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DISCUSSION

M. W. Larinoff[2]

The authors are pioneering a new area of technological development in the power plant field which can be compared to that of the "reheat" and "supercritical pressure" cycles of the 1940's and 1950's. Their concepts concern change and innovation in power cycle equipment such as modified steam turbine exhaust ends, direct-contact condensers, high-head/high-volume condensate pumps, air-cooled heat exchangers, large air-moving equipment, and hybrid cycle arrangements. Their concept also suggests a review of the conventional economic evaluation yardstick which normally examines only the hardware costs involved in a single power plant. They recommend instead the acceptance of a broader approach which recognizes the inherent design and operating flexibility of the utility's entire power generating and transmission systems. The authors are to be commended for their timely analysis of the problem and innovative suggestions. It is this type of vision and effort which has built our electric utility industry to its high state of technological development that exists today.

I would like to give additional emphasis to what the authors already said concerning the need for reducing the value of lost capability during summer peak temperatures. Our economic studies of dry cooling tower systems presented at the 1970 American Power Conference by Mr. E. C. Smith and myself showed the following relationship between the first-cost of a dry cooling tower system, installed in a 750 MW fossil plant, and the value of the capability loss charged against the system:

Design Condenser Pressure @ 100 deg F Ambient	Dry Cooling Tower System Investment(*)	Capability Debit @ \$100/ KW Value (BASE is $3^1/_2$ in. Hg abs)	Capability Value as Percentage of System Investment
5.5 in. Hg abs.	\$23.60/KW	\$ 3.00/KW	13%
8	19.70	6.50	33
10	17.30	8.60	50
12	15.70	10.40	66
14	14.20	12.00	85

(*) Includes condenser, circ pumps, piping, dry cooling tower, fans, motors, controls, etc.

[2] Vice-President, Hudson Products Corp., Houston, Texas.

The above capability debits show the economic penalty which the dry cooling tower system sustains when employing the conventional steam turbine cycle with a conventional steam turbine annulus area. The tabulation shows that a system designed for a 10-in. Hg abs condenser pressure with 100 deg F ambient may have a capability debit in the order of 50 percent of the system investment. Such debit figures show the urgent need for innovation in turbine rear-end design and the application of the "cycle design alternatives" which the authors so ably discuss.

No one is more keenly aware of the need for pushing the frontiers of electric power plant technology, nor has anyone pushed them as hard and accomplished as much, as Mr. Philip Sporn. In recent private correspondence which the writer had with Mr. Sporn concerning dry cooling tower systems, he said:

> "The only thing that retarded the development of the idea and the bringing of it into practical use was economics and really pressing need. The former can be improved by invention and engineering development and the latter is now developing rather fiercely by the almost panicky concern for environmental pollution."

The electric utility industry and its equipment suppliers are presented today with a tool which has grown out of the "concept" stage and is now in the "hardware" stage. Work still remains to be done to optimize the thermal power cycle and reduce costs as the authors and Mr. Sporn point out, but the direction of the future is clearly indicated. The Dry Cooling Tower System is now ready for the industry, and when the industry optimizes its power cycle equipment and system operations to accept dry cooling tower systems, the system will become economically competitive in many more situations. This will allow more utilities to take full advantage of the economics and the many desirable collateral benefits offered by the system.

E. S. Miliaras[3]

The authors are to be commended for once again spotlighting an area of power plant design that is acquiring urgency.

The writer agrees with their conclusions and recommendations regarding priorities in cycle optimization and major equipment selection, when dry cooling systems are to be utilized for waste heat rejection.

The authors consider dry cooling systems for base load power plants, as the approximate costs given for these systems per plant kw output and the applications considered in the references are for base load plants.

The advantages of dry cooling systems are stated as freedom from siting requirements near cooling water supplies and transmission line construction savings by locating near load centers, balanced against higher inland fuel transportation costs and lower plant efficiency.

The writer believes that a sector of power plant design where the advantages offered by the dry cooling systems can be utilized, with the disadvantages reduced, is the low capital cost peaking/cycling fossil plant.

A plant intended to operate for a six hour weekday period will total 1500 hrs of operation per year, or about a 17 percent plant capacity factor and will require several times less fuel than a base load plant, proportionally reducing fuel transportation costs.

Similarly, the lower efficiency resulting from the high back pressure of a dry cooling system will not be a great disadvantage with such a low plant capacity factor; indeed, the back pressure (vs. dry cooling system cost) will optimize at a considerably higher value than for a base load plant, with a sharp decrease of the dry cooling system cost.

The peaking/cycling plant can be located near load centers, with savings in transmission line construction and with the sites

[3] Winchester, Mass. Mem. ASME.

near cooling water sources better utilized for base load plants.

The writer believes that low investment cost peaking/cycling plants with dry cooling systems, utilizing the available low cost peaking type boilers expressly designed for this service[4], with the turbine capable of operating with higher and variable back pressure and the simple cycle plant designed for fast starting/cycling, will find a niche in utility system planning.

The current high investment cost of fossil and nuclear plants, that will be considerably increased by the high dry cooling system cost and further augmented by cycle improvements to minimize waste heat rejection, argues against the adoption of dry cooling systems for base load plants, except for the most arid areas.

Authors' Closure

The authors wish to thank Messrs. Larinoff and Miliaras for their favorable comments, and especially for their viewpoints which provide further insight into the application of dry cooling towers to the power industry.

The authors do wish to review Mr. Miliaras' suggestion that the dry cooling tower system might be economically advantageous when incorporated into a low cost, peaking/cycling, fossil plant operating on a 17 percent plant capacity factor.

For a dry tower system of the Heller type as discussed herein. the high unit capital cost of the system at \$25–\$35 per kilowatt is likely to stay within that range whether the power plant is designed for base load or for peaking/cycling purpose. The attainment of a low cost, peaking/cycling plant employing the dry cooling system would have to realize savings from balance of plant major components and/or systems.

The authors have not attempted to appraise the magnitude of capital cost savings of such a peaking/cycling plant. However, the following tabulations (Tables 3 and 4) may reveal the scalar level of economic comparison of a base load plant and a peaking/cycling plant. Three assumed peaking/cycling plants are illustrated as Plants A, B, and C. It is considered unlikely that even the lowest cost plant, Alternate C, could compete economically with a comparably-sized gas turbine unit.

As to the appraisal of plant operations, the peaking/cycling plant, by nature of its intended purpose, should possess a quick-starting capability from a cold shut-down condition. The peaking/cycling boiler plant can be designed to meet such stringent operating requirements. However, for a dry tower system of the Heller type, the quick-starting capability could be greatly limited if the ambient dry-bulb temperature is below freezing conditions. Freeze protection of the fin-tubed heat exchangers is an essential factor of plant design. In cold climatic regions, a plant shutdown necessitates the complete and rapid draining of condensate inside the finned tubes followed by displacement with an inert gas such as nitrogen. Prior to restarting the plant, the nitrogen must be purged and the condensate pumped back into the heat exchangers as it is warmed sufficiently in the spray condenser. Such operational procedures would obviously handicap the dry tower plant for peaking/cycling services.

To fulfill the quick-starting requirement, a gas turbine plant might be more suitable. These units have proven quick-starting capability, low capital cost, and require only small quantities of cooling water.

Dry cooling tower application to power plants has just begun to receive increased interest from the power industry. Certainly, various applications to satisfy various sets of constraints (such as; site climatic conditions, elevations, water sources, fuel sources, load center distances, environmental considerations, economic unit sizes relative to the system demand) and other factors have to be fully analyzed. Cycle variations, single purpose or combined cycles, have to be fully explored as additional operating experience is gained and as prices of equipment are more firmly established. The authors greatly appreciate Mr. Miliaras' discussion, and only through expressions of this type is state-of-the-art of the power industry further advanced.

Table 3 Plant capital cost comparison

	Dry tower base load plant	Dry tower peaking/cycling plant A	B	C
Design output	1 − Kw	1 − Kw	1 − Kw	1 − Kw
Capital cost, \$/Kw	200	170	140	110
Cost savings, \$/Kw	base	30	60	90
Plant capacity factor, %	75	17	17	17
Annual generation, Kwhr.	6570	1489	1489	1489
Annual fixed charges on capital, @ 14 percent, \$	28	23.8	19.6	15.4
Unit cost on capital, Mils/Kwhr.	4.26	15.98	13.16	10.34

Table 4 Generation cost comparison

	Dry tower base load plant	Dry tower peaking/cycle plant A	B	C
Unit Cost on Capital, Mils/Kwhr.	4.26	15.98	13.16	10.34
Fuel Cost, Mils/Kwhr.	3.00	3.00(+)	3.00(+)	3.00(+)
O & M Cost, Mils/Kwhr.	1.00	1.00(+)	1.00(+)	1.00(+)
Generation Cost, Mils/Kwhr.	8.26	19.98	17.16	14.34
Comparison:	100%	242%	208%	174%

[4] Clayton, W. H., Singer, J. G., and Tuppeny, W. H., Jr., "Design for Peaking/Cycling," ASME Paper No. 70-Pwr-9.