BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of)
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)
Consolidated Edison Company of) Docket No. 50-247
New York, Inc.)
(Indian Point Station, Unit No. 2))

Testimony of

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on

Alternatives to Once Through Cooling at Indian Point Unit No. 2

October 30, 1972

1. Condenser Cooling Techniques

Condensers associated with steam-electric stations are water cooled. Large quantities of water are required. For nuclear units water usage ranges from 1/2 to over 2gpm per kilowatt of installed capacity. More typically the requirements are around 1 to 1.5 gpm per kilowatt of installed capacity (1). The cooling water passes through the condenser either in a single or multiple pass flow pattern, typical exit water temperatures being between 15 to 20°F warmer. The degree of water heating or ΔT°F depends primarily upon water flow: larger water volumes resulting in a lower ΔT, the total heat dissipated in BTU being constant. The range of ΔT's encountered in the U.S. is from below 9 to over 40°F (1). Optimal quantities of condenser cooling water are decided by many factors in addition to a desirable ΔT including water availability, water inlet temperature, effluent temperature standards, pumping and pipe sizes and requirements.

Proposed cooling water requirements for the Indian Point #2 unit are 840,000 gpm or approximately 1 gpm per kw installed capacity. This compares favorably with nationwide operating data of similar units especially since the Indian Point 2 unit has an average ΔT of 14.9°F.

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1. Industrial Waste Studies: Steam Generating Plants. 1971 EPA Contract WQO 68-01-0032. Prepared by E. Aynsley et al.

These large quantities of cooling water are typically abstracted from rivers, lakes, estuaries or the ocean. Inlet water temperatures to the condenser from these water bodies can vary both on a daily and a seasonal basis. Extreme variations of inlet water temperature from freezing to 90°F are common nationwide. In this Hudson River location seasonal river water variations of 32°F to almost 90°F are encountered with maximum daily variations of ± 5°F occuring mainly in spring and fall.

Recent implementation of effluent water thermal criteria has caused power station operators to alter cooling water practices in order to limit or reduce ΔTs and/or effluent water temperatures. Such techniques for these once through type cooling systems include:

a) increasing water flow through the condenser and thereby reducing the ΔT,

b) adding dilution water to the condenser cooling water effluent to reduce the ΔT,

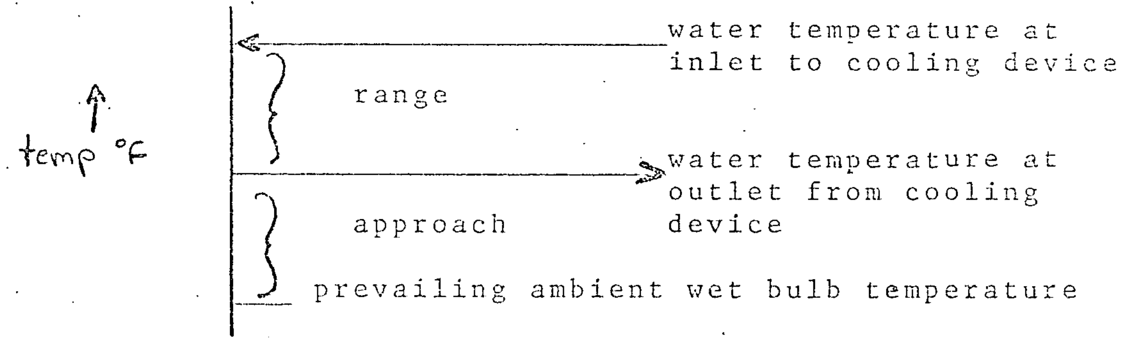
c) incorporating a water cooling device at the condenser effluent.

Utilizing these modified once through systems, no penalty is imposed on loss of station capacity due to reduction of cooling efficiency, as compared to once through, since the degree of cooling achieved is the same. That is, cooling is dependant entirely upon inlet or river water temperature.

The problems of heated discharges and withdrawal of large volumes of water from the water source can further be overcome by using or recirculatory water cooling system, instead of a once through system. Such a system incorporates a cooling device (i.e. tower, pond ,etc.) within the closed loop recirculatory cooling water system. A schematic illustration of these alternative cooling water flow schemes is illustrated later in the latter part of Section 3 in the discussion concerning water balances, evaporation and drift loss.

With the recirculatory cooling water system two basically different water cooling techniques can be employed both of which vent the heat to the atmosphere. The most common cooling system is an evaporative or wet system. This includes towers, sprays, lakes, canals and combination systems using 2 or more of these alternatives. These evaporative or wet systems rely on the fact that the latent heat required for the water evaporation is taken from the cooling water itself. In this way the water is cooled and a warm humid exhaust is vented to the atmosphere.

However with wet or evaporative systems the degree of water cooling is dependant upon the prevailing wet bulb temperature, and not the river water temperature. In practice the water is cooled over a temperature range, frequently referred to as the range. This is the difference between the inlet and outlet water temperatures to the cooling device (tower etc.). The outlet water temperature tends towards or approaches the wet bulb temperature. The difference between the outlet water temperature and the prevailing wet bulb is known as the approach. These factors are illustrated schematically below.



In contrast to wet or evaporative cooling systems dry cooling systems can be employed. These are similar to automotive radiators in that the heat is dissipated directly to the atmosphere. These types of cooling systems have not to date found any place in dissipation of heat from steam electric stations due to the relatively low inlet water temperatures and the inherently large cooling surface areas required.

Returning to wet-evaporative cooling systems it can be seen that a penalty is imposed upon steam electric station operations. Wet bulb temperatures, although variable are frequently the same as or higher than temperatures of water bodies in the same area. Superimposed upon this is the approach temperature. Consequently exit water temperatures from a cooling device or condenser inlet cooling water temperatures with a recirculatory system are frequently higher during daytime summer loads with a wet-evaporative cooling system than with a conventional once through cooling system.

As such a major factor affecting power plant operations where wet-evaporative cooling systems are employed is the wet bulb temperature. This is so since the wet bulb determines the degree of cooling obtained which in turn determines the return water temperature of the cooling water flow to the condenser. This in turn determines the degree of cooling in the condenser, which dictates the exhaust steam temperature and subsequently condenser vacuum. Exhaust steam temperature and vaccum have a direct effect on overall efficiency of the turbine.* Higher exhaust steam temperatures (and correspondingly lower vacuums), caused by higher inlet cooling water temperatures associated with wet-evaporative cooling systems, invariably result in loss of efficiency of power production and subsequent derating of unit at periods of high wet bulb temperatures.

There are currently operating in the northern Appalachian

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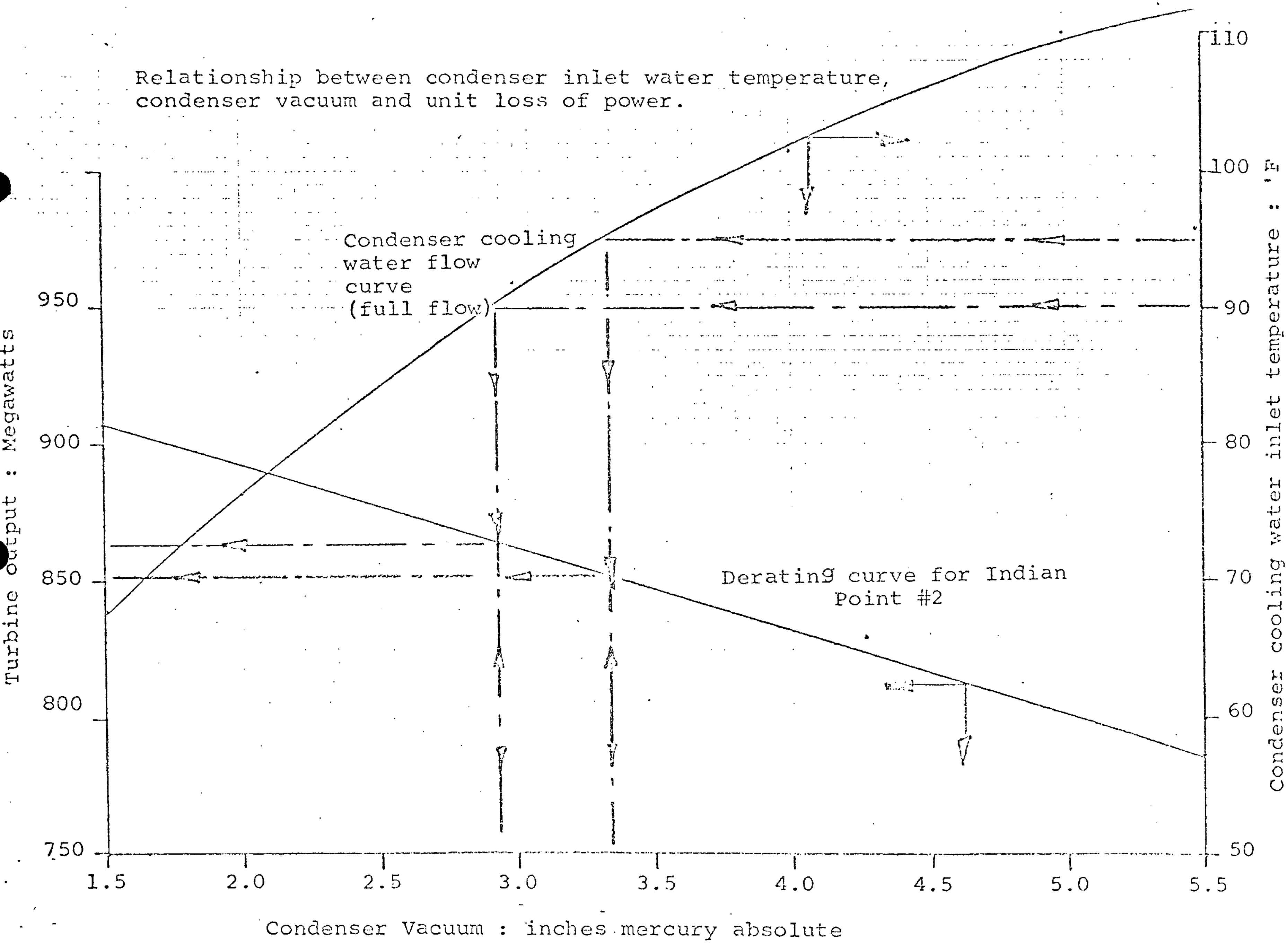
* Temperatures associated with the exhaust steam in the condenser are dependant on the vacuum. At 1 inch Hg abs the temperature is 120°F and 170°F at 2 1/2 inch Hg abs.

region a number of power plants with natural draft towers. In these cases a design wet-bulb of 70 to 72°F has been used. Similarly with these operating units a tower approach of between 15 to 20°F is experienced giving a maximum return water temperature of 92°F. Consequently it is reasonable to assume similar conditions will prevail at Indian Point. Even allowing for a higher prevailing wet-bulb of 75°F, return water temperatures of 90°F can be obtained with a natural draft unit having an approach of 15°F. The degree of approach obtained with mechanical draft units, around 10 to 15°F is closer than the typical range of approach values obtained with natural draft units, typically 15 to 20°F.

Using this type of technique it is possible to determine the loss of turbine efficiency and unit derating due to increases in temperature of the return water flow to the condenser with recirculatory systems.

Con Ed has supplied information on load correction factors to be applied for condenser vacuums which deviate from the design of 1.5" Hg abs. The following graph incorporates this data and illustrates the loss of efficiency resulting from higher condenser water inlet temperatures resulting in loss of condenser vacuum.

Considering a condenser return water temperature of 90°F a turbine output of around 864 MW is possible. Similarly a temperature of 95°F corresponds to around 851 MW. These figures correspond to initial guarantee figures supplied by Con Ed and vendor's data.



Relationship between condenser inlet water temperature, condenser vacuum and unit loss of power.

2. Costs of Alternative Water Cooling Devices

A number of recent surveys have documented the additional capital costs incurred by including water cooling devices as an alternative to once through systems in steam electric stations. Generally natural draft towers are the most expensive, followed by mechanical draft towers and then spray and/or coolings ponds or lakes.

A selection of recent cost estimates is provided in Table I.

The lower figures are based upon cost information available in 1969-1970. The higher figures are the more recent ones and include a number of cases of retrofitting rather than plants which were designed with cooling towers in mind. Consequently, the actual capital costs of a complete turn-key installation at Indian Point 2 are of the order of:

Natural draft	$17.5 to 30 million
Mechanical draft	$13 to 19 million

These figures refer to capital costs of the cooling unit itself and do not include the capital cost of the condenser, pumps, piping and ancillaries which are required in both once through systems and the cooling tower alternatives. Generally the capital costs of the condenser and pumps of cooling tower alternatives which are in additon to the cost of

TABLE I

Cooling Technique	Additional Capital Costs Incurred Over Once-Through Cooling ($/KW)	
Natural Draft Towers	11	(1)
	6.5-11	(2)
	11	(3)
	6.5	(4)
	10-12*	(Tichenor)
	15-25.4	(D.C. Cook)
	31.3	(Kewanee)
	18.7	(Waukegan)
	41.0	(State Line)
	59.0**	(Point Beach)
	35.8	(Zion)
Mechanical Draft Towers	7	(1)
	4.5-9	(2)
	7	(3)
	2.6-2.95	(4)
	10*	(Tichenor)
	28.6	(D.C. Cook)
	21.4-28.7***	(Palisades)
	18.5-18.9	(Kewanee)
	13.5	(Waukegan)
	28.4	(State Line)
	22.0**	(Point Beach)
	32.6	(Zion)
Sprays	2.3	(4)
	21.1	(Kewanee)
Cooling Ponds/Lakes	0.54-1.47	(4)
	2.5	(1)
	27.1	(D.C. Cook)
	33.1	(Kewanee)

*$3.8/kw will be required in addition for plant modification.

**These figures include interest, escalation charges and land purchases.

***These figures include other equipment, principally a radwaste system, in addition to the cost of the cooling towers.

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1. Eicher G.J., "Cooling Lakes can be a Pleasant Solution" Elec. World. p. 90, April 14, 1969
2. Fitch N.R., " Control of Thermal Discharges at Northern States Power Company's Steam Generating Plants" Materials Research & Standards, 9 (12) p. 26, Dec. 1969.
3. Parker F.L. and Krenkel P.A., "Physical and Engineering Aspects of Thermal Pollution" CRC Press, Cleveland 1970
4. Department of the Interior, "Feasibility of Alternative Means of Cooling for Thermal Power Plants near Lake Michigan" September 1970

a once through system are covered by the following ranges:

Cooling Technique	Capital Costs of Condenser and Pumps $/KW
Natural draft tower	5.14 - 5.40
Mechanical draft towers	5.64 - 6.03
Sprays	5.72 - 6.09
Cooling Ponds/Lakes	5.67 - 6.19

The above itemized costs for alternative cooling techniques do not include backfitting costs. There appear to be no published cost figures for backfitting. However, it is reasonable to assume the additional backfitting costs will be a fraction of the additional capital cost of the cooling device.

3. Environmental Problems Associated with Alternative Cooling Techniques at Indian Point

Water Loss. The ultimate fate of all waste heat generated in a steam electric station is the atmosphere. Although there are a number of water cooling techniques they differ only in the way in which the heat is released to the atmosphere.

With the most common once through systems the heat put into the river, lake or estuary ultimately reaches the atmosphere by a combination of convection,

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1. Department of the Interior, "Feasibility of Alternative Means of Cooling for Thermal Power Plants near Lake Michigan" September 1970

conduction, radiation and evaporation mechanisms. This heat dissipation is both slow, due to the low excess temperatures resulting from dilution and the large surface area of water involved.

Similarly with dry cooling techniques the heat is dissipated directly to the atmosphere, without any evaporation and from a more concentrated emission source.

However with wet cooling techniques, mechanical and natural draft towers and spray ponds, the waste heat is disposed of primarily by evaporation. Consequently the heat vented to the atmosphere is associated with large volumes of water, and in the case of towers this effluent is concentrated, being emitted from the stack top, while with sprays the effluent is emitted over a larger area at ground level.

As a result of the major role played by evaporation in the wet cooling techniques there are a number of undersirable environmental effects which can occur. Total water loss, directly to the atmosphere, with wet cooling techniques, both natural draft and mechanical draft towers, is usually in the range of 1 to 2% of circulating water flow. The exact figure depends on degree of cooling and prevailing temperatures and humidity. This figure is composed of water loss due to evaporation, the major fraction, and drift loss where water drops are lost as such. Draft is typically between 0.1 to 0.01% of circulating water flow. Con Edison's Environmental Report Supplement No. 3 gives figures for evaporation and drift loss that are realistic and are within the typical operating ranges outlined here.

These water losses and particularly the evaporation are significant. Potential detrimental side effects that can occur include fogging and winter icing, cloud initiation and formation and extensive down-wind water droplet plumes which are highly visible. In the case of natural draft towers, local fogging and winter icing do not present significant problems due primarily to the height of these towers, from 300 to 500 feet high. Most often the visible plume extends between a few hundred and a few thousand yards downwind depending on prevailing weather conditions, before it evaporates and disperses. However, due to the heat and mositure present the plume can rise to significant altitudes and has the potential to initiate cumulus clouds.

Occasionally extensive and dense plumes can occur which will persist and travel many miles downwind forming a stratus cloud layer. Such plumes tend to occur more freqnently in fall and winter and under stable and moist atmospheric conditions. Similarly night and early morning conditions are more conducive to formation of dense and stratified plumes.

On the great majority of days the visible plume extends to between 200 and possibly 1000 yards downwind before it disappears completely.

Plume effects of hyperbolic towers in the Indian Point location are anticipated to be very similar to those in the Appalachian region where no significant adverse effects have been observed in the course of the last four years.

Con Edison's conclusion in Environmental Report Supplement No. 3 that at the Indian Point site, under weather conditions recorded there, there will be no significant adverse environmental impact due to the plume caused by operation of natural draft cooling towers is realistic.

With mechanical draft towers the moist warm plume is emitted at a much lower altitude, up to 50 to 75, possibly 100 feet. Consequently, local fogging problems and winter icing can present more of a significant hazard. Depending upon the local terrain and atmospheric stability the fogging potential can vary widely. For this Hudson River location it is very possible that local and possibly extensive valley fogs will result on a significant number of days with the use of a large mechanical draft installation.

Drift loss can and does occur with both natural and mechanical draft towers. Drift loss figures for natural draft towers have not been adequately reported and information tends to be closely guarded if it is indeed known. Drift loss for mechanical draft towers can vary widely from at least 0.1% down to possibly 0.01% of water flow. Newer units are frequently supplied with a drift loss guarantee of less than 0.02%. Due to operational differences between nautural and mechanical draft towers, drift loss with the natural draft systems will be less. To my knowledge there are no recent documented cases of drift loss causing a problem. However theoretical estimates indicate problems can occur. Many of these theoretical estimates are unnecessarily pessimistic tending to use a high drift loss figure as an argument against the use of towers.

Drift loss figures quoted by Con Edison in Environmental Report Supplement No. 3 are realistic. Indeed they indicate a tower figure of 0.0025% for natural draft towers. Con Edison's conclusion that at Indian Point there will be no significant adverse effect due to drift from natural draft towers is also realistic.

Spray cooling systems are relatively new. As such there is little documented evidence pertaining to potential detrimental effects from fogging and drift. However by analogy with mechanical draft towers problems of fogging and winter icing will be of at least the same order of magnitude. Additionally drift loss will be at least the same as mechanical towers, there being the potential for increasing drift losses as wind speed increases. In Environmental Report Supplement No.3, Con Edison indicatea drift loss figure of less than or equal to 1% based upon spray pond module vendors information. In the absence of any documented tests these figures cannot be confirmed. However, drift losses of 0.1 to 1.0% appear quite realistic when a spray operation is considered. This high potential drift loss might indeed be the major factor which has to date limited the popularity of spray pond usage.

A comparison of consumptive water losses by evaporation for each type of system is difficult due to the variations caused by both plant operations such as ΔT and such weather parameters as wet bulb, dry bulb, cloud coverage, wind speed etc. However, taking once through cooling as a base the other techniques are proportionately increased:

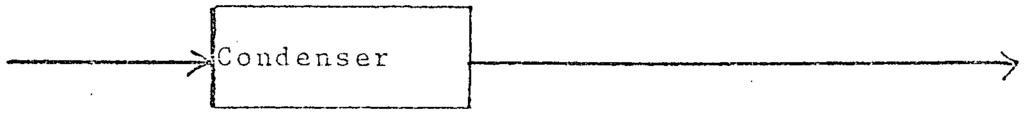
Once through	1
Natural Draft	1.25 - 1.35
Spray	1.3 - 1.35
Mechanical Draft	1.4 - 1.45

Using the evaporative water loss figures for Indian Point No. 2 supplied by Con Edison, that is 1.51% of 870,000 gpm, which is 13,137 gpm, it is possible to estimate consumptive water losses for other cooling techniques using the above comparative ratios for Indian Point Number 2:

Cooling System	Evaporative loss in g.p.m.
Once through	10,100
Natural Draft	13,137 (base)
Mechanical Draft	14,400
Sprays	13,400

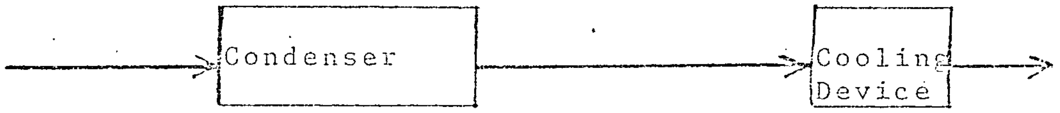
<u>Concentrations in Cooling Water</u>. All of the foregoing evaporative cooling techniques can be operated as a cooling device with a once through system or as a cooling device within a recirculation system. These general classes are illustrated as follows:

1.



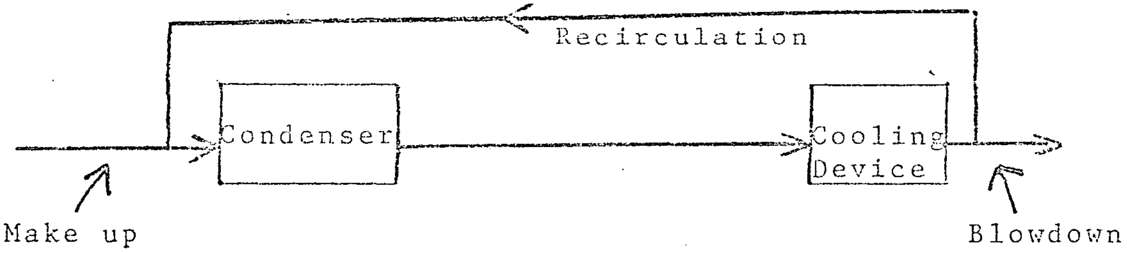
Once through

2.



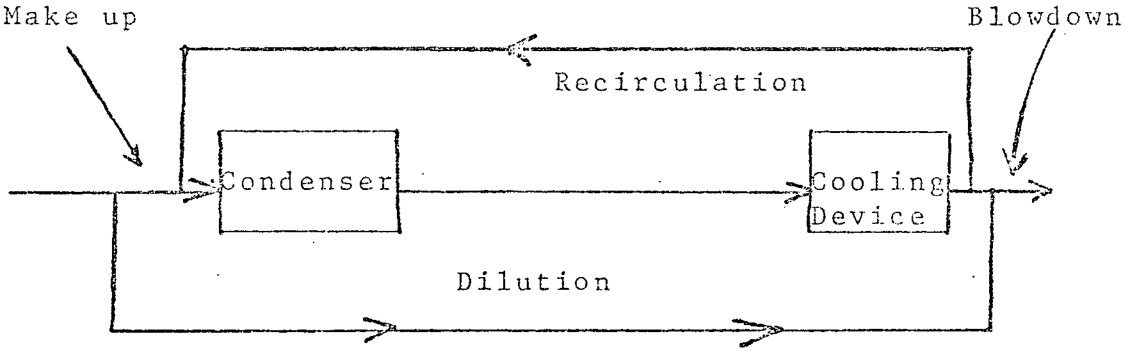
Once through with cooling device

3.



Recirculation

4.



Recirculation and Dilution

With all of the evaporative cooling systems there is a continual water loss by evaporation. Using evaporative cooling with recirculation the water loss has to be balanced. This evaporation and makeup cause a concentration effect within the system. There is a practical limit to the number of concentrations which can be allowed within the system.

Generally the total dissolved solids (TDS) within the circulating system is the limiting factor in number of concentration cycles. The upper TDS limit is in the region of 1000 - 2000 ppm. Although the TDS consists primarily of calcium sulfate this limit can extend to 2000 ppm at pH7. Consequently a number of concentrations can be effected within the system. Dependant on the input water quality the range of concentrations is between 3 and 8 although 4 to 6 is more typical. These figures pertain to surface waters having a TDS in the range 100 to 300 ppm. Con Edison indicates a twofold concentration factor in their report. Although this is low compared with nationwide average data it has the benefit that at Indian Point No. 2 the blowdown will contain less dissolved solids and lower concentrations of treatment chemicals.

The blowdown from a recirculating cooling system can be readily determined from a water mass balance, knowing the concentrating factor, thus:

$$B = \frac{E}{C-1}$$

Where B is blowdown in gpm

E is evaporation in gpm

C is the number of concentrations

Similarly the makeup M in gpm can be estimated:

$$M - E \frac{C}{C-1}$$

Using this technique and Con Edison's proposed number of concentrations, blowdown figures agree with those of Con Ed.

By way of illustration the variation in quaniity of blowdown with number of concentrations effected in the system is illustrated. The base for this data is

Cooling Water Flow	870,000 gpm
ΔT	15.1 °F
Evaporation	13,137 gpm

Number of concentrations	Blowdown gpm
2 (proposed by Con Ed)	13,137
3	6,568
4	4,379
5	3,294
6	2,627

With any recirculatory cooling water system it is necessary to treat the water chemically. The purpose of this water treatment are to:

(1) Control scale formation or inhibit corrosion

(2) Prevent bacterial activity

(3) Control pH

(4) Provide dispersing agents

As a result recirculatory systems can and will contain in the blowdown discharges any one or combination of the following treatment chemicals:

(1) organic or sodium phosphates, 2 to 5 ppm

(2) chromates, 15 to 50 ppm

(3) phosphate-chromate combinations with zinc, 10 to 40 ppm

(4) synthetic organics, up to 100 ppm

(5) shock chlorination levels to 1 to 1.5 ppm

(6) biodegradable organics to 20 or 30 ppm

(7) low molecular weight biodegradable polymers, 20 to 50 ppm

(8) polyelectrolytes and non ionic ploymers, 1 to 2 ppm

Noise. Environmental quality with regard to noise is becoming more an important consideration. Noise is categorized by sound level or intensity generally as some function of decibels (db) and frequency as Hertz (Hz, cycles per second). Typically there are eight frequency bands or octaves.

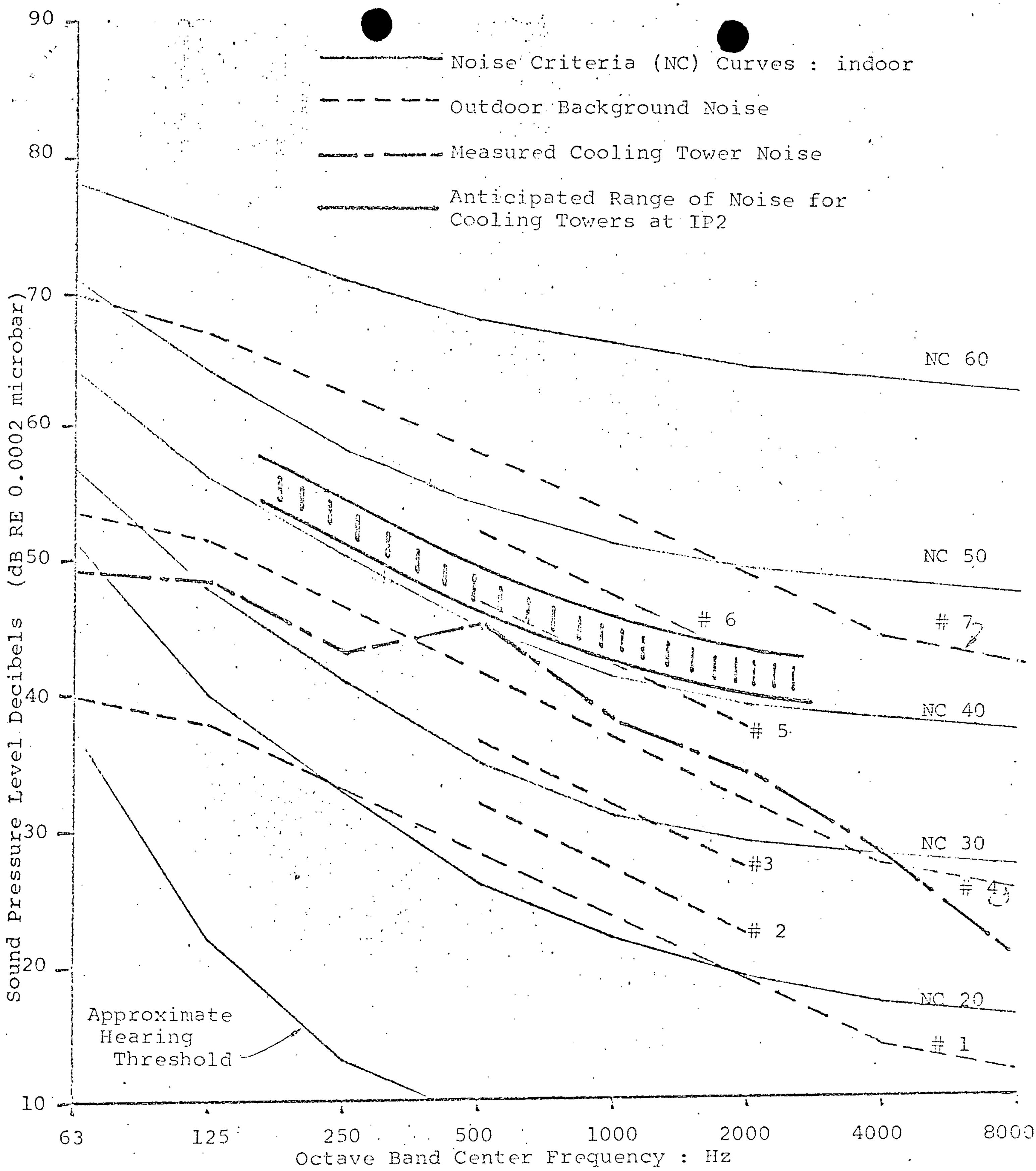
To illustrate potential effects of cooling tower noise it is necessary to delineate typical noise criteria (NC) curves which are acceptable and typically occur in certain activities. These are illustrated in the following figure.

The thin solid lines indicate noise criteria (NC) curves. These are acceptable levels of noise both measured and recommended for many indoor activities viz:[1]

Sleeping, resting, relaxing	NC 20 to NC 30
Excellent Listening Conditions	NC 15 to NC 20
Very Good " "	NC 20 to NC 30
Good " "	NC 30 to NC 35
Fair " "	NC 35 to NC 40
Business Areas	NC 40 to NC 45
Working Conditions i.e. industrial areas, kitchens garages	NC 45 to NC 55

The thin dotted lines delineate typical outdoor noise levels vis:

1, e.g., Eng. Manuel 251, Baltimore Aircoil Co., Inc.



Comparison of Cooling Tower and Background Noises

Line #1 Rural nighttime; no traffic
Line #2 Suburban nighttime; no traffic
Line #3 Urban nighttime; no traffic
Line #4 Urban daytime; little to no traffic
Line #5 Within 300 ft. of continuous light traffic
Line #6 Within 300 ft. of continuous medium-density traffic
Line #7 Within 300 ft. of continuous heavy-density traffic

The heavy dotted line illustrated the noise measured at 300 feet from a small mechanical draft tower[1]. For distances over 50 feet the noise falls off rapidly, an inverse square law applying for sound reduction with distance.

For the purposes of comparison I have illustrated the typical range of noise to be expected at a distance of around 300 feet from a mechanical draft cooling tower unit associated with Indian Point Unit 2. This is based upon personal experience and not upon any field measurements. To my knowledge there are no data on noise from natural draft towers. But it may be assumed that noise from such towers will be substantially less than from mechanical draft towers.

In conclusion it can be stated that noise associated with normal operation of both mechanical and

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[1] Eng. Manuel 251, Baltimore Aircoil Co., Inc.

natural draft cooling towers at power station locations has not and does not present a problem. Cooling tower noise problems only tend to manifest themselves with smaller towers associated with building air-conditioning units where the location is a high population density, residential or business area and towers are poorly located in courtyards, on low roof tops or against reflecting surfaces.

4. Time Requirements for Construction of Alternative Cooling Devices

The time required for the selection of a contractor to design and construct an alternative water cooling system can be categorized into a number of steps. These are briefly outlined below.

The time required by the utility operator to decide to go ahead with an alternative water cooling technique and the selection of one from the general categories of techniques available would be at least one month, and quite possibly substantially longer.

To obtain a number of design and price quotes would require from two to three months with a further one month for evaluation. Based upon the foregoing there is a minimum time requirement of four months. This is a minimum and is more realistically around six months for completion of paper work and possibly even longer. The above time requirements are variable and run into years in the case that there is no extreme urgency or the unit is in the very early planning stages.

Having made a firm decision to go ahead, construction could be initiated within a matter of weeks. However some delay could be experienced should this occur if operations commenced in winter.

The actual construction time requirements for water cooling towers can be delineated quite well. For natural draft towers the time requirements for construction including breaking ground to final completion are typically eighteen to twenty-four months. However, this can be expedited to nearer twelve months in exceptional cases. As a general rule the companies involved in construction of natural draft towers execute the complete project from design through to preparation of foundations, pouring the basin and construction.

In the cases of mechanical draft towers, the actual tower construction period is substantially less. Typically a one cell unit can be constructed in three weeks. However for larger units the time requirement is reduced on a per cell basis so typically a ten cell unit would take less than thirty weeks and more probably nearer twenty-five weeks. These figures do not, however, include ground preparation and installation of footing and concrete pads. Time requirements for these operations would typically be around two months. Total time requirements for complete construction of larger mechanical draft units is typically of the order of twelve months, although it is anticipated this figure could well be reduced by two to three months in exceptional cases. These time requirements for towers are based upon familiarity with currently building and recently completed units and discussions with the companies involved.

In the case of spray canals, it is a little more difficult to quote figures due to the relative newness of this type of cooling device. However, a realistic and typical time requirement is probably around twelve months for performance and completion of construction.