RESEARCH PROJECTS IN INDUSTRIAL TECHNOLOGY

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INTRODUCTION

The purpose of this booklet is to briefly describe ongoing and completed projects being carried out by Bonneville Power Administration's (BPA) Industrial Technology Section. In the Pacific Northwest, the industrial sector is the largest of the four consuming sectors. It accounted for thirty-nine percent of the total firm demand in the region in 1987. It is not easy to assess the conservation potential in the industrial sector. Recognizing this, the Northwest Power Planning Council established an objective to gain information on the size, cost, and availability of the conservation resource in the industrial sector, as well as other sectors, in its 1986 Power Plan. Specifically, the Council recommended that BPA "operate a research and development program in conjunction with industry to determine the potential costs and savings from efficiency improvements in industrial processes which apply to a wide array of industrial firms." The Industrial Technology Section is one of two sections under BPA's Industrial Programs Branch. The section, composed of multidisciplinary engineers, provides technical support to the Industrial Programs Branch by designing and carrying out research relating to energy conservation in the industrial sector.

The projects contained in this booklet are arranged by sector--industrial, utility, and agricultural--and, within each sector, chronologically from ongoing to completed, with those projects completed most recently falling first. For each project the following information is given: its objective, approach, key findings, cost, and contact person. Completed projects also include the date of completion, a report title, and report number.

Additional copies of this document or reports with a DOE number can be obtained by contacting BPA's Public Information Office at 1-800-841-5867 within Oregon or 1-800-624-9495 in other Western states.

INDUSTRIAL SECTOR

HIGH EFFICIENCY ELECTRIC MOTOR GUIDEBOOK

OBJECTIVE: To produce a guidebook on high efficiency electric motors for use by the industrial sector.

APPROACH: An outline for the High Efficiency Electric Motor Guidebook was prepared as part of Phase I of this project. Phase II consists of the actual writing of the book. The compilation is an expansion and updating of a guidebook developed in 1983 by the Contractor.

The guidebook will discuss the characteristics, economics, and benefits of standard versus high efficiency motors in the five to five hundred horsepower range. The database on motors in this range will include current information on manufacturers, motor designation, enclosure type, RPM, price, nominal, full and part load efficiencies, as well as full load power factor. Factors effecting motor selection, application, and operation will be covered. A section on potential energy savings will include utility rate schedules,

procedures for estimating energy savings, worksheets for determining economic feasibility, and the economics of motor selection. A minimum of three case studies concerning the industrial application of high efficiency motors will be conducted and the benefits and barriers encountered will be highlighted. Additionally, worksheets will be included in the text for analyzing simple payback in high efficiency motor selection.

KEY FINDINGS: This is an ongoing project; the findings will be presented in the published version of the guidebook.

COST: \$68,000

STATUS: Ongoing
Target Completion: October 1990

CONTRACTOR: Washington State Energy Office, Olympia, Washington

PROJECT ENGINEER: Joe Flores
(503) 230-3462

HIGH EFFICIENCY ELECTRIC MOTOR REWIND STUDY

OBJECTIVE: To confirm and evaluate the performance of a new technology used for rewinding electric motors.

APPROACH: This advanced rewinding method which makes use of unique circuitry, claims to offer a number of benefits including increased motor efficiency, reduced power consumption, and prolonged motor life. A lack of conclusive evidence on its capability has led BPA to initiate a data collecting study on the new technology. The tests will be conducted at the motor test facility at Oregon State University. A General Electric Energysaver ten horsepower, three-phase induction motor will be subjected to a series of tests with and without power factor correction. The motor will then be modified using the new motor rewind technology. In both modified and unmodified states, the test procedure will determine:

- * the motor parameters for equivalent circuit machine analysis;
- * motor losses including core, stator winding, and rotor conductor losses;
- * efficiency and power factor for a range of load conditions;
- * harmonic performance for a range of load conditions;
- * motor acoustic noise for a range of load conditions;

- * standstill torque and pullout torque and slip; and
- * temperature after operation at rated load for thirty minutes.

Calibration checks will be periodically made to assure the data being collected is both reliable and accurate.

KEY FINDINGS: This is an on-going project; no findings are yet available.

COST: \$21,000

STATUS: Ongoing
Target Completion: November 1990

CONTRACTOR: Oregon State University, Corvallis, Oregon

PROJECT ENGINEER: Joe Flores
(503) 230-3462

DEMONSTRATION OF ADVANCED TECHNOLOGIES IN FOOD PROCESSING

OBJECTIVE: To evaluate the energy efficiency and cost effectiveness of new technologies for use by the food processing industries.

APPROACH: In Phase I, currently underway, the most suitable sites for demonstrating new energy efficient food processing devices are to be determined. The devices to be assessed are microwave, radio frequency and sonic cooking and drying; freeze concentration; membrane separation; and water knife. Manufacturers of these

devices are being contacted to obtain technical data and application criteria. The site selection process will begin with a telephone survey of between fifty and one hundred food processors to develop a list of four possible candidates for each device. Up to twenty five sites will then be visited and assessed. Finally, a ranked list of the visited sites will be compiled from which ten will be recommended for testing of the devices. The ranking procedure will consider factors such as:

- * energy efficiency;
- * applicability of the device to other Northwest locations;
- * environmental impacts; and
- * quality impacts.

GENERAL ARRANGEMENT OF INDUSTRIAL MICROWAVE EQUIPMENT

KEY FINDINGS: This is an ongoing project; no results are currently available. The findings of Phase I will determine whether Phase II, actual testing of the devices, will be undertaken.

COST: \$36,607/Phase I

STATUS: Ongoing
Target Completion: November 1990

CONTRACTOR: Walker Engineering,
Pocatello, Idaho

PROJECT ENGINEER: Alan Budner
(503) 230-3460

PINCH TECHNOLOGY STUDY

OBJECTIVE: To conduct a thermal analysis of the processes of a pulp and paper plant in the Northwest using pinch technology.

APPROACH: Pinch technology is an advanced methodology used to predict the potential gains in the overall energy efficiency of plant processes and as such can be used to optimize the design, placement, and application of heat exchangers or heat pumps, power cycles, and utilities. Phase I is being done as a joint effort with EPRI. It is concerned with testing the methodology in a Northwest pulp and paper plant. The analysis should provide the following:

- * Identification of the proper mix, quantities, and levels of all hot and cold plant process streams;
- * recommendations for improving the energy efficiency of the plant--process changes and heat exchanger or heat pump installation; and
- * recommendations for improving overall plant operation, eliminating capacity bottlenecks and mitigation of environmental impacts.

If no cost effective measures are uncovered, the analysis should provide a detailed explanation as to why not. As part of this work a companion workshop on the fundamentals of pinch technology will be held for utility and industry representatives.

KEY FINDINGS: This work is just underway. Should this phase of the project target cost effective measures, a second phase would involve selecting and designing energy saving measures and, in a third phase, implementing the measures and verifying their effects.

COST: \$57,800

STATUS: Ongoing
Target Completion: June 1990

CONTRACTOR: EPRI/Linhoff March, Inc., Palo Alto, California

PROJECT ENGINEER: Gayland Smith
(503) 230-3445

CASE STUDY ON DEHUMIDIFICATION DRYING OF LUMBER

OBJECTIVE: To investigate the economics and performance of dehumidification drying for use by the lumber industry.

APPROACH: Dehumidification drying technology, which can produce thermal energy savings as high as 60 percent, appears to be a cost effective alternative to conventional drying practices for the lumber industry. This work consists of a case study of a dehumidification system being installed at Diamond Wood Products in Eugene, Oregon, which will be the largest such facility of this type in the region. A comparison with conventional drying will be carried out at Bohemia's Vaughn, Oregon facility where much of Diamond's custom drying of excess lumber has been done. While one kiln of each type will be studied comprehensively, additional kilns will be monitored when possible to determine the cumulative energy consumption. The same wood species and grade will be used for both drying techniques. Data collection will begin on a now operational dehumidification kiln consisting of two seventy-five horsepower compressors capable of extracting 2,700 gallons of water per day at peak drying.

Factors to be determined by the analysis include:

- * the quality and quantity of wood dried;
- * the drying rate;
- * the energy use on a Btu/unit basis for electric power,

natural gas, and hogged fuel;

- * energy efficiency;
- * operating conditions; and
- * environmental impacts.

The economic assessment will determine capital costs, depreciation, annual maintenance, overhead, and labor costs for a typical mill. Sufficient data will be collected to estimate annual energy consumption.

KEY FINDINGS: No findings are available as this is an ongoing project.

COST: \$63,122

STATUS: Ongoing
Target Completion: September 1990

CONTRACTOR: Oregon State University, Corvallis, Oregon

PROJECT ENGINEER: Brad Miller
(503) 230-3464

DEVELOPMENT OF AN ENERGY EFFICIENT DESSICANT DEHUMIDIFIER

OBJECTIVE: To investigate potential applications for an Energy Efficient Dessicant Dehumidifier (EEDD) in the industrial, commercial, and agricultural sectors of the Pacific Northwest.

APPROACH: This work was done in two phases: application assessment and prototype design, fabrication, and testing. Phase I determined potential applications for an EEDD by examining various dehumidification concepts and collecting and reviewing data on energy use from each of the three sectors in the region. The data was used to calculate the total electric power consumption for applications of the technology in all three sectors. Phase II consisted of the design, fabrication, and testing of a prototype EEDD. Performance testing was carried out at the IIT Research Institute to determine the following: 1) the ability of infrared energy to penetrate the desiccant wheel; 2) moisture removal capabilities; 3) the coefficient of performance in terms of moisture removal to energy supplied ratio; and 4) the EEDD measured performance compared to the estimated performance of the state-of-the-art desiccant dehumidifier.

KEY FINDINGS: The assessment portion of the study indicated that the EEDD unit could provide energy savings of approximately 40 percent over conventional vapor compression systems. When compared with a theoretical state-of-the-art desiccant dehumidifier, energy savings were about 8 percent better efficiency with the EEDD. No potential applications for the EEDD were identified in the agricultural sector. In the industrial and

commercial sectors, space air conditioning in the former and space conditioning, refrigeration, and freezing in the latter were the major applications identified.

Phase II showed the EEDD to be a promising technology with testing of the prototype unit averaging a moisture removal to energy ratio 59 percent better than that estimated for the state-of-the-art desiccant dehumidifiers. However, no direct comparison tests between the two types were conducted.

Phase III, installation and demonstration of an EEDD, was not undertaken for three reasons: 1) the cost to develop a commercial scale model was prohibitive; 2) the applications identified did not currently warrant further research; and 3) no significant efficiency improvement over currently available technologies, i.e., the dehumidification heat pump, were demonstrated.

COST: \$129,839

STATUS: Completed March 1990

CONTRACTOR: IIT Research Institute, Chicago, Illinois

PROJECT ENGINEER: Gayland Smith
(503) 230-3445

ANALYSIS, DESIGN, AND DEMONSTRATION OF A VENEER COOLER/SORTER

OBJECTIVE: To determine the economic and technical feasibility of a veneer/cooler system for use with radio frequency (RF) redryers in the plywood manufacturing industry.

APPROACH: Thus far, the work has been accomplished in two phases. An electronic spreadsheet program was developed to model veneer drying in an Oregon-based plywood plant to determine the overall suitability of introducing RF redrying into the manufacturing process. A working scale model was built to verify the computer predictions. Establishing the basic design of a veneer cooler system was then undertaken in Phase II.

KEY FINDINGS: The veneer drying analysis showed that for this study plant, the application of RF veneer drying with forced cooling could result in an increase in total plant production, a reduction in veneer drying costs, or both. However, an analysis of the costs and benefits of the system should be performed on an individual basis to determine cost-effective application.

A full-scale cooler system was designed for use with redryers based on removing an appropriate amount of heat from a veneer piece through exposure to a forced air stream for a sufficient amount of time. Cooling curves for three veneer thicknesses--1/10th, 1/6th, and 7/32th inches--were calculated to be 18.2, 30.3 and 39.8 seconds, respectively. These times were then used in developing the length

of the cooler.

Working copies of the manufacturing drawings are available on computer diskette format. The cost for a fabricated system is estimated to be \$99,000. A third phase, which was not contracted due to limited industry response at the time, would have involved fabrication, installation, and demonstration of a prototype unit.

COST: \$66,683

STATUS: Completed July 1989

CONTRACTOR: Carroll, Hatch & Associates, Portland, Oregon

REPORT TITLE AND NUMBER:

PROJECT ENGINEER: Brad Miller
(503) 230-3464

ADJUSTABLE SPEED DRIVE: APPLICATIONS GUIDEBOOK

OBJECTIVE: To develop a guidebook that would assist industry in identifying applications that favor adjustable speed drives (ASD) in industrial processes driven by electric motors.

APPROACH: A format was devised that would allow potential users to identify their load type and determine what, if any, ASD is commercially available to apply to that type of load. A survey of ASD manufacturers and industrial users was conducted to gather material on the primary considerations in ASD application. A wide range of applications were incorporated in the guidebook including the less familiar such as material handling, assembly lines, machine tools, mixing/proportioning operations and winding/unwinding operations.

KEY FINDINGS: A guidebook was prepared that describes drive systems, the requirements of industrial processes, and ASD types, and also compares

conventional drives with ASDs. The guidebook demonstrates how the control of certain processes can be improved with the use of an ASD. Advantages and disadvantages associated with the technology are discussed. Also included are an Application Matrix and ASD Case Examples as well as Technical and Economic Screening Guides for use in the preliminary scoping of a project to determine feasibility.

COST: \$111,500

STATUS: Completed November 1989

CONTRACTOR: Ebasco, Bellevue, Washington

REPORT TITLE AND NUMBER:
Adjustable Speed Drive:
Applications Guidebook
DOE/BP-34906-1/May 1990

PROJECT ENGINEER: Gayland Smith
(503) 230-3445

Figure 1.18 Basic Block Diagram of an ASD System

ELECTRIC ARC FURNACE STUDY

OBJECTIVE: To improve the efficiency and reduce the electrical noise in electric arc furnaces during the start-up and meltdown processes of ferrous scrap charges.

APPROACH: BPA's work on this project was carried out as an exchange of services with the Bureau of Mines (Bureau). The Bureau had conducted experimental tests on a small scale electric arc furnace in its research center in an effort to understand electric arc behavior. BPA was asked to cooperate by providing test trailer equipment needed to monitor an industrial scale electric arc steelmaking furnace. The week long monitoring process was designed to verify tentative conclusions drawn during earlier testing. The tests

were carried out on a 25-MVA electric arc furnace at the Oregon Steel Mills, Portland, Oregon. Data was collected eight hours each day. The data is to be analyzed and interpreted by the Bureau.

KEY FINDINGS: BPA is awaiting the Bureau's report on the outcome of this work.

COST: \$32,600/Exchange of Services

STATUS: BPA work completed September 1989

CONTRACTOR: Bureau of Mines, Albany, Oregon

PROJECT ENGINEER: Alan Budner
(503) 230-3460

BORE DOWN

MELTDOWN

REFINING PERIOD

INDUSTRIAL HEAT PUMP ASSESSMENT STUDY

OBJECTIVE: To assess the potential for cost effective application of heat pump technology in industries served by BPA and its preference customers.

APPROACH: A four-step methodology was developed to estimate the potential for heat pumping in BPA service area industries. The first, consisted of generating a list of industries where heat pump technology might be applied. The industries on the list were next categorized by SIC codes, of which forty-two were represented. Prioritization of the list began with reviewing the list based on two factors: the fossil fuel use of an industry and the potential for reducing fossil fuel consumption in an industry through heat pumping application. The third step consisted of using representative process data for each industry to determine the characteristics of heat pump application, its effects on the process, and its economics. Finally, fuel savings, electric power use, and capital costs were then estimated and a simple payback determined.

KEY FINDINGS: A potential for applying heat pump technology economically does exist for industries served by BPA. Six industries were chosen as being the most promising: pulp mills; paperboard mills; paper mills; canned fruits and vegetables; beet sugar refining; and bread and related products. Heat pumps were considered cost effective when the simple payback was under two years. The greatest potential

exists within the largest industry, the pulp and paper. Fuel savings for this industry would be about 10.2 trillion Btu/year with an increase in electric power use of 24.3 average MW. At the low end, fuel savings for the canned fruit and vegetable industry were estimated to be 0.2 trillion Btu/year. In the aggregate, the estimated fuel savings for the six industries is 22 trillion Btu/year, or 13 percent of the current annual fuel use.

COST: \$100,000

STATUS: Completed March 1989

CONTRACTOR: Idaho National Engineering Laboratory, Idaho Falls, Idaho

REPORT TITLE AND NUMBER:
Industrial Heat Pump Assessment Study
DOE/BP-36246-1/June 1989

PROJECT ENGINEER: Barry Kennedy
(503) 230-3463

ENERGY EFFICIENT SOFTWARE DIRECTORY FOR THE INDUSTRIAL CUSTOMER

OBJECTIVE: To develop a directory of computer software packages that can be used by the industrial sector in determining the potential energy savings and costs associated with more efficient use of electric power.

APPROACH: A list of available software packages was compiled. The programs were screened for their applicability to the industrial sector and to confirm their availability.

KEY FINDINGS: A directory containing over one hundred micro- and mainframe software computer programs for use by those in charge of energy management within the industrial sector was compiled. The software packages can be used to perform a range of functions including:

- * forecasting energy consumption;
- * calculating mass and heat balances;
- * modeling processes; and
- * determining performance.

Each entry contains the name of the program, a program description, computer/equipment specifications, the programming language, price, terms, and conditions, and contact information. The descriptions of the software packages are organized into three major sections: power engineering; process industries, and equipment and machinery. A directory includes a program name index, a vendor name index, and an

application index.

COST: \$32,180

STATUS: Completed February 1989

CONTRACTOR: Engineering Information, Inc., New York, New York

REPORT TITLE AND NUMBER: Energy Efficient Software Directory for the Industrial Customer
DOE/BP-34673-1/May 1990

PROJECT ENGINEER: Brad Miller
(503) 230-3464

POWER FACTOR CONTROLLER STUDY

OBJECTIVE: To determine those conditions which favor application of a Power Factor Controller (PFC), a power electronics device that senses the voltage requirement of a motor.

APPROACH: The first phase of the study consisted of an historical and current assessment of the use of PFCs. The work included analyzing the circuitry and performance characteristics of PFCs. In the demonstration phase, PFCs were installed at three promising sites and measured energy savings were compared with calculated savings.

KEY FINDINGS: The study confirmed the earlier belief that PFCs can only be cost effectively applied in certain situations. Specifically, this work clarified further those conditions which most favor economic PFC application. Among these conditions are:

- * Purchasing the PFC as an optional feature on a soft-start motor starter to minimize its first cost.
- * Standard efficiency motor designs, such as T-frames, provide better opportunities than high efficiency designs for the PFC to save on motor losses as their losses are higher and there is more energy available to save with PFC use.
- * Motors used for high inertia/high torque loads, where use of high efficiency motors is prohibited, offer

opportunities for loss reduction with a PFC.

- * Since the PFC reduces motor losses only at very low load, the motor's operation should consist of extended periods of duty at very low or no load.
- * The option of stopping and restarting the motor periodically, rather than running it, must not exist as it would eliminate any chance for the PFC to save any motor losses.

COST: \$127,000

STATUS: Completed December 1988

CONTRACTOR: Knudson Engineering, Inc., Portland, Oregon

REPORT TITLE AND NUMBER: Power Factor Controller Study
DOE/BP-64849-1/Aug 1989

PROJECT ENGINEER: Gayland Smith
(503) 230-3445

ADJUSTABLE SPEED DRIVE STUDY

OBJECTIVE: To provide a brief but comprehensive screening procedure for determining which, if any, adjustable speed drive (ASD) type to use for the smaller horsepower size applications; and to support this with an extensive treatment of performance and cost characteristics of the ASD types.

APPROACH: A small air circulation fan that is part of an existing heating, ventilation, and air conditioning system was used as the basis for simulating a range of conditions in the laboratory in order to enable precise measurements. The investigation included six ASDs: three established, two emerging technology, and one experimental.

KEY FINDINGS: Of the ASDs tested, the high efficiency induction motor pulse width modulation drive is most appropriate for HVAC application. However, the payback period is about ten years for this five horsepower size. The drives studied all had very good efficiency which improved with higher speeds. Also, the drives all exhibited poor power factor and were considerable sources of very broad band electromagnetic noise.

While the permanent magnet motor/pulse width modulation inverter drive provides high efficiency and low vibration and noise, it is currently expensive and offered only in small horsepower size. Similarly, the switched reluctance motor drive is costly but its tough simplicity makes it suitable for use in potentially hostile environments (explosive or caustic vapors). The disadvantages associated with direct current motor drives are low efficiency and, again, a premium price. The series resonant converter, still in the experimental stage, was overrated for this application. The findings are presented in two separate, but related reports.

COST: \$182,000

STATUS: Completed September 1988

CONTRACTOR: Oregon State University, Corvallis, Oregon

REPORT TITLE AND NUMBER:
Adjustable Speed Drive Study:
Part I/Summary Report and
Part II/Appendices
DOE/BP-23169-1/Aug 1989
DOE/BP-23169-2/Aug 1989

PROJECT ENGINEER: Joe Flores
(503)230-3462

Fig. 6 HVAC ASD Installation Schematic

ENERGY SAVINGS IN A SILICON FURNACE THROUGH IMPROVED REDUCTANT TECHNOLOGY

OBJECTIVE: To determine if energy savings are technically and economically feasible in the silicon smelting process using new raw materials.

APPROACH: Tests were conducted in a 25,000 kVA arc furnace in a silicon producing plant in Springfield, Oregon. Two new raw materials were used: coalchar, a coal product) and charcoal (a hardwood product). Each was subjected to a two week smelting test as part of the plant's regular operation.

KEY FINDINGS: Energy consumption for the coalchar was 5.68 kilowatt-hours per pound (kWh/lb) of silicon produced. For charcoal, the energy consumption was 5.60 kWh/lb of produced silicon. This compared favorably with the historic 6.4 kWh/lb energy consumption of standard materials. The cost savings over 1987 standards were 4.7 percent and 5.7 percent for the coalchar and charcoal, respectively.

The charcoal achieved better performance in the furnace than the coalchar, maintaining both a steady state of operation and efficient production of silicon. The major disadvantages associated with the use of charcoal were dust and fixed carbon variability in the reductant. The dust problem was rectified by soaking the charcoal in water until saturated and the variability of the reductant was resolved by stepping up and improving the sampling technique used so that the amount of charcoal could be adjusted. It was

recommended that charcoal be adopted for use at this site's smelter.

COST: \$134,200

STATUS: Completed December 1987

CONTRACTOR: Dow Corning Corporation, Springfield, Oregon

REPORT TITLE AND NUMBER: Energy Savings in a Silicon Furnace Through Improved Reductant Technology
DOE/BP-31023-1/Feb 1988

PROJECT ENGINEER: Alan Budner
(503) 230-3460

DESIGN AND APPLICATION OF AN ADVANCED INDUSTRIAL WASTE-TO-ENERGY RANKINE CYCLE POWER SYSTEM

OBJECTIVE: To establish the technical and economic criteria for a full-scale industrial Rankine-cycle power generating system installation in the Pacific Northwest.

APPROACH: This work, an investigation of the commercial feasibility of an advanced industrial waste-to-energy generating system, consisted of five tasks accomplished in two phases. Phase I provided 1) environmental criteria; 2) a preliminary system design; 3) an investment model with a listing of economic assumptions; and 4) a preliminary site screening analysis and survey of the wood products industry in the region. In Phase II, baseline design parameters for a complete waste-to-energy system (boiler, turbine, and main ancillary items) were established and three economic profile scenarios were developed. The final task was concerned with setting up a screening matrix for twenty-five potential installation sites and determining the requirements of potential investors.

KEY FINDINGS: The requirements of economically feasible application were found to include: a minimum of 4,000 operating hours, 20,000 lb/hr steam production, an electric power utility rate of 0.05 per kWh and a debt equity rate of three or more. Particulate emissions were the primary environmental concern and could be controlled with the use of a scrubber except in non-attainment areas where the addition of a baghouse would be required. The

economic viability of the system was shown to be favorable for all three scenarios considered. The findings for the low and medium electric rate profile were nearly identical and between the medium and high profiles the difference was less than 10 percent. Potential installation sites were identified. However, no plant operators were interested in installing the system in spite of the favorable economics. The study did conclude that this kind of system has immediate potential for plants with steamflow sufficient to produce at least 1,800 kW and at least 6,000 hours of operation.

COST: \$122,000

STATUS: Completed October 1986

CONTRACTOR: Mechanical Technology, Inc., Latham, New York

REPORT TITLE AND NUMBER: Design and Application of an Advanced Industrial Waste-to-Energy Rankine-Cycle Power System
DOE/BP-15108-1/May 1987

PROJECT ENGINEER: Joe Flores
(503) 230-3462

ADDITIONAL SAWMILL ELECTRICAL ENERGY STUDY

OBJECTIVE: To study the potential for reducing electrical energy use at lumber dry kilns through a reduction in fan speed in the course of the lumber drying process.

APPROACH: This study was undertaken after an earlier study identified fan speed reduction as a potential energy conservation opportunity. The work consisted of three tasks: 1) quantifying the achievable energy savings for a dry kiln under normal operating; 2) determining electrical energy use levels at other sawmills and the transferability of the technology developed in Task 1; and 3) developing a guidebook on the technology for use by mill owners. A kiln at the Frank Lumber Sawmill Company in Mill City, Oregon was equipped with a variable frequency drive control. Fan speed could be varied from normal speed down to less than 40 percent of normal. Testing was carried out for over one year.

KEY FINDINGS: Field tests indicated fan speed reduction to be a valid energy conservation measure. The study determined that fan slowdown cannot begin until the end of the heat transfer limited period, when the kiln has reached the point where surface water is removed and the kiln is up to temperature. Both timing and the level of fan speed reduction are critical so as not to adversely effect the quality of the drying lumber. Fan speed can be controlled on a manual (line shaft systems only), semi-automatic, or automatic basis. In this study,

electrical energy savings of 40 percent were regularly realized with the fan speed control on automatic or semi-automatic. Savings as high as 50 percent were also experienced.

Average energy savings were 13.5 kWh per thousand board feet for an estimated annual savings per kiln of between \$3,200 and \$4,300. There is an opportunity for energy conservation in all types of lumber drying operation using this technology including the nineteen surveyed in this study. The most likely candidates are those with high energy costs or high energy consumption. Regionwide adoption of fan speed reduction could result in energy savings of 151,200,000 kWh per year.

COST: \$79,000

STATUS: Completed December 1986

CONTRACTOR: Carroll, Hatch & Associates, Portland, Oregon

REPORT TITLE AND NUMBER:
Additional Sawmill Electrical
Energy Study
DOE/BP-23462-2/Feb 1987

PROJECT ENGINEER: Joe Flores
(503) 230-3462

VARIABLE SPEED LINE SHAFT DRIVE

SAWMILL ELECTRICAL ENERGY STUDY

OBJECTIVE: To gather information on electric energy consumption and the potential for energy conservation opportunities in a representative sawmill.

APPROACH: The work for this study was performed at the Frank Lumber Sawmill Company, in Mill City, Oregon. The research effort included the development of a logical method to analyze how and where energy is used in this, or any, sawmill.

KEY FINDINGS: It was found that energy is consumed in three separate ways, each reflecting a type of load--the base, utility, and process loads. These loads account, respectively, for 54, 36, and 10 percent of the energy consumed.

A total of seventeen Energy Conservation Measures (ECMs) were identified at this mill. The potential energy savings of these measures were calculated to be 15 percent of total electric power consumption. The five most cost effective investment opportunities were recommended for

implementation. Of these, three involved revising current operating procedures with no capital outlay: 1) reduce use of electrical space heater; 2) reduce use of lighting; and 3) revise equipment stop/start control. The remaining two would require an investment of capital: 1) install a variable speed drive in line shaft kilns and 2) install unloaders in all large air compressors. The ECM offering the greatest conservation benefit would involve reducing the fan powered air flow at the mill's dry kilns during the drying process.

COST:

STATUS: Completed October 1984

CONTRACTOR: Carroll, Hatch & Associates, Portland, Oregon

REPORT TITLE AND NUMBER: Sawmill Electric Energy Study: Part I
DOE/BP-15104-1/Oct 1984

PROJECT ENGINEER: Joe Flores
(503) 230-3462

DEMONSTRATION PROJECT FOR ENERGY CONSERVATION IN ALUMINUM SMELTING

OBJECTIVE: To test the energy saving potential of a coating material for aluminum reduction cells.

APPROACH: The contractor had conducted tests using this low cost coating material on six cells previous to this work. For this study, the titanium-boron coating material of proprietary nature was applied to the bottom (cathode) of twelve cells. A comparison was made of the twelve coated cells with twelve uncoated cells. Performance of both the test and control units was monitored under normal operating conditions to determine energy savings, cost effectiveness, and life expectancy of the coating. Monitoring was carried out for one year. The testing was done at a Commonwealth Aluminum smelter in Goldendale, Washington.

KEY FINDINGS: Earlier testing had led the contractor to believe that energy savings would result from a reduction in the cathode's electrical resistance due to the coating. Based on the findings of this study, the resistance is nearly equal for both coated and uncoated cells. Rather, energy savings accrue from the increased uniformity of the magnetic and electrical fields created by the presence of the coating. Because this reduces the movement of the molten metal, the top of the cell (anode) can be brought closer to the cathode, reducing the voltage across the cell and thus reducing the power needs of the process.

Energy consumption for each pound of aluminum produced was reduced by .18 kWh with the use of the coating. The life expectancy of the coating is estimated to be at least five years. The study results also suggest that extended cell life and easier operation are additional benefits derived from using this material. For the years 1985--2000, costs for a typical aluminum smelter were compared with and without the coating on its cells. The rate of return was calculated to be 75 percent with a payback of four years.

COST: \$464,300

STATUS: Completed September 1984

CONTRACTOR: Commonwealth Aluminum Corporation, Bethesda, Maryland

REPORT TITLE AND NUMBER:
Demonstration Project for Energy Conservation in Aluminum Smelting
DOE/BP-13770-1/June 1986

PROJECT ENGINEER: Alan Budner
(503) 230-3460

UTILITY SECTOR

CONSERVATION VOLTAGE REDUCTION PILOT/DEMONSTRATION PROJECT

OBJECTIVE: To develop a method for assessing the cost effectiveness of conservation voltage reduction (CVR) for BPA and its customers thus encouraging the implementation of CVR on distribution systems where it is economic.

APPROACH: Phase I of this four phase project is aimed at developing an Assessment Plan that can be used as a guideline in monitoring and modeling the energy savings effect of CVR techniques. The techniques for estimating the conservation potential of CVR will be tested on a sample of distribution circuits in the Snohomish County PUD No. 1 service area. This utility began a CVR pilot program in 1988. Two approaches for estimating energy savings resulting from CVR implementation are being studied. One makes use of statistical procedures to establish a relationship between measured energy savings and the primary factors that determine energy consumption. The second involves

determining the savings potential from the data intensive Distribution System Analysis and Simulation (DSAS) computer program developed for EPRI in 1985. In developing the Assessment Plan consideration will be given to using existing ELCAP data versus developing new data in predicting energy savings from CVR techniques. A cost/benefit analysis will be carried out to assist BPA in determining the best level of data collection and analysis for use in the pilot project. Additionally, criteria for selecting sample circuits in the Snohomish system will be determined in this phase.

Phase II of the project will be concerned with computer modeling using the DSAS program and monitoring the effects of CVR techniques on the Snohomish distribution system. Phase III and IV will involve evaluating and modifying the DSAS computer program and refining and distributing the revised program to BPA customers.

KEY FINDINGS: Preliminary findings appear to indicate that other utilities have not used the DSAS computer program due to its intensive data requirements. BPA may be able to use ELCAP data to drive the DSAS computer program.

COST: \$68,881

STATUS: Ongoing
Target Completion: Phase I July 1990/Phase II July 1991

CONTRACTOR: United Industries Corporation, Bellevue, Washington

PROJECT ENGINEER: Barry Kennedy
(503) 230-3463

a. With LDC During Periods of Light and Peak Demand.

AMORPHOUS METAL TRANSFORMER DEMONSTRATION PROJECT

OBJECTIVE: To test the reliability and confirm the electric energy conservation opportunities on distribution systems using amorphous metal transformers (AMT).

APPROACH: BPA undertook this study as part of an EPRI-sponsored program to confirm the energy saving capabilities and reliability of this low no-load loss technology. BPA bought and tested twelve 25-kVA AMTs and installed them in place of existing station service transformers at BPA substations. The core losses of all twelve units were measured upon arrival, and then on two units at one year intervals for two consecutive years. A preliminary report on BPA's and the industry's experience with AMTs was prepared for use as guidance in determining whether further application of the technology by BPA and its customers was warranted.

KEY FINDINGS: Amorphous metal transformers offer the potential of a 60-70 percent reduction in the energy consumed by no-load losses in distribution transformer cores. Generally, amorphous core transformers are a cost-competitive product alternative to traditional transformers for utilities that value losses at \$5 or more per watt.

Over the two year monitoring period, no-load watts loss measurements of BPA's twelve AMTs showed no significant changes from the nineteen watts reading upon delivery. BPA has three opportunities for application of this technology: 1) the replacement of existing transformers due to age

or damage; 2) the replacement of PCB-contaminated transformers that exceed the contaminant limit; and 3) new transformers. The preliminary analysis recommended that BPA adopt a policy for purchasing commercially available AMTs as new and replacement units are needed.

COST: \$22,800

STATUS: Completed December 1989

CONTRACTOR: EPRI/General Electric
Palo Alto, California

REPORT TITLE AND NUMBER:
Amorphous Metal Transformer
Demonstration Project, Final Report
December 1989

PROJECT ENGINEER: Barry Kennedy
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ASSESSMENT OF CONSERVATION VOLTAGE REDUCTION APPLICATION IN THE BPA SERVICE REGION

OBJECTIVE: To evaluate the appropriateness of Conservation Voltage Reduction (CVR) as a energy saving resource for the BPA service area.

APPROACH: The purpose of this work was threefold: 1) to evaluate state-of-the-art CVR; 2) to develop conservation supply curves for CVR for the region; and 3) to provide guidance on CVR implementation. A literary review was undertaken to determine utility experience with CVR application and the effects of CVR on both distribution systems and end-use loads. In estimating supply curves, a probable range of energy savings was determined. Supply curves for the Pacific Northwest as a whole and for the publicly-owned utilities were developed.

KEY FINDINGS: The assessment of this conservation approach found

CVR to be both a proven and cost effective energy saving measure. Both supply curves indicate that the CVR resource potential is significant. At a cost of 0.1 cent/kWh in 1985 dollars, virtually free savings are available: between 92-145 average megawatts (AMW) for the region as a whole and 35-60 AMW for publicly-owned utilities. At a cost of less than 1.0 cent/kWh in 1985 dollars, the savings for the region are estimated to be 142-230 AMW and, for publicly-owned utilities between 51-95 AMW. At 5.4 cents/kWh in 1985 dollars, additional savings are available for the region and publicly-owned utilities--170-268 and 65-112 AM, respectively. To achieve the highest energy savings at the lowest cost using CVR, the utility feeders should be less than three miles in length. While longer lines could be included in a CVR program, the cost of energy savings would increase. Because most utilities have a mix of lines, determining the cost effectiveness of CVR application is best done on an individual basis through empirical or computer modeling studies.

COST: \$100,000

STATUS: Completed November 1987

CONTRACTOR: Pacific Northwest Laboratory, Richland, Washington

REPORT TITLE AND NUMBER:
Assessment of Conservation Voltage Reduction Application in the BPA Service Region
DOE/BP-14031-1/Dec 1987

PROJECT ENGINEER: Barry Kennedy
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TRANSMISSION AND DISTRIBUTION EFFICIENCY IMPROVEMENT R&D SURVEY

OBJECTIVE: To identify and quantify those technologies that could provide the greatest benefits for improving transmission and distribution (T&D) system efficiency for utility customers in the Pacific Northwest.

APPROACH: Of the forty-nine state-of-the-art technologies and thirty-nine future technologies reviewed, fifteen from the former list and seven from the latter were chosen as having the most potential and then submitted to an evaluative test. The test made use of a modeled sample system for Benton County PUD, a utility with characteristics typical of a BPA customer system.

KEY FINDINGS: The most cost effective state-of-the-art technology was found to be "Conservation Voltage Reduction" which involves reducing end-use voltage on secondary distribution

systems to decrease the energy consumption of electrical users when possible. "Voltampere Reactive Optimization" is a similarly cost effective alternative. The most significant loss reduction on a T&D system would be realized through the substitution of standard transformers with high efficiency transformers, such as amorphous metal core transformers.

Of the future technologies analyzed, "The Distribution Static VAR Generator" appears to be the most promising in terms of technological innovation and, in time, commercialization. "Improved Dielectric Materials" with relatively low cost and high potential for efficiency improvement, deserve consideration. The least cost effective technologies identified were "Extruded Three-Conductor Cable" and "Six- and Twelve-Phase Transmission" programs. As a result of this study, a number of research projects into state-of-the-art efficiency technologies were launched.

COST: \$247,000

STATUS: Completed September 1986

CONTRACTOR: Advanced Systems Technology, Pittsburgh, Pennsylvania

REPORT TITLE AND NUMBER:
Transmission and Distribution
Efficiency R&D Survey
DOE/BP-17102-1/Sept 1986

PROJECT ENGINEER: Barry Kennedy
(503) 230-3463

DISTRIBUTION SYSTEM EFFICIENCY IMPROVEMENT GUIDEBOOK/COMPUTER PROGRAM

OBJECTIVE: To provide a method that could be used to evaluate the cost effectiveness of alternative measures for improving distribution system efficiency.

APPROACH: A Guidebook was designed to address the section in the Pacific Northwest Electric Power Planning and Conservation Act which states that BPA's customer service policy will encourage among other items, energy loss reduction for customer distribution systems. Methods to reduce losses were identified. These loss reducing measures included: 1) replacing existing conductors with larger units; 2) increasing the system voltage; 3) replacing service transformers with larger or more efficient models; 4) adding shunt capacitors to improve power factor; 5) adding phases; and 6) balancing phases. Theoretical and economic guidelines for each of these loss savings approaches were prepared.

KEY FINDINGS: A guidebook was compiled that can be used in determining if a capital investment can be made on a distribution

system to reduce losses based upon an economic justification. The guidebook approach was originally adapted for use on a computer in 1983. The program was then modified for use on IBM mainframe and then later for IBM-PC compatible computers. The material was thus made accessible to a wide customer audience. The software program allows the user to determine the cost effectiveness of as many distribution system upgrade options as desired.

COST: \$100,000

STATUS: Completed December 1981/October 1983

CONTRACTOR: C2HM Hill, Portland, Oregon

REPORT TITLE AND NUMBER:

Distribution System Efficiency Improvement Guidebook
DOE/BP-171

Distribution System Efficiency Improvement Program and User Manual
DOE/BP-35622-1/Aug 1989

PROJECT ENGINEER: Barry Kennedy
(503) 230-3463

ANALYSIS OF LOSS REDUCTION METHODS OF PENINSULA LIGHT COMPANY'S LOCKER ROAD DISTRIBUTION FEEDER

OBJECTIVE: To assess the economic feasibility of upgrading a typical distribution system in the Pacific Northwest to reduce losses.

APPROACH: The Locker Road Feeder at the Artondale Substation on the Peninsula Light Company system was chosen as a typical system for the analysis. Options for reducing losses on the system were investigated for cost effectiveness. Each loss reduction method was reviewed from two perspectives: Peninsula Light's (the Company) and BPA's. The cost of power as valued for the Company was what it currently pays and expects to pay in the future. The marginal cost of power was the value used for BPA.

KEY FINDINGS: System reconfiguration and shunt capacitor application were found to be the

most cost effective options for both BPA and the Company although neither resulted in large savings in absolute values. While reconductoring and parallel circuit additions offer a substantial reduction in losses, this option, if implemented immediately, is only economical based on a marginal cost analysis. Replacement of distribution transformers was found to be a cost-effective conservation measure only for units that are heavily loaded. Selective replacement was suggested. Because the system area studied was a capacity limited system, and since the reduction in losses did not cover conversion costs, increasing the primary voltage level from 12.47 to 24.94 was not considered to be economic. However, a system covering a larger service area could benefit from this option. The loading on the feeder was not large enough to justify substituting distribution system conductors.

COST: \$25,000

STATUS: Completed May 1981

CONTRACTOR: Engineering Design Associates, Tigard, Oregon

REPORT TITLE: Analysis of Loss Reduction Methods of Peninsula Light Company's Locker Road Distribution Feeder

PROJECT ENGINEER: Barry Kennedy
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AGRICULTURAL SECTOR

IMPROVED SELECTION PROCEDURES FOR IRRIGATION SPRINKLERS

OBJECTIVE: To study the relationship between droplet energy and the maximum depth of water that can be applied without runoff to the major sprinkler irrigated soils in the region. Additionally, the droplet energy of common irrigation sprinklers was to be measured.

APPROACH: Samples of nine soils known to be prone to sealing in the field were collected. Tests to learn about the sealing properties of the soils were conducted in a laboratory using a variety of sprinkler heads. The characteristics of the soils were studied before and after sealing. The time taken for ponding to begin was measured.

KEY FINDINGS: Energy flux is the power per unit area that falling water delivers to the soil. The energy flux of the sprinkler determines the time ponding begins. Equations were developed to determine the maximum energy flux corresponding to the desired

depth of applied water without runoff. The efficiency of existing sprinkler systems and the design of new ones can be improved through the knowledge gained in this study. Estimates of the energy savings possible with proper sprinkler selection are 100,000 megawatt hours per year for the region based on the irrigation load measured by BPA.

COST: \$42,074

STATUS: Completed January 1990

CONTRACTOR: Washington State University, Pullman, Washington

REPORT TITLE AND NUMBER:
Improved Selection Procedures for
Irrigation Sprinklers
DOE/BP-35677-1/Feb 1990

PROJECT ENGINEER: Alan Budner
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Time to Ponding vs. Droplet Energy Flux
Cheney Fine Sandy Loam

OPTIMAL REAL-TIME PUMP AND IRRIGATION SCHEDULING FOR CENTER-PIVOT SPRINKLING SYSTEMS

OBJECTIVE: To develop a dynamic irrigation scheduling algorithm for pressurized center-pivot irrigation systems to minimize pumping costs while fulfilling the water requirements of optimum crop production.

APPROACH: Methods for optimizing irrigation water using crop models were reviewed. An optimization method was chosen that generally ensures the ability to schedule pivot operations and maintain favorable soil water levels. A case study of a regional farm system with over one hundred center-pivots and four pumping stations was conducted to demonstrate the optimal scheduling algorithm.

KEY FINDINGS: An irrigation scheduling model has been designed for use on personal micro-computers. The algorithm includes a scheduling analysis to provide recommendations on water application timing and quantity as well as on optimal selection to determine the most cost effective pump combinations. The program works by delaying or interrupting irrigation in high energy cost periods and shifting the process to a period with lower energy costs. A simulated application of the scheduling algorithm to the case study farm indicates a 33 percent savings in energy pumping costs over normal irrigation management practices. A 17 percent reduction in water use was also indicated using optimal scheduling.

COST: \$26,800

Figure 1.1 Typical Center-Pivot Irrigation System

STATUS: Completed September 1988

CONTRACTOR: Colorado State University, Fort Collins, Colorado

REPORT TITLE AND NUMBER: Optimal Real-Time Pump and Irrigation Scheduling for Center-Pivot Sprinkler Systems
DOE/BP-35571-1/Aug 1989

PROJECT ENGINEER: Alan Budner
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EVALUATION OF VERY LOW PRESSURE SPRINKLER IRRIGATION AND RESERVOIR TILLAGE FOR EFFICIENT USE OF WATER AND ENERGY

OBJECTIVE: To assess the performance characteristics and economic implications of very low pressure irrigation devices used in combination with reservoir tillage for a variety of crops, soils, and slopes representative of the region.

APPROACH: This study was a continuation of work begun in the 1985 season to assess very low pressure irrigation devices. Two types of low pressure devices were tested: spray nozzles and furrow drops (bubblers). The center-pivot irrigating systems were located in Oregon, Washington, and Idaho. Two linear-move systems were tested in research facilities.

KEY FINDINGS: Tests indicated that for sloping fields, the combination of reservoir tillage with very low pressure irrigation systems reduced or eliminated runoff while crop yields remain consistent or increase slightly. Due to a reduction in spray evaporation and drift losses, less water is applied. By lowering operating pressure and increasing application efficiency, energy savings can, under the right circumstances, be an additional benefit. The benefits of reservoir tillage with very low pressure irrigation systems for flat or gently sloping fields were less certain. Timing of a tillage operation is important and depends on crop type. Due to the high potential for runoff as well as the system management problems associated with furrow bubblers, their use is not recommended for many areas in the region. The effectiveness of reservoir tillage

is dependent on the ability of reservoirs to store surface water until it infiltrates. If the reservoir cannot, an increase in runoff and erosion would occur. The performance of the pressure regulator tested was adequate. With proper design and maintenance, application uniformity with low pressure spray systems is comparable to its high pressure counterpart. For some example systems the payback period is less than four years.

COST: \$85,500

STATUS: Completed February 1988

CONTRACTOR: U.S. Department of Agriculture, Agricultural Research Service, Kimberly, Idaho/University of Idaho, Moscow, Idaho

REPORT TITLE AND NUMBER:
Evaluation of Very Low Pressure Sprinkler Irrigation and Reservoir Tillage for Efficient Use of Water and Energy
DOE/BP-62961-1/Feb 1988

PROJECT ENGINEER: Alan Budner
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CALIBRATION OF IRRIGATION FLOW METERS

OBJECTIVE: To find a convenient and accurate survey device for measuring the flow rate of irrigation systems.

APPROACH: Laboratory tests were conducted on different meters under various flow rates. Three of the devices tested work on the Doppler effect which involves sound waves striking particles or bubbles in the water flow to measure the velocity of water. Three additional ultrasonic meters that are based on other principles--two on transit time and one on eddy correlation--were monitored. Three Hall-type model meters, used currently by BPA in its conservation programs, were also tested. These are pitot tube type meters that sense the average velocity across the pipe cross section.

KEY FINDINGS: The Doppler meters were found to perform both inaccurately and inconsistently on a variety of pipe sizes and materials even though some were compact and easy to use. The two meters that work on the transit time principle were found to

perform accurately but are currently only available for permanent installations and not as survey instruments. The unit based on the eddy correlation principle did not measure flow accurately but it has potential since it can operate under adverse flow conditions. Using the calibration factor developed in this study, Hall meters can have accuracy of better than ± 3 percent. Recommendations on their proper use were made. It was also recommended that a transit time meter suitable for portable measurements be developed.

COST: \$15,000

STATUS: Completed February 1988

CONTRACTOR: Oregon State University, Corvallis, Oregon

REPORT TITLE AND DATE:
Calibration of Irrigation Flow Meters/Feb 1988

PROJECT ENGINEER: Alan Budner
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Figure 11. Tokyo Keiki, Panameter 6068, USGS Meter Results on 8" PVC Pipe.

PARTIAL IRRIGATION FEASIBILITY STUDY AND DEMONSTRATION PROJECT

OBJECTIVE: To demonstrate and document the practice of partial irrigation to determine if it is a appropriate conservation strategy for the Pacific Northwest.

APPROACH: In this three year study (1984-1987) the irrigation practices of a total of twelve working farms in Washington and Oregon were observed. A single crop (winter wheat) was studied in 1984 with corn added the second year. Potatoes, a less likely candidate for partial irrigation, were added in the final year in an effort to better understand how irrigation practices in the region are influenced by this crop. The monitoring program was designed to determine energy and water consumption, crop yields, and all production costs.

KEY FINDINGS: The data illustrated the roughly linear relationship between water

consumption and variable costs. For those farms practicing partial irrigation, fixed costs were generally lower. The reduced costs offset revenue reductions caused by lower yields due to a decrease in water use. However, partial irrigation intensifies any net loss on a crop due to low prices. Conversely, under profit conditions, minimized water use can maximize the profit.

Partial irrigation of wheat combined with fully irrigated potatoes was found to be a profitable strategy. Over-irrigation of wheat is more costly than under-irrigation for the range of water use close to the full irrigation mark. To achieve a maximum profit per acre the water level appears to be at 80-90 percent of the full irrigation requirement. Using partial irrigation, the regional energy savings are estimated to be 23 and 6 average megawatts for wheat and corn, respectively, for a total of about 6 percent of the energy used for sprinkler irrigation in the region.

COST: \$347,000

STATUS: Completed September 1987

CONTRACTOR: Northwest Economic Associates, Vancouver, Washington

REPORT TITLE AND NUMBER: Partial Irrigation Feasibility Study and Demonstration Project
DOE/BP 15109-1

PROJECT ENGINEER: Alan Budner
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COST OF PRODUCTION & GROSS INCOME

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