COOLING TOWERS, THE NEGLECTED ENERGY RESOURCE

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ABSTRACT: Loving care is paid to the compressors, condensers, and computer programs of refrigeration systems. When problems arise, operators run around in circles with expensive "fixes", but historically ignore the poor orphan, the cooling tower perched on the roof or located somewhere in the backyard. When the cooling water is too hot, high temperature cut-outs occur and more energy must be provided to the motors to maintain the refrigeration cycle.

Cooling Towers:

1) ... are just as important a link in the chain as the other equipment,
2) ... are an important source of energy conservation,
3) ... can be big money makers, and
4) ... operators should be aware of the potential of maximizing cold water.

Most towers designed over 20 years ago were inefficiently engineered due to cheap power and the "low bidder" syndrome. Operating energy costs were ignored and purchasing criteria was to award the contract to the lowest bidder.

This paper investigates internal elements of typical towers, delineates their functions and shows how to upgrade them in the real world for energy savings and profitability of operation.

HISTORICAL NEGLECT

From the very beginning, cooling towers were ignored. Figure 1 is an illustration from the ASHRAE Basic Fundamentals Refrigeration Manual (1) that delineates the refrigeration cycle consisting of compression, evaporation, expansion, and condensing. The discussion continues on and explains that heat is not generated or destroyed, it is just moved from one location to another. What is ignored though, is "How is that waste heat dissipated?" As we know, it is picked up by the circulating water and brought to the cooling tower where it is discharged into the atmosphere.

While the cooling tower seems like a simple mechanism, it is just as important to the refrigeration cycle as any of the other units. If the cooling tower does not function properly, high head temperatures require that additional electricity be pumped into the system to make it operate and at a critical point, the equipment will shut the system down if the cooling tower cannot produce sufficient cold water for the equipment.

REFRIGERATION ECONOMICS

A cost-effective approach to the solution of conserving energy (and therefore, money) would be to reduce the power input to your system while maintaining maximum efficiency. The power is either purchased from a public utility in the

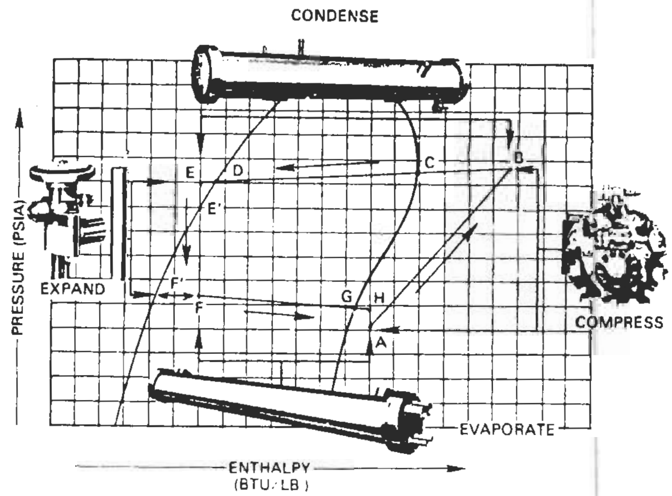

Figure 1: Equipment diagram for basic vapor compression cycle.

form of electricity or steam, or is generated by the facility by purchasing fuel oil for a diesel engine to power the system.

The following basic principles explain how colder water from the cooling tower conserves energy to create a cost-effective rapid dollar return for cooling tower upgrading expenditures.

Whether it be heat rejection from compressors, electric motor, or chemical process equipment, the cost of "hotter" cooling water is expensive in requiring additional energy to run the equipment at efficient levels to reduce head pressures and temperatures. Excessive heat will create maintenance problems, deteriorate the equipment, and cause shut downs of the process.

A typical example of this is where a refrigerant is cooled (condensed) in the condenser and in turn cools "chilled" water to reduce the temperature of the circulating air throughout the facility to maintain comfortable conditions. Input (electricity or steam) and output (tons of refrigeration) depend upon the speed (rpm) of the compressors and refrigerant temperature (condenser temperature). At any particular speed, both the power requirements and capacities of the refrigeration machine will vary significantly with the refrigerant pressure and temperature. These refrigerant conditions are determined by the cooling in the refrigerant condenser. The quantity and temperature of the condenser water (tower water) determines the available cooling. When operating at full condenser water flow a reduction in condenser water

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temperature will reduce refrigerant temperatures and pressures. This will permit producing similar refrigeration capacities at lower machine speeds (rpm) and lower power (steam and electricity requirements.)

It can be seen that for various types of refrigeration machinery, colder condensing water off the cooling tower increases the coefficient of performance. For example, a 5°F reduction to a reciprocating compressor can result in a 7% increase in coefficient of performance. Translating this to dollars and cents, if it cost $250,000.00 to operate the system a year, this 5°F colder water can result in a savings of almost $44,000.00 a year in compressor operating costs since the head temperatures are considerably lowered.

Enthalpy charts for refrigerants indicate that for every degree of colder water to the equipment, a 3½% reduction in energy input can be attained. (3)

If, for example, the refrigeration system utilizes $400,000.00 of electricity per year (typical for a 2,000 ton installation) and a 4°F reduction of cooling tower water is obtained, this will lower the utility bill by $56,000.00 ($400,000.00)(4)(.035). With utility costs soaring, this savings will increase each year.

The facts are readily available in most Operating and Maintenance Departments to determine the cost of energy used, and the reduction in water temperature that can be obtained, indicating the cost savings involved. By comparing the cost savings as against the retrofit cost, a payback will usually occur within 6 months to a year and a half depending upon the conditions of the cooling tower before retrofit.

Many authorities point out that lower temperature cooling tower water can produce significant savings for refrigeration equipment. The cooling tower plays one of the key roles in the efficiency of your air conditioning machines. Energy consumption is measured in kilowatt hour usage and this reflects efficiency. If your tower does not create the proper heat transfer, your machine will work harder to compensate for the loss and inefficiency (4). Figure 2 clearly indicates that colder condensing temperatures will improve the performance of a compressor significantly. This can result in a substantial energy and dollar savings.

The role of the cooling tower is to remove waste heat in the refrigeration or chemical reaction. The degree of elevation of the discharge temperature above ambient conditions is the sum of the tower's approach of the cold water to the Wet Bulb temperature, i.e., the difference between cold water and Wet Bulb, the cooling range (which equals the temperature rise in the heat exchanger), and the terminal difference in the exchanger. A reduction in operating temperature, always desirable for economic reasons, may be obtained by increasing the capability of the cooling tower's performance (5).

REAL WORLD PRACTICALITIES

Due to the inaccessible location of the cooling tower (usually installed to conserve real estate on the top of a building, or in the backyard) maintenance personnel are many times hard

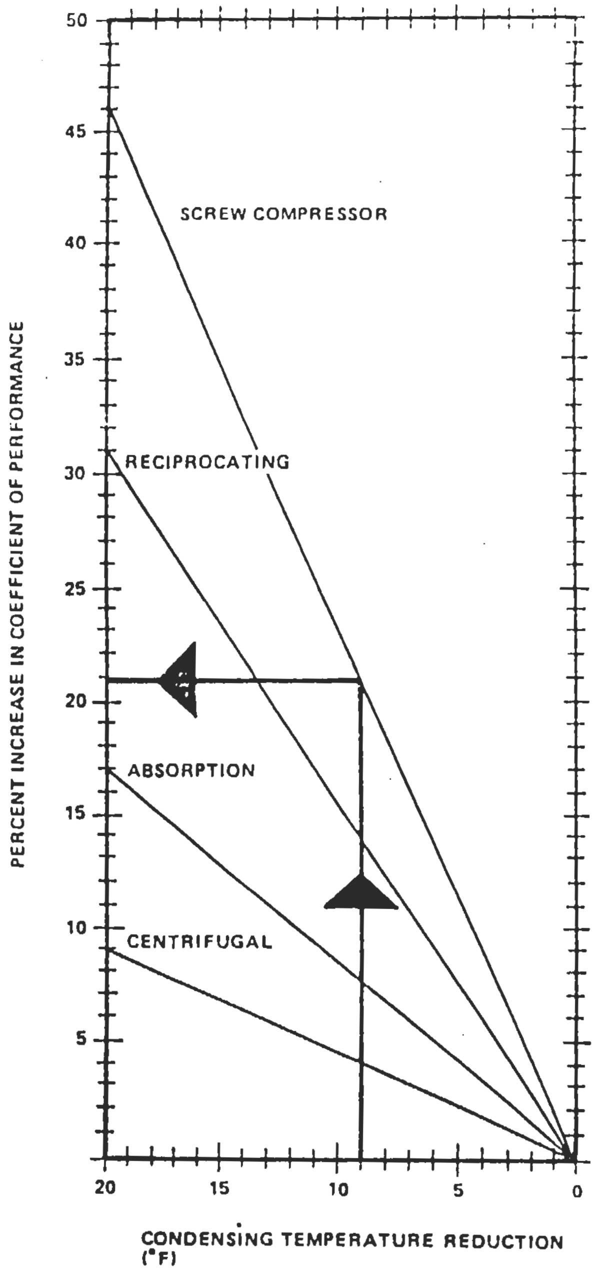

Figure 2 - The effect of condenser temperature on the chiller coefficient of performance (COP). (2)

pressed to adequately service the equipment.

Training and misplaced priorities tend to keep the operating engineers more closely attuned to the requirements of the compressors, condensers, and evaporators rather than to the quality of cold water being discharged from the cooling tower.

Since the cooling tower is open to the atmosphere, it can quite readily deteriorate due to corrosion of the ferrous parts, and bacteriological and chemical attack of the wood.

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Many maintenance people feel that if it is ignored, it will go away. But, of course, being familiar with Murphy's Laws - this does not happen.

COOLING TOWER MODERNIZATION

A great majority of cooling towers operating today, even though some are newly installed, have been engineered with techniques over 20 years old. Today's technology can be utilized to retrofit practically all towers and upgrade their capability of producing colder water or cooling greater volumes of circulating water (6).

Listed below in ascending order of cost are some of the major components that can be upgraded. It is axiomatic that the greater the dollar input, the more rapid and profitable the return that can be obtained.

a) Air Handling - More air volume results in better thermal transfer and colder discharge water. By pitching the fan blades up to a higher angle, which is determined by the plate amperage, additional air can be generated for the same horse power. Velocity regain (VR) Venturi Stacks should be investigated for increasing air flow through the tower while reducing fan motor horse power.

b) Drift Eliminators - Conventional two-pass wood slat herringbone or steel "zig-zag" configurations usually have a higher pressure drop than the new PVC cellular units, Figure 3. By eliminating the solid droplets of water to a higher degree and at a lower pressure loss, the cellular drift eliminator provides additional cooling air through the tower for colder temperatures.

c) Water Distribution Systems - By installing metered orifice target nozzles in older crossflow towers, a more uniform water pattern is obtained and the resulting uniformity will improve the tower's performance. Counterflow towers with spray systems can be greatly improved by installing the new square spray ABS practically non-clogging nozzles. An added advantage of this newer type nozzle is that maintenance and cleaning are greatly simplified due to upwards of 75% fewer nozzles required than the conventional small orifice conical pattern spray units.

d) The greatest improvement in performance modernization is obtained by changing out the old wood splash bars, Figure 6, and installing self-extinguishing PVC cellular film fill, Figure 5, together with the new efficient nozzles, Figure 4.

EXAMPLES OF UPGRADING:

Blow Through Squirrel Cage Tower

The subject three cell metal tower had a water distribution system of 960 small orifice nozzles on 1½" pipe, Figure 5, and was operating at high head temperatures. The clogged and corroded water distribution system was removed from the tower and the rusted clogged steel plate corrugated wet decking fill was also disposed of. After sandblasting and coating with moisture cured urethane, the new spray system consisting of 36 nozzles on 3" diameter PVC pipes was installed together with new PVC cellular fill.

Figure 3 - Left, old-fashioned herringbone heavy wood slat drift eliminators with high static pressure loss which are prone to deterioration, permitting solid droplets of water to escape. Right, modern high efficiency low pressure drop, self-extinguishing PVC cellular eliminator replacements on typical crossflow tower.

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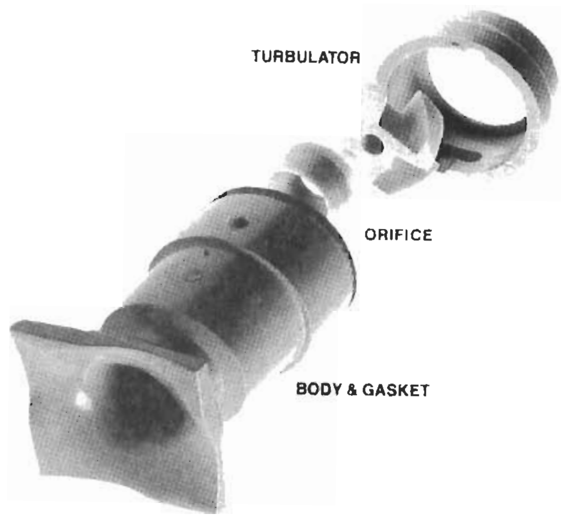


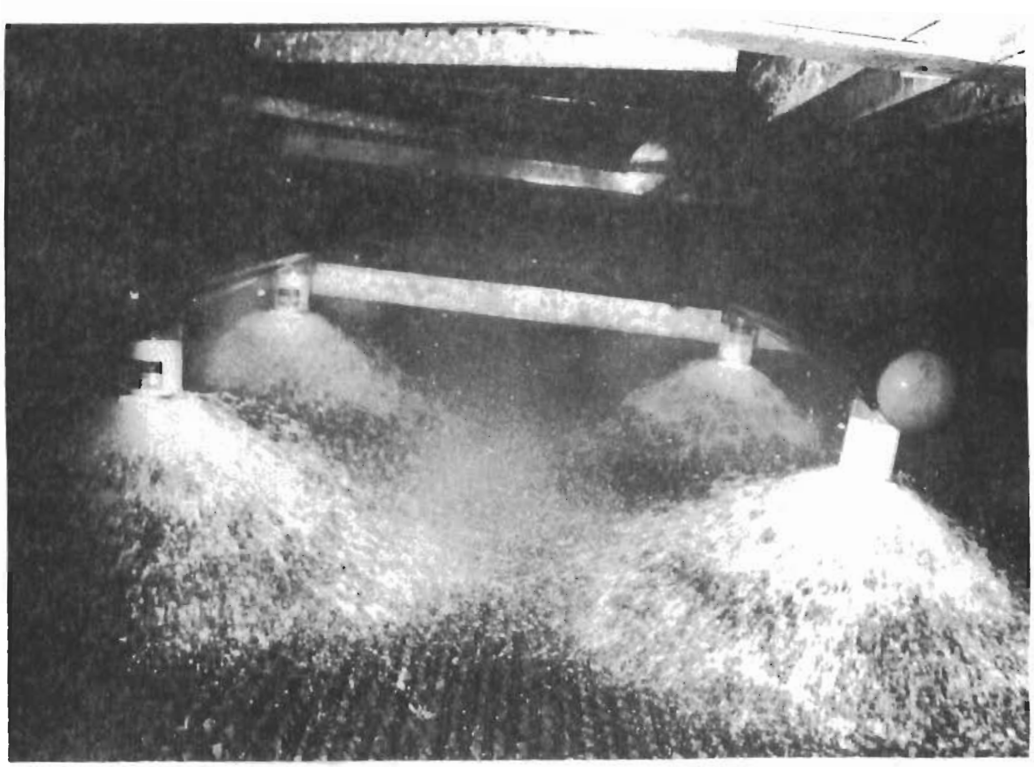


Figure 4 - A startling improvement in performance by producing colder water or cooling greater volumes of circulating water can be obtained by installing cellular fill and square spray non-clogging nozzles.

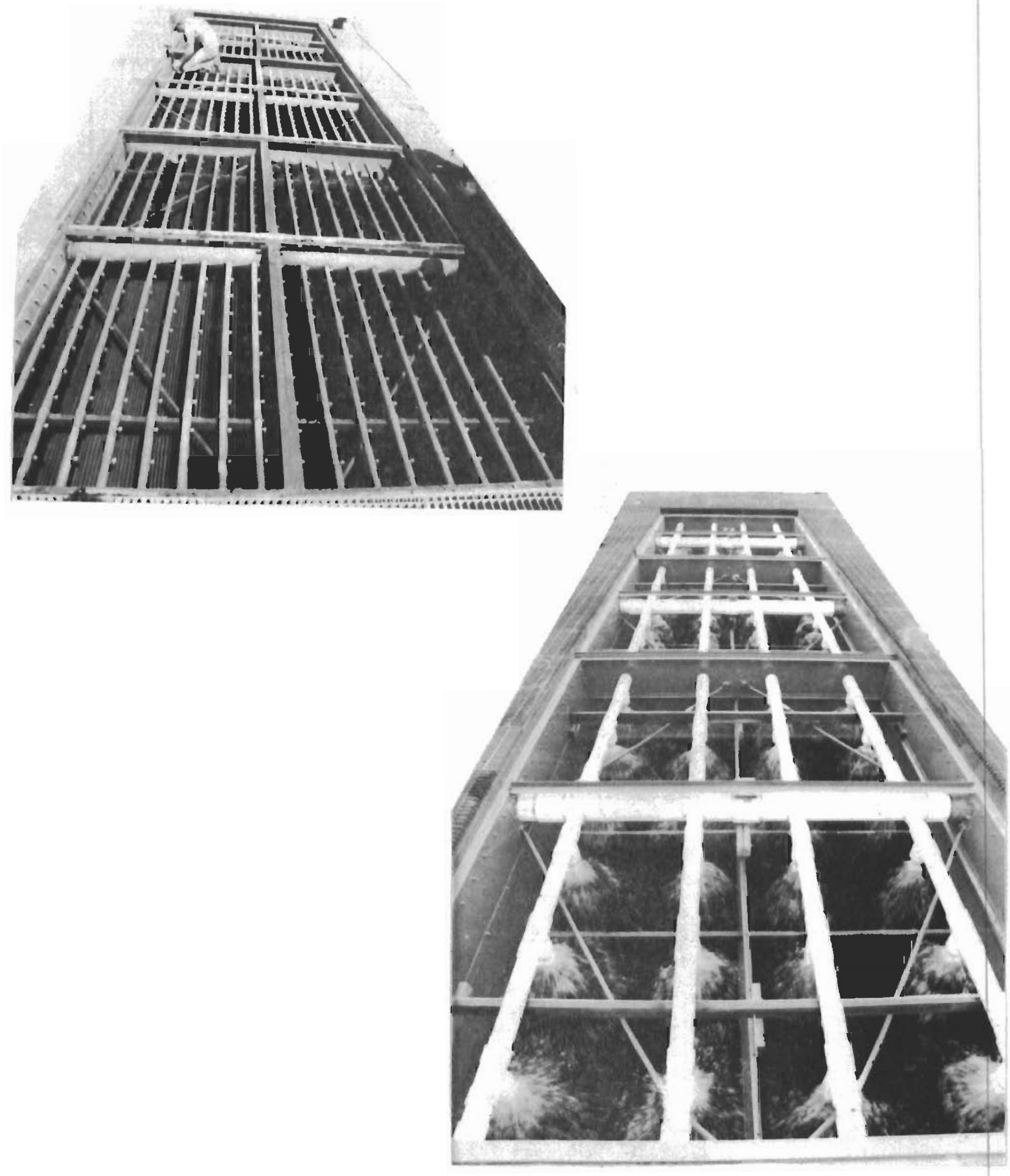


Figure 5 - By changing 388 small orifice nozzles to 36 non-clogging square spray type and installing cellular fill, 5°F colder water was obtained.

This chart illustrates the rapid payback for converting the tower, illustrated in Figure 5. Enthalpy charts for Freon indicate that 3½% of the electrical energy to the compressors and condensers can be saved for every 1°F colder water (3). The subject cooling tower was tested in accordance with the Cooling Tower Institute Acceptance Test Code 105 which indicated that 5°F colder water was obtained after retrofit. Since the rebuilding for colder water cost $38,500.00, the return on the investment was realized in approximately 9 months with a projected ten year savings of close to $500,000.00.

BLOW THRU

WATER IN @ 100°F OUT @ 90° @ 78 F°WBT
960 NOZZLES ON 1 1/2" PIPE
OPERATING WITH HIGH HEADS

36 NOZZLES + CELLULAR FILL
PRODUCES DESIGN OF 95°– 85°– 78

5 APPR • 3 1/2% SAVES 17% ENERGY

17% • $250.000 = $43.750 /YEAR

10 YEARS = $437,500 EARNED

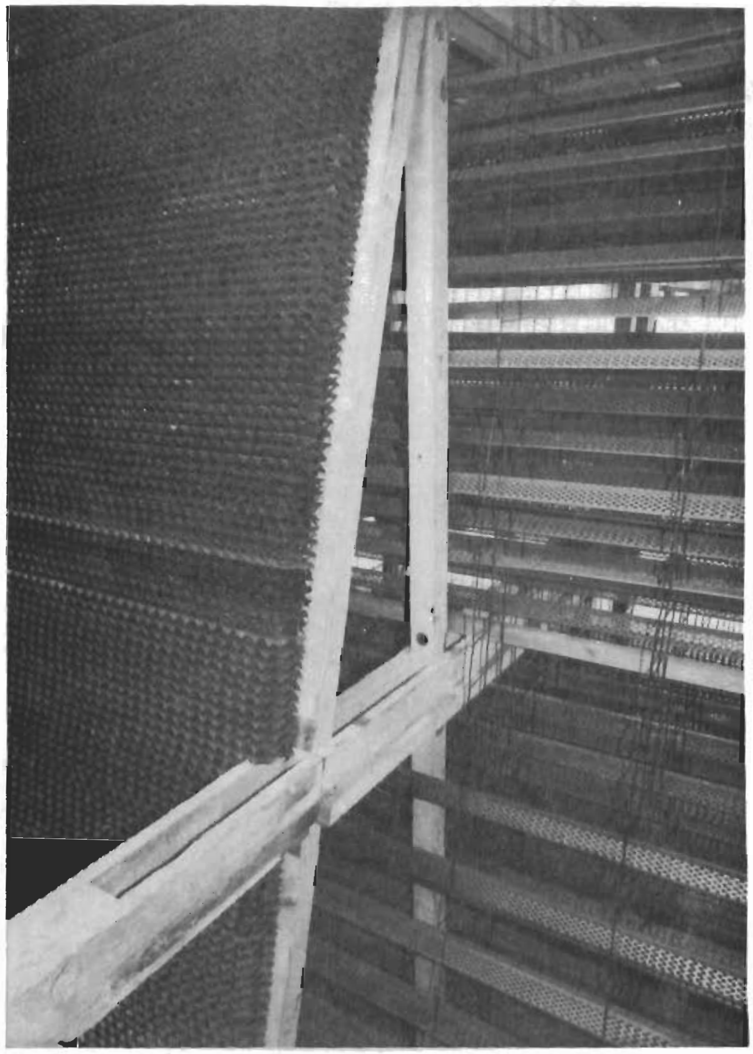
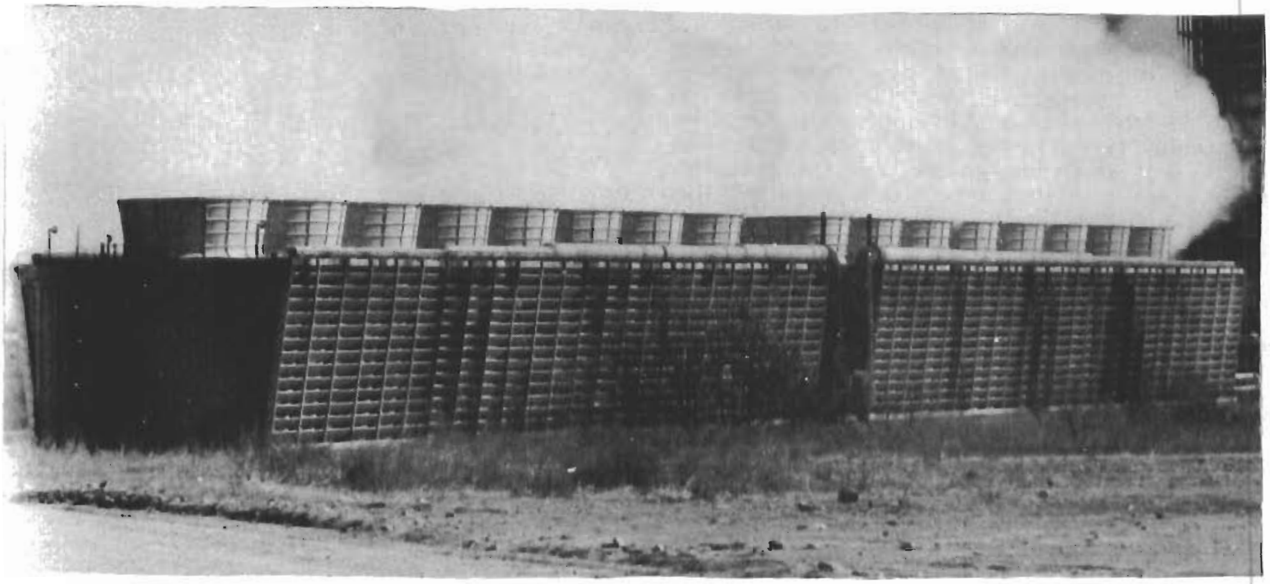


Figure 6 – Inefficient wood fill and leaking drift eliminators were retrofitted with new state of the art self-extinguishing PVC high heat transfer cellular fill and drift eliminators, which reduced the discharge water temperatures by 5°F, representing an approximate 600,000 kilowatt hour and $45,000 energy savings at 7½¢ KwH utility charge.



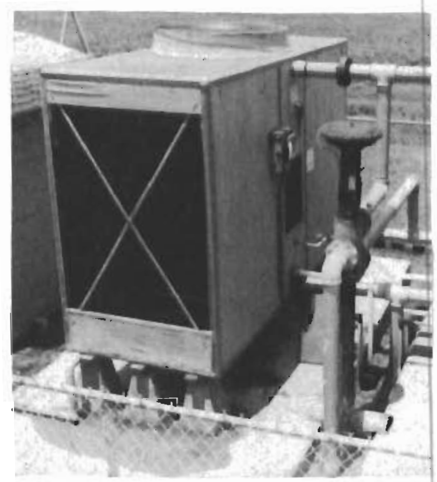


Figure 7 - The techniques, thermal, mechanical, engineering, and structural retrofit for all sizes of cooling towers are practically the same. The difference being the size and cost.

CONCLUSION

If a refrigeration/air-conditioning system is operating marginally due to high head temperatures, it behooves the owner and operator to investigate the possibility of upgrading the existing cooling tower rather than installing another O.E.M. unit which may or may not the necessary colder water. It should be well understood that colder water can save energy and create an operating profit. Cooling towers are hidden bonanzas for energy conservation and dollar savings when properly engineered and maintained. In many cases, the limiting factor is the quality and quantity of cold water coming off the cooling tower (8).

The thermal upgrading and structural retrofitting technology of all types of cooling towers is the same, only the size is different, as illustrated in Figure 7.

It would be prudent for the engineer with responsibility for the efficient operation of the refrigeration/air conditioning system to have a professional inspection of the cooling tower done by a consultant who can analyze the energy savings potential of his installation. In these days of high energy costs, the savings accrued from a well engineered and retrofitted cooling tower bringing it into the 1980's can make a significant impact on a company's profit and loss statement.

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