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THERMAL POLLUTION AND ITS TREATMENT*

THE IMPLICATIONS OF UNRESTRICTED ENERGY USAGE
WITH SUGGESTIONS FOR MODERATION OF THE IMPACT

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"An abundant supply of low-cost energy is the key ingredient in continuing to improve the quality of, our total environment"

L. A. DuBridge from hearings before
the Joint Committee on Atomic Energy
October - November, 1969 Ref. (1)

As we enter the final thirty years of the 20th century, these words summarize the principal thrust of the energy policy of the United States as it has existed from its inception to the present. Yet as these very words were recorded, the forces at work within the technological economy have been giving prominent signals that a new policy may be thrust upon us. During the year since these hearings, there has been an awakening interest in the consequences of man's activities on earth which can be compared to no other period in the nation's history. Climatologists, long among the most cautious of environmental scientists now seem to have reached relatively full agreement that man can affect the climatic conditions of the earth by means of the systematic release of heat and materials which change the opacity of the atmosphere. This atmosphere of ours, once regarded as limitless as the sky itself, now grows more confining every day. How shall an economy such as ours, based on the use of cheap energy employed without limit, react to the concept that a new frontier of thrift and moderation in its use appears around the corner?

For over a century the notion of physical growth and financial expansion have been generally regarded as synonymous with success. The Fabian Socialists of the 19th century based an entire political philosophy on the concept that the limitless use of basic resources was a natural right of man. Many of the notions of modern resources management continue to reflect these concepts. There is no single segment of Western society which has contributed more to the advancement of man on earth than energy technology, yet all of these achievements will be of little value if

the management of energy and formation of energy policy fails to recognize the need to protect the gains of the past.

In order to gain perspective it is necessary to briefly review the state of the art in energy technology, primarily electrical power technology, in relation to the need to consider the potential effects of the present course of action in this field. An important point to stress is the fact that energy demand and energy release to the environment are synonymous. All of the energy converted from nuclear or fossil sources appears in the environment as heat to be added to the earth's thermal budget. Hence, in the discussion of electrical energy demand, it is appropriate to consider the subject in terms of the thermal energy released to satisfy the demand. In this context, the projected growth of electrical power assumes a position of paramount importance in the total picture of the year 2,000 AD.

Because of the increased knowledge of the environmental interaction of power policy with terrestrial resources, the making of forecasts has become a hazardous business. The most recent total energy survey published by the Office of Science and Technology (Ref. 2) is used as a basis for the remarks in this section. Other appraisals can and will be made; in the interim, the reference survey is sufficiently timely to be useful. From this publication, other Battelle authors have converted the energy forecast to a consideration of environmental impact in a paper (Ref. 3) given at Atlanta in the spring of 1970. This paper is the basis for the figures which follow.

Figure 1, based on a total U.S. population of 300 million by 2,000 AD, places the expected overall energy usage per capita in perspective. Energy usage per capita is expected to increase by some 250% based on 1960 estimates and electrical energy (kilowatts at the busbar) is expected to increase by 1,350% in the same period.

Because population growth is critical to the integration of estimates on a percapita basis, Figure 2 has been provided to show the total growth of energy including reject heat from electrical power generation. Figure 2 shows energy demand in British Thermal units, the heat equivalent of the various input energy sources to which they all decay after useful work is performed. Brief comments which follow, which are extracts from references 1 and 2 support the various categories of energy input as they relate to the total system.

The growth, shown in Figure 2, will occur primarily in the use of electricity to replace traditional heat sources in the conversion industries and for space heating. Because of the high cost of air-conditioning and lighting of large buildings, better design is expected to reduce the percapita consumption largely by elimination of incandescent lighting, low efficiency fluorescent lighting, and employment of regenerative systems to reduce heating and cooling loads. Table I is included as a general guide to the understanding of the relative input of people related activities. Of note is the considerable energy release of the private motor car. Even conversion to a total electric automobile economy would only cut the total energy release to the environment by a factor of two because, at projected efficiency growth rates in the electrical industry, 50% thermal efficiency appears a barely achievable goal under current energy policies by 2000 AD.

Of interest to the chemical and conversion industry is the projection of excellent progress in reductions of per unit heat (energy) requirements for the production of steel using the basic oxygen process and other related new reduction processes. However, total energy use by industry is expected to increase about twice as fast as factors related to population. These energy values are summarized in Figure 3. Also of interest is our projection that the use of exothermic energy

PER CAPITA ENERGY USE BY DECADES THROUGH
2000 AD

FIGURE 1 PER CAPITA ENERGY
USE BY DECADES THROUGH 2000 AD

(from Reference 3)

TABLE I

Heat Rejection Rates of Interest
(Btu/hr)

One human being	450 (At Rest)
Electric lighting for a typical office	
Incandescent	2500
Fluorescent	900
Theoretical, 100% efficient	82
Air-conditioning for typical office	600
Heating to maintain 25°F ΔT for typical office	
Electrical resistance*	1000
Heat pump*	350
Furnace, oil or gas	1600
4000 lb automobile at 70 mph	
I.C.	750,000
Electric*	150,000

*Does not include generation or transmission losses

PROJECTED TOTAL ENERGY DEMAND IN U.S.

FIGURE 2 PROJECTED TOTAL ENERGY
DEMAND IN THE UNITED STATES

(from Reference 3)

in the petroleum production will show a decrease of about 7% to about 590,000 BTU/barrel by the year 2,000 AD.

Since the electrical energy requirements for the entire United States are expected to be the predominant growth factor in the next 30 years rising from a present 21.5% of all energy requirements in 1965 to 52% of all requirements by the year 2,000, the primary emphasis on the analysis of future needs is largely determined by that sector of the growth function. It is also in this area where because of the legislative history, research and development in the multi-purpose use of related materials involved in the production of electrical energy has been delayed the greatest extent. Despite the fact that the number of large operating utility companies is slowly decreasing and that less than 250 firms now control over 99% of the generating capacity in the United States compared to 1,000 in 1945, integration has been largely vertical. The Holding Company Act of 1935 (Ref. 4) limited the effectiveness of mergers in the utility field as a means of integrating the transmission system of the industry. The Act has also served to concentrate R&D in the industry on conversion processes which are single purpose and are limited to the direct interest of the industry as constituted under the Act of 1935. In other areas of industry, aggressive development of related business opportunities have permitted wide distribution of the cross fertilization of technology in comparison to the utility field. In the latter area, the developments which have occurred have been narrow in scope. Furnace design is a principal example.

The modern pulverized coal furnace-boiler commonly used in the conversion of heat energy in coal to steam for electrical generation has followed a uniquely single purpose path. Commencing with its adoption in the early 1920s as a means of creating an ash so fine as to be readily dispersed to the atmosphere in preference to the

NONELECTRICAL ENERGY RELEASES BY INDUSTRY THROUGH 2000 AD

FIGURE 3 NONELECTRICAL ENERGY
RELEASES BY INDUSTRY THROUGH 2000 AD

(from Reference 3)

sooty particles from incomplete carbon combustion prevalent from stoker systems of that era, this combustion system continues to be optimized on the basis of an incinerator instead of that of a chemical reactor which it really should more properly emulate. Combustion processes are common in the oil refinery business and a majority of the fuels and major petroleum products are involved in high temperature transformations using flame technology.

As a result, the chemical industry is in a unique position to retain valuable side streams of otherwise useless materials and recycle them for other in-plant processes or use them for sale. However, even chemical processes are cheaper to operate with relatively pure input materials, and the availability of relatively cheap sulfur from underground deposits has not produced a high incentive for aggressive recycling of the various sulfur by-products. This low cost has been in part attributable not only to large supplies of pure materials, but to national policy on depletion allowances and related incentives to the mining and conversion industry which on the whole do not encourage the use of scrap or reclaimed materials. During the 30s and continuing through the 1941-45 War the simple pragmatism of more and more production at lower and lower prices held full sway. In the intervening period the sulfur production estimated at 10×10^6 tons is closely matched by the discharge of wasted sulfur as SO_2 from the utility industry of about 7×10^6 tons. Other valuable chemicals such as vanadium follow similar trends. It has been suggested by Squires et al (Ref. 5) that this trend in the single purpose development of the pulverized coal furnace would have taken an entirely different turn if the patents of Winkler and others which led to the fluid-bed reactor which later became standard in the petroleum industry had been adopted by the utility industry.

While these two industries, utility on the one hand and chemicals on the other have been perfecting their individual processes, the availability of cheap, relatively pure input fuels and ores has declined. Notwithstanding, however, because of the availability of foreign oil and more recently natural gas in liquid form, research in the use of native resources such as coal and oil shale for the production of liquid and gaseous fuels has not made great progress. Economic incentives for the success of the Fisher Tropsch process currently do not exist because of the losses of energy in the conversion process.

A similar fate has befallen the highly successful WW II German Bergius coal hydrogenation process and early developments for feasible use of oil shale as a source of carbon for synthesis reactions. These processes share a common difficulty; they each release from 40 to 60% of the available combustion energy of the available carbon as "waste heat." This "waste heat" is released at temperatures in excess of steam temperatures successfully used in the light water nuclear reactor program, whose supporters have capitalized on organized thermodynamic inefficiency on a monumental scale.

This leads to a second example of the trends in the growth of thermodynamic efficiency (Fig. 4) in the utility industry with some projections for the future based on the R&D projections available from the late 1960 period. The Figure shows three important facts:

- The Depression and the 1941-45 War had a devastating effect on the natural growth rate of efficiency in cycle development.
- Even the highest estimates of potential improvement of cycle efficiency fail to materially improve the projected upper level for the average of all plants through the year 2,000 AD.

- The period 1960-70 produced a leveling of the growth of thermodynamic efficiency comparable to that of the 1930-45 period. It appears that the economic policies which have led to relatively cheap fuel prices in respect to plant investment and interest costs have caused this trend.

These trends reflect the transition of the design in power plants from fossil based Rankine cycle in the early 1930s to the nuclear age. During the current transitional period, when some loss in momentum of the efficiency improvement trend as pointed out in Figure 4, the basic efficiency ranges of the major plant types are as follows:

Nuclear Light Water	20-23%
Brayton (Gas Regenerative)	34-35%
Nuclear LMFBR or HTGR	40-42%
Fossil Rankine	41-45%

Figure 5 shows a comparison of these cycles with respect to the important parameter of condenser back pressure for a family of cross-compound, optimum efficiency turbine generator sets. More recent practices tend to produce single shaft machines with curves of lesser slope, but generally higher average losses throughout the condenser operating range. This is due to the practice of "high back end loading" of single shaft machines to reduce capital cost and in turn incur higher operating costs. High back end loaded machines are generally used on cooling tower plants to decrease the sensitivity of the system to water temperature changes, but once such a machine is built and the operating parameters set, the net losses cannot be reduced by the later application of cooler water because of the inherent losses in the terminal blading of such a machine.

Table 2 is a summary of the expected costs and cost penalties which are associated with the various types of cooling systems for turbine generator sets, optimized for construction conditions in the Pacific Northwest.

TRENDS IN PLANT THERMAL EFFICIENCY BY YEARS

FIGURE 4 TRENDS IN PLANT
THERMAL EFFICIENCY BY DECADES
(from Reference 3)

FIGURE 5 RANGE OF EFFECTS OF
HIGHER CONDENSER TEMPERATURES
ON PLANT EFFICIENCY

TABLE 2

SUMMARY SHEET
TYPICAL PLANT COOLING SYSTEMS COSTS
NUCLEAR ELECTRIC PLANTS - 1000 MW

System Type	Typical Cost*	Cost Above Base Case*	Typical Power Costs mllt/kwh Public Financing			Typical Power Costs mllt/kwh Investor Financing		
			Capital Charges	Operating Cost	Net Cost	Capital Charges	Operating Cost	Net Cost
<u>Once-Through: Fresh Water</u>								
Canal Discharge	5,850	--	--	--	4.00	--	--	--
Deep Discharge	6,290	440	0.005	--	4.005	0.010	--	4.010
<u>Once Through: Sea Water</u>								
Canal Intake & Discharge	6,425	575	0.006	--	4.006	0.012	--	4.012
Deep Intake - Canal Discharge	8,425	2,575	0.027	--	4.027	0.055	--	4.055
Deep Intake - Deep Discharge	11,425	5,575	0.058	--	4.058	0.119	--	4.119
<u>Evaporative Systems:</u>								
Cooling Pond	10,856	5,006	0.052	0.031	4.083	0.116	0.031	4.147
Natural Draft Towers	16,648	10,798	0.112	0.145	4.257	0.228	0.145	4.373
Induced Draft Towers	11,866	6,016	0.063	0.194	4.257	0.129	0.194	4.323
<u>Dry Cooling Systems:</u>								
Natural Draft Towers	37,620	31,770	0.330	0.270	4.600	0.673	0.270	4.943
Induced Draft Towers	26,240	20,390	0.212	0.388	4.600	0.433	0.388	4.821

* All costs in thousands of dollars.

It is clear from the cost information tabulated that the distinctions fall into three major categories, namely; among the following groups:

1. Ponding or direct discharge to natural water bodies.
2. Cooling towers.
3. Dry towers (Non aqueous air cooling systems).

The other distinctions such as the varying configurations for direct cooling in fresh or marine systems, or for the selective withdrawal or release at varying depths all appear to be questions of designers choice rather than fundamental distinctions. This fact is significant in the present circumstances where the siting of plants is being examined for the first time against the standards and operating regulations resulting from the Water Quality Act of 1965. What does become critical in the examination of the direct cooling or ponding alternatives is the amount of space available to the site development, the relation of the site to the surrounding community both present and future, and questions related to point of discharge in relation to joint uses of the receiving waters such as fisheries and recreation.

The technical factors which tend to blur these distinctions are all primarily related to the large size and flowage requirements of the future plants being planned. Flows of 1,500 to as high as 3,600 cfs are not unusual and will require piping systems which employ diameters of from ten to sixteen feet, and separations of intake and release points which may involve hundreds or even thousands of feet to avoid tidal influences or to take advantage of the stratification in lakes and reservoirs. The environmental requirements imposed on direct discharge plants involve additional investment for discharge to stream thalwegs rather than bank discharge to maximize mixing and minimize the size of higher temperature zones with their attendant

ecological effects on the littoral zone in the outlet vicinity. The size of the receiving water body required to effectively equilibrate the heat rejection of a 1000 MW_e plant can be expected to approach 2,500 acres or more depending on such factors as temperature of discharge, local weather and wind conditions, and receiving water body geometry. This latter factor becomes involved in the establishment of non-linear vapor pressure gradients because of relative air saturation over large cooling ponds which tends to appreciably decrease the effectiveness of a large pond in the central region most subject to boundary layer limitations.

Turning to cooling towers, and not considering the interesting structural problems of interest to the civil engineering profession, the choices between natural or induced draft systems do not appear to be clear. The higher operating cost of induced draft towers is counter balanced by the lower first cost. Both systems involve the evaporation of some 30 cfs per 1000 MW_e in addition to blow-down requirements of approximately equal magnitude. Such evaporation rates are not inconsiderable, and in the case of multiple plants in areas where water diversions are under close scrutiny, such as resulted from the Maris decision in the Chicago Sanitary District diversion of Lake Michigan, could raise serious questions of international scope if counted in the apportionments allocated. In addition, the location on Western reservoirs which are essentially one hundred percent appropriated such as the American Falls reservoir on the Upper Snake, the evaporation rates could involve the requirement for purchase of equivalent quantities of water rights from users deprived of rights.

In the case of the dry, non evaporative systems, serious consideration must be accorded to the induced circulation of the immense air plumes which would rise above the installation. On relatively quiet days of near inversion conditions, it has been

estimated that such dry towers could induce sufficient vertical circulation to produce cumulus clouds of extensive magnitude over the release point. The resulting opportunities for involvement in weather are not inconsiderable and remain as one of the significant research areas for the future.

Having illustrated two principal problems involved in meeting the public energy needs as presently forecasted, it is necessary to examine in a general way, the overall effects of the current trend of doubling energy releases to the environment every 7 or 8 years. No clear agreement on the subject exists because the subject is too new to have accumulated the proper ratio of dispassionate observers and the data base is too small to make classic stochastic or statistical observations without a serious degree of professional risk and possibility of adverse criticism. This latter factor has tendency to group scientists and engineers into two overlapping groups as follows:

- A general grouping of investigators who have not been deeply involved in environmental matters and fail to react completely to new and revised requirements for integrated environmental thinking.
- A general grouping of investigators who are fully involved with matters of environmental concern, but because of previous training or experience fail to include conditions of practical necessity into action plans proposed for protection of the environment. In this case we use the word environment in its broadest sense, that of the total socio-economic physical surroundings of man.

Experience has shown that the truth lies somewhere in-between, and varies in a dynamic way from situation to situation. A brief review of the major determinations concerning energy effects on the environment is contained in the following condensed statements:

- . When examined on an entirely global perspective, and with the singular exception of particle emission in the upper atmosphere and stratosphere, troposphere and ionosphere, the foreseeable effects of the release of energy and the by-products of energy conversion do not provoke the need for crisis thinking in the institutional management of resources.
- . Particle emission and changes in the atmospheric opacity resulting from artificial cloud seeding, thermal islands are highly suspect as potential sources of serious dislocations in the weather patterns, rainfall and general surface energy budget of the earth (Ref. 6).
- . On a regional basis of the scale of 10^6 km^2 , distinctly observable patterns of effect related to the release of products of combustion, moisture and thermal energy (the end state of all useful energy of interest to this discussion) are known to exist and to be increasing in size and intensity. Without control of accelerating urbanization, one can predict with certainty that climatic changes will increase from a purely local scale to a regional scale and will appreciably affect present ecological balance. Known changes include increased cloudiness, reduction of winds, concentration of pollutants (smog), drastic changes in run-off of rainfall, and profound, but as yet quantitatively unmodeled effects of the immense quantities of gaseous and suspended materials ejected to the metropolitan atmosphere. (H.E. Landsberg, Ref. 7).
- . In the utility field, because of its potential dominance of the energy releases to the environment, serious consideration needs to be given to the combined end effects of pollution policy on prime mover efficiency, regional weather patterns and national fuel and anti-trust policy. The

available facts suggest that uncoordinated national policy is directly related to a great number of the present economic dislocations which appear as pollution of the environment.

- . A large number of the more useful tools for predicting effects such as simulation modeling remain relatively underdeveloped because of the present reliance on the adversary proceeding as the basis for taking action. The distribution of pollutants in relation to the planning of abatement facilities must be systematically investigated and related to local and regional goals. Clearly, institutional development and reform congruent to scale of expected energy releases is a question of highest priority. The creation of simulation and prediction centers of politically uncommitted excellence appears as an indispensable step in the arbitration of competing needs for the use of energy on the grand scale foreseen for the coming decades.
- . The growth of mass energy consumption and the consequent relations of waste materials, emissions and nuclear hazards can be expected to have major international implications. The rain-out of sulfur dioxide discharges from sources to the south and west of the Scandanavian Peninsula has already caused marked changes in the chemical properties of lakes and soil in the southern end of that territory, (Erickson 1969, Ref. 11). Policies which force Midwestern United States utilities to use cooling towers conflict with consumptive withdrawal limits of the 1906 Boundary Water Treaty with Canada. Weather modifications resulting from the Detroit-Windsor heat island are becoming a source of international concern in the policy area.

Even the erection of the pipeline to deliver petroleum from the North Slope fields is subject to inspection of the environmental consequences primarily because of questions relating to value of displaced Canadian lands for the benefit of United States interests. Lands flooded by Columbia Treaty dams in Canada appear to have been grossly undervalued in relation to the long range power benefits to both the United States and Canada, (Krutilla, 1967 Ref. 8), and the ecological consequences of full power development of the Columbia River do not appear to have been studied to a depth commensurate with the value of the resources involved. New concepts of riparian rights in relation to the world atmosphere appear certain to be proposed; all of which can be expected to require the utmost in statemanship and imagination.

As a broad generalization, it appears that the countries which are relatively underdeveloped in respect to the United States may begin to measure and evaluate potential and actual changes in their physical environment which reflect foreign trade and development policy of their more highly developed neighbors. Such physical comparisons may suggest a reduction of the already uneasy stability of the balance of trade and power among the families of nations.

Accordingly, it is proposed that a solution to the dilemma of rising power station costs and increasing opposition to single purpose hydro-development near metropolitan areas, which often floods useful land and causes unmanageable water flow fluctuations, would be the creation of a system of canals of relatively large size--flows up to 15,000 cfs--which would serve as elongated cooling ponds for the dissipation of condenser heat of large industrial complexes. This idea arises from

the concept of using thermally warmed water for the irrigation of crops - a concept which, while attractive in detail, is essentially not well understood by the professional engineering fraternity much less the public at large.

The stimulation of the production of tubers and cereal grains by physical warming of the ground has been of interest to agronomists for many years. Despite some laboratory success, general use of the method has not developed because 1) sufficient supplies of warmed water are not available for a low enough price and 2) the development of crop parasites and diseases appeared to increase with productivity. However, the real reason for lack of progress is as much tied up with the high cost of field distribution and reluctance on the part of the presently constituted utility industry to participate in the added costs of field distribution.

Relatively few people consider the scale of water flows involved in generation of power. A 1000 MW thermal station requires the passage of from 800 to 1,200 cfs (360,000 to 580,000 gallons per minute) of water through the condenser system. The flow of two of these plants would supply the entire water use needs of the cities of Chicago, Los Angeles or metropolitan New York. These are major hydraulic works involving considerable planning and investments. By comparison, the Columbia Basin irrigation system in the State of Washington is currently sized to use 9,600 cfs during the irrigation season. The cost of developing this system is currently estimated to exceed 1.5 billion dollars if carried to the full development originally conceived. Clearly, the collateral use of warmed effluent requires planning on a scale in keeping with the size of the resource under consideration, as well as the long-range needs and requirements of the public.

Based on a number of supporting studies (Ref. 3,9) and the experience of the recently completed study of thermal plant siting in the Northwest, (Ref. 10) the following concept was developed. A great number of locations in the United States can be identified. Among these are flow improvement systems for the principal rivers of the Northeast with sources in or near the Great Lakes, and proposed Ohio Canal which could use water from the presently overflowing Great Lakes to supplement the Ohio River. Plans to irrigate Texas, Arkansas and other nearby areas with seasonal Mississippi River water (or alternatively Canadian water) could profit from broadening of the multipurpose scope of the projects to include cooling facilities and recreational lakes. The success of the artificial cooling lakes of the City Public Service Board system at San Antonio is an example of how the potential for multipurpose development could be achieved with improved planning.

Figure 6 is a schematic illustration of the basic concept of a canal lake cooling system. It consists of a series of either natural or artificial waterways covering an extensive distance and providing a central power spine system for redirecting the growth of population centers. The canal system could also provide supplementary flow as water supply for the new cities and industries along the route, as well as local transportation and navigation, where desirable. Parks and green belt areas would be an intrinsic part of the development plan. Its principal objective would be to provide an extended heat sink of major proportions away from presently regulated public water courses, capable of supporting large thermal stations all along the route of the canal system, reusing the water as many times as practicable. It is assumed that the opportunities for pumped storage plants along the canal route would be limited only by the electrical requirements.

In order to lend realism to the technical consideration of such a potential system, the authors applied the planning concept, Figure 7, to one of the routes suggested for Pacific Northwest water diversion--that proposed by F. Z. Pirkey (Ref. 11). While

FIGURE 6 SCHEMATIC OF NUCLEAR-PUMPED
STORAGE - CANAL LAKE SYSTEM

From "Engineering Aspects of Diversion Proposals"
 P. C. Klingeman - SEMN WR 007.67
 Oregon State University, Corvallis

FIGURE 7 PROPOSED WATER
 TRANSPORT PLANS

a detailed study of the entire technical impact of such a proposal is beyond the scope of this paper, the COLHEAT simulation model, (Ref. 12) was used to determine the physical relation of canal lengths, plant size and resulting evaporation on such a potential system. The sizes of the canals, the flow quantities and scope of the system have been materially reduced, but the original route was preserved in order to test the use of the model under a wide variety of weather circumstances. The primary route of the Pirkey Western Water Project transferred water up the Deschutes River in Oregon, further up the Crooked River by a series of pumped storage dams to a large, arid inland valley west of Burns, Oregon. The Water would enter Northeastern California at a natural lake (Goose Lake) and then travel southeasterly in Nevada via a series of lakes and canals along the California-Nevada border through Pyramid Lake, Walker Lake and hence to discharge into Lake Mead.

Tables 3 and 4 illustrate and summarize the technical features of the system of interest in this discussion. The temperature rise of the artificial canal-lake system was arbitrarily held to 9°F (5°C). This gave surface temperatures no higher than 32°C (90°F) at any point. With this conservative constraint, the installed thermal capacity of the canal-lake system was very close to 30,000 MW electrical as firm capacity with substantial potential for erection of pumped storage peaking along the line of flow. As would be expected, total evaporation in the summer was high, about 50% of the inlet flow of 12,000 cfs, but the portion allotted to thermal plant cooling amounts to 750 cfs or about 70% of the evaporation expected from an equivalent capacity in a cooling tower system. No thermal plants were sited on the Deschutes portion of the canal system in order to avoid temperature changes in that reach. The majority of electrical plants were sited on artificial lakes and reservoirs.

While the siting of nuclear plants did consider the known location of faults and other seismically active areas such as Goose Lake and the Western Nevada counties,

TABLE 3DETAILS OF CANAL SYSTEM SECTIONS

	January	July
<u>OREGON SECTION (Miles 990 → 635)</u>		
Thermal Plants - 14.5 GW		
Surface Area - 137,000 ^e Acres		
Evaporation Loss - No Thermal Plants	0.83 IN./MO	10.6 IN./MO
Evaporation Loss - With Thermal Plants	1.70 IN./MO	12.6 IN./MO
Evaporation Loss - Direct Cooled Thermal Plants	332 AF/DA	845 AF/DA
<u>NORTH NEVADA SECTION (Miles 336 → 635)</u>		
Thermal Plants - 13.2 GW		
Surface Area - 260,000 ^e Acres		
Evaporation Loss - No Thermal Plants	0.98 IN./MO	10.0 IN./MO
Evaporation Loss - With Thermal Plants	1.50 IN./MO	11.2 IN./MO
Evaporation Loss - Direct Cooled Thermal Plants	400 AF/DA	835 AF/DA
<u>SOUTH NEVADA SECTION (Miles 0 → 336)</u>		
Thermal Plants - 2.3 GW		
Surface Area - 12,000 ^e Acres		
Evaporation Loss - No Thermal Plants	1.4 IN./MO	7.9 IN./MO
Evaporation Loss - With Thermal Plants	2.5 IN./MO	11.2 IN./MO
Evaporation Loss - Direct Cooled Thermal Plants	30 AF/DA	109 AF/DA

MAXIMUM SURFACE TEMPERATURES AT
VARIOUS LOCATIONS ON A TRIAL SYSTEM °C

	<u>NATURAL SYSTEM</u>		<u>WITH THERMAL PLANTS</u>	
	<u>January</u>	<u>July</u>	<u>January*</u>	<u>July</u>
Deschutes River	2.0	18.9	5.0	18.9
Crooked River	1.0	18.9	6.0	23.9
Southern Oregon	Frozen	24.2	3.0	28.9
Pyramid Lake	1.2	27.0	5.7	31.0
Walker Lake	1.5	27.0	6.1	32.0
Lower Canal	3.0	26.1	8.0	30.8

*At 50% of summer thermal loads

TABLE 4

TENTATIVE DATA FOR A 990 MILE PUMPED
STORAGE COOLING CANAL (SOUTHWESTERN ROUTE)

a) Potential Thermal Power

Oregon - 14.5 GW_e
North Nevada - 13.2 GW_e
South Nevada - 2.3 GW_e

Total Firm Power 30.0 GW_e

b) Potential Peaking Power (not firm)* - 60.0 GW_e

c) Potential System Peak - 90.0 GW_e

d) Canal-Lake Data

Total Length	990 Miles	
Surface Area	409,000 Acres	
Active Volume	5,000,000 AF	
Initial Flow	12,000 CFS	(8.8 × 10 ⁶ AF/YR)
Natural Evaporation (July)	(5,730)CFS	
Thermally Induced Evaporation (July)	(775)CFS	
<hr style="width: 100%;"/>		
Minimum Delivery at Exit (July)	5,500 CFS	(4.02 × 10 ⁶ AF/YR)
Maximum Delivery at Exit (Jan.)	>10,500 CFS	(7.65 × 10 ⁶ AF/YR)
Pumping Requirements (Gross)	7.5 GW _e	
Recoverable Energy 30%	2.2 GW _e	
<hr style="width: 100%;"/>		
Net Pumping	5.3 GW _e	

*Based on a 33% load factor - system would supplement other firm systems.

any such optimization was considered beyond the scope of the investigation. Of outstanding significance was discovery of the following:

- A total of 30 GW_e, a substantial fraction of the Western firm power requirements through the year 2000 could be sited on the canal system.
- The annual evaporation chargeable to the thermal plant system using the canal-lake complex was 30% lower than the equivalent in direct cooling tower capacity (452,000 AF vs. 650,000 AF) annually.
- The total evaporation of the canal lake system was substantial (approx. 350,000 AF/month in July), an order of magnitude higher than that required for thermal plants themselves.
- A substantially larger canal throughout would not increase the base evaporation levels, and smaller systems optimized for thermal cooling canals would suffer relatively large disadvantages from evaporation unless considered as multipurpose for irrigation and land development in arid regions.
- The development or creation of an extended canal-lake system for the purpose of cooling thermal generating station effluent is technically feasible and offers outstanding possibilities in the added justification of large water redistribution projects. Significantly, it must also be borne in mind that the flow from large thermal stations is sufficiently high that essentially all projects involving the use of warmed water are immediately in a large project category.
- The multipurpose use of canal-lake systems as cooling conduits, in conjunction with other uses appears to offer considerable advantage in the redirection of metropolitan growth rates along planned lines.

PRINCIPAL BENEFITS OF PROPOSED CANAL-LAKE SYSTEM

We believe that the demonstration was very successful in showing the great potential of a previously neglected feature of cooling technology with many associated benefits in resources allocation and planning fitting the development of national goals (Ref. 14). Advantages of the proposed canal-lake system are:

1. Nuclear stations can be located far from centers of population.
2. The large transmission system could parallel and reinforce local grids.
3. Where impoundments can be made to decrease canal construction cost, the possibility of large nuclear pumped storage peaking stations in conjunction with base load plants could be exploited.
4. The canal-lake system provides very large heat dissipative capacity without disturbing environmental esthetics of existing population centers.
5. The canal-lake system could be used to supplement irrigation requirements of agricultural areas by using and reusing condenser water in transit down the canal-lake system, or to supplement groundwater supplies.
6. Developing the irrigation potential existing along the line of the system offers a means of diversifying the economic base and creating new directions of economic expansion.
7. Impounded portions of the canal-lake route offer great recreational opportunities to water short areas without distracting from the basic purpose of the canal-lake system.
8. The water quality of portions of the canal-lake system can be optimized for industrial, municipal, or recreational purposes without upsetting existing fisheries or related use patterns.
9. The opportunity to plan and develop the transmission system from the beginning reduces right-of-way acquisition costs and permits close control

of and opportunity for on-site power contracts as a means of relocating industry along the line of the canal. The electrical distribution system then plays a role similar to, but potentially stronger than that of the early western railroads in the development of economic centers along the route.

10. Instead of assigning the entire cost to agriculture, water redistribution costs can be allocated more broadly and efficiently with immediately apparent benefits to the many persons participating along the line of the canal system.

Recommendation

We recommend that in keeping with conclusions of the report of National Goals Research Staff, the National Water Commission and the various river basin commissions, devote serious attention to this concept as a means for accomplishing the job of expanding the resources base of the United States away from present population centers. This would permit more national distribution of resources throughout the country and reverse the trend toward concentration of energy releases in metropolitan areas beyond the capacity of the physical environment to absorb the impact. Such a recommendation is a specific part of the recent White House staff report on the establishment of urban de-concentration as a primary national goal (Ref. 14).

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