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A NATIONAL PROGRAM TO INCREASE ENERGY EFFICIENCY IN IRRIGATED AGRICULTURE

An Executive Summary

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It currently takes 0.34 quadrillion Btu's of energy to irrigate the nation's crops. Of this, 86 per cent is used in 13 western states. A national program to increase energy efficiency in irrigated agriculture can be focused in the West.

PROGRAM OBJECTIVE

Irrigation experts, during a Department of Energy workshop, concluded that energy efficiency could be doubled with the use of alternative hardware, improvements in scheduling, and education of irrigators.(1) Dr. James Gilley, of the University of Nebraska, concluded that energy savings in the range of 40 to 50 per cent are realistic and attainable.(2) Based on these estimates, a national program was designed to save 0.15 quadrillion Btu's of energy in irrigated agriculture by 2000.

There are about as many ways to manage a U.S. Federal Government program as there are programs. Social programs with broad undefined objectives appear to have been the least successful. Programs with a specific objective, such as putting a man on the moon within a decade, are considered the most successful. The object of this program is to double the energy efficiency of irrigated agriculture to achieve a savings of 0.15 quadrillion Btu's by 2000. In order to establish this objective, an initial task was to conduct an analysis to determine where and how energy is being used in irrigation and who is presently doing research and developing energy-efficient irrigation techniques.(1)

In the initial task it was found that while some irrigation occurs in all 50 states, 79 per cent of the irrigated acreage lies within the boundaries of 11 states. These 11 states used 89 per cent of the total energy used for irrigation nationally. Five crops which are produced in these 11 states account for 55 per cent of the total energy used for irrigation in the nation.

More than two-thirds of the total energy used for irrigation is consumed in pumping water from the source to the field level. Consideration of pumping lift levels is essential in the design of a national program. For example, Nebraska has 5 times more irrigated acreage than Arizona and pumps 82 per cent more water. Arizona consumes 30 per cent more energy because the average pumping lift is 3.8 times as great as the average lift in Nebraska. An early program priority would be to disseminate energy efficient pumping technology to Arizona.

On the basis of the initial analysis to determine where and how energy was being used in irrigation, it was concluded that projects should be selected which:

(1) Are most applicable to cultural practices used in Texas, Nebraska, Kansas, Arizona, New Mexico, California, Washington, Oklahoma, Idaho, Colorado, and Oregon.

(2) Are applicable to production of sorghum, cotton, wheat, corn, and alfalfa.

(3) Reduce the energy required to pump ground water to the surface.

In an abridged survey of energy conservation research, 62 research projects were identified at universities in the 11 states. Only 14 of these projects dealt with increased energy efficiency in wells, pumps, and prime movers. Less than one-quarter of the projects dealt with more than two-thirds of the energy use. For this reason, it was felt that Department of Energy funds should be concentrated on energy efficiency wells, pumps, and prime movers.

PROJECT SELECTION

Following the issuance of a Program Opportunity Notice, 28 proposals were submitted to the Department of Energy. Of these, five dealt with increasing the efficiency of wells, pumps, and prime movers. Eleven focused on increasing the efficiency of application techniques. Six could broadly be classified as dealing with scheduling. Three were classified as agronomic.

Initial acceptance of each proposal was predicated on criteria established in the Program Opportunity Notice. Proposals which met the established criteria were then evaluated on the basis of the results of the initial analysis described above. Conversations were conducted between representatives of the Department of Energy and each bidder to allow for reconsideration of specific elements of each proposal. Final selection resulted in a program made up of projects that created a continuim of water flow in irrigation from ground water supply analysis through wells, pumps, distribution, application, and instrumentation to scheduling.

It has long been thought that water wells are energy inefficient, but a simple, consistent method to analyze these inefficiencies and correct them has not been developed. The purpose of the project being conducted by the University of California at Davis is to investigate the causes of energy inefficiencies resulting in the extraction of ground water. The objectives of the project are to:

(1) Identify factors of well and pump inefficiencies,

(2) Analyze and rank them,

(3) Recommend methods to reduce the inefficiencies.

The investigators estimate the potential energy conservation at .005 quad per year.(3)

The purpose of the project being conducted at the Irrigation Center, Staples Area Vo-Tech Institute, is to document and demonstrate the differences in energy requirements among irrigation wells constructed in unconsolidated aquifers. Ten production irrigation wells will be designed and constructed using alternative types of commercially available well screens. The wells will be tested for draw down following three stages of well development to determine hydraulic efficiency. Investigators estimate an energy savings of .006 quad.(4)

The Aerospace Research Corporation is analyzing the differential between field pump efficiencies and laboratory pump efficiencies in order to recommend procedures to reduce the differential. Efficiencies for commercial multi-stage centrifugal pumps range from 65 to 76 per cent. The efficiency of 76 per cent can be increased to 80 per cent by polishing impeller and difuser surfaces and close fitting the impeller to the housing to reduce recirculation loss. Efficiency losses in the column pipe can be reduced by sealing the well casing at the pump and using the well casing as the conduit, thereby eliminating the column pipe. The bearing losses can be reduced by stiffening the line shaft segments so that bearing spacings can be increased. The contractor estimates an energy saving of .13 quad.(5)

Foster-Miller Associates are developing an energy efficient variable speed pump utilizing a variable DC motor drive, directly coupled with a pump to produce a system with a "wire to water" efficiency of better than 78 per cent. This system is being constructed out of commercially components using one moving part. It is estimated that .003 quad could be saved with this technique.(6)

Keller Engineering is streamlining, updating, and documenting for public use an existing commercial computerized life-cycle-costing irrigation system pipeline network design program. This program is designed to minimize the sum of capital, pumping, maintenance, and operational costs during the life of the system. It will also minimize the energy required to move water through the system. Utilizing a computer program to perform what is traditionally done manually will allow installers of irrigation systems to determine the cost of energy savings over time. It is estimated that .001 quad of energy can be saved per year with the incorporation of this system.(7)

Several center-pivot manufacturers currently offer reduced pressure systems which operate at a pivot pressure between 25 and 35 psi. The systems used either a low pressure impact sprinkler or a spray nozzle system to distribute the water. Several different types of spray nozzles are now available for use on center-pivot systems. However, each of these reduced pressure systems has the disadvantage of increased water application rates which may restrict their use to certain locations.

The University of Nebraska is combining field and modeling work to design, develop, and demonstrate reduced pressure center-pivot irrigation systems used in combination with reduced tillage practices. A center-pivot has been modified to include:

(1) A high pressure conventional system,
(2) A low pressure impact sprinkler head system, and
(3) A low pressure spray nozzle system.

The three tillage methods are:

(1) Chop stalks in the spring, till, plant, and cultivate;
(2) Two discings in the sprink, plant, and cultivate; and
(3) Fall subsoil, chop stalks in the sprink, till, plant, and cultivate.

Empirical data will be utilized to construct mathematical models to test the effect of: (1) reduced system capacity, (2) increase speed of rotation, (3) modified application rate pattern, and (4) modified cultural practices.[8]

Five times more energy is used to operate sprinkler systems on one-third of the acreage than is used in surface irrigation. Automation in gravity irrigation has awaited the availability of inexpensive flow control valves. Such valves are now being manufactured and marketed. The purpose of the research being conducted at Kansas State University is to automate a gated pipe irrigation system using a radio control transmitter and receivers to direct the flow of the water through flow control valves. Field data will be collected to determine the best irrigation management practices for automated gated pipe systems used for cutback, head, and constant head irrigation. If irrigation efficiency could be increased from 65 per cent to 92 per cent with automated gated pipe, the estimated energy saving would be .023 quad.[9]

Texas A & M University is taking another approach to achieve energy efficiency in windy areas on soils with low intake rates. They have designed and are testing a mobile flood irrigation system which operations in conjunction with a mechanical bordering tool. The development of this system is divided into:

(1) Systems hydraulic design for uniform distribution,
(2) Outlet design to operate in the 1 to 5 psi range,
(3) A guidance system which combines a mechanical sensing element with a pneumatic direction control circuit,
(4) A variable speed drive and alignment system,
(5) A water conveyance system, and
(6) An intermediate pressure system and valve arrangement.[10]

Prossen Industries is designing an instrumentation system for irrigated agriculture based on:

(1) The optimization of plant performance,
(2) Instrumentation techniques,
(3) Application of computer systems, and
(4) Automation of data collection and transmission.

The objective is to produce a complete electronic system to optimize energy use in irrigation.[11]

Harza Agricultural Services, in conjunction with the Pacific Gas and Electric Company, is documenting the effect of an irrigation scheduling system on irrigation consumption for a representative sample of 46,500 acres in the central San Joaquin Valley. The Valley has been divided into unique farming environments based on climatology, soil variation, water resources, and cropping patterns. Each parcel will be monitored under varying concepts of irrigation scheduling during cropping systems in order to determine the impact of commercial scheduling services on energy use.[12]

PROGRAM MATRIX

The majority of the ten projects described above are regional or local in nature. Information generated from the ground water optimization project at the University of California could be distributed to well drillers throughout the country. The pump efficiency research at the Aerospace Research Corporation could be disseminated to pump manufacturers with national sales outlets. Without considerable effort, it is likely that technology generated in the other projects would not be widely dispersed throughout the country. The first step in achieving national application to technology generated in this program is to create a matrix system of management. Within such a matrix, the column vectors can be identified by each of the ten projects. To create row vectors, it is necessary for each of the 10 contractors to write research reports which are identical in format. Therefore, each contractor has been asked to deliver a final report to the Department of Energy which consists of seven chapters. These chapters are:

(1) Introduction
(2) Data Specification
(3) Data Analysis
(4) Technical Results
(5) Cost Analysis
(6) Industry Acceptance
(7) Potential for Energy Conservation

Each of these seven chapters identify a row vector in the matrix.

The first, second, and third chapters are unique to each of the ten projects. Within each project the first three chapters form the basis to establish the technical results, the cost analysis, industry acceptance, and the potential for energy in conservation. Asking each contractor to write a report of common format allows us to aggregate the technical results of each of the 10 projects and compare them with energy efficient technology being developed in the public sector and the private sector. Aggregating each of the chapters describing cost analysis allows us to determine the pervasive effect of a standard set of relative factor and product prices thought to prevail in irrigated agriculture at the turn of the century on the acceptance of the technology developed in the program. Aggregating the analyses of data describing initial acceptance collected during the demonstration phase of the program will give the Department of Energy insight into the speed of market penetration. The bottom line for the Department of Energy is the amount of energy that can be conserved. Aggregating the Chapter 7's from each of the ten reports creates a vehicle for testing the hypothesis that 0.15 quadrillion Btu's of energy can be saved in irrigated agriculture by 2000. It also allows policy makers to determine the potential impact of alternative national incentives to technological adoption.

In order to complete the design of a national program to increase energy efficiency in irrigated agriculture, each of the 10 chapters 4 through 7 must be aggregated into common reports which take a national perspective. These reports are initially identified as:

(1) An Analysis of the Research and Development Effort in the Private Sector to Reduce Energy Consumption in Irrigated Agriculture.

(2) An Analysis of the Research and Development Effort in the Public Sector to Reduce Energy Consumption in Irrigated Agriculture.

(3) An Analysis of the Irrigated Agricultural Economy with Respect to Energy.

(4) An Analysis of the Potential Response of the Agricultural Industry to Energy Conserving Technology in Irrigation

(5) An Analysis of Federal Incentives to Reduce Energy Consumption in Irrigated Agriculture.

The technical results of each of the ten projects will be compared with an analysis of research and development efforts in the private and public sector to reduce energy consumption in irrigated agriculture. Two reports are thought necessary because of the differing requirements in data collection and analysis between the private sector and public sector.

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