Availability of geothermal resources will probably preclude geothermal development to provide alternative energy for 297 of the identified 365 Alaskan Communities listed by region in Table 17-1.

The Northwest, Interior and Southwest Regions have the largest number of communities considered likely for development of local geothermal resources for residential space heating. No communities in the Arctic Region seem to have this potential because of the scarcity of surface manifestations of the resource.

SITING FUEL CELLS

The major criteria for siting fuel cells as an alternative energy system is the size of the community and its associated power needs. Inasmuch as fuel cells are not dependent on a locally available fuel source such as is needed for wind, hydropower and geothermal systems, a local fuel source isn't a siting condition. However, the community must have the capability of receiving and storing naptha, propane or whatever fuels are used in the fuel cells.

It is assumed for this preliminary evaluation that Alaskan communities must have a present population of at least 100 persons to make the 40-Kw fuel cell reasonably cost effective. Using this population size as a guide, over 60 percent of the communities listed in Table 17-1 are considered likely locations to utilize fuel cells. The population is too small in 101 places for fuel cells to be considered effective and more information is needed for 39 communities to determine whether fuel cells are an appropriate alternative energy application.

Fuel cells are judged appropriate for use in all regions in Alaska. At least half of the communities in each region listed in Table 17-1 are considered potential places for future use of fuel cells, that is, beyond the year 1986, or so, when fuel cell technology is expected to be available off-the-shelf.

EVALUATION OF SYSTEM APPLICABILITY

Table 17-1 is a preliminary evaluation which lists the appropriateness of using four alternative energy applications for 365 Alaskan communities. Each community is listed alphabetically, by Man-in-the-Arctic Region. The alternative energy applications are coded "H" for very small hydropower generators; "G" for low temperature geothermal systems for home space heating; "W" for wind energy conversion systems, and "F" for fuel cells.

Useability at each community site is listed as either "L" for likely or potential future use, "U" for unlikely future use, or "M" for more information needed to determine use potential. These categories are somewhat vague due to the present unavailability of complete and accurate information to make more positive judgements. The wind for example, is listed as an "unlikely future use" at the village of Wainwright in the Arctic Region. This could be because the wind speed measurements were not taken at the most propitious location to determine whether the wind resource is indeed adequate for use there. Rather than judge wind energy conversion system use at Wainwright unqualifiedly "not for future use," winds are evaluated as "unlikely future use." This leaves room for more information, but indicates the prospects for using wind as an alternate energy resource are not good. The site evaluations on Table 17-1 should be considered as indicators of applicability rather than the final word. As more information becomes available the Table will be updated.

Future use for fuel cells, as shown on the Table, is thought to be beyond 1986 when it is anticipated that hardware will be available in the marketplace. Future use for other alternate energy systems is beyond 1979.

At the end of Table 17-1 are regional and statewide summaries of the usability of the four alternative energy systems totaled by "likely," "unlikely" and "more information needed" categories. In the Arctic Northwest, Interior and Southwest Regions the summaries most often point out fuel cells as a likely alternative energy application (of the four listed) for use on a regional basis. In the Southcentral and Southeast Regions, very small hydropower is considered the most likely for use of the four categories. The Southwest Region, with 125 of the 365 communities listed on the Table, has the largest total number of communities and the Arctic Region, with 13 settlements, has the fewest. Further, from among the six regions there is less known about the potential for use of alternate energy applications in the Southwest Region than any other region. Wind is the alternative energy application where decidedly more information is needed in every region except in the Interior where very small hydropower needs to be investigated in more communities.

With 225 communities on a statewide basis, fuel cells, are most often considered likely for use. Very small hydropower is second most likely with 115 communities. Low temperature geothermal is third most likely with 39 communities and wind, with 26, is considered the fourth most likely alternative energy application. Most unlikely for use is low temperature geothermal for home heating with 297 communities tentatively ruled out; second most unlikely is fuel cells with 101 communities listed; third most unlikely is wind energy conversion systems with 33 communities listed. Wind energy conversion systems have the largest number of communities, with 306, where more information is needed to determine use potential; very small hydropower technology has the second largest number of communities, with 174, where more information is needed to determine use; fuel cells, with 39 communities, and geothermal, with 29 communities, have the third and fourth largest number of communities where more information is needed to determine use.

PRELIMINARY EVALUATION OF 365 ALASKAN COMMUNITIES FOR SELECTED ALTERNATE ENERGY APPLICATIONS

KEY

ALTERNATE ENERGY APPLICATIONS
- H-Very Small Hydropower
- G-Low Temperature Geothermal for Space Heating
- W-Wind Energy Conversion Systems (WECS)
- F-Fuel Cells

USEABILITY OF APPLICATION AT SITE
- L-Likely future use
- U-Unlikely future use
- M-More information needed to determine use.

Note: Future use means beyond 1978 except fuel cells future use is beyond 1986 or so.

ARCTIC REGION

H	G	W	F	
U	U	M	L	Anaktuvuk Pass
U	U	M	L	Arctic Village
U	[illegible]	M	U	Atkasook (Meade River)
U	[illegible]	L	L	Barrow
U	U	M	L	Deadhorse
U	U	L	L	Kaktovik (Barter Island)
U	U	U	M	Lonely
U	L	M	L	Nuiqsut
U	L	L	L	Point Hope
U	L	L[3]	U	Point Lay
U	U	M	L	Prudhoe Bay
U	U	U	M	Umiat
U	U	U	L	Wainwright

NORTHWEST REGION

H	G	W	F	
U	U	M	L	Ambler
U	U	M	L	Brevig Mission
U	U	M	L	Buckland
U	U	M	U	Candle
U	U	L	U	Cape Lisburne
U	L	M	U	Council
U	L	M	L	Deering
U	L[4]	M	L	Elim
U	U	L	L	Gamble
U	L	M[1]	L	Golovin
U	U	M	L	Ignalik (Diomede)
U	L	M	L	Kiana
U	U	M	L	Kivalina
U	M	M	U	Kobuk

NORTHWEST REGION CONTINUED

H	G	W	F	
U	U	L[3]	L	Kotzebue
U	L	M	L	Koyuk
U	U	M	L	Little Diomede Island
U	M[4]	L	M	Moses Point
U	U	M	L	Noatak
U	M	M	L	Nome
U	U	M	L	Noorvik
U	M	L	M	Northeast Cape
U	U	M	L	St. Michael
U	U	M	L	Savoonga
U	U	M	L	Selawik
U	U	M	L	Shaktoolik
U	U	M	L	Shishmaref
U	M	M[2]	L	Shungnak
U	U	M	U	Solomon
U	U	M	L	Stebbins
U	M	M	L	Teller
U	U	L[3]	L	Unalakleet
U	U	M[2]	L	Wales
U	M	M	M	White Mountain

INTERIOR REGION

H	G	W	F	
M	L	M	U	Alatna
M	L	M	L	Allakaket
M	U	M	L	Anderson
M	U	M	M	Aurora
M	U	M	M	Beaver
M	U	M	U	Bettles (Evansville)
M	U	U[3]	L	Big Delta

INTERIOR REGION CONTINUED

H	G	W	F	
M	U	M	U	Birch Creek
M	U	M	M	Cantwell
M	L	M	U	Central
M	U	M	U	Chalkyitsik
M	L[3,4]	M	U	Chena
M	U	M	U	Chicken
M	U	M	U	Circle
M	L[3,4]	M	U	Circle Hot Springs
M	U	M	U	Clear
M	U	M	M	College
M	U	M	L	Crooked Creek
M	U	M	L	Delta Junction
M	U	M	U	Dot Lake
M	U	M[3]	L	Eagle
M	M	M	M	Eagle Village
M	U	M	L	Eielson AFB
M	U	M	L	Ester
M	U	U	L	Fairbanks
M	U	M	L	Fort Greely
M	U	M	L	Fort Wainwright
M	U	U	L	Fort Yukon
M	U	U	L	Galena
M	M	M	M	Graehl
M	U	M	U	Healy
M	U	M	U	Healy Lake
M	U	M	L	Hughes
M	U	M	L	Huslia
M	U	M[1]	L	Kaltag
M	U	M	L	Koyukok
M	U	M[2]	U	Lake Minchumina
M	L	M[1]	U	Livengood
M	L[3,4]	M[1]	U	Manley Hot Springs

INTERIOR REGION CONTINUED

H	G	W	F	
M	L	M	L	Minto
M	U	M	L	Moose Creek
M	U	U	L	Nenana
M	U	M	U	New Koyukuk
M	U	M	L	North Pole
M	U	U	L	Northway
M	U	M	L	Nulato
M	U	M[3]	M	Poorman
M	L	M	U	Rampart
M	L	M[1]	L	Ruby
M	U	M	U	Stevens Village
M	U	M	U	Suntrana
M	U	M[2]	L	Tanacross
M	U	U	L	Tanana
M	U	M	L	Tetlin
M	U	M	L	Tok
M	U	M	U	Usibelli
M	U	M	L	Venetie
M	U	U	U	Wiseman

SOUTHWEST REGION

H	G	W	F	
M	L[4]	L	L	Adak
M	U	M	L	Akiachak
M	U	M	L	Akiak
M	U	M	L	Akolmuit
M	L	M	U	Akutan
U	U	M	L	Alakanuk
M	U	M	L	Aleknagik
U	U	M	L	Andreafski

TABLE 17-1 (Cont.)

PRELIMINARY EVALUATION OF 365 ALASKAN COMMUNITIES
FOR SELECTED ALTERNATE ENERGY APPLICATIONS

SOUTHWEST REGION CONTINUED

H	G	W	F	
M	U	U	L	Aniak
M	U	M	L	Anvik
M	L	L	M	Atka
M	U	M	L	Atmautluak
M	L	L	U	Attu Island
M	L	M	U	Belkofsky
M	U	L	L	Bethel
M	U	M	M	Cape Newenham
M	U	L	M	Cape Romanzof
M	L	L	U	Cape Sarichef
M	U	M	U	Chanilliut
U	U	M	L	Chefornak
U	U	M	L	Chevak
M	M	M	U	Chignik
M	M	M	M	Chignik Lagoon
M	M	M	M	Chignik Lake
U	U	M	L	Choolunawick
M	U	M	L	Chuathbaluk
M	U	M	M	Clarks Point
M	L	L	M	Cold Bay
M	U	M	L	Crooked Creek
M	U	M[2]	L	Dillingham
M	U	M	L	Eek
M	U	M	L	Egegik
M	U	M	U	Ekuk
U	U	M	L	Emmonak
M	U	M	L	Ekwok
M	L	M	M	False Pass
M	L	M[1]	U	Flat
M	L	L	M	Fort Glen
M	U	M	L	Fortuna Ledge
M	U	M	L	Goodnews Bay (Mumtrak)
M	U	M	L	Grayling
U	U	M	U	Hamilton
M	U	M	U	Holitna
M	U	M	L	Holy Cross
U	U	M	L	Hooper Bay
M	U	M	U	Igiugig
M	M	M[2]	U	Iliamna
M	U	M	U	Ivanoff Bay

SOUTHWEST REGION CONTINUED

H	G	W	F	
U	U	M	L	Kalskag (Lower)
U	U	M	L	Kalskag (Upper)
M	U	M	U	Kanakanak
M	M	M	L	Kasigluk
M	L	M	L	King Cove
M	U	M	L	King Salmon
U	U	M	L	Kipnuk
M	U	M	M	Kokhanok (Kakhonak)
M	U	M	L	Koliganek
M	U	M	L	Kongiganak
U	U	M	L	Kotlik
M	U	M	L	Kwethluk
U	U	M	L	Kwigillingok
M	U	M	L	Levelock
M	U	M	U	Lime Village
M	U	M	L	Manokotak
U	U	M[34]	L	Marshall (Fortuna Ledge)
M	U	U	L	McGrath
M	U	M	U	Medfra
U	U	M	L	Mekoryuk
U	U	M	L	Mt. Village
M	U	U	L	Naknek
M	U	M	M	Napaimiut
M	U	M	L	Napakiak
M	U	M	L	Napaskiak
M	L	M[3]	U	Nelson Lagoon
M	U	M	U	New Knockhock
M	U	M	L	New Stuyahok
M	U	M	M	Newhalen
U	U	M	L	Newtok
U	U	M	L	Nightmute
M	U	M	M	Nikolai
M	L[4]	L	U	Nikolski
M	U	M	L	Nondalton
M	M	L	M	Nunivak Island
U	U	M	L	Ohogamuit
M	U	M	M	Olgsenakale
M	L[34]	M	U	Ophir
M	U	M	U	Oscarville
M	U	M	U	Pauloff Harbor

SOUTHWEST REGION CONTINUED

H	G	W	F	
M	U	M	U	Pedro Bay
M	U	M	L	Perryville
M	U	M	M	Pilot Point
U	U	M	L	Pilot Station
U	U	M	M	Pitka's Point
M	U	L	U	Platinum
M	U	L	U	Port Heiden
M	M	M	U	Port Moller
M	U	M	M	Portage Creek
M	U	M	L	Quinhagak
M	U	M	U	Red Devil
U	U	M	L	Russian Mission
M	U	M	L	St. George
U	U	M	L	St. Marys
M	U	L	L	St. Paul
M	U	M	U	Sanak
M	U	M[2]	L	Sand Point
U	U	M	L	Scammon Bay
M	U	M	L	Shageluk
M	U	M	U	Shageluk (Old)
U	U	M	L	Sheldon's Point
M	U	L	L	Shemya AFB
M	U	M	L	Sleetmute
M	U	M	L	South Naknek
M	U	M	U	Squaw Harbor
M	U	M	M	Stony River
M	U	M	U	Takotna
M	U	M	U	Telida
M	U	M	L	Togiak
U	U	M	L	Toksook Bay
M	M	M	L	Tuluksak
M	U	M	L	Tuntutuliak
U	U	M	L	Tununak
M	U	M	U	Twin Hills
M	U	M[3]	U	Ugashik
M	L	M	L	Unalaska

SOUTHCENTRAL REGION

H	G	W	F	
L	U	M	L	Akhiok
L	U	U	L	Anchorage
L	U	M	L	Anchor Point
U	U	M	L	Basher
L	U	M	L	Bell Flats
L	U	M	L	Birchwood
L	U	M	L	Butte
L	U	M	U	Cape Chiniak
L	U	M	U	Chistochina
L	U	M	U	Chitna
L	U	M	L	Chugiak
L	U	M	U	Clam Gulch
L	U	M	M	Cohoe
L	L	M	L	Copper Center
L	U	U	L	Cordova
L	U	M	L	Eagle River
L	U	M	U	Eklutna
L	U	U	L	Elmendorf AFB
L	U	M	L	English Bay
L	U	M	U	Eyak
L	U	M	L	Fire Lake
L	U	U	L	Fort Richardson
M	U	M	U	Gakona
L	U	M	L	Girdwood
U	U	M	L	Glen-Alps
M	L	M	L	Glennallen
M	M	U	U	Gulkana
M	U	M	U	Halibut Cove
L	U	U[3]	L	Homer
L	U	M[3]	U	Hope
M	U	M	L	Houston
M	U	M	L	Kachemak
M	U	M	L	Karluk
L	U	M	U	Kasilof
L	U	U	L	Kenai
M	U	M	L	Kenny Lake
L	U	M	M	Knik
L	U[3]	M	L	Kodiak
L	U	U	U	Kodiak Coast Guard Station
L	U	M	L	Larson Bay

TABLE 17-1 (Cont.)

PRELIMINARY EVALUATION OF 365 ALASKAN COMMUNITIES
FOR SELECTED ALTERNATE ENERGY APPLICATIONS

SOUTHCENTRAL REGION CONTINUED

H	G	W	F	
M	U	M	L	Meakerville
M	U	M	U	Mentasta Lake
M	U	L	U	Middleton Island
L	U	M	M	Moose Pass
M	L	M	U	Nebesna
M	M	M	L	Nikolaeusk
L	U	M	L	Ninilchik
L	U	M	L	Old Harbor
L	U	M	L	Ouzinki
L	U	U[3]	L	Palmer
M	U	M[34]	U	Paxson
L	U	M	L	Port Graham
L	U	M	L	Port Lions
L	U	M	M	Salamatoff
L	U	M	L	Seldovia
L	U	M[3]	L	Seward
M	U	M[2]	U	Skwentna
L	U	M	L	Soldotna
L	U	M[3]	L	Spenard
L	U	M	L	Sterling
M	U	M[2]	U	Summit
L	U	M	M	Sunrise
L	U	M	U	Sutton
L	U	U	L	Talkeetna
L	U	M	L	Tatitlek

SOUTHCENTRAL REGION CONTINUED

H	G	W	F	
M	M	M	U	Tazlina
M	M	L	L	Tin City
M	M	M	M	Tonsina
L	M	M	L	Tyonek
L	M	M	U	Uganik
L	U	U	L	Valdez
L	U	M	L	Wasilla
L	U	M	L	Whittier
L	U	M	L	Willow
L	U	M	U	Woody Island
L	U	U	M	Yakataga

SOUTHEAST REGION

H	G	W	F	
L	U	M	L	Angoon
L	U	M	L	Annette
L	U	M	L	Auke Bay
L	L[34]	M	U	Bell Island Resort
L	M	M	U	Biorka Island
L	U	M	L	Cape Pole
L	U	M	L	Charcoal Point
L	U	M	U	Chatham
L	U	M	L	Clover Pass

SOUTHEAST REGION CONTINUED

H	G	W	F	
L	U	M	L	Craig
L	U	M	L	Douglas
L	U	M	L	Edna Bay
L	U	M	U	Elfin Cove
L	U	M	M	Excursion Inlet
L	U	M	L	Fritz Cove
L	U	M	U	Glacier Bay
L	U	U	U	Gustavus
L	U	U[3]	L	Haines
L	U	M	L	Hamilton Bay
L	U	M	L	Hawk Inlet
L	U	M	L	Herring Cove
L	U	M	M	Hollis
L	L	M	L	Hoonah
L	M	M	L	Hydaburg
L	U	M	U	Hyder
L	U	U[3]	L	Juneau
L	U	M	L	Kake
L	U	M	L	Kaasan
L	U	M[1]	L	Ketchikan
L	U	M	L	Klawock
L	U	M	L	Klukwan
L	U	M	U	Kupreanof
L	M	M	L	Lemon Creek
L	U	M	L	Lena Beach

SOUTHEAST REGION CONTINUED

H	G	W	F	
L	U	M	L	Mendenhall
L	U	M	L	Metlakatla
L	U	M	L	Mountain Point
L	L	M	L	Mud Bay
L	U	M	U	Myers Chuck
L	U	M	L	North Douglas
L	M	M	L	Pelican
L	U	M	U	Pennock
L	U	U	L	Petersburg
L	U	M	U	Point Baker
L	U	M	U	Port Alexander
L	U	M	L	Port Chilkoot
L	U	M	L	Refuge Cove
L	U	M	U	St. John
L	U	M	L	Saxman
L	U	M	L	Scow Bay
L	U	M	U	Shakan Bay
L	L	U	L	Sitka
L	U	U	L	Skagway
L	L[34]	M	L	Tenakee Springs
L	U	M	L	Thane
L	U	M	L	Thorne Bay
L	U	M	L	Ward Cove
L	U	M	U	West Petersburg
L	M	M	L[2]	Wrangell
L	U	U	L	Yakutat

Notes:

1. Some data have been obtained. For more information, contact Dr. Tunis Wentink, Geophysical Institute, University of Alaska, Fairbanks, Ak.
2. Some data have been obtained. For more information, contact James Wise, Climatologist, University of Alaska, Arctic Environmental Information Data Center, Anchorage, Alaska.
3. Alternate Energy Technology has been or is being used.
4. See appropriate chapter in text.
5. See appendix for detailed wind data.

REGIONAL AND STATEWIDE SUMMARIES

ARCTIC REGION

	H	G	W	F
L	0	0	4	9
U	13	13	3	2
M	0	0	6	2
Tot.	13	13	13	13

INTERIOR REGION

	H	G	W	F
L	0	10	0	29
U	0	46	8	22
M	58	2	50	7
Tot.	58	58	58	58

NORTHWEST REGION

	H	G	W	F
L	0	6	6	26
U	34	21	0	5
M	0	7	28	3
Tot.	34	34	34	34

STATEWIDE

	H	G	W	F
L	115	39	26	225
U	76	297	33	101
M	174	29	306	39
Tot.	365	365	365	365

SOUTHCENTRAL REGION

	H	G	W	F
L	55	3	2	47
U	2	66	12	23
M	19	7	62	6
Tot.	76	76	76	76

SOUTHEAST REGION

	H	G	W	F
L	60	5	0	43
U	0	50	7	15
M	0	5	53	2
Tot.	60	60	60	60

SOUTHWEST REGION

	H	G	W	F
L	0	15	14	72
U	27	102	3	34
M	98	8	108	19
Tot.	125	125	125	125

CHAPTER 18

WOOD RESIDUE

CHAPTER 18
WOOD RESIDUE

INTRODUCTION

People have long used wood in construction, for tools, and as fuel. With increasing industrialization, the uses of wood have grown, as has the quantity of wood discards. Fortunately, a corresponding advance in technology has absorbed much of this increase in wood residues.

With increasing pressure on world energy resources, greater attention has been focused on reducing waste. The utilization of a larger portion of wood residue is a means of both conservation and substitution of wood for nonrenewable fuels.

This chapter will place its emphasis on the wood residues, although a complete separation of wood utilization and wood residues is impossible. The history, technology, applicability to Alaska, and environmental impact will be examined.

BACKGROUND

The use of wood as fuel was one of the earliest technological developments of humans. Undoubtedly, a portion of this fuel was discarded from other utilizations of wood. As technology advanced, the quantity of wood "wastes" increased, followed by new ways of using these discards.

Fuel shortages are not something new. They were experienced in cultures and areas as distant as England during the 16th century and what is now the western part of Peru. Each discovered that the forests were unable to keep pace with growing energy demands and they were forced to cut back their consumption. With only enough fuel for cooking, the space heating of homes was abandoned (National Science Teachers Association, 1978).

Wood still accounts for 90 percent of the fuel used in developing countries. A poor man's energy crisis is evident in many parts of the world as the number of people dependent on wood for energy (currently 1.5 billion) grows and supplies dwindle. Wood supplies three-fifths of all energy used in Africa, over two-fifths in the Far East (excluding China), one-fifth in Latin America, and 14 percent in the Near East (Whiting, 1978).

Wood still supplied over 90 percent of the United States' energy during the mid-1800's before the nation converted to coal. The possibility of developing trees specifically for fuel was given considerable attention during the 1940's (Fowler, John and Kathryn, ND).

During World Wars I and II, when gasoline shortages occured in Germany and France, vehicles of all sorts used wood burners in the rear or in trailers. Wood chips were distilled to make alcohol vapors that included carbon monoxide and hydrogen; these vapors would drive the vehicle. In 1938, 9000 wood-burning cars were used in Europe. "Power alcohol" (ethanol) was also used by France and Germany to supplement gasoline supplies and stimulate alcohol production for anticipated use in munitions production (Anderson, 1976).

Although "wood wastes" is an accepted term for discarded wood, it should be mentioned that it carries contradictory connotations. Waste is useless, superfluous, and usually involves a cost for its collection and disposal. Residues, however, are what is left after part has been taken away. Residues often have some positive value, as is the case with most wood discards which, for example, produce benefits when returned to the soil. While these benefits may not warrant commercial exploitation, they nonetheless require consideration when examining alternative uses for wood residues (Fowler, ND).

Residues can be classified generally as logging residue; forest residue, which includes both logging residue and other unused material in the woods; primary mill residue, such as from sawing or veneer peeling; secondary plant residue, which originates from manufacturing operations such as mill work and furniture production and is usually dry and bark-free; and urban wood residue.

National forest residue has been estimated to be about 9.6 billion cubic feet:

Logging Residue	3.6 billion cu. ft.
Insect, Disease, and Fire-damaged Timber	4.5 billion cu. ft.
Pre-commercial Thinnings	1.5 billion cu. ft.
Total	9.6 billion cu. ft.

Logging residue in the Pacific Northwest is especially high, averaging 57 dry tons per acre on national forest timber sale areas in the Coastal Douglas-fir region (material less than 4 inches in diameter and 4 feet in length was not included). Figure 18-1 provides a rough breakdown of the parts of a tree showing those parts that are often left as residue.

The marginal or submarginal economic value of forest residue severely limits its recovery. To reduce waste and environmental impact, some areas require YUM (yarding unutilized material), also known as PUM (piling unutilized material), total yarding, and gross volume yarding. With yarding investments already made, the operator is required to remove all material down to a specified size which would probably not otherwise be removed. This provides the opportunity for the salvage of additional material, more efficient burning of YUM piles, and some other environmental advantages (Estep, 1973).

The use of primary mill residues has increased dramatically during the last quarter century. Table 18-1 shows 1970 unused residues at 26 percent. This growing usage has been shared across the nation; four-fifths of the fuelwood residues were used on the Pacific Coast. It was predicted in 1974 that essentially all coarse softwood residue (slabs, edgings, veneer cores, and other plant residues suitable for chipping) and a substantial portion of the hardwood residues will be utilized, primarily for pulp and particleboard (Estep, 1973) (Figure 18-2). In 1972, 92 percent of the primary mill residue was already being used in the State of Washington (Grantham, 1974).

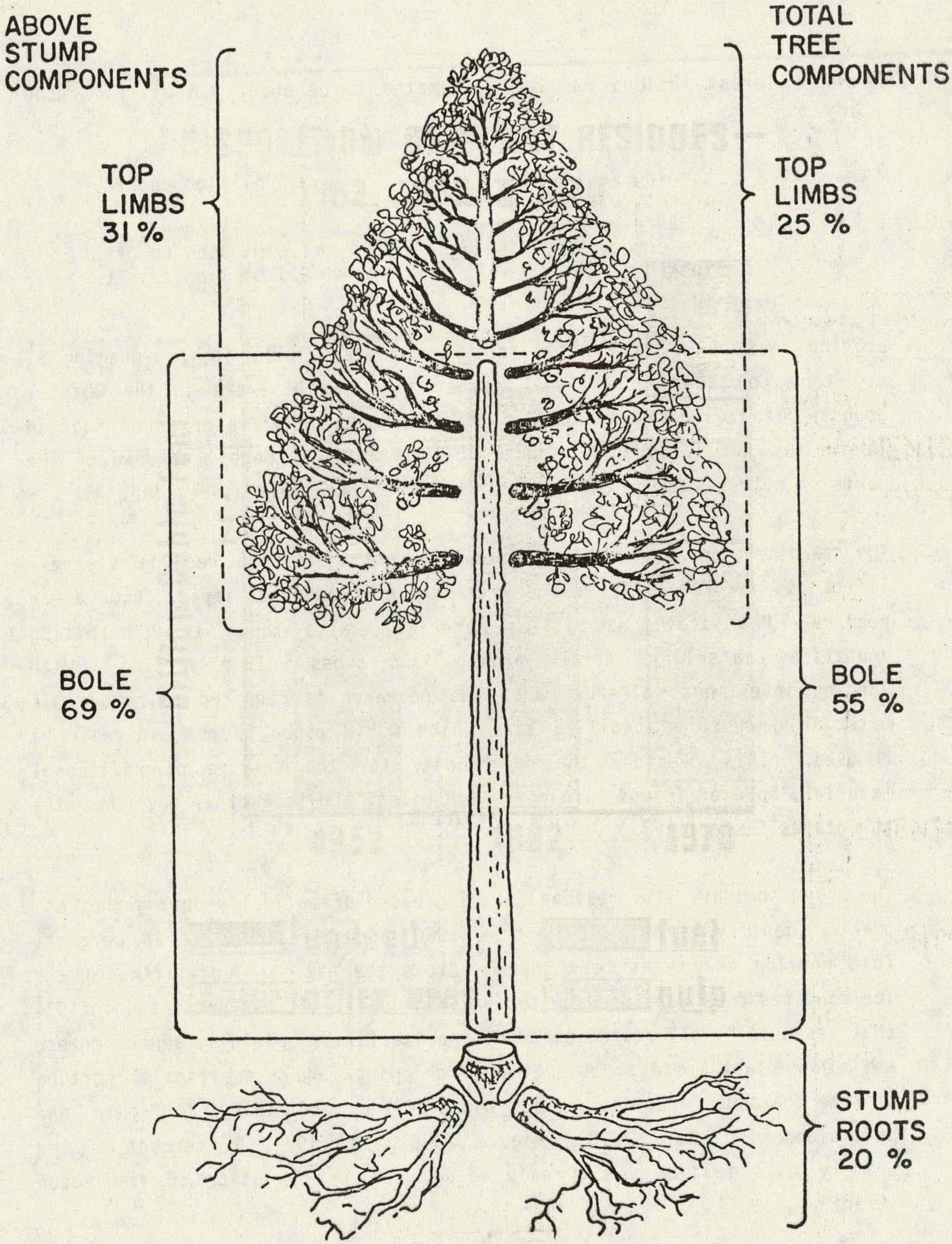


Figure 18-1

Component Proportions of Fresh Weight of Complete Trees and Shrubs

Source: North Central Forest Experiment Station, Forest Service - U.S. Department of Agriculture, St. Paul, Minnesota, Forest Residues Energy Program, March 1978, p. 114.

TABLE 18-1

RESIDUES AT PRIMARY WOOD PROCESSING PLANTS IN THE U.S.
USED FOR BY-PRODUCTS AND UNUSED, 1970 (MILLION CUBIC FEET)

Item	All Species		Softwoods		Hardwoods	
	Volume	Percent	Volume	Percent	Volume	Percent
Used:						
Pulp	1,773	46.6	1,514	49.9	259	33.7
Fuel	776	19.1	599	19.7	127	16.5
Other Products	313	8.2	241	7.9	72	9.4
Total Used	2,813	73.9	2,354	77.5	459	59.6
Unused:						
Coarse	403	10.6	270	8.9	132	17.2
Fine	591	15.5	412	13.6	179	23.2
Total Unused	993	26.1	682	22.5	311	40.4
TOTAL RESIDUES	3,806	100.0	3,036	100.0	770	100.0

Source: Eldon M. Estep, U.S. Forest Service, "Wood Residue--What and Where," Presented at annual meeting of Midwest Section of Forest Products Research Society, October 9-10, 1973.

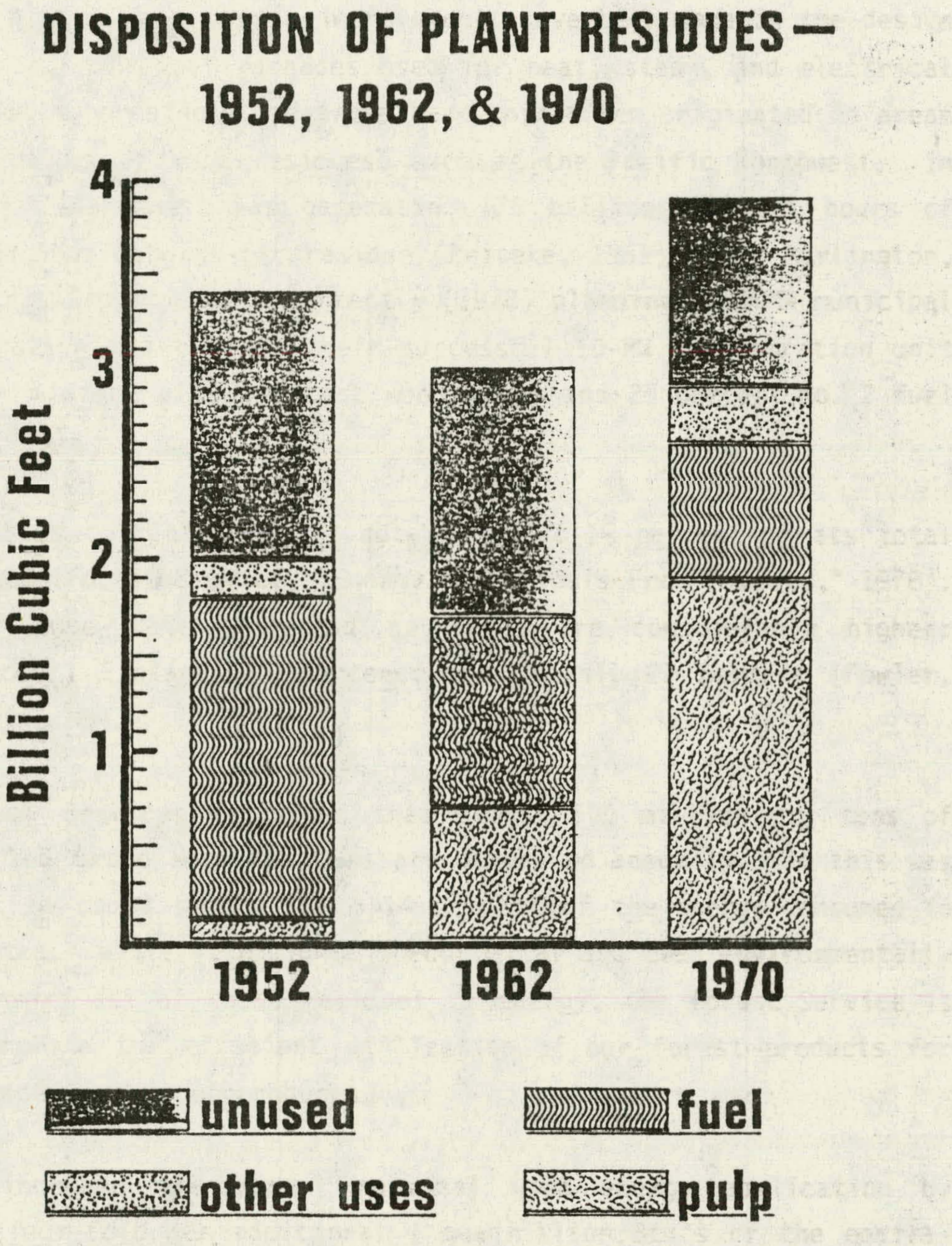


Figure 18-2

Source: Eldon M. Estep, U.S. Forest Service, "Wood Residue - What and Where," Presented at annual meeting of Midwest Section of Forest Products Research Society, October 9-10, 1973.

While bark represents a substantial part of the wood residue (69 percent in 1970), rising demand and advancing technology has led to its increasing utilization as fuel, mulches, livestock bedding, charcoal, and in particleboard.

Since secondary plants are generally small and widely scattered, statistics on residual generation are not readily available. Estimates are that 900 million cubic feet of secondary plant residue are produced annually in the United States. A survey in the Midwest reveals that 30 percent is used as fuel there (Estep, 1973).

The energy of wood can also be captured when the finished product is eventually discarded. Wood comprises 5 percent of the organic portion of municipal garbage and paper makes up about half of it. The remaining 5 percent is from plastic and 17 percent from food discards. While contributing only half the weight, paper provides over two-thirds of the total heat value. This is not meant to suggest that more energy would be saved by burning these wood products than recycling them.

Many European cities burn garbage to produce process steam and steam for space heating. During recent years several cities in the United States have begun burning garbage to generate electricity and/or steam (Fowler, ND). The Muncipality of Anchorage, Environmental Protection Agency, Fort Richardson, and Elmendorf Airforce Base have funded a study to determine the feasibility of burning garbage from the Anchorage Bowl to generate electricity. The system would utilize a shredder presently under construction and existing boilers at Fort Richardson (Brust, 1978).

The use of wood for heating has resulted in rapid advances in wood-burning equipment and methods, especially during the last few decades. While ordinary fireplaces may lose 90 percent of the heating value of the wood, correct use of a chimney damper, proper building materials, and efficient circulation design will reduce this loss substantially (Reineke, 1961). By comparison, an efficient wood stove will lose only about 25 percent (Roberts, 1978). Efficient, slow-combustion stoves have been used for some time in Europe. Although a few were imported in the late thirties, American designers have been slow to adopt the European innovations.

As with the home application of wood combustion, based upon a better understanding of how wood burns, improvements have been made in the design of industrial and municipal furnaces used for heat, steam, and electrical generation. Not surprisingly, advances have most often originated in areas with large supplies of wood residues, such as the Pacific Northwest. In 1924 the Pacific Northwest was generating 175 billion kilowatt hours of electric power from Douglas-fir residue (Reineke, 1961). The Burlington, Vermont, Electric Department is currently (1978) planning a 50-MW municipal electric generation plant after their successful 10-MW demonstration unit which burned a mixture of 75 percent wood chips and 25 percent No. 2 fuel oil (Cronin, 1978).

The United States currently (1978) obtains about 1½ percent of its total energy from wood (Forest Service, "Energy & Chemicals From Forests," 1978). Estimates for some other forested countries are considerably higher: Sweden, 8 percent; Finland, 15 percent; and Brazil, 27 percent (Fowler, John and Kathryn, ND).

The U.S. Forest Services estimates that almost 500 million dry tons of forest, mill, and urban wood residues are generated annually. If this was all converted, it could supply 11 to 14 percent of the energy consumed in the United States. While it would be uneconomical and even environmentally unsound to convert all of these residues to energy, the Forest Service is mandated to promote the efficient utilization of our forest products for energy and a wide variety of products.

Planning to increase the annual national wood energy application by approximately four-fold (an additional 4 quadrillion Btu's or the equivalent of 650 million barrels of oil), the Forest Service is examining these areas:

Site specific data on availability and quality of forest residues and urban waste.

Development of a mobile harvester in cooperation with the Department of Energy and Industry for the processing of residues in the field to facilitate transportation.

Feasibility demonstration using mill residues for process steam and direct-firing dry kilns.

Encouragement of gasification and pyrolysis system development.

Promotion of efficient application of industrial and residential wood heating.

Engineering research to improve refuse combustion.

Fuel plantations study.

(Forest Service, "Energy & Chemicals from Forest, 1978)

Various government agencies and the private sector have jointly and separately been developing new ways in which to obtain, process, and utilize wood residues. A few examples include stump pullers, mobile chippers, gasification, wood alcohol (Forest Service, Feb. 1978) and pelletized fuel (Forest Service, May, 1978).

One of the problems associated with energy production from wood residue is the lack of assured long-term supplies. In part this is because of the wide variety of other uses competing for the residues: animal and poultry bedding, floor sweeping compounds, particleboard, charcoal, linoleum, explosives, and plastics (Carpenter, 1977). The United Nations has estimated that wood demand will double by the year 2000 (Galea, 1978).

Energy plantations are a related field of investigation. It has been estimated that 6.5 percent of the United States land area could fuel the nation in 1985. Dr. George Szego calculates that costs would range from \$.30 to \$.45 per million Btu's, depending upon growing conditions. This compares to 1976 coal prices of \$.75 and oil prices of \$2.00 per million Btu's (Fowler, John and Kathryn, ND).

WOOD RESIDUE ENERGY TECHNOLOGY

The use of wood and wood residues for the purpose of space heating has been addressed earlier. Since dry wood has a heating value per pound as great as many of the Alaskan coals, it is not surprising that wood, a renewable resource, has been used even for electrical energy production. In fact, one question which continually surfaces is. . ."Why is wood not used to a greater extent for energy production?" As always, the answer, one way or other, is economics. However, economics of the past may be quite different from economics of the future.

Some steps involved in the use of wood and wood residue for energy are (1) production (growing), (2) recovery (harvesting), (3) transportation and (4) utilization.

While ongoing research on tree growth is very exciting, the scope of this report does not include any detail on this subject. Forest scientists do hope to grow "supertrees" and then harvest them six to eight years later with a "scissors" type of apparatus. The studies addressing wood residue assume that the wood has already been produced and part of it going to waste. Attention has not been given to growing and harvesting.

In Alaska, sources of wood residue may be floating logs in the Yukon (or ocean), cuttings from the clearing of land in the Delta farming region or products from sawmills and the forest products industry at Ketchikan and Sitka.

SLASH EQUIPMENT

With respect to the technology, equipment and methods for the treatment and utilization of slash, Harrison (1975) covers logging, road construction and timber stand improvement slash treatment. The report describes the operations with photographs of the equipment in the field and gives a summary in tabular form. A summary of the treatment and utilization of slash is given in Tables 18-2, 18-3 and 18-4.

TRANSPORTATION

The only area in Alaska where wood residue has been used successfully over a period of time is in communities in the Southeast. These mill residues

TABLE 18-2

TREATING AND UTILIZING LOGGING SLASH

Equipment or Method	Slope limitation (%)	Size limitation: Diameter (in)	Size limitation: Length (ft)	Cost, including support equipment ($/ton)	Point-of-View Acceptability: Aesthetics	Watershed	Fire Mgt.	Timber Mgt.	Engineering	Suitable areas for treatment	Support equipment needed	Most notable shortcomings	Most notable advantages
Tractor crushing	30	4 to 6	None	3.50	3	2	3	3	2	Not recommended	None	Very inefficient	None
Young Tomahawk & ATECO Compactor	30	4 to 6	None	3.10	2	2	2	2	2	Any, within size & slope limitations	Tractor, D6 or larger	Marginal results – treats only brittle material on hard ground	None
Towed Rolling Choppers	20	4 to 8	None	6.80	3	3	2	3	4	Southeastern U.S.	Tractor, D6 or larger	Sensitive to rocks—blades break; treats only soft species	None
Morbark Chiparvestor & Precision Tree Harvester	Limit of skidders	22	None	3.30 (chipping only) 10.00 2/ (total)	1	2	1	1	3	Clear cuts	Truck–tractor, tractor, feller-buncher, & grapple skidders	Large initial investment; must be market for total chips	Very high quality treatment; provides "clean logging"
Nicholson Ecolo Chipper	Limit of skidders	24	None	?	1	2	1	2	3	Any, within size & slope limitations	Grapple skidder	Large initial investment	Very high quality treatment
Tree Eater	20	10	None	?	1	2	1	1	4	Any, within size & slope limitations	None	High down time	Thorough treatment
Wagner–Bartlett Stump Splitter-Remover	Limit of loader	96	None	$3.50/stump	NA 4/	NA	NA	1	1	Any, within size & slope limitations	Loader	Treats stumps only	Best currently available stump treatment tool
Broadcast Burning	None	About 4 1/	None	4.10 3/	5	4	2	4	1	Any	Full fire protection	Incomplete treatment; soil damage; air pollution; high fire escape danger	Inexpensive in terms of area treated ($70/acre)
Pile Burning	30 (Limit of piling tractor)	About 6 1/	None	4.00 3/	4	3	2	3	1	Any, within size & slope limitations	Fire protection	Essentially same as broadcast burning	Simple and easy
DriAll Air Curtain Destructor	Limit of yarding method	96	Length of pit	5.70	1	2	2	2	2	Stable soil	Crane, backhoe	Only for large quantity of unusable material	High quality job; longer burn season than pile burns
Camran Air Curtain Combustion Unit	Limit of yarding method	48	20	8.00	1	1	3	2	3	Any	Truck-tractor	Large initial expense; danger of spot fires	High quality job; longer burn season than pile burns; mobile, no pit needed
Exportation	Limit of yarding method	None	None	?	1	3	1	2	2	Any	Tractor, D8 or larger; stump splitters/removers	Disposal can be impractical	Can lead to utilization
Burying in Cells	30 (Limit of piling tractor)	None	None	3.80	2	4	1	5	1	Areas needing intensive cleanup	Tractors, D4 for piling & pushing; D8 for digging	Removes area from timber production	Hides slash from view

1/ Depends on burning conditions.

2/ Based upon 75 ton/acre lodgepole pine; total slash reduction show—does not include road costs, loading, or hauling chips from site, and does not allow any credit for possible sale of chips (8).

3/ Based upon 140 ton/acre old-growth Douglas-fir logging slash.

4/ Not applicable.

Source: Robin T. Harrison, "Equipment and Methods for Treatment and Utilization." U.S. Forest Service, April, 1975.

TABLE 18-3

TREATING AND UTILIZING ROAD CONSTRUCTION SLASH

Equipment or Method	Slope limitation (%)	Size limitation		Cost, including support equipment ($/ton)	Point-of-View Acceptability				Suitable areas for treatment	Support equipment needed	Most notable shortcomings	Most notable advantages
		Diameter (in)	Length (ft)		Aesthetics	Watershed	Fire Mgt.	Engineering				
Nicholson Ecolo Chipper	Must work from road	24	None	?	2	2	2	3	Any, within size & slope limitations	Grapple skidder	Large initial investment	High quality job
Vermeer 671 Log Chipper	20	30	6	10.00	1	2	2	3	Accessible areas needing intensive cleanup	Tractor, with brush rake & a loader	Applicable only for intense cleanup in landscape mgmt. zones	None
Roy Ecological Demolisher	Must work from road	96	25	?	2	2	2	4	Any, within slope limitation	Crane	Huge initial investment	High quality job
Wagner-Bartlett Stump Splitter-Remover	Limit of loader	96	None	$3.50/stump	NA[2]	NA	NA	1	Any, within size & slope limitations	Loader	Treats stumps only	Best currently available stump treatment tool
Pemco Cable Cruncher	Must work from road	30	None	1.15	3	2	3	2	Any, within size & slope limitations	Crane, 20-ton or larger	Limited to piled slash	None
Pile Burning	Limit of yarding method	About 6[1]	None	4.00	4	3	2	1	Any	Tractor w/rake; fire protection	Incomplete treatment; weather dependent; air pollution	Simple and easy
DriAll Air Curtain Destructor	Limit of yarding method	96	Length of pit	5.70	1	2	1	2	Stable soil	Crane; backhoe	Only for large quantity of unusable material	High quality job; longer burn season than pile burning
Camran Air Curtain Combustion Unit	Limit of yarding method	48	20	8.00	1	1	1	3	Any	Truck-tractor	Large initial expense	High quality job; longer burn season than pile burning; mobile, no pit needed
Exportation	Limit of yarding method	None	None	?	1	3	1	2	Any	Tractor, D8 or larger; stump splitters/removers	Disposal can be impractical	Can lead to utilization
Burying in toe of fill	Limit of yarding method	None	None	4.30	1	2	2	1	Fill area	None	Possibility of degrading road quality, if improperly used	Simple and non-polluting

1/ Depends on burning conditions.
2/ Not applicable.

Source: Robin T. Harrison, "Equipment and Methods for Treatment and Utilization." U.S. Forest Service, April 1975

TABLE 18-4

TREATING AND UTILIZING TIMBER STAND IMPROVEMENT SLASH

Equipment or Method	Slope limitation (%)	Size limitation Diameter (in)	Size limitation Length (ft)	Cost, including support equipment 1/ ($/ton)@(ton/hr)	Point-of-View Acceptability: Aesthetics	Watershed	Fire Mgt.	Timber Mgt.	Engineering	Suitable areas for treatment	Support equipment needed	Simultaneous thinning and treatment	Most notable shortcomings	Most notable advantages
Tractor crushing	30	4 to 6	None	0.80 @24	4	3	3	3	2	Not recommended	None	No	Very inefficient	Some breaking and compacting accomplished
Young Tomahawk & ATECO Compactor	30	4	None	0.70 @32	3	3	2	2	2	Western U.S.	Tractor, D6 or larger	Yes	Slow & not too efficient - needs hard ground and brittle material	Good results with small, dry material
Towed Rolling Choppers	15	4 to 8	None	1.60 @24	3	3	2	2	4	Relatively flat, "easy" country	Tractor, D6 or larger	Yes	Sensitive to rocks-blades break; damages leave trees	Good results with small-stem material
National Hydro-Ax	30	6	None	2.00 @24	2	2	1	2	3	Any, within size & slope limitations	None	Yes	Leaves sharp stubble which can damage tires & tracks	Most thorough treatment
Kershaw Klear-way	25	6	None	2.00 @24	2	2	1	2	3	Any, within size & slope limitations	None	Yes	Leaves sharp stubble which can damage tires & tracks	Most thorough treatment
Trakmac/ Trailmaker	35	18	None	6.50 @7	3	2	1	3	4	Any, within size & slope limitations	None	Yes	High down time	Low ground pressure
Tree Eater	20	10	None	2.50 @32	1	3	1	1	5	Any, within size & slope limitations	None	Yes	Undependable; damages leave trees	Thorough treatment

1/ Based upon 40 ton/acre heavy precommercial thinning trees up to 8-in dbh-ponderosa and lodgepole pine, and mixed stands of fir larch and hemlock (1, 2, 7).

Source: Robin T. Harrison, "Equipment and Methods for Treatment and Utilization." U.S. Forest Service, April 1975 have the advantage of being available at a single site rather than scattered as logging residues are. Transportation is limited to movement from one mill to another or one part of a mill to another.

Where possible, logs are usually transported by water to reduce costs. Unfortunately, rafting of residues is not as practicable. Whether by land or water, the end result is that transportation costs are often to high to economically justify the utilization of logging residues.

An interesting possibility is the movement of wood chips by pipeline. It has even been suggested that the Trans-Alaska Pipeline might someday transport wood chips from Alaska's interior forests once the oil is exhausted.

Dr. William A. Hunt, Professor of Civil Engineering and Engineering Mechanics at Montana State and Rulon B. Gardner of the Intermountain Station's Forestry Sciences Laboratory, Bozeman, Montana have developed the technology to transport wood chips by hydraulic pipeline. The study shows that the hydraulic pipeline concept has potential for wide application. And, the energy-efficient characteristics of the concept make it especially attractive.

Transporting wood chips by hydraulic pipelines can mean substantial savings. Particularly promising applications include moving chips from areas of concentrated sawmill and plywood mill operation, where the chips are a byproduct, to a pulpmill or port. Also, chips could be piped from satellite chipping operations in interior forests where roads are inadequate. In areas where the chips would be transported by pipeline to a lower location--a mill or a seaport--the system would operate by gravity flow, without conventional energy sources.

According to Gardner's report, the U.S. Pulp Industry consumed 40.8 million tons of wood chips in 1974--most of it transported by truck. This volume is expected to triple by the year 2000. The researchers estimate that if pipelines replaced trucks for only half that volume, over one million barrels of oil could be saved annually.

Hunt and Gardner point to other advantages of a wood-chip pipeline, including the potential to reduce mill inventories through continuous operation; and elimination of log storage, handling, and protection at the pulpmill.

Additional information is included in the publication, "Transporting Wood-chips by Hydraulic Pipeline," by Rulon B. Gardner. Single copies are available free from the Intermountain Station, 507, 25th Street, Ogden, UT 84401 (Zerbe, 1978).

UTILIZATION

Fluidized Bed Burners

The technology that is important in wood waste energy utilization is the method that is used to convert wet wood waste to useful energy. The following description of fluidized bed burner is based upon a paper by wood technologist Allen Wiley (1978).

A bed of particles such as sand is supported by a porous metal plate and enclosed on all sides. Gas is forced up through the holes in the plate so that it flows upward through the particles to the space above. As the rate of flow increases, the pressure drop across the bed increases until the force on the particles resulting from this pressure drop is equal to the weight of the bed. The particles will begin to "float" on the moving gas and the gas-solid medium takes on many characteristics of a liquid; for example, it will have a hydrostatic head, and light objects will float on its surface while heavy ones will sink. Thus the medium is referred to as a fluidized bed.

The fluidized bed may be used to enhance the combustion characteristics of solid fuels and the transfer of heat into boiler tubes. Consider one of the main problems of burning solid fuels--transfer of heat from the furnace gases to the solid particles. The faster this can be accomplished, the smaller the fuel pile in a furnace and the smaller the required furnace and grate for producing a given rate of heat or steam. Thus, particles of wood or coal are ground as finely as is economically feasible to increase surface area per unit weight. When a hot solid is brought into contact with a cold solid, heat transfer per unit area is much faster than when the cold object is surrounded by a gas of the same temperature as the hot solid. Thus, a bed of non-combustible particles may be fluidized with combustion air, the temperature of the particles increased by combustion of liquid or gaseous fuels, and the wood fuel introduced directly into the fluidized bed to provide rapid combustion. Once combustion of the wood begins, the reaction becomes self-sustaining and ignition burners may be turned off.

Particle size requirements are less stringent in fluidized bed combustors than in conventional furnaces because of the rapid heat transfer. Fuel particles can be larger and more variable, and can also have a higher moisture content since drying takes place quickly due to the rapid heat transfer. Because the time required for combustion is lower, less smoke due to incomplete combustion normally results.

Fluidized bed combustors may be used in combination with an existing boiler, or tubes may be located within the combustor (either buried in the bed or in the form of water walls) to provide efficient heat transfer, with greatly reduced surface area, to the boiler water. They can also be used to provide direct heat for drying applications.

The main components of a fluidized bed combustion system are:

- a gas distributor plate for supporting the bed and distributing the combustion air evenly through the bed,
- a plenum below the distributor plate to encourage even flow of combustion air through the distributor plate,
- a blower to force combustion air through the bed at a rate that will result in fluidization,
- a bed of inert particles to be fluidized by the combustion air,
- a reactor shell to confine the process,
- a feed mechanism, normally located at the top of the shell, to introduce fuel to the system,

- an ignition burner, located somewhere below the bed for startup,
- a particulate collection system.

Finding a satisfactory bed material was a major obstacle in the development of fluidized bed combustors. The material must be non-reactive with ash and oxygen at temperatures up to 2,000° F. Sand has been found to slag in combination with ash at such temperatures. Another problem results from fines being completely blown from the system by high gas velocities. This loss of fines is called elutriation. Since the particles are constantly impacting one another, attrition may result in the formation of new fines which in turn are elutriated, resulting in a steady diminution of bed material. The ideal bed material should, therefore, be resistant to abrasion and thermal fracture such as a refractory sand which meets both requirements of chemical inertness and abrasion resistance.

Fluidization is a system that is ideally suited for combustion of wood wastes, particularly where steam requirements are not too great. Most of the units in production range from 5,000 to 80,000 pounds of steam per hour. Figure 18-3 shows a diagram of a fluidized bed burner that is in use and uses log fuel to produce useful energy.

Fluidized bed burners are designed to burn hog fuel, without fine grinding or drying. The fuel is completely consumed in the refractory bed and the hot exit gases can be used directly or indirectly. Recent experiments followed by several production units prove that wood with a water content as high as 63 percent can be burned in a fluidized bed and also air quality requirements can be met.

Microoganisms

From the beginning of his history, man has learned how to use micro-organisms for his benefit. Today many microoganisms, considered by some just as undesirable germs and usually associated with spoilage of food, smelly rotten matter, or with various diseases, play an important role in modern-day living. They benefit mankind in hundreds of ways--they convert

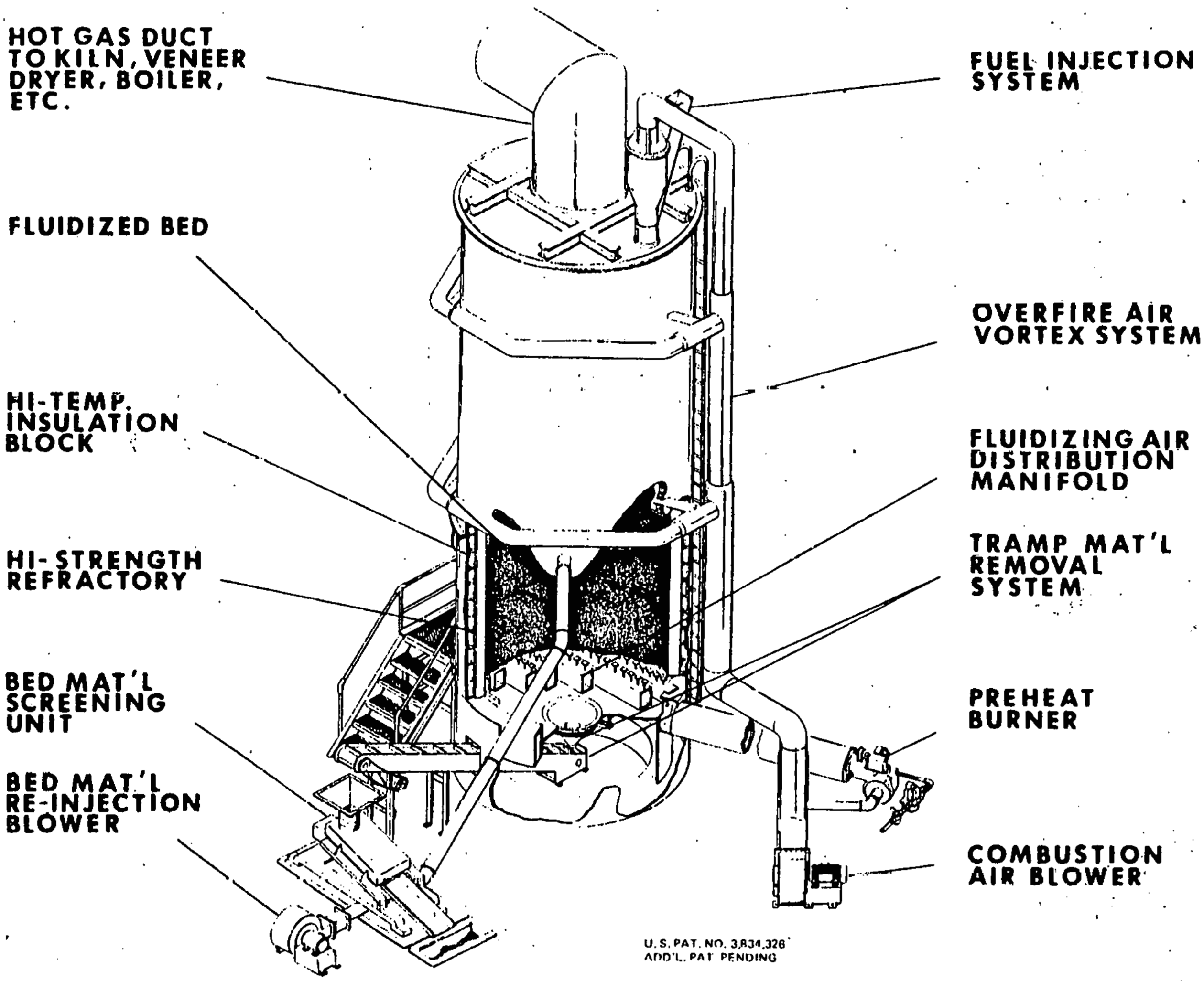


Figure 18-3

A COMMERCIAL FLUIDIZED-BED BURNER USING HOG FUEL

Source: Energy Products of Idaho

less desirable raw materials into highly desirable products such as bread, butter, coffee, wine, beer, enzymes, antibiotics, just to name a few--some can turn starch into sugar, sugar into wine, wine into vinegar, vinegar into water and carbon dioxide, and others sugar into starch; they even make life possible on earth. Of specific interest to Alaska is the utilization of the wood sugar wastes at the Louisiana Pacific Paper and Pulp plant in Ketchikan for the formation of protein which can be used as animal or human food.

Dr. A. W. Anderson of the Department of Microbiology at Oregon State University in Corvallis, Oregon visited the Ketchikan facility and followed up with a trip to Russia and Finland. Excerpts of his trip report (Anderson, 1977) are given below:

> The next morning, Dr. Forss met me and took me out to the Finnish Pulp and Paper Research Institute. I was especially interested in a new process that Dr. Forss had developed at the Institute known as the Pekilo Process. The initial investigations were sponsored by a Finnish industrial group and a Finnish hammermill group. The research was carried out at the Finnish Pulp and Paper Research Institute, with the main objective to find a competitive method for the production of protein from carbohydrate-containing solutions. This work resulted in the development of the Pekilo Process, where micro-fungi are continously cultivated in a submerged culture. In 1963, research work to produce protein begin at the Finnish Pulp and Paper Research Institute by a working group headed by Dr. Kaj Forss. It was soon discovered that extensive cooperation was necessary due to the size of the project. A development group was formed for studying SCP from sulfide liquor. The results of the development work is a method based on the cultivation of microfungi in spent liquor of a sulfide pulping operation. About one third of the dissolved organic material of sulfide liquor is made up of monosaccharide, polysaccharide, carbohydrate derivatives, and acetic acid; most of them utilizable in the Pekilo Process. According to their laboratory tests, this process can also be utilized in waste liquor from sugar, potato industries, pressboard industries and other waste manufacturing processes characteristic of the many industries of the Northwest. The microfungi resulting from the fermentation process considerably less expensive than the usual process using Candida utilis. The sulfide pulp mill, based on acid and calcium bisulfate and has an annual production of 100,000 tons, can produce approximately 10,000 to 15,000 tons of Pekilo Protein a year. The Pekilo Process is installed between the cooking department and the evaporation plant of the pulp mill. The method reduces the effluent load in a pulp mill with existing recovery of some liquor, as the fungi utilizes the organic acids which are otherwise discharged together the evaporator condensates.

The process is a closed system with all the water recycled resulting in no pollution, thus it contributes maximum protection of environment. This was my main reason for visiting the plant, to observe a process which appears to have possibilities in the Northwest.

Before major application can be made of the Pekilo Process, or any similar process, it is necessary to complete tests required by the Federal Food and Drug Administration to assure safety for humans and animals.

Wood Stoves

For home use there is considerable interest in Alaska in stoves. The Alaska Northwest Publishing Company recently published (1977) a book Wood Stoves: How to Make and Use Them by Ole Wik. This book covers design, efficiency, safety, and even the personality of wood stoves and gives a list of manufacturers of wood stoves and related equipment.

Mobile Gas Producers

The utilization of wood to supply the energy to propel autos and tractors has been of interest in Alaska. Therefore, information was obtained from the Volvo Car Marketing Division in Sweden. A photo of the unit and technical information are presented in Appendix 18. Note that the manufacturer states that "the Volvo program for these [wood] gas producers is intended for periods of crisis, e.g. an energy crisis, and is not competitive under other circumstances."

APPLICABILITY TO ALASKA

Native and early Alaskans were often dependent on wood for fuel, shelter, and tools, as are many of those who maintain subsistence lifestyles today. With the discovery of gold, thousands of cords of wood were cut to fuel steamers and to thaw gold-bearing gravels. The settlement and development of the Interior depended heavily upon forest resources up until World War II (Braathe, 1977).

Sixteen percent of the forest lands of the United States are located in Alaska. Of these 119 million acres, 28.2 million acres are considered commercial, i.e., capable of a minimum annual production of 20 cubic feet of industrial wood per acre (Hutchison, 1967). While the potential sustained annual timber yield of Interior Alaska is estimated to be about 360 million cubic feet on a 100-year rotation basis (Braathe, 1977), much of the forest land will be controlled by the Native corporations (Brady, 1978). Although Natives have long made use of forest products, large scale exploitations of forest resources may conflict with their social and religious views (Nelson, 1977).

Although much of this resource is located in remote areas that make logging uneconomic, the forest industries are still very important to Alaska, especially in the Southeast. The State's pulp and paper industry is able to absorb a large portion of the wood residue generated. Louisiana Pacific Corporation in Ketchikan generates power from its own wood residues and also those from Ketchikan Spruce and Annette Hemlock. In Wrangell, Alaska Lumber and Pulp and Alaska Wood Products, Inc. (Wrangell Lumber Company and Alaska Wood Products) use their residues for power generation. Alaska Wood Products sells excess electricity to the town of Wrangell.

Estimated logging residue in 1970 in coastal Alaska was 39 million cubic feet from growing stock and 27 million cubic feet from other sources. These figures do not imply that all of the materials were available at a reasonable price. Unused primary manufacturing residue (excluding bark) for the same period was estimated to be 8 million cubic feet (Grantham, 1974) (Table 18-5).

An important source of wood residue is that which washes up on the coastal shores of Alaska. While much of this occurs naturally, logs lost during river transportation are also a major contributor. It has been estimated that as much as 200 million board feet may be available in Southeast Alaska. The question of legal ownership of some of the logs is one of the barriers preventing exploitation of this wood residue.

TABLE 18-5

ESTIMATED LOGGING RESIDUE AND FOREST PRODUCTS MANUFACTURING RESIDUE IN THE UNITED STATES, 1970

Region	Logging Residue: From Growing Stock	Logging Residue: From Other Sources	Unused Primary Manufacturing Residue: Wood	Unused Primary Manufacturing Residue: Bark	Unused Secondary Manufacturing Residue
	(Millions of Cubic Feet*)				
Coastal Alaska	39	27	8	--	--
Douglas-fir Subregion	347	247	133	--	--
Ponderosa pine subregion	34	45	46	--	--
California and Hawaii	106	268	152	--	--
Pacific Coast Subtotal	526	587	339	213	30
Northern Rocky Mountain	84		93	66	--
Southern Rocky Mountain	19		46	23	--
South	483		343	165	--
North	283		172	180	--
TOTAL U.S.	1,595		993	624	

* To convert to bone-dry tons, assume an average weight of 30 lb/ft^3 and multiply the above figures by 0.015; e.g., 1,595 million ft^3 = 23.9 million tons.

Source: John B. Grantham and Thomas H. Ellis, "Potentials of Wood for Producing Energy," *Journal of Forestry*, September, 1974, p. 554

A large quantity of wood that has fallen naturally into the waters of the Yukon and Kuskokwim Rivers is carried out to sea. A larger portion of these logs was once used by those living along the river for subsistence needs. The declining use of wood by the region's residents is perhaps due in part to a belief that fuel oil is a more modern source of energy (Brady, 1978). In contrast, expensive new homes even in the cities are almost sure to have a wood-burning fireplace. Properly managed use of forest resources can provide a renewable substitute for a part of the fossil fuels now being consumed.

John Galea of the U.S. Forest Service has suggested the increased use of wood for fuel in the Alaskan bush. Most rural communities use expensive diesel fuel even when they live in forested areas. A pilot project could subsidize the conversion to wood and cover any costs over normal diesel expenses. Residents could gather and process the wood, providing local employment and greater control over fuel supplies (Galea, 1978).

However, large scale use of wood for energy may not be practical. Richard Seifert estimates that an annual timber harvest of about 16,000 acres would be required to meet only one-half of the home heating requirements of the Fairbanks North Star Borough's present population of 42,000 civilians. High grade timber covers approximately 800,000 acres of the Borough, but it is doubtful that such a high yield could be sustained (Seifert, 1977).

A current example of the wood residue problem is seen in the Delta area southeast of Fairbanks. The State has agreed to clear 50,000 acres of land recently sold for agricultural purposes. It is estimated that a minimum of 1.5 million board feet of trees and stems as well as an additional 10 tons per acre of non-sawable organic material could be recovered. Removal of this material would take with it about $180 to $300 worth of nutrients per acre. But even ignoring this cost, this fall's 2000-acre test suggests that the residue will simply be burned due to high removal costs (Linn, 1978).

Similarly, logs are being burned on Unalaska Island after clearing river channels of log jams. Floating from Southeastern Alaska and Canada, the logs clog the rivers of the Alaska Peninsula and block the migration of salmon. The State Division of Fisheries Rehabilitation, Enhancement, and Development feels it will require at least four years to complete the clearing project ("Streams Cleared for Migrating Salmon," 1978).

Table 18-6 lists some of the potential wood residue sources in the State.

ENVIRONMENTAL ISSUES

LOGGING RESIDUE

Viewed immediately after logging, residues are the leftover--that material without enough commercial value to justify its removal. This material is organic and can have a profound effect on the ecosystem. Brief descriptions of the most important environmental issues follow.

A major concern is that of fire control. Substantial resource losses each year result from wildfires in commercial timber stands. Logging residues have a dual effect when fire is a consideration. Firstly, the dead, dry wood creates a major fire hazard, especially if there are hunters or campers in the area. Secondly, suppression of wildfires can be aggravated by accumulations of slash in the fire area.

Another consideration in the accumulation of logging residues is its effect on soil composition. Removing the canopy in an old-growth forest allows increased solar radiation to penetrate and warm the soil. The result is a proliferation of rapidly growing forbs, shrubs and tree seedlings. In addition, the increased solar penetration will cause the residue to decompose at a faster rate leading to a temporary rise in soil nutrients, particularly nitrogen. Logging further affects the soil by compacting or mixing the duff (organic humus). This has the effect of altering the supply of available plant nutrients which in turn affects soil productivity. Compaction will also decrease the survival of germinating vegetative seeds.

T 8-6

WOOD RESIDUE - POTENTIAL SOURCE LOCATIONS

Land Ownership	Project Name	Acreage	Vegetative Types And Sizes	Operator	Comments
SOA Agricultural leases	Delta Barley Clearing	2,000 - Oct '78 58,000 - Spring '79	Mostly Jack Spruce estimated 200 acres are economically salable	SOA	Varying quantities of biomass per acre are available with a minimum of a million and a half board feet; 10 tons per acre of brush stems and 20-25 tons per acre in vegetative matter. Future clearing potential of 30-75,000 acres will be available as agricultural activity permits. Debris must be removed or burned to allow for farming.
	Perenosa Timber Sale (Afognak Island)	6,027	Sitka Spruce, 23" average DBH	Kodiak Lumber mills	
USG Chugach National Forest	Rocky Top (Esther Passage Prince William Sound -- Seward D-3)	200	Spruce and Hemlock; 20" DBH	Two Brothers Lumber Company	
USG Chugach National Forest	Esther Bay (Near Esther Passage)	30	Spruce and Hemlock, 23" average DBH	Two Brothers Lumber Company	
USG Chugach National Forest	Hanning Bay #2 (Montague Island Prince William Sound)	86	Spruce and Hemlock, 26" average DBH	Kenai Lumber	
USG Chugach National Forest	Sinkhole (1 1/2) miles north of Bear Lake)	100	Spruce and Hemlock, 21" average DBH	Kenai Lumber	
USG Chugach National Forest	La Touche (La Touche Island)	90	Spruce and Hemlock 22" DBH	Kenai Lumber	
USG Chugach National Forest	Macleod Harbor (Montague Island)	82	Spruce & Hemlock, 24" DBH	Kenai Lumber	
USG Chugach National Forest	Westside (Montague Island)	104	Spruce & Hemlock 24" DBH	Southcentral Timber Development	
USG Chugach National Forest	Moose Range Project	21,699 (304 Oct '78)	White Spruce Paper Birch	U.S. Forest Service	From 1978 - 1988 the U.S. Forest Service will systematically burn 21,699 acres to provide better pastures for moose; see summary of annual prescribed burn acres and cost (Table 18-7) and prescribed burnsite acres by area (Table 18-8).
USG Federal Game Preserve	Moose Range (Kenai)	310,000	Semi-Climax mature Spruce, Aspen, Birch and some Cottonwood	U.S. Fish & Wildlife	The U.S. Dept. of Fish and Wildlife initiated a program to burn off 3,000 acres a year to create moose browse range. In addition, in 1978 Fish and Game issued 368 cutting permits for cabin logs and firewood.
USG Tongass	Information not received by date of publication	55,653 acres cut 1974-1977	Hemlock, Spruce & Alder	Information not received by date of publication	Residues available include logging residue, thinning waste, and maverick logs and unmerchantable material on beaches.

TABLE 18-6 (Cont.)

WOOD RESIDUE - POTENTIAL SOURCE LOCATIONS

Land Ownership	Project Name	Acreage	Vegetative Types And Sizes	Operator	Comments
State of Alaska	Talkeetna	5,000	Cottonwood	Kenai Lbr. Co.	
State of Alaska	Cape Yakataga	13,700	Spruce, Hemlock	SC Timber	
State of Alaska	Tyonek	210,000	Spruce, Hardwoods	Kodiak Lbr. Mills	
State of Alaska	Seward	122	Spruce, Hemlock	Kenai Lbr. Co.	
State of Alaska	Ninilchik	40	Spruce	Kenai Sawmill	
State of Alaska	Kenai	200	Spruce, Hardwoods	Kenai Sawmill	
State of Alaska	Ninilchik	60	Spruce	Kenai Sawmill	
State of Alaska	Ninilchik	80	Spruce	Anchor Forest Pdct.	
State of Alaska	Ninilchik	80	Spruce	Doug Gamma	
State of Alaska	Homer	20	Spruce	Tom Simmons	
State of Alaska	Anchor Point	15	Spruce	Brothers Enterprises	
State of Alaska	Anchor Point	80	Spruce	Kenai Sawmill	
State of Alaska	Talkeetna	20	Cottonwood	Paul McLaughlin	
State of Alaska	Talkeetna	100	Spruce	Raymond Erandel	
State of Alaska	Seward	15	Spruce	Delmar Branson	
State of Alaska	Fairbanks	210	Spruce	O.K. Lbr. Co.	
State of Alaska	Fairbanks	2,640	Spruce, Hardwood	Northland Wood Products	
State of Alaska	Fairbanks	80	Spruce	Olson Lbr. Co.	
State of Alaska	Delta	15	Spruce	Dry Creek Enterprises	
State of Alaska	Fairbanks	25	Spruce	Northland Wood Products	
State of Alaska	Tok	180	Spruce	Anchor Forest Pdt.	
State of Alaska	Fairbanks	10	Spruce	Four Star Lbr. Co.	
State of Alaska	Fairbanks	20	Spruce	Jerry Gustafson	
State of Alaska	Fairbanks	20	Spruce	Leroy Holland	
State of Alaska	Delta	15	Spruce	Dry Creek Enterprises	
State of Alaska	Fairbanks	22	Spruce	Northwood Products	
State of Alaska	Fairbanks	15	Spruce	Four Star Lbr. Co.	
State of Alaska	Tok	13	Spruce	George Pine	
State of Alaska	Yakatat	625	Spruce, Hemlock		

TABLE 18-7

SUMMARY OF ANNUAL PRESCRIBED BURN ACRES AND COST

Year	No. Sites	Acres	Cost $
1977	7	475	10,451
1978	20	958	21,200
1979	23	2719	25,690
1980	13	2394	25,880
1981	4	2570	26,360
1982	12	2508	26,190
1983	20	2432	30,290
1984	20	2376	29,370
1985	12	2193	26,730
1986	8	3074	23,029
TOTALS	139	21,699	245,081

TABLE 18-8

PRESCRIBED BURN SITE ACRES BY AREA

Area	Acres	Highest Priorities
Canyon Cr.	918	
Chickaloon R.	2136	5
Cooper-Kenai L.	2135	4
Cooper Cr.	410	
E. Fork Cr.	2364	8
Grant L.	659	
Indian Creek	430	
Juneau Cr.	2800	1
Kenai R.	273	3
Ptarmigan L.	247	
Quartz Cr.	2982	2
Resurrection Cr.	3067	6
Six Mile Cr.	874	
Trail R.	471	7
Trail Cr.	1743	

Source: USDA Forest Service. Environmental Statement, Chugach Moose-Fire Management Program, 1978.

Insect and disease management is also a matter of consideration. Logging operations usually do not include trees which are diseased or infested with insects. As a result, residue has a tendency to become a breeding ground; in Alaska this is especially true of the Sitka spruce beetle (Dendroctonus obesos).

Logging residue can also have a profound effect on wildlife management. With destruction of the old-growth forest, there is a change in the underbrush ecosystem. If there are no standing trees, many species of birds will not nest in the area. If soil erosion is a possible factor, smaller chunks of residue such as bark, wood chips, twigs and needles, can damage fish habitats in spawning and rearing streams. Larger accumulations from logging residue can choke streams and hinder or even block the migration of fish.

Yet another component of logging residues is its effect on esthetics. Although public reactions to timber harvesting usually focuses more on the loss of the cover than on logging debris, the presence of large amounts of logging debris (slash) is considered by many people as evidence of forest devastation and a waste of wood fiber. Fishermen as well as campers complain of streams made murky by logging operations and concomitant dumping of slash coupled with soil erosion. With the increased recreational use of the forest, distant views of denuded hillsides littered with slash create a poor public image.

The environmental issues involved in the proper disposition of logging residue have yet to be resolved. A current proposal is to drag off the residue for use in energy related enterprises. Slash could be burned in place of oil or natural gas for the generation of power. Large scale marketing of smaller diameter limbs and diseased trunks for home fireplaces could be initiated. Even the chipping wastes could be collected for sale as an esthetic ground cover for yards and gardens. Inevitably the problem of logging debris must be resolved, if not in the interest of ecology, then in recognition of the importance of energy conservation.

PRIMARY MILL RESIDUE

As is the case with logging residue, environmental problems resulting from mill residue are recognized, but have gone unmonitored in the past. Most mills used teepee burners to dispose of wood residues until stricter environmental controls came into effect. While teepee burners are not explicitly prohibited, they are unable to meet particulate emission standards and are therefore effectively precluded (Sturdevant 1979).

In 1972, when the stricter standards went into effect, those firms operating the approximately one dozen teepee burners were obliged to apply for a variance to continue. The granting of the variance was dependent upon the submission of an alternative plan for residue disposal. Alternatives have included sale to other firms able to utilize the residues, land or intertidal fills, reduction of residue, and power production. There are currently no teepee burners operating in the State. A mill in Seldovia has a variance allowing the use of a teepee burner until fall, 1980, but it has already eliminated its residue by exporting logs in the round rather than cants (Hanna, 1980).

Filling with residue has a potentially damaging impact on fresh water or poorly flushing intertidal zones. Lignins, tanins and toxic leachates are released from the wood and the COD (chemical-oxygen demand) is high. Also, decomposition is sometimes accompancied by a foul odor (Sturdevant 1979).

Wood residue discharges by Alaska Wood Products and Alaska Lumber and Pulp Company in Wrangle and by Louisiana Pacific Corporation in Ketchikan have been permitted into intertidal zones. These discharges however, have only been allowed on a temporary basis until more environmentally acceptable facilities could be put in place. In both cases a dike was required and also a cap to cover the completed fill. The Wrangell site, which is still being filled, will provide a surface area for material which would have been handled in the water otherwise (Lamoreaux, 1979).

The Alaska Department of Environmental Conservation (DEC) inspects mills at least annually. More frequent monitoring is conducted if there have been problems with compliance to standards or approved modification schedules require it. While citations have been issued and operations at one mill were even suspended, environmental quality has been improved substantially.

DEC has actively encouraged the use of residue for power, providing economic and technical assistance in some cases. Although there are emissions from these boiler systems, their overall impact has been beneficial. As described above, the impact of both teepee burning and land filling has sometimes been significant. Electrical generation from wood residue has not only diminished environmental impact, but also helped to supply both plants and communities with power.

Also, it is noteworthy that a number of households have recently converted to wood for space heating. In the Juneau area, where perhaps 30 percent now burn wood, there has been a visible deterioration in air quality. While air quality standards are for particulates not being violated, the difference is measurable (Hanna, 1980).

RECOMMENDATIONS

(1) Determine the quantity, quality, and location of wood resources and residues in Alaska. Special attention should be given to an assessment of the availability of wood energy to rural communities.

(2) Encourage the utilization of driftwood along the coast and rivers.

(3) Begin a pilot project in several communities along the Yukon River to convert residents from imported fuel oil to driftwood supplied by local labor.

(4) Investigate the possibility of using microorganisms (Pekilo type process) to convert wood waste sugars to useful proteins. Begin early testing of product safety to meet Federal Food and Drug Administration standards.

(5) Develop a prototype fluidized bed burner for small village and household use.

SUMMARY

While wood residues often present a situation calling for costly disposal of materials, they simultaneously offer an opportunity for more efficient use of our natural resources.

The feasibility of collecting scattered residues and those of marginal value is unstable. Supply is changing with new logging and processing techniques as well as legal and environmental considerations. Demand continues to rise as traditional fuel prices climb and technological advances provide new products and increased efficiency.

In addition to industrial uses of residues, the utilization of wood in rural, forested areas of Alaska that are presently dependent on imported diesel may prove to be economically and socially advantageous.

KEY CONTACTS

Terry Brady
Forests North, Ltd.
2805 Dawson # 205
Anchorage, Alaska 99503
(907) 276-2902

John Galea
Forester
U.S. Forest Service
Alaska Planning Team
2221 E. Northern Lights Blvd.
Anchorage, Alaska 99504
(907) 278-3358

Al Johnson
Forester
U.S. Fish & Wildlife Service
Kenai Moose Range
Kenai, Alaska 99611
(907) 262-4525

Ken Kilborn
Forest Products Specialist
U.S. Forest Service
State and Private Lands
2221 E. Northern Lights Blvd.
Anchoarge, Alaska 99504
(907) 276-0939

Allan Linn
Director, Division of Agriculture
Department of Natural Resources
State of Alaska
P.O. Box 1088
Palmer, Alaska 99645
(907) 745-3236

Frank E. Price, Jr.
Director, Timber Management
U.S. Forest Service
P.O. Box 1628
Juneau, Alaska 99802
(907)

U.S. Forest Service
Chugach National Forest
2221 E. Nothern Lights Blvd.
Anchorage, Alaska 99504
(907) 272-4485

REFERENCES

Anderson, A. W., Department of Microbiology, Oregon State University. Private communication to Gene Rutledge, 1976.

Anderson, A. W. (Department of Microbiology, Oregon State University). "Report on Symposium on Single Cell Protein held in Moscow, Russia, June 2-11, 1977."

Braathe, Peder, Hilmar, Holman, and Aarne Nyyssonen. "Forestry Potential in Interior Alaska," North American Forest Lands at Latitudes North of 60 Degrees. Proceedings of a symposium held at the University of Alaska, Fairbanks: September 19-22, 1977, pp. 299-312.

Brady, Terry. Forests North, Ltd., Anchorage, Alaska. Interview with Gene Rutledge and Greg Edblom, October 23, 1978.

Brust, Stan, Solid Wastes Coordinator, U. S. Environmental Protection Agency. Telecon October 6, 1978.

Carpenter, Eugene M. "Secondary Wood Residue: Production, Use, and Potential in the Twin City Area." Research Paper NC-144. St. Paul, Minnesota: Forest Service, U.S. Department of Agriculture, May 1977.

Cronin, Timothy S. "New Wood-Fired Generating Unit Brings Savings," Public Power. January-February 1978, pp. 32-33.

Estep, Eldon M. (U.S. Forest Service, State and Private Forestry). "Wood Residue - What and Where." Presented at annual meeting of Midwest Section of Forest Products Research Society, "Environmental Challenges are Opportunities for the Forest Products Industries." Madison, Wisconsin, October 9-10, 1973.

Forest Service, U.S. Department of Agriculture. "Energy & Chemicals From Forests." Madison, Wisconsin: 1978.

Forest Service, U.S. Department of Agriculture. "Quads." No. 1. February, 1978.

Forest Service, U.S. Department of Agriculture. "Quads." No. 2. May, 1978.

Forest Service, U.S. Department of Agriculture. Report of Close Timber Utilization Committee. June, 1972.

Fowler, John M. and Kathryn. "1. Fuels From Plants: Bioconversion," Factsheet. Produced by the National Science Teachers Association for the Energy Research and Development Administration, now the U.S. Department of Energy. GPO 917-329. Undated.

Fowler, John M. "2. Fuels From Wastes: Bioconversion," Factsheet. Produced by the National Science Teachers Association for the Energy Research and Development Administration, now the U.S. Department of Energy. GPO 917-329. Undated.

Galea, John. Forester, U.S. Forest Service, Anchorage, Alaska. Interview with Gene Rutledge and Greg Edblom, September 29, 1978.

Grantham, John B., and Thomas H. Ellis. "Potentials of Wood for Producing Energy," Journal of Forestry. September 1974, pp. 552-556.

Hanna, Thomas R. Chief, Air Quality Control, Alaska Department of Environmental Conservation. Telecon with Greg Edblom, January 11, 1980.

Harrison, Robin J. "Slash. . .Equipment and Methods for Treatment and Utilization." ED & T Report 7120-7. San Dimas, California: U.S. Department of Agriculture-Forest Service, Equipment Development Center, April, 1975.

Hutchison, O. Keith. Alaska's Forest Resource. Resource Bulletin PNW 19. Juneau, Alaska: Forest Service, U.S. Department of Agriculture, 1967.

Lamoreaux, Bill. Sanitation Engineer, Environmental Protection Agency, Alaska Operation Office. Telecon with Greg Edblom, December 13, 1979.

Linn, Allan K. Director, Alaska Department of Natural Resources, Division of Agriculture, Interview with Gene Rutledge and Greg Edblom, September 26, 1978.

National Science Teachers Association. An Energy History of the United States. Prepared for U.S. Department of Energy. HCP/U 3841-0004. January, 1978.

Nelson, Richard K. "Forest Resources in the Culture and Economy of Native Alaskans," North American Forest Lands at Latitudes North of 60 Degrees. Proceedings of a symposium held at the University of Alaska, Fairbanks: September 19-22, 1977, pp. 299-312.

North Central Forest Experiment Station, Forest Service, U.S. Department of Agriculture. Forest Residues Energy Program. Prepared for Energy Research and Development Administration. St. Paul, Minnesota: March, 1978.

Reineke, L. H. "Wood Fuel Combustion Practice." Forest Products Laboratory Report No. 1666-18. Madison, Wisconsin: Forest Service, U.S. Department of Agriculture, reviewed and reaffirmed May, 1961.

Roberts, Ken. "Wood stoves--an old idea that works," Alaska Advocate. September 28-October 4, 1978, p. 13.

Seifert, Richard. "Energy for the North--the near-term options," The Northern Engineer. Spring 1977.

"Streams Cleared for Migrating Salmon," The Great Lander, October 18, 1978, p. 4.

Sturdevant, David C. Alaska Department of Environmental Conservation. Telecon with Greg Edblom, December 13 and 18, 1979.

Volvo, AB Volvo, Car Division. Goteborg, Sweden. Correspondence to DEPD April 5, 1978.

Whiting, Kenneth L. "For 1.5 Billion, Firewood is Critical," The Anchorage Times. October 30, 1978, p. 13.

Wiley, Allen. "Fluidized Bed Combustion Of Wood Waste," Forest Products Notes. Lufkin, Texas: Texas Forest Products Laboratory, January, 1978.

Zerbe, John I. "The Many Forms of Wood as Fuel." American Forests. October, 1978.

APPENDIX 18-A

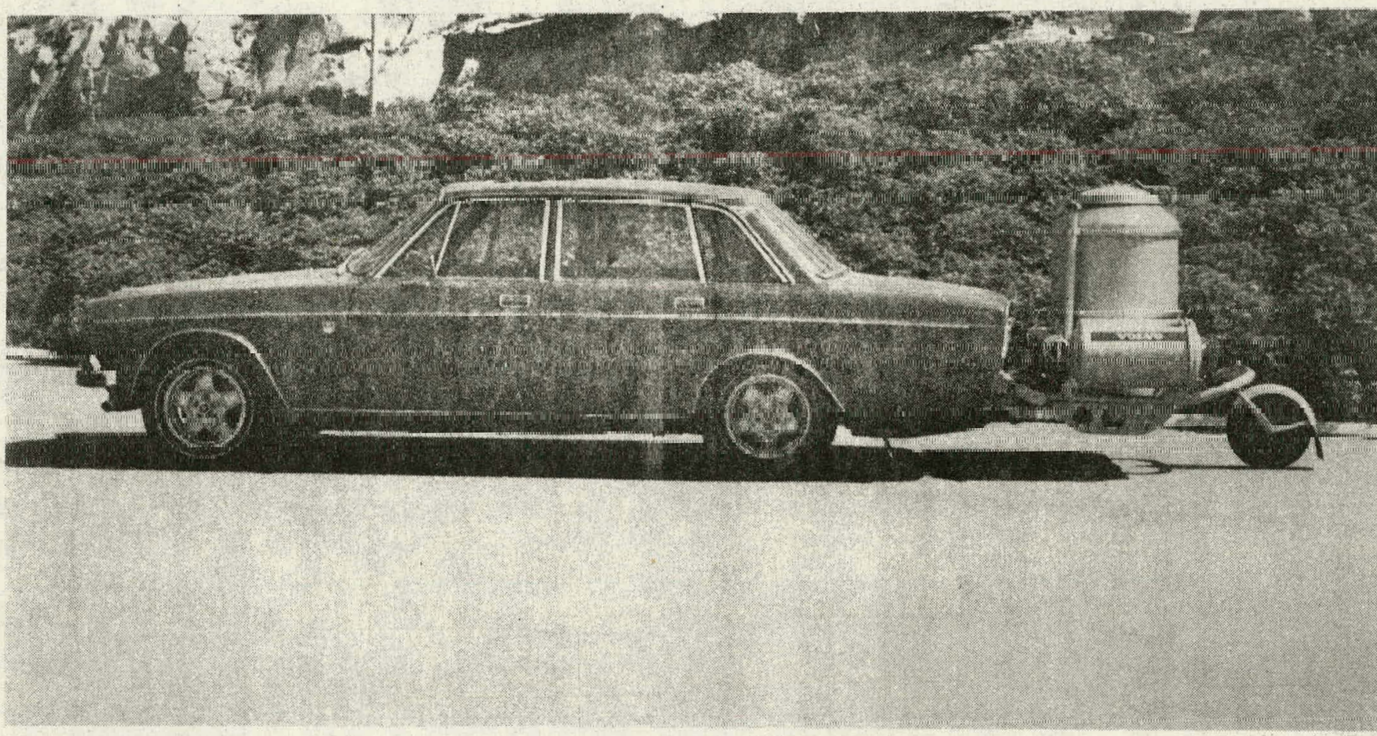


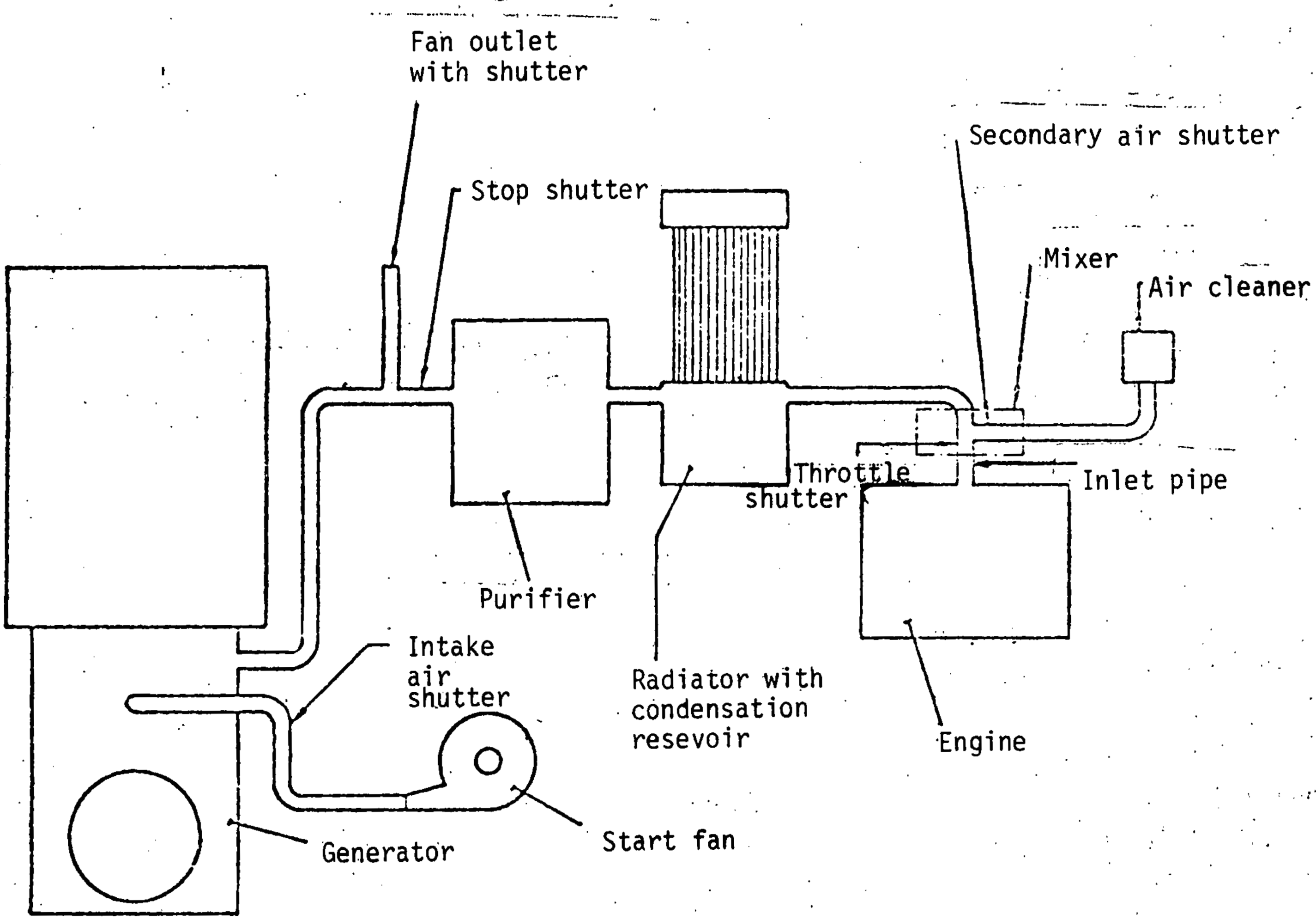
Figure 18-A-1

VOLVO MOBILE GAS PRODUCER

Source: Volvo, Car Division, S-405 08 Goteborg, Sweden, Correspondence to DEPD, April 5, 1978.

Figure 18-A-2

BASIC DIAGRAM OF A PRODUCER GAS UNIT



TECHNICAL CONDITIONS

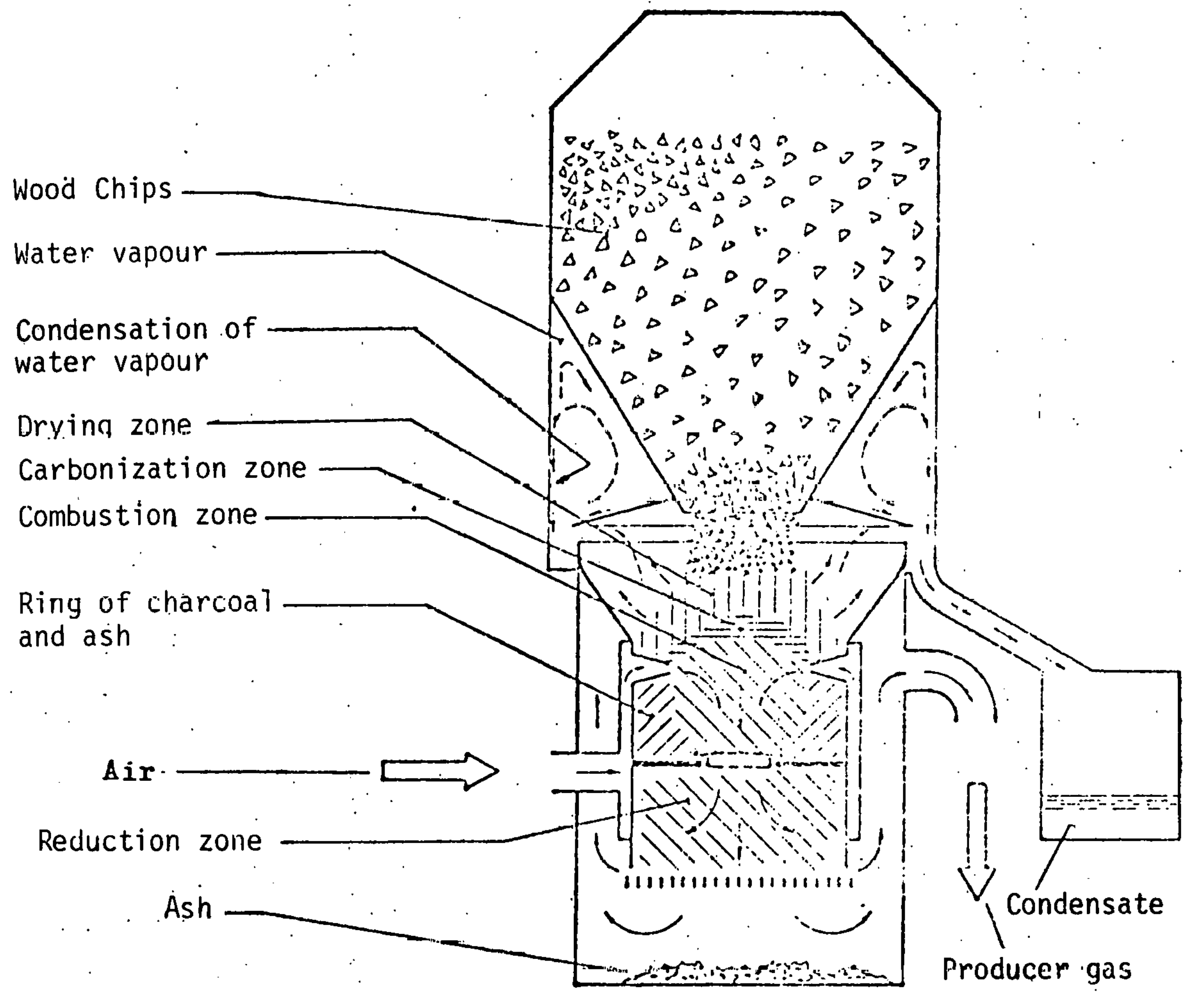
Fundamental Principle

In order to make producer gas suitable for the driving of an engine a producer gas unit is required, the main components of which are a gas generator, pruifier, radiator and mixer.

Producer gas is formed in the generator. The gas passes firstly through the purifier where soot and dust is removed, then through the radiator where a drop in temperature takes place and lastly through the mixer where the gas is mixed with a suitable volume of air from the air cleaner. The gas then passes the throttle shutter before being drawn into the engine. (The start fan is only used during ventilation of the generator when the engine is cut off and the stop shutter closed).

Figure 18-A-3

INTERNAL PROCESS IN A GENERATOR USING WOOD CHIPS AS FUEL



Extraction of producer-gas

Producer gas is formed by the combustion of solid fuel in a gas generator. The terms "wood gas" and "coal gas" are also used dependent upon whether wood or charcoal is used as fuel.

Differing from combustion in general, which takes place with an excess of air, producer gas is formed with a shortage of air i.e. the process is equivalent to a carburation of the fuel. The Figure shows how producer gas is formed according to the principle of downward combustion.

Drying and carbonization. Air is fed to the generator through the air-jets, inside which the combustion zone is formed. Heat from this source dries and carbonizes above wood chips which are gradually fed down through the bottom part of the fuel jacket. Much of the water found in the wood chips will be vaporized upwards between the outside of the fuel jacket and the inside of the fuel container where condensation takes place.

CHAPTER 19

WASTE HEAT

CHAPTER 19
WASTE HEAT

INTRODUCTION

Heat always seeks an equilibrium temperature. Until it reaches that equilibrium, it is capable of doing work. Once the energy has been released, the concern becomes how much work can be obtained before equilibrium is attained.

The machines we use are not 100 percent efficient; most of the inefficiencies of conversion appear in the form of heat. Thus, any machine which does not convert all of the fuel it consumes into useful energy, such as heat, electricity, or motive power, can be considered as a source of waste heat.

Heat recovery includes a wide range of technologies, beginning perhaps with a simple situation such as drying clothes next to a cooking fire. Advancing technology, increasing fuel costs, environmental limitations, and conservation concerns have led to greater interest and sophistication in heat recovery techniques. These are of special interest to Alaska, where energy consumption and costs are exceptionally high.

HISTORY

The simple use of waste heat, perhaps more appropriately termed residual heat, is very old. An example would be the heating of a home with the heat escaping from a cooking fire.

The development of more sophisticated heat recovery methods paralleled the industrial revolution and increasing utilization of heat. Boilers were used during the last century to recover heat from hot wrought-iron industry gases. Despite early failures of waste heat boilers in the steel industry, by the early part of this century 190 open hearth furnaces had been fitted with waste heat boilers in the United States alone. Gas was another industry that met most of its steam requirements with heat recovery.

As technology advanced, boilers were improved, notably the multitubular shell type developed about 1921. Retort settings of the gas industry and open hearth furnaces were similarly replaced by modern methods. However, steel reheating furnaces, diesel-powered ships, garbage incineration, and other new opportunities for heat recovery have appeared (Gunn, 1976).

Cogeneration represents a large fraction of the total electricity produced in Western Europe and Scandanavia. In the United States, however, cogeneration has declined from 22 percent of total electric sales in 1920 to 18 percent in 1940, 9 percent in 1960, and to a low of 4 percent in 1976 (Harding, 1978). The development of the technology using a variety of working fluids other than water has been important in heat utilization. The thermodynamic properties of these fluids permit greater heat recovery potential over a wider range of temperatures.

While residual heat can sometimes be used for process steam or electrical generation, temperatures are generally too low for these applications. Utilization of low grade heat continues to expand, now sometimes integrating a series of uses, each requiring a lower temperature input than the preceding operation. Examples of low grade heat applications include space and water heating, drying operations, preheating of process air and fluids, sidewalk snow melting, warming of sewage lines, and heating of greenhouses, soil, and water for increased agricultural and aquacultural production.

WASTE HEAT TECHNOLOGY

Waste heat, especially from industrial processes, is usually in the form of Btu's in a liquid (frequently water) or gas (usually air). The hot coolant from an engine or industrial process can be piped directly or via a heat exchanger to radiators in the space to be used. Similarly, stack gas or flue gas from combustion processes can be piped either directly or via heat exchangers to heat space or processes.

In general, the cost of moving low grade waste energy from the point of availability to some point of use is high. For comparison, the transportation costs of moving oil from the Kenai to Anchorage via pipeline runs about one cent per mile per barrel of oil which is equivalent to 5.8 MMBtu. The cost of moving waste heat could be 50 to 200 times greater than the above oil transportation cost.

WASTE ENERGY IN WATER--COST OF TRANSPORTATION

Installed pipe costs in rural Alaska are estimated by Robert W. Retherford Associates in Table 19-1. The figures are based on estimated 1978 materials and labor costs using village laborers with a plumber and supervisor from outside the village.

An analysis of the cost of low temperature (LTW), medium temperature (MTW) and high temperature water (HTW) pipelines has been made by John Beebee (1978). The temperature range, pressure, and materials of construction are given in Table 19-2. Using cost data from many sources (converted to 1976 U.S. dollars using current exchange rates and the pipeline construction cost index), the physical properties of water (vapor pressure, Btu/ft^3, etc.), an annual cost of the pipeline at 15 percent of the total cost, and a load factor of 0.5, Beebee develops Figure 19-1 which shows the cost of moving heat energy as a function of pipe diameter for low and high temperature water. In order to make a comparison with other energy transportation costs published in these projects, the cent per mile per barrel of oil (energy equivalent) has been added to Figure 19-1, recognizing that the numbers are very approximate. Clearly, the cost of moving the Btu's in water is expensive; the use of the waste energy must be near the source.

A study by Charles Meyer shows that the cost of transporting high-temperature water is higher than for natural gas or oil but is comparable to the cost of overhead high-voltage transmission and significantly lower than for underground high-voltage transmission (Figure 19-2). Meyer suggests that the latter comparison is a fair one since hot

TABLE 19-1

Estimated Installed Cost Per Foot* For Pipe in Rural Alaska
Various Types and Sizes
(1978)

Material	Interest Rate (percent)	Pipe Size		
		4 inch	6 inch	8 inch
Asbestos	7	$36	$42	$52
	9	44	50	63
	12	56	64	80
Fiberglass	7	43	50	70
	9	52	60	85
	12	66	77	108
Ductile Iron	7	65	82	121
	9	78	99	146
	12	101	127	187
Carbon Steel	7	70	99	125
	9	85	119	150
	12	108	152	193
Insulated Fiberglass	7	94	111	149
	9	113	134	179
	12	145	171	230
Insulated Ductile Iron	7	121	152	209
	9	146	182	251
	12	187	234	322
Insulated Carbon Steel	7	127	168	216
	9	153	202	260
	12	196	259	334

*Median cost for coastal locations, using village labor.

Source: Robert W. Rethford Associates, Waste Heat Capture Study, June 1978.

TYPE	SENDOUT TEMPERATURE RANGE (Typical ΔT)	WORKING PRESSURE	CONSTRUCTION	UTILITY
LTW	140-212°F (ΔT=50 F°)	10 BAR (145 psi)	New Technology- copper, plastic, concrete, polymer concrete, asbestos concrete pipe, urethane insulation, all plastic pipe-in-pipe system. Possibly untreated water and single-pipe system.	Distribution (small pipe sizes) or one-way transmission.
MTW	176-266°F (ΔT=117°F)	15 BAR (217 psi)	Pipe-in-Pipe system, steel carrier pipe, urethane insulation, plastic casing; direct burial May be same as for HTW below. Treated water (closed loop).	Distribution or transmission from dual purpose power plant.
HTW	248-400°F (ΔT=180 F°)	25 BAR (363 psi)	Steel carrier pipe (sched 40), mineral wool or calcium silicate insulation in covered concrete canal, rock tunnel or poured concrete envelope. Treated water (closed loop).	Transmission or distribution.

TABLE 19-2
Types of Pipeline

Source: John Beebee, private communication to Gene Rutledge, November 2, 1978.

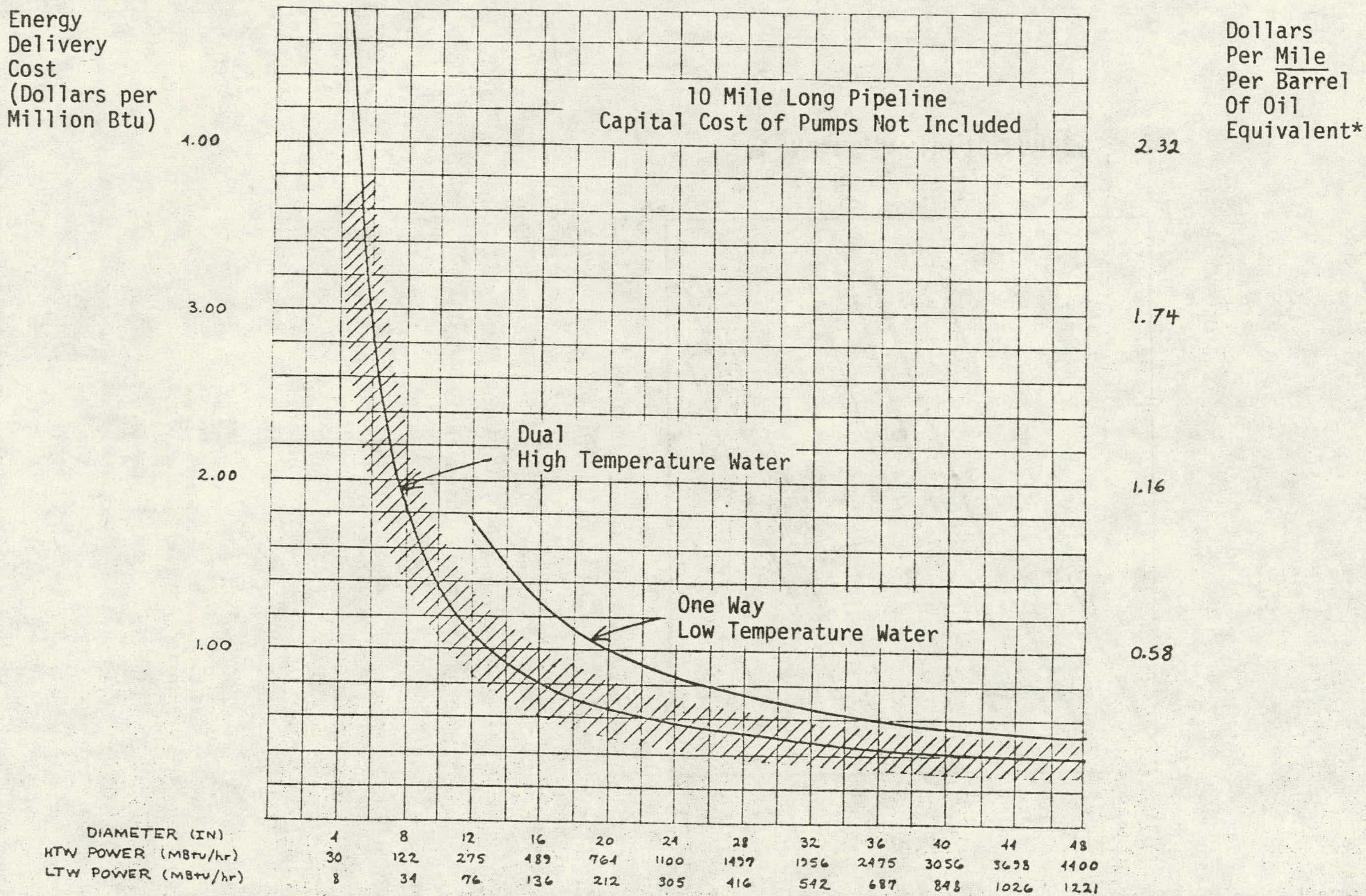


Figure 19-1

Energy Delivery Cost as a Function of Power

Source: John Beebee, private communication to Gene Rutledge, November 2, 1978.

*Calculations added to source document.

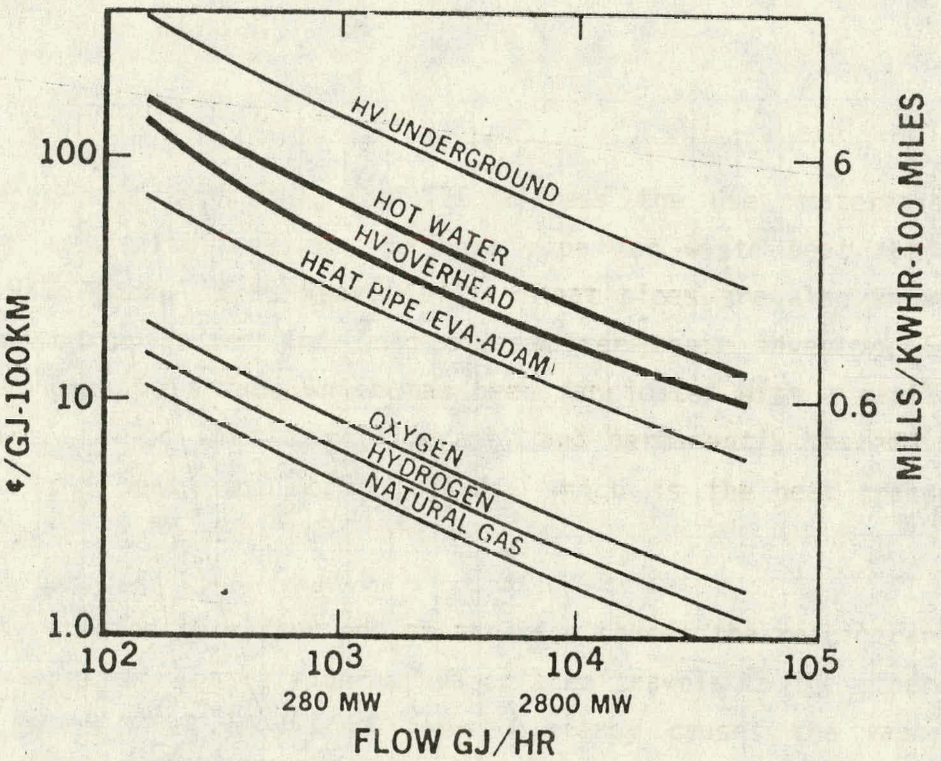


Figure 19-2

Energy Transport Costs in 1975 Dollars

Source: Charles F. Meyer, "Status Report on Heat Storage Wells," Water Resources Bulletin, April 1976, p. 245.

water for district heating would be carried through urbanized areas where construction of overhead high-voltage transmission meets such stiff opposition that the lines are often forced underground (Meyer, 1976).

ENERGY FROM FURNACE STACKS

The movement of the energy in exhaust gas is also expensive. Gas is difficult to pump any distance unless high pressures are maintained. Exhaust gas is normally of relatively low pressure because engines and turbines lose efficiency rapidly as exhaust pressure increases. Since five-ounces per square inch is a practical limit, direct heating by exhaust gas is limited by back pressure. Also, gas leaks in a direct gas-to-air exchanger can be dangerous.

Stack temperatures necessary for economic heat recovery are determined largely by the cost of heat recovery equipment versus fuel price. When fuel costs were in the order of 40 cents per million Btu, stack temperatures of about 700-750°F were acceptable. Today, with fuel costs as high as $2.00 per million Btu, much lower temperatures are acceptable for proper energy conservation and efficiency.

Reed notes that for a "heater requiring absorption of 50 MM/BTU/Hr., the savings can amount to approximately $58,000 per year by reducing the temperature from 700 to 500°F. Obviously, the cost of additional coils for heat recovery or use of extended surface tubes, etc., can be readily evaluated against such savings (Reed, 1976).

Also, SO_3 formation and condensation necessitate designs that avoid sulfuric corrosion.

HEAT PUMPS

Waste heat recovery could involve such hardware as the heat pump, heat pipe and the heat wheel (or Rotary Regenerator). The heat pump is very common, the most familiar application being the refrigerator found in most American kitchens. A more detailed description of the heat pump is presented in Chapter 14, Geothermal. The history of the use of heat pumps, a description of the operation, a cost comparison for nine cities and a list of manufacturers is given in the September 1976 issue of Popular Science.

HEAT PIPES

A number of recent technical articles address the use, materials of construction, and advantages of the heat pipe for waste heat recovery (Basiulis, 1975; Ruch, 1975; Reay, 1977). Heat pipes are also known as frost tubes, thermal piles and Long piles after their inventor, Edwin Long. A heat pipe is a tube which has been fabricated with a capillary wick structure, filled with a refrigerant, and permanently sealed. The wick contains the heat pipe working fluid, which is the heat transport medium.

Thermal energy applied to either end of the pipe causes the refrigerant at that end to vaporize. The refrigerant vapor then travels to the other end of the pipe where the removal of thermal energy causes the vapor to condense into liquid again, thus giving up the latent heat of condensation. The condensed liquid then flows back to the evaporator section (i.e., the hot end) to be reused, thus completing the cycle. Basically, then, the heat pipe operates on a closed loop condensation/evaporation cycle which is continuous as long as there is a temperature difference to drive the process.

A pump is not required for the heat pipe. However, gravity can be utilized to assist the capillary action in returning the condensate to the evaporator section by operating the heat pipe on a slope with the hot end below horizontal. Conversely, by placing the heat pipe on a slope with the hot end above horizontal, gravity retards the condensate flow. Thus, changing the slope of a heat pipe offers a means of controlling the amount of heat to be transfered. This feature can be utilized to regulate the performance of a heat pipe heat exchanger.

A number of fluids can be used in a heat pipe and the choice depends upon the temperature range of the application. Some of these fluids, with useful temperature range, are given in Table 19-3.

HEAT PIPE HEAT EXCHANGERS

A heat pipe heat exchanger consists of a bundle of externally finned heat pipes of the type just described. The heat pipe evaporation/condensation cycle effects the transfer of heat from the "evaporators" are located in the duct carrying the counter-current gas stream, from which heat is to be recovered, to the "condensers" in the adjacent duct carrying the air which is to be preheated.

As mentioned in the previous section, heat pipes are influenced in their performance by the angle of operation. In the heat pipe heat exchanger, the tube bundle may be horizontal or vertical with the evaporator sections below the condensers. Because of this sensitivity, the angle of the heat pipes may be adjusted as a means of controlling the heat transport.

Features of heat pipe heat exchangers which are attractive in industrial heat recovery applications are:

No moving parts--Each exchanger is completely self-contained and each heat pipe is permanently sealed. Thus, there are no nuisance failures or system breakdowns.

Long life--Since the thermal recovery units have no continuously moving parts and each heat pipe is permanently sealed, they operate indefinitely within the design temperature range.

No cross-contamination--A sealed partition separates the two counterflow airstreams preventing contamination of one airstream by the other; only energy is transferred.

System flexibility--A wide range of sizes are available that can be installed individually or together in modules to match the airflow of almost any system. The availability of a wide variety of row and fin spacings allows selection of any system which not only has the desired recovery performance, but also is well suited for cleanability considerations.

TABLE 19-3

OPERATING TEMPERATURE RANGES OF SOME HEAT PIPE WORKING FLUIDS

Medium	Melting Point (° C)	Boiling Point At Atmos. Press. (° C)	Useful Range (° C)
Ammonia	-78	-33	-60 - 100
Freon 11	-111	24	-40 - 120
Pentane	-130	28	-20 - 120
Freon 113	-35	48	-10 - 100
Acetone	-95	57	0 - 120
Methanol	-98	64	10 - 130
Ethanol	-112	78	0 - 130
Heptane	-90	98	0 - 150
Water	0	100	30 - 150
Mercury	-39	361	250 - 650
Sodium	98	892	600 - 1200

Source: David A. Reaz, "The Heat Pipe Exchanger: A Technique for Waste Heat Recovery," <u>The Heating and Ventilation Engineer</u>, January 1977.

Compactness--The units are generally no more than 15 inches deep in the direction of flow. This compact design not only allows more space for other equipment, but also reduces installation costs.

Reversibility--The heat pipe heat exchanger is fully reversible--i.e., heat can be transferred in either direction.

The applications of these devices fall into three categories.

(1) Heat recovery in air-conditioning systems, normally involving comparatively low temperatures and duties.

(2) Recovery of heat from a process exhaust stream to preheat air for space heating.

(3) Recovery of waste heat from processes for reuse in the process, e.g., preheating of combustion air. This area of application can involve a wide range of temperatures and duties.

THERMAL WHEEL (ROTARY REGULATION)

There are a large number of techniques for recovering heat from exhaust air or gas streams. Commercially available systems fall into two categories--recuperators and regenerators. The recuperator, of which the heat pipe heat exchanger is one particular type, functions in such a way that the heat flows steadily and continuously from one fluid to another through a containing wall. A regenerator, however, involves the intermittent flow of heat, and is typified by the rotating regenerator or "thermal wheel." In this unit, a matrix of metal comes into contact alternately with the hot and cold fluid, first absorbing heat and then rejecting it.

Recently the "Rotary Regenerator" has been popularized by the various automotive gas turbine attempts. It is an old device which, while very efficient and compact, has a high contamination factor. The basic priniciple of operation is quite simple. A wheel with good heat (and possibly humidity) absorbing capability is continuously rotated with one half of the diameter enclosed in the "hot" air and the other half in the "heated" air. The wheel absorbs heat and possibly humidity from the exhaust or "hot" portion of the system and transfers it to the incoming air or "heated" portion. Used to transfer heat in a heater, it will be near ideal in conserving heat and humidity and also near perfect in returning everyone's exhaled breath and perspiration. Such devices are receiving increasing attention in applications for commercial buildings.

BOTTOMING CYCLES

In a bottoming cycle, waste heat is diverted to a vaporizer (heat exchanger) where it heats the fluid that drives additional generating equipment (Figure 19-3). Interest in these cycles is growing as fuel costs rise. They are available, simple, relatively inexpensive, and devoid of new technical problems. Bottoming cycles using liquids other than water do, however, introduce new operational problems. Leaks may be fire hazards, toxic hazards, or corrosion hazards besides being expensive. (Water costs pennies per thousand gallons, bottoming cycle fluids may costs dollars per gallon.) Bottoming cycles are not yet (1978) a commercial reality for diesel engine heat recovery but are for multi-megawatt gas turbines.

One company, Riley-Beaird, Inc., P.O. Box 1115, Shreveport, Louisiana, is interested in installing heat recovery exhaust silencers on engines as small as 1-2 HP if a market exists. They now make and sell exhaust boilers for automotive sized diesels. Even these small exhaust boilers need periodic service to remain operational and efficient. Should they be ignored for days at a time they will soot up, run cold, and put back pressure on the engine, lowering efficiency and burning valves.

In Volume I, Phase 1 of this project report, the use of the binary power cycle for geothermal water-dominated system in the 150°C temperature range is addressed (McConkey, 1978). The technology for recovery of energy from waste hot water and geothermal waters can be very similiar.

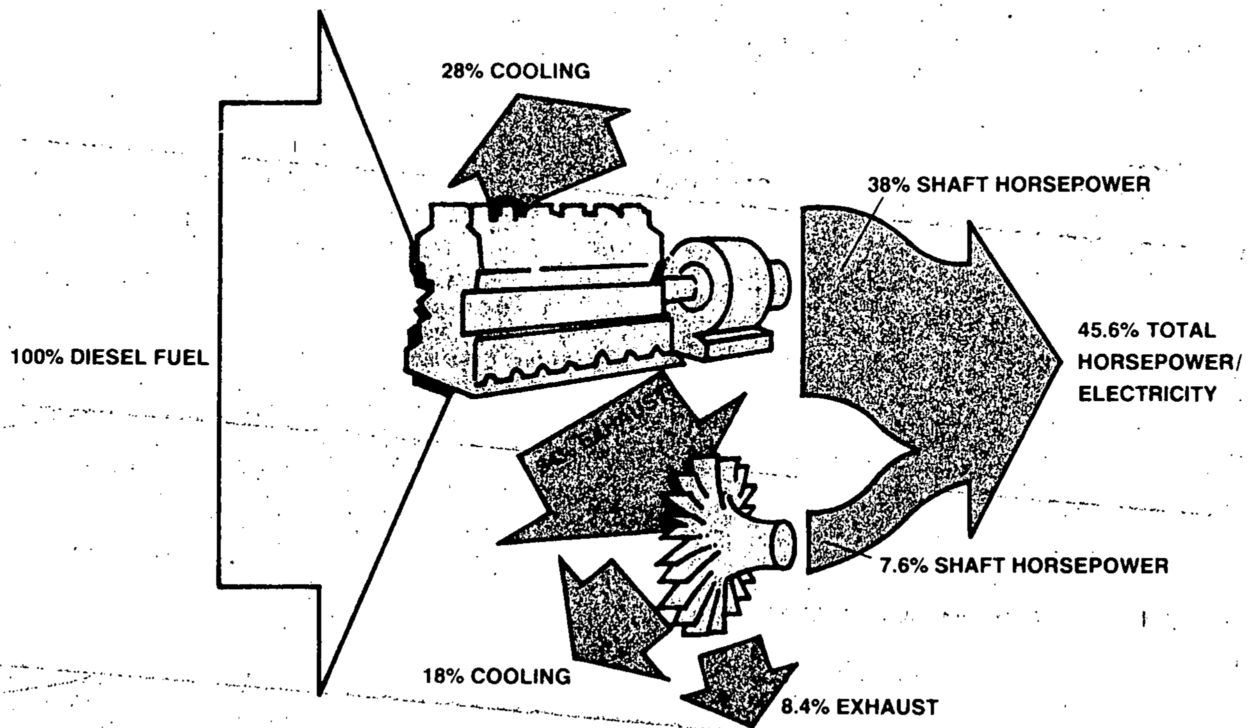


Figure 19-3

The Organic Rankine Bottoming Cycle

Source: Energy Research and Development Administration Office of Public Affairs, EDM-1020R (5-77).

APPLICABILITY TO ALASKA

Residual heat utilization in Alaska has become quite common among municipal and private electric power generators in the state and regional population centers. Barrow, Kotzebue, Nome, Bethel, Fairbanks, and Anchorage all use or plan to use residual heat. Smaller communities such as Copper Valley, Naknek, Ruby, and Unalakleet also have waste heat recovery systems (Rusnell, 1978).

Recovery methods and utilization range from heating the Naknek school with jacket water heat to the more sophisticated system of Chugach Electric Association, Inc. in Anchorage. Chugach Electric Association has a 55-MW and a 65-MW natural gas electric generator that are regenerative, recycling exhaust gas to preheat the generator's incoming air and thereby improving combustion efficiency. It is estimated that in 1977 these units saved a total of 2.70 million mcf of natural gas. To be completed next year (1979) is a 66-MW generator that will be powered by the exhaust gases of two 68-MW generators and is expected to conserve 6.0 million mcf of natural gas (Markley, 1978). Tables 19-4 and 19-5 list the major waste heat utilization and projected utilization in the State. In addition to electrical generation, space heating, and some process steam generation, residual heat is often used in Alaska to heat municipal water supplies.

The large number of Alaskan villages using diesel electric generators have the potential of utilizing the waste heat. The greatest constraint will be the economic factor determined largely by the proximity of the space or water to be heated. Proper design and operation can minimize disadvantages such as noise, fuel odor, and fire danger. The Waste Heat Capture Study (Robert W. Retherford Associates, 1978) lists possible waste heat applications for 18 Alaska Village Electric Cooperative (AVEC) villages (Table 19-6). The study suggests that a fuel savings of as much as 25 percent could result from designing and locating facilities to take advantage of presently wasted heat.

TABLE 19-4

UTILIZATION OF WASTE HEAT IN ALASKA

LOCATION	OWNER/OPERATOR	PROJECT DESCRIPTION
Fairbanks	Fairbanks Municipal Utility System (FMUS)	For many years Fairbanks has provided Heating Steam in the downtown area as a by-product of electrical generation.
Fairbanks	University of Alaska (UAF)	UAF has installed electric and heat co-generation facilities.
Fairbanks	Eielson Air Force base	Eielson AFB and Golden Valley Electric Association, Inc. (GVEA) maintain an energy interchange agreement.
Anchorage	University of Alaska (UAA)	UAA has installed electric and heat co-generation facilities. UAA is also in the process of developing an energy interchange agreement with Anchorage Muncipal Light and Power (ML&P).
Anchorage	Elmendorf Air Force Base	
Anchorage	Chugach Electric Association, Inc. (CEA)	CEA has sold process steam from its Knik Arm Power Plant since 1959.
Bernice Lake	CEA	Sale of steam to Standard Oil.
Kotzebue	Kotzebue Electric Association (KEA)	KEA installed exhaust silencer/waste heat boilers on two of its generators in 1969. Presently, KEA has these boilers on four of its generators. Three of these units help provide the heat for the city's water system.
Naknek	Naknek Electric Association, Inc. (NEA)	NEA has supplied waste heat to the Naknek Elementary Schools since 1968. Exhaust heat silencer/boilers were originally used but now NEA uses only jacket water heat.

Source: Robert W. Retherford Associates, Waste Heat Capture Study, for the State of Alaska, Division of Energy and Power Development, June, 1978.

TABLE 19-5

PROJECTED WASTE HEAT UTILIZATION

LOCATION	OWNER/OPEATOR	PROJECT DESCRIPTION
Anchorage	ML & P	ML & P has a combined cycle steam turbine under construction which uses high quality steam from a waste heat boiler.
Anchorage	CEA	CEA expects to complete a combined cycle turbine installation at the Beluga plant in 1979.
Barrow	North Slope Borough	The North Slope Borough plans to install a waste heat boiler on a new gas turbine in Barrow.
North Pole	Golden Valley Electric Association (GVEA)	GVEA has installed two "regenerative cycle" gas turbines.

Source: Robert W. Retherford Associates, Waste Heat Capture Study, for the State of Alaska, Division of Energy and Power Development, June 1978.

TABLE 19-6

POSSIBILITIES FOR WASTE HEAT CAPTURE AT THE AVEC VILLAGES

Village	Heat Load(s)	Use	Comments
Chevak	School	Space Heating	--
Elim	Armory or School	Space Heating	Long transmission distance
Emmonak	School	Space Heating	School has 3 buildings
Goodnews Bay	School	Space Heating	Power plant may be too small
Kiana	Primary School	Space Heating	--
Lower Kalskag	PHS Pump House	Water Heating	--
Kivilina	Community Hall	Space Heating	--
Nunapitchuk	School	Space Heating	Power plant may be too small
Quinhagak	Health Clinic	Space Heating	Power plant may be too small
Scammon Bay	Community Hall and Health Clinic	Space Heating	Power plant may be too small
Selawik	Primary School and Health Clinic	Space Heating	Possible with adequate load factor
Shageluk	PHS Pump House and Community Hall	Space and Water Heating	--
Shishmaref	PHS Pump House and High School	Space and Water Heating	Next door to pump house, fairly close to school
Shungnak	Store and Warehouse	Space Heating	Construction camp a possibility
St. Mary's	PHS Pump House	Water Heating	Power plant isolated
St. Michael's	PHS Pump House and Community Hall	Water and Space Heating	--
Toksook Bay	Primary School	Space Heating	--
Wales	PHS Pump House and Post Office	Space and Water Heating	Power plant may be too small

Source: Robert W. Retherford Associates, Waste Heat Capture Study, for the State of Alaska, Division of Energy and Power Development, June 1978.

Stack robbers are often used in Alaskan homes. A heat capturing box equipped with a fan is attached to the exterior of a smokestack. A bush application of heat recovery technology is the double Yukon stove. Attached to the smokestack above the first horizontal converted oil drum is a second, which can be used as an oven.

RECOMMENDATIONS

(1) The State should cooperate with federal agencies and private groups to encourage awareness and implementation of waste heat recovery in both new and existing structures.

(2) The economic feasibility of the utilization of heat wasted at existing and planned power installations should be examined. Usually, at least plant shops and offices can be heated. In some cases, moving the present facilities may be justified to lower heat transportation costs.

(3) Application of heat recovery need not be limited to space heating. Opportunities such as greenhouse, acquaculture, drying, sidewalk clearing, soil warming, fish hatcheries, and other innovative uses of low temperature heat should be examined.

(4) Special attention should be given to waste heat utilization in Willow and other locations where new facilities are being planned.

(5) Governmental permitting processes should be modified to incorporate the identification of potential users of waste heat from large and small projects.

(6) The development of more effective exhaust silencers is needed to reduce reluctance to live or work near power plants.

(7) Heat storage tanks should be considered as a means of providing a steady heat source regardless of engine load.

SUMMARY

Heat can be recovered at almost any level, from the campfire, home, or large scale industrial utilization. Alaskans do take advantage of recovered heat in a variety of ways, but the potential for much greater usage of this energy source remains.

The primary restraint is usually the economics of the recovery mechanisms as they compare to the benefits derived from the residual heat utilization. While retrofitting is often worthwhile, special attention should be given to incorporating heat recovery methods into the design of new systems. Estimates of fuel consumption reductions of 25 percent have been made for some villages using diesel electric generators.

Heat recovery is beneficial not only to the party utilizing the energy, but is also important as a means of conserving non-renewable resources. Environmental impact is usually mitigated by heat recovery.

The Waste Heat Capture Study prepared by Robert W. Retherford Associates is recommended as a source of additional information concerning waste heat and Alaska.

<u>KEY CONTACTS</u>

John C. Beebee
Energy Systems, Inc.
P.O. Box 3075
Anchorage, Alaska 99510
(907) 243-1942

Dr. John P. Howe
Professor of Wood Utilization
College of Forestry, Wildlife, and Range Sciences
University of Idaho
Moscow, Idaho 83843
(208) 885-6126

Lawrence D. Markley
Manager of Environmental Systems
Chugach Electric Association, Inc.
731 Gambell
Anchorage, Alaska 99501
(907) 276-3500

Chi-Wu Wang
College of Forestry
University of Idaho
Moscow, Idaho 83843
(208) 885-6444

REFERENCES

Beebee, John, Energy Systems, Inc. Private communication to Gene Rutledge, DEPD, November 2, 1978.

Basiulis, A., and M. Plost. "Waste Heat Utilization Through the Use of Heat Pipes." The American Society of Mechanical Engineers, 75-WA/HT-48. For presentation at the Winter Annual Meeting, Houston, Texas, November 30-December 4, 1975.

Gunn, D. C. "Waste heat recovery in boilers," Energy World. February 1976 pp. 2-6.

Harding, Jim. "Hot Prospects for Reusing Heat, Steam," Not Man Apart. Mid-September/October 1978, pp. 20-21.

Markley, Lawrence D., Manager of Environmental Systems, Chugach Electric Association, Inc., Telecon to Greg Edblom, October 13, 1978.

__________, Manager of Environmental Systems, Chugach Electric Association, Inc., Telecon to Kyle Weaver, October 20, 1978.

McConkey, W., D. Lane, C. Quinlan, M. Rahm, and G. Rutledge. Alaska Regional Energy Resources Planning Project--Phase I. Alaska's Energy Resources--Findings and Analysis. Anchorage, Alaska: Alaska Division of Energy and Power Development, October, 1977.

Meyer, Charles F. "Status Report on Heat Wells," Water Resources Bulletin. American Water Resources Association; April, 1976, pp. 237-252.

Reay, David A. "The heat pipe heat exchanger: a technique for waste heat recovery," The Heating and Ventilation Engineer. January, 1977.

Reed, Robert D. "Recover energy from furnace stacks," Hydrocarbon Processing. January, 1976, pp. 127-128.

Retherford, Robert W. Associates. Waste Heat Capture Study. Prepared for Division of Energy and Power Development, State of Alaska. June, 1978.

Ruch, Michael A. "Heat Pipe Thermal Recovery Units," IECEC '75 Record. 1975, pp. 1507-1510.

Rusnell, Dale W., Chief of Power Development, Division of Energy and Power Development, Department of Commerce and Economic Development, State of Alaska, October 13, 1978.

U.S. Energy Research and Development Administration. "Waste Heat Recovery: More Power From Fuels." EDM-1020R. Washington, D.C.: ERDA, May, 1977.

ALASKA REGIONAL ENERGY RESOURCES

PLANNING PROJECT

PHASE II

REGIONAL ASSESSMENT INVENTORY UPDATE

PART FOUR

CHAPTER 20

Identification and Assessment Programs

PART FOUR

REGIONAL ASSESSMENT INVENTORY UPDATE

CHAPTER 20

IDENTIFICATION AND ASSESSMENT PROGRAMS

CHAPTER 20

IDENTIFICATION AND ASSESSMENT PROGRAMS

INTRODUCTION

Federal and State agencies, consultant and businesses are continuing exploration, evaluation and assessment activities to examine the locations, extent and characteristics of the Alaskan energy resources. A letter of inquiry, sent by the State Division of Energy and Power Development, resulted in positive responses from eleven agencies and organizations (listed at the end of this section) responsible for conducting surveys or inventory activities relating to oil, natural gas, coal, hydropower, uranium, geothermal, wind, and wood resources. Descriptions of their programs appear in Table 20-1. The results of these activities will contribute to the continuing expansion and updating of information on Alaska's potentially recoverable energy resources.

Many other offices are actively engaged in evaluating or conducting inventories of other mineral resources, or energy resources not within the purview of this report. Numerous agencies are involved in secondary or peripheral tasks associated with inventory assessment. The programs of these groups have not been included in the table; however, as their efforts are related to the continuing cataloging of resources, brief descriptions of some of these programs are given below:

(1) The State of Alaska, Department of Natural Resources, Planning and Research Section maintains a computerized resource assessment system for the major resources of the State. This is continually updated on a statewide basis. In the summer of 1978, the system was being revised for use as an objective inventory tool or as an assessment tool requiring subjective judgement.

(2) Battelle Pacific Northwest Laboratory (PNL) has been working on a National Coal Utilization Assessment program which includes estimates of the environmental, health, safety and economic impacts of various hypothetical coal development scenarios. In Fiscal Year 1979, PNL is planning to lead a national assessment of oil, gas and oil shale technologies with an emphasis on oil shale. Additionally, they will participate in national assessments of solar and conservation technologies.

(3) The National Oceanic and Atmospheric Administration of the Department of Commerce is conducting a solar radiation program with the National Weather Service monitoring solar radiation for energy potential. The basic program is 70 years old, but special data quality control was begun in 1977 with help by the U.S. Department of Energy. The monitoring network serves many users including the solar energy community and hydrologists and will ultimately be part of a monitoring and forecasting program that aids coal, oil and natural gas suppliers and public utilities to plan for energy requirements.

TABLE 20-1, Page 1 of 7

ENERGY RESOURCE IDENTIFICATION AND ASSESSMENT PROGRAMS

Resource	Agency	Program Description	Product
Mineral Resources	U.S. Department of the Interior, Geological Survey (U.S.G.S.)	Alaska Mineral Resource Assessment Program (AMRAP): appraisal of mineral resources through geologic mapping, geophysical and geochemical analyses, and interpretation of Landsat imagery. AMRAP assessment areas: Ambler River, Philip Smith Mountains, Survey Pass, Chandalar, Goodnews and Hagemeister Island, Chignik-Sutwik Island, Lake Clark, Seward-Blying Sound, Valdez, Ketchikan-Prince Rupert and Bradfield Canal.[2] Other regional mineral-resource assessment areas: Yukon-Tanana, Mount Hayes, Petersburg and Juneau. Geologic mapping, geochemical sampling, geophysical survey. 1978.[2]	Reports and maps (at 1:1,000,000)
Mineral Resources & Coal	USGS cooperative with Bureau of Land Management (BLM) and Bureau of Mines	Mineral resource assessment study of National Petroleum Reserve in Alaska (NPR-A) for: (1) determination of the distribution, character, and stratigraphic and structural relation of rocks that are potentially mineral bearing; (2) systematic sampling of rocks and soils in areas of mineral potential in order to determine their geochemistry; and (3) determination of the types and values of mineral commodities present.[2]	Report

TABLE 20-1, Page 2 of 7

ENERGY RESOURCE IDENTIFICATION AND ASSESSMENT PROGRAMS

Resource	Agency	Program Description	Product
		For coal assessments the following activities have been conducted: (1) examination of the method of determining the distribution and thickness of coal beds, and (2) reconnaissance geologic mapping of coal-bearing rocks.[1]	
Mineral Resources (including oil shale and Uranium)	U.S. Department of Interior, Bureau of Mines	Evaluation of mineral potential, including energy producing minerals, of NPR-A, d-2 lands and Native lands at Elim, where there is a possibility of uranium potential, and Annette. Final report is in preparation on oil shale field work on Venetie lands, in northeastern Alaska.[1]	Open-file Reports
Mineral Resources	C.C. Hawley and Associates	Appraisal of McKinley, Talkeetna, Lime Hills, and Tyonek areas. DOE contract (through Bendix). 1978[1]	Report to contracting agency.
Oil	State Division of Geological & Geophysical Surveys (DGGS)	Mapping, geochemical sampling and petroleum studies of the North Sound area, including Nunivak Island.[3] Photo-interpretation, looking for construction materials and conducting oil-related geologic studies of the coastline of Norton Sound. Cooperative effort with USGS.[1]	Open-file report.
Oil & Gas	State Division of Minerals and Energy Management	Producing detailed analysis of Prudhoe Bay/Beaufort Sea area reserves over the next year plus some work in the Cook Inlet and older reservoirs.[1]	

ENERGY RESOURCE IDENTIFICATION AND ASSESSMENT PROGRAMS

Resource	Agency	Program Description	Product
Oil	USGS Office of Energy Resources Branch of Oil & Gas Resources	North Slope Petroleum Program. Appraisal of petroleum potential by means of surface and subsurface geological, geophysical, and geochemical studies. Cooperative with ONPR-A. 1978[2]	
Oil	USGS ONPR-A	Geophysical exploration of the National Petroleum Reserve in Alaska to acquire and interpret common depth point seismic, gravity and aeromagnetic data for use in locating drilling sites for exploratory wells and to aid in assessing the petroleum potential of NPR-A. 1977-78[2]	
Oil	USGS cooperatively with State DGGS	Assessment of petroleum reservoir and source rock potential and determine the hydrocarbon maturation level within the basin.[2]	State of Alaska Open-file Publication series.
Oil & Gas	USGS Branch of Oil & Gas Resources Resource Appraisal Group	Development of pre-nomination reports on areas in the Beaufort Sea and the Northern Gulf of Alaska for the BLM for OCS lease sales; review of Department of Interior's assessment work on NPR-A; and planning for revision, updating and expanding of USGS Circular 725, <u>Geological Estimates of Undiscovered Recoverable Oil & Gas Resources in the United States</u>.[1]	
Gas	USGS ONPR-A	Development and operation of gas fields in the Point Barrow area; to explore the Barrow area, to determine presence of hydrocarbon accumulations, especially gas, to	

ENERGY RESOURCE IDENTIFICATION AND ASSESSMENT PROGRAMS

Resource	Agency	Program Description	Product
Gas cont.	USGS ONPR-A	determine reserves of known and discovered fields and to develop and maintain such fields. Continuing.[2]	
Coal	USGS Office of Energy Resources Branch of Coal Resources	Coal resource assessment, statewide: (1) to evaluate coal resources in the NPR-A and AMRAP areas of Alaska by geologic mapping, drill core data and geophysical methods; (2) to provide resource estimates by area and bed; and (3) to assess coal quality by use of Btu values, sulfur and ash content, and major-, minor-, and trace-element concentrations.[2]	
Coal	USGS Conservation Division, Office of the Area Geologist	Preliminary investigations of coal occurrences on the north flank of the Alaska Range in the vicinity of Farewell; sampling of coal beds; resource assessment. 1977-78[1]	Open-file report.
Coal	DGGS	Reconnaissance geology of the west side of the Susitna basin. 1978.[3] Reconnaissance mapping of discrete coal areas in western portion of the Susitna field and north of Chuitna-Capps Glacier. Beluga area. Measuring of coal seams and utilization of core hole data. 1978-1979[1]	Maps, cross sections, correlations, resource estimates.
Coal	DGGS	Inspection of Beluga Coal Field with emphasis on hydrology. Cooperative program with USGS. 1978[1]	Baseline data for future development.

TABLE 20-1, Page 5 of 7

ENERGY RESOURCE IDENTIFICATION AND ASSESSMENT PROGRAMS

Resource	Agency	Program Description	Product
Coal	DGGS	Investigation of Galena-Unalakleet area for coal. 1978[3]	
Coal	DGGS	Investigation of Yukon River area (near Galena-Unalakleet) for coal. 1978[3]	
Coal	DGGS	Reconnaissance mapping of selected areas at Herendeen Bay and Chignik Bay coal fields to establish resource values. 1978[1]	Reconnaissance maps, selected cross sections, estimates of coal resources.
Uranium	USGS Office of Energy Resources Branch of Uranium & Thorium Resources	Stratigraphic studies and geochemical analysis of uranium potential of tertiary basins, statewide, with present emphasis in Cook Inlet, Susitna lowlands, Matanuska Valley, and Copper River basin;[2] reconnaissance and petrologic studies of granites in east-west belt across center of the State; examination of uranium potential of sedimentary rocks or part of the North Slope; continuing field work at Bokan Mountain. 1978[1]	
Uranium	DGGS	Investigation of the Galena-Unalakleet area for uranium. 1978[3]	
Uranium	DGGS	Visit mining districts of Southeastern particularly Quartz Hill, Bokan Mountain, and Admiralty Islanc. 1978[3]	

TABLE 20-1, Page 6 of 7

ENERGY RESOURCE IDENTIFICATION AND ASSESSMENT PROGRAMS

Resource	Agency	Program Description	Product
Uranium	DGGS	In Talkeetna (D5) quad examine a small pluton and surrounding area for uranium potential. 1977-78[1]	Open-file reports, 1978.
Uranium	DGGS	Uranium and thorium analyses on 2,000 stream sediments samples. DOE control. 1978[1]	Results to be published.
Geothermal	USGS Office of Mineral Resources Branch of Alaskan Geology, 1209 Orca St., Anchorage, AK	Reconnaissance of Interior Alaska, Aleutian Islands, Alaska Peninsula and Wrangell Mountains; Geologic mapping, petrologic studies. 1978[2]	Reports in preparation.
Geothermal	USGS-Geologic Division Office of Earthquake Studies Tectonophysics Branch 345 Middlefield Road Menlo Park, CA 94025	Thermal gradient measurements in boreholes and collection of samples, statewide, to determine the regional distribution of heat flow and its relation to tectonic processes in Alaska and to determine the relations among the thermal regime of permafrost, shoreline movements, and Pleistocene climatic history in the Arctic coastal regions.[2]	
Geothermal	DGGS	Field work at Mr. Wrangel; summarization of available information on glacier-volcano interactions; estimation of future activity and hazard potential.[1]	Special report in 1979.
Geothermal	University of Alaska Geophysical Institute	Assessment of low and moderate temperature geothermal energy resources, including study and verification of primary water well data, evaluation of oil well tempera-data and a geochronologic study of young volcanic fields. 1978 DOE control.[1]	Published report designed for use of energy planner, energy companies and potential users of non-electric geothermal energy.

ENERGY RESOURCE IDENTIFICATION AND ASSESSMENT PROGRAMS

Resource	Agency	Program Description	Product
Wind	University of Alaska Geophysical Institute	Detailed analysis of wind regime at Alaskan sites, with power predictions. 1978 continuing.[1]	Reports
Hydro	USGS cooperative with Alaska Power Administration, USAF, Corps of Engineers, U.S. Forest Service; State Department of Fish and Game, State Department of Highways, Department of Natural Resources, Municipality of Anchorage, Kenai Peninsula Borough.	Monitoring a network of stream, lake and estuary gaging stations. Statewide surface water stations. Continuing.[2]	Data published annually in "Water Resources Data for Alaska."
Wood Waste	U.S. Department of Agriculture, Forest Service.	Assessment of timber volumes within the State of Alaska. Continuing.[1]	

Source: 1. Letter from agency. See list of respondents at end of this section.
2. U.S. Geological Survey Circular 772-A, The United States Geological Survey in Alaska: Organization and Status of Programs in 1978.
3. State of Alaska, Department of Natural Resources, Division of Geological and Geophysical Studies, "Mines and Geology Bulletin," Volume XXVII No. 2, June, 1978.

KEY CONTACTS

United States Department of the Interior
Geological Survey
Office of Energy Resources
Branch of Uranium and Thorium Resources
Terry W. Offield, Chief
Box 25046
Denver Federal Center
Denver, Colorado 80225

U.S. Department of Interior
Geological Survey
Conservation Division
Office of the Area Geologist
J. E. Callahan
P.O. Box 259
Anchorage, Alaska 99510

U.S. Department of Interior
Geological Survey
Branch of Alaskan Geology
A. T. Ovenshine, Chief
345 Middlefield Road
Menlo Park, California 94025

U.S. Department of Interior
Geological Survey
Office of Energy Resources
Resource Appraisal Group
Dr. Betty M. Miller, Program Chief
Box 25046 MS 971
Denver Federal Center
Denver, Colorado 80225

U.S. Department of Interior
Geological Survey
Office of National Petroleum
Reserve in Alaska
Arthur L. Bowsher, Chief,
345 Middlefield Road
Menlo Park, California 94025

State of Alaska
Department of Natural Resources
Division of Geological &
Geophysical Surveys
Ross G. Schaff
State Geologist
3001 Porcupine Drive
Anchorage, Alaska 99501

State of Alaska
Department of Natural Resources
Division of Minerals &
Energy Management
Patrick Dobey, Petroleum Manager
323 E. 4th Ave.
Anchorage, Alaska 99501

State of Alaska
Department of Natural Resources
Planning & Research
Bob Klein
Deputy Chief
323 E. 4th Ave.
Anchorage, Alaska 99501

University of Alaska
Geophysical Institute
Donald L. Turner
Associate Professor of Geoloty
Fairbanks, Alaska 99701

University of Alaska
Geophysical Institute
Tunis Wentink, Jr.
Professor
Fairbanks, Alaska 99701

U.S. Department of Commerce
National Oceanic and Atmospheric
Administration
National Weather Service - Alaska
Region
Stuart G. Bigler, Director
632 W. 6th Ave.
Anchorage, Alaska 99501

C.C. Hawley and Associates, Inc.
5109 Shaun Circle
Anchorage, Alaska 99507

Batelle Pacific Northwest
Laboratories
Environmental Policy Analysis
Darryl L. Hessel, Manager
Battelle Boulevard
Richland, Washington 99352