









**EMPLOYING AN EFFECTIVENESS MODEL  
FOR CALCULATING COOLING TOWER  
PERFORMANCE**

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C. 1

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## LIST OF ABBREVIATIONS

- $A_v$  - surface area of water droplets per volume of cooling tower
- $C_{pa}$  - constant pressure specific heat of moist air
- $C_{pw}$  - constant pressure specific heat of liquid water
- $C_s$  - derivative of saturation air enthalpy with respect to temperature
- $h_a$  - enthalpy of moist air per mass of dry air
- $h_C$  - convection heat transfer coefficient
- $h_D$  - diffusion mass transfer coefficient
- $h_g$  - enthalpy of water above reference state for liquid water at  $T_{ref}$
- $h_s$  - enthalpy of saturated air
- $m_w$  - mass flow rate of water
- $m_a$  - mass flow rate of air
- $m^*$  - ratio of air flow rate to water effective capacitance rate for effectiveness analysis
- $Le$  - Lewis number
- $Ntu$  - overall number of transfer units
- $Q$  - actual heat transfer rate
- $T_{ref}$  - reference temperature for zero enthalpy of liquid water (32 °F)
- $T_w$  - water temperature
- $V$  - volume
- $e_a$  - air-side heat transfer effectiveness
- $w_a$  - air humidity ratio
- $w_s$  - humidity ratio of saturated air



## Additional Subscripts

- a - air stream conditions
- i - inlet state conditions
- o - outlet state conditions
- T - total
- w - water stream conditions

## SUMMARY

Optimization of the design of chiller/cooling tower systems for large office buildings require an accurate detailed model for the cooling tower. This model must be precise and allow for varying air and water flow rates, ambient air conditions and entering water temperatures. The optimization computational requirement is very time consuming, however, due to the tower model requiring solution of three simultaneous differential equations.

The purpose of this project was to develop a computer program utilizing an effectiveness model to reduce computational time while maintaining good correlation to existing programs. The methodology involved the use of a tower model program developed by Eric Weber [1988] and the modifications made unto by Thane Joyce [1990] that integrated a centrifugal chiller model, cooling tower model, and system optimization strategy. The effectiveness model generated by James Braun [1988] was utilized in place of Weber's tower model.

The results are very encouraging. The computational time required to optimize the design was reduce approximately 75% while maintaining an accuracy of tower water temperature range of approximately 15%. This reduction in computer time will allow an engineer the flexibility to examine many systems and determine the optimum design in a shorter time frame.

## INTRODUCTION

The design of heating, ventilation and air conditioning (HVAC) for large buildings tasks the engineer with manipulating a plethora of design parameters. With limitations on funding and typically a short fused deadline, engineers rely on rule-of-thumb or past experience when designing these systems. No attempt is made to optimize the system as a unit bringing together all component parts: pumps, chiller, cooling tower, pipe size, etc.

An optimization methodology for the chiller/cooling tower system was developed by Thane Joyce. The results of his work show that an optimized system can save both construction and operating costs. The computational requirements to perform the optimization, however, is very time consuming and therefore the methodology was not applicable as a design tool. In order to make the program more useful, the computational time needed to be reduced. This is accomplished by employing Braun's effectiveness model in lieu of the Weber cooling model in Joyce's program. The resulting program was then compared to the original Joyce program for accuracy and reduction in computational time.

# DEVELOPMENT OF EFFECTIVENESS COMPUTER MODEL

The effectiveness model used to replace the tower model developed by Weber is based on the work by James Braun. A schematic of a counterflow cooling tower is provided in figure 1.

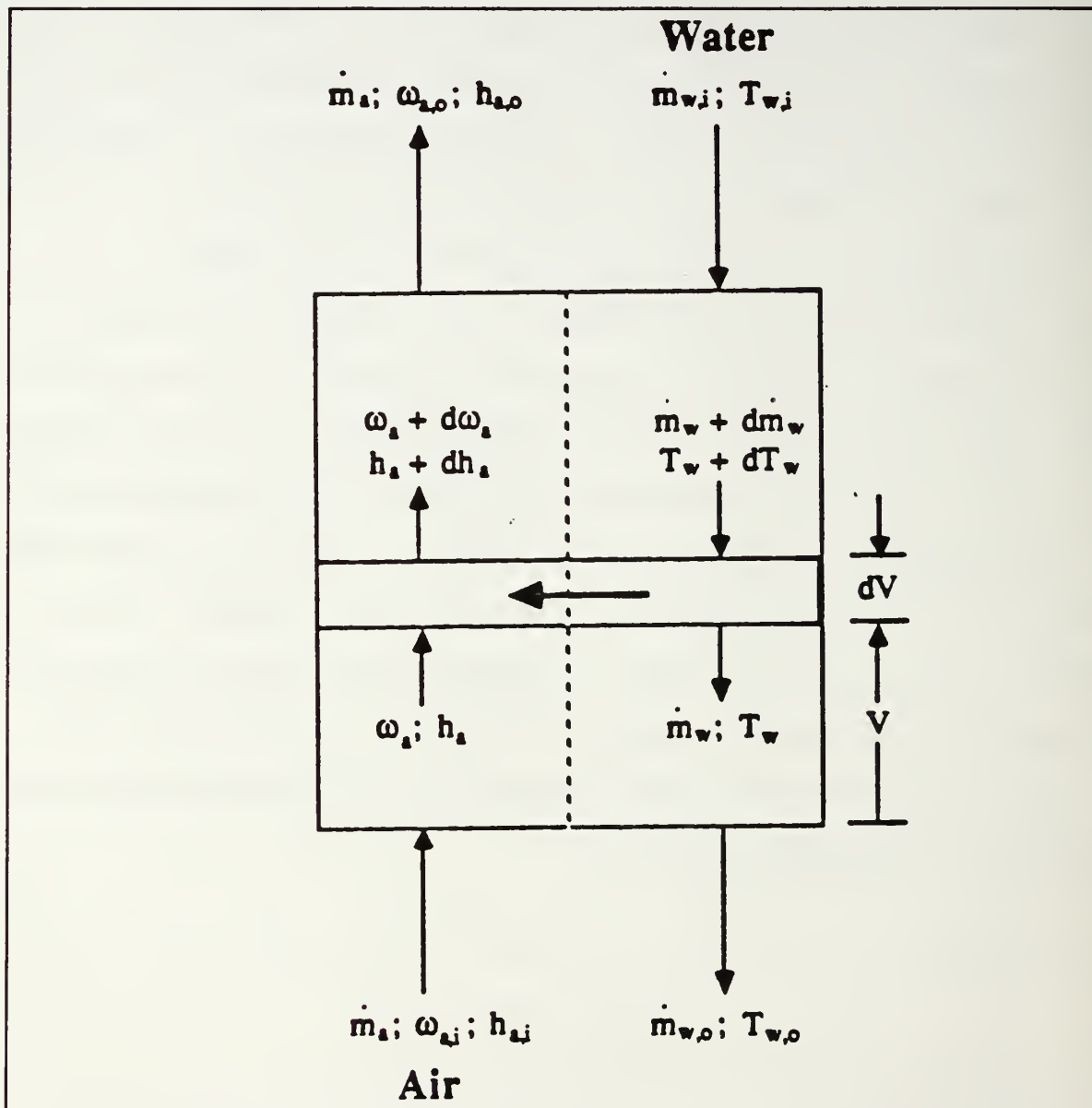


Figure 1. Schematic of a Counterflow Cooling Tower [Braun, 1988]

The following assumptions were made by Braun to derive the basic model equations:

1. Heat and mass transfer in the direction normal to flows only.
2. Negligible heat and mass transfer through tower walls to environment.
3. Negligible heat transfer from the tower fans to the air or water streams.
4. Constant water and dry air specific heats.
5. The mass fraction of water vapor in the mixture of air and vapor is approximately equal to the humidity ratio.
6. Uniform temperature throughout the water stream at any cross section.
7. Uniform cross-sectional area of the tower.

From steady-state energy and mass balances on an incremental volume, refer to figure 1, the following differential equations are developed by Braun and Weber:

$$\frac{d\omega_a}{dV} = - \frac{Ntu}{V_T} (\omega_a - \omega_{s,w}) \quad (1)$$

$$\frac{dh_a}{dV} = - \frac{Le Ntu}{V_T} [(h_a - h_{s,w}) + (\omega_a - \omega_{s,w}) \left(\frac{1}{Le} - 1\right) h_{g,w}] \quad (2)$$

$$\frac{dT_w}{dV} = \frac{\frac{dh_a}{dV} - C_{pw} (T_w - T_{ref}) \frac{d\omega_a}{dV}}{\left[ \frac{\dot{m}_{w,i}}{\dot{m}_a} - (\omega_{a,o} - \omega_a) \right] C_{pw}} \quad (3)$$

where

$$Le = \frac{h_c}{h_D C_{pa}}$$

$$Ntu = \frac{h_D A_v V_T}{\dot{m}_a}$$

Knowing the inlet conditions, the number of transfer units, and the Lewis number, the exit state of both the air and water streams can be determined. Using these same equations, Weber took an iterative approach with respect to the outlet humidity ratio and the exit water temperature, numerically integrating the equations over the entire volume from air inlet to outlet.

The effectiveness model simplifies this analysis considerably. By employing Merkel's assumptions of neglecting water loss and setting the Lewis number equal to unity, the three differential equations reduce to:

$$\frac{dh_a}{dV} = - \frac{Ntu}{V_T} (h_a - h_{s,w}) \quad (4)$$

$$\frac{dT_w}{dV} = \frac{\dot{m}_a (dh_a/dV)}{\dot{m}_w C_{pw}} \quad (5)$$

Equation (5) can be written in terms of air enthalpies only by introducing a new variable,  $C_s$ , termed the saturation specific heat:

$$\frac{dh_{s,w}}{dV} = \frac{\dot{m}_a C_s (dh_a/dV)}{\dot{m}_w C_{pw}} \quad (6)$$

where

$$C_s = \left[ \frac{dh_s}{dT} \right]_{T=T_w} \quad (7)$$

$C_s$  is equivalent to the derivative of the saturated air enthalpy with respect to temperature evaluated at the water temperature and has the units of specific heat. Braun indicates that if the saturation air enthalpy were linear with respect to temperature then the exit conditions could be solved for analytically. His figure 2, shown below, depicts the variation of the saturation enthalpy with temperature for typical water inlet and outlet points along with a straight line connecting the points.

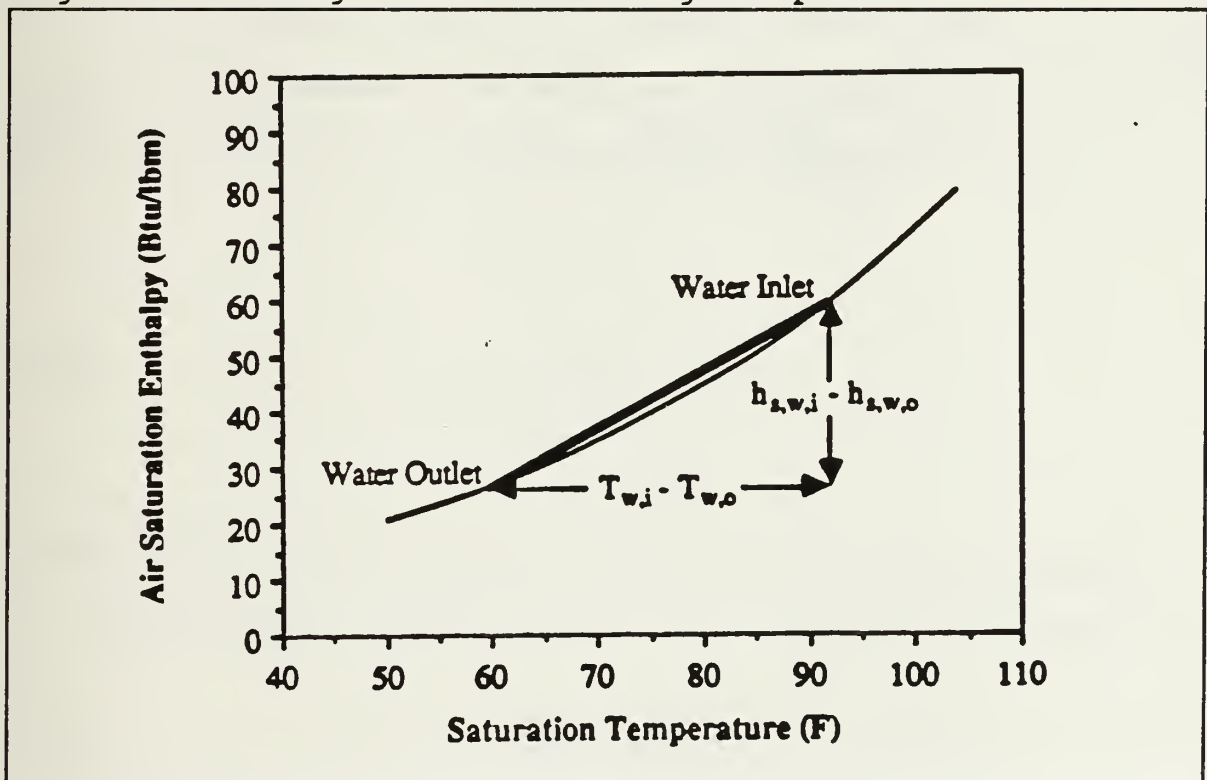


Figure 2. Saturation Air Enthalpy versus Temperature [Braun, 1988]

It is clear from the figure that the saturation air enthalpy does not vary linearly with temperature, however, by choosing an appropriate average slope between the inlet and outlet states, an air-side effectiveness relationship in terms of  $C_s$  can be developed. This air-side effectiveness is defined as the ratio of the actual heat transfer to the maximum possible heat transfer if the exiting air were saturated at the temperature of the incoming water (i.e.,  $h_{a,o} = h_{s,w,i}$ ).

Writing the heat transfer in terms of this effectiveness yields:

$$\dot{Q} = \epsilon_a \dot{m}_a (h_{s,w,i} - h_{ai}) \quad (8)$$

where

$$\begin{aligned} \epsilon_a &= \text{air-side heat transfer effectiveness} \\ &= \frac{1 - \exp(-Ntu(1 - m^*))}{1 - m^* \exp(-Ntu(1 - m^*))} \end{aligned} \quad (9)$$

and

$$m^* = \frac{\dot{m}_a}{\dot{m}_{w,i} (C_{pw}/C_s)} \quad (10)$$

The average value for the saturation specific heat is estimated as the average slope between the inlet and outlet state points:

$$C_s = \frac{h_{s,w,i} - h_{s,w,o}}{T_{w,i} - T_{w,o}} \quad (11)$$



The outlet air enthalpy and water temperature can then be calculated using the following equations:

$$h_{a,o} = h_{a,i} + \epsilon_a (h_{s,w,i} - h_{a,i}) \quad (12)$$

$$T_{w,o} = \frac{\dot{m}_{w,i} (T_{w,i} - T_{ref}) C_{pw} - \dot{m}_a (h_{a,o} - h_{a,i})}{\dot{m}_{w,o} C_{pw}} + T_{ref} \quad (13)$$

In the computer model employing the air-side effectiveness, the water loss is neglected, so  $m_{w,i}$  is set equal to  $m_{w,o}$ . Since  $C_s$  depends upon  $T_{w,o}$ , the solution for the exit conditions is iterative using equations 9 through 13. The saturation specific heat,  $C_s$ , is only weakly dependent upon  $T_{w,o}$ , however, so any reasonable initial guess for  $T_{w,o}$  (such as the inlet wet bulb temperature of the air) typically results in convergence in only two iterations.

## CONCLUSIONS

The results of this exercise are very promising. The computational time savings for the effectiveness method was as much as 83% over the Joyce method, while the percent error in calculating the energy consumed was less than 14% for all cases.

The first portion of the project is dedicated to evaluating the affect of employing the effectiveness model on the delta temperature across a counterflow cooling tower. Weber's computer program is used to generate the control data set. The revised program generated the test data set. Figure 3 displays the results of this evaluation. Numerical data is found in Appendix B.

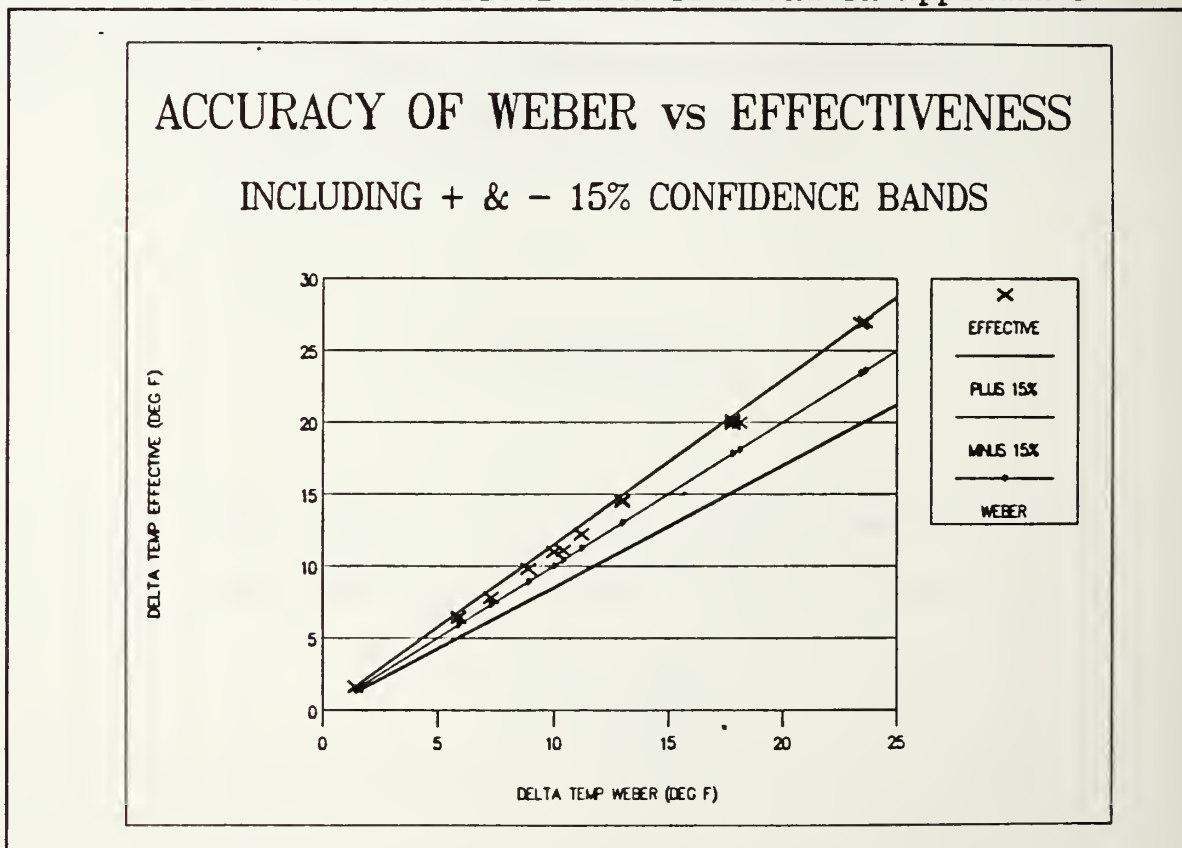


Figure 3. Accuracy of Weber versus Effectiveness Model

The effectiveness model computer program is provided as Appendix A. This model gives a larger delta temperature across the cooling tower in all cases compared with the exact data set. One reason why the effectiveness model overpredicts the tower delta temperature is that Weber's model is developed for a crossflow cooling tower while Braun's analysis is for a counterflow cooling tower. If improved accuracy in calculating the delta temperature across the tower is desired, a crossflow correction factor can be applied to the effectiveness model. Linearization of saturation enthalpy between the inlet and outlet points tends to overpredict the tower heat transfer and is another factor contributing to this error.

To test and compare the effectiveness model to the Weber cooling tower model in Joyce's program, several variables are manipulated while holding others constant. The variables investigated are: 1) air flow rate through tower (cfm), 2) tower size, and 3) pump size (gpm). These variables are considered the primary parameters for designing cooling towers. Figures 4 through 9 show the results of the comparisons for these various parameters. The results are encouraging and in each case the trends for both models are similar. Appendix C contains the numerical data used in generating these figures.

Figure 4 depicts the plot of effectiveness data versus Joyce data for various air flow rates through the cooling tower (CFM). The trends in both computational methods for this design parameter are very similar.

# ACCURACY OF JOYCE VS EFFECTIVENESS FOR VARIOUS CFM'S

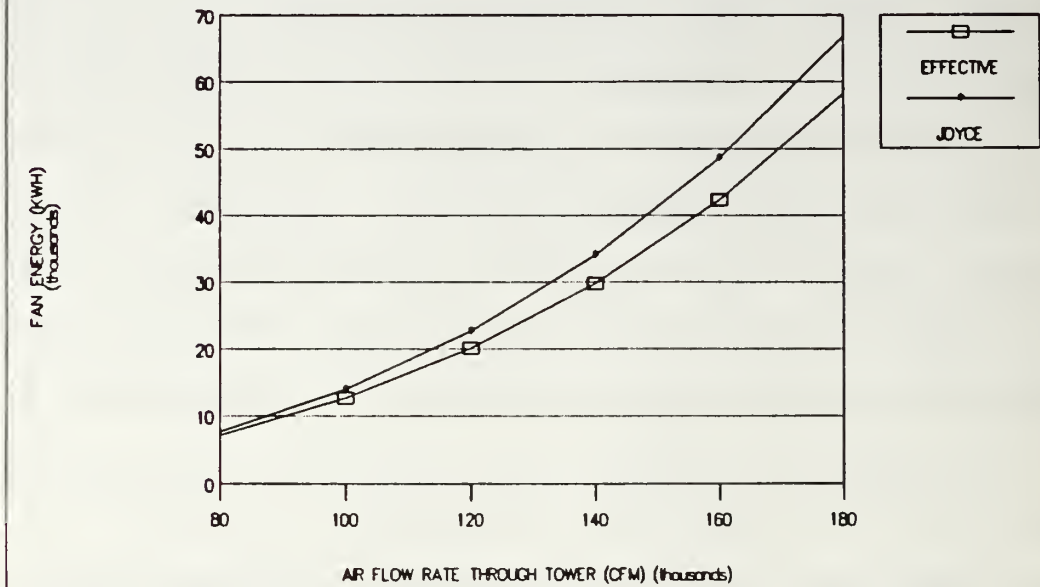


Figure 4. Plot of Effectiveness versus Joyce Data for Various CFMs.

The time savings for this variable are substantial, as shown in figure 5.

Six different tower air flow rates were used while holding the other variables constant. The maximum error, of 12.8%, occurs at a flow rate of 160000 CFM. The time savings are between 33 and 37 minutes, or roughly 81% improvement over the more exact Joyce model.

The next variable manipulated is tower size. Actual manufacture's performance data for Baltimore Aircoil series 3000 is used as input parameters. The results are very favorable giving

## TIME SAVINGS AT VARIOUS CFMs

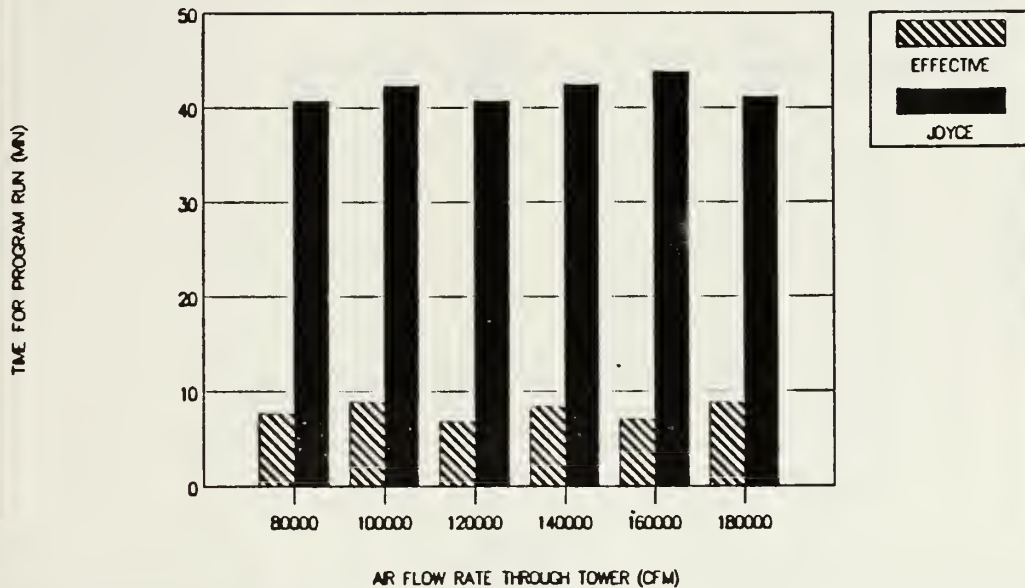


Figure 5. Time Savings at Various CFMs.

similar trends for both models, figure 6. The time savings using the effectiveness model over the Joyce method for this parameter are also quite impressive, refer to figure 7.

Six different tower sizes were used in the analysis. The effectiveness model underpredicts the tower fan energy used in all cases. The largest error, 13.7%, is found at tower number 19 which denotes a Baltimore Aircoil, series 3000, model number 3269. Savings in computational time is very impressive for this test variable. Approximately 34 minutes of saved time is seen for all cases, roughly an 80% improvement in computational run time.

# ACCURACY OF JOYCE VS EFFECTIVENESS FOR VARIOUS TOWER SIZES

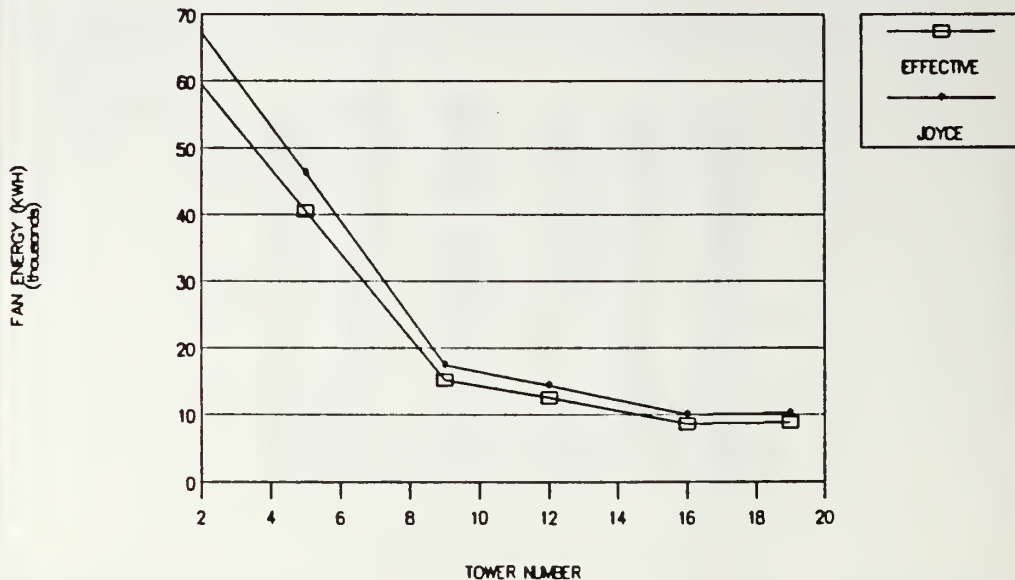


Figure 6. Plot of Effectiveness versus Joyce Data for Various Tower Sizes.

The final variable manipulated is condenser water pump size. Pump sizes between 750 GPM and 1500 GPM were used and the affect on both fan and pump energy (KWH) were tabulated. The results are promising, producing like trends for both the effectiveness model and Joyce method, refer to figure 8. Computational run time savings are also favorable for this parameter. Figure 9 presents the time savings for the new program as compared with the existing program for various pump sizes.

## TIME SAVINGS AT VARIOUS TOWER SIZES

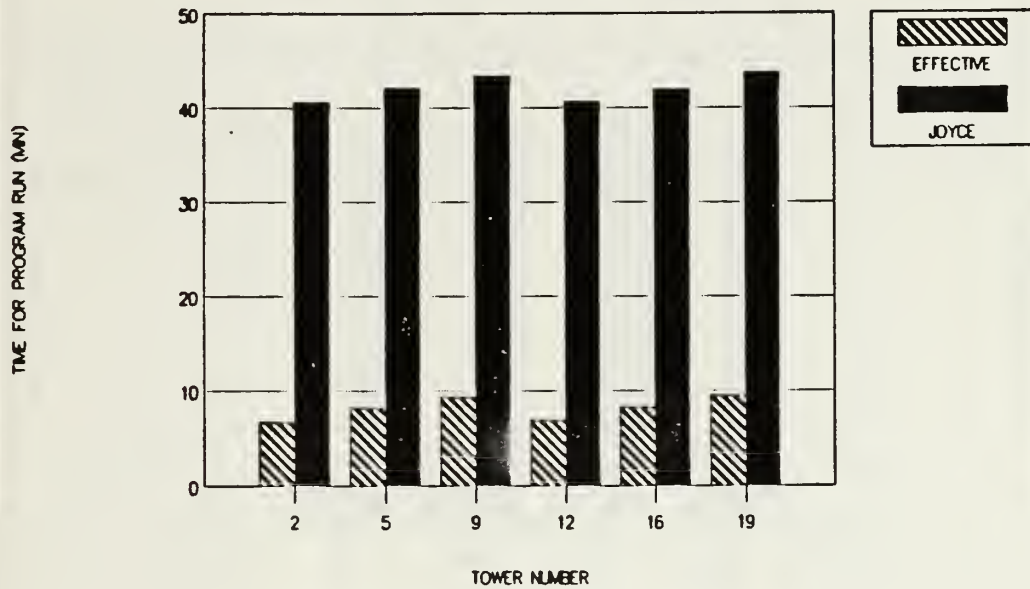


Figure 7. Time Savings at Various Tower Sizes

Again the effectiveness model underpredicts the fan and pump energy as compared to the Joyce method in all cases. The trends for both models, however, are very similar giving the same minimum and maximum point. The maximum error is roughly 10% and occurs at a pump size of 1000 GPM. Computer run time savings is very impressive at approximately 34 minutes or 81% as compared to the control data program.

As is shown in all the figures, the trends for both the effectiveness model and the Weber model in Joyce's program are very similar.

# ACCURACY OF JOYCE VS EFFECTIVENESS

## PUMP SIZE

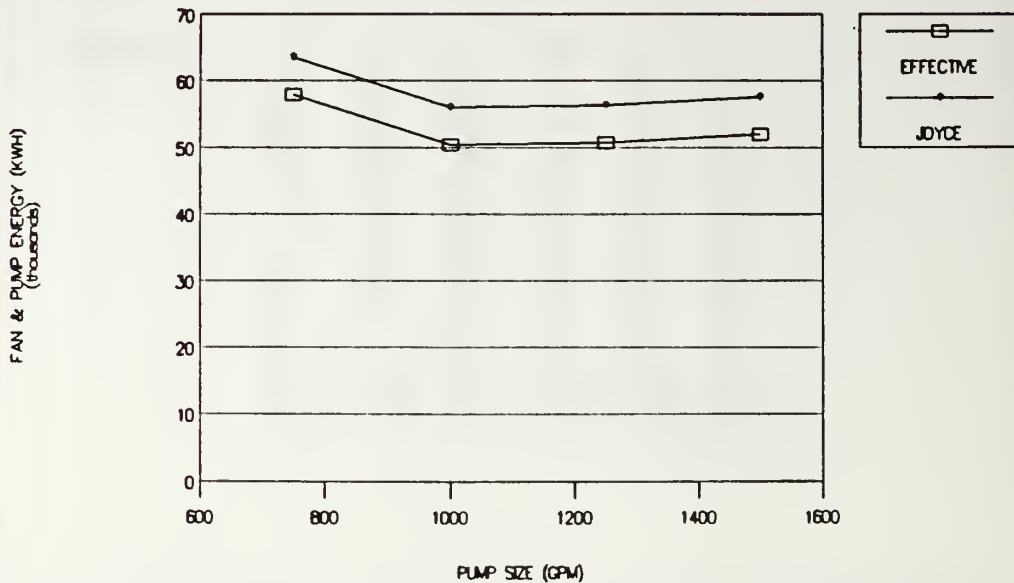


Figure 8. Plot of Effectiveness versus Joyce Data for Various Pump Sizes.

In order to improve the accuracy of the effectiveness method, crossflow correction factor should be applied and the water loss from the cooling tower should be included. The affect on computer run time, however, will be adverse as several other iteration loops would have to be utilized. Another improvement could be using a more accurate curve fit for the saturation specific heat  $C_s$ . This will also take additional computational time and would result in only a minimal improvement in accuracy.



## TIME SAVINGS AT VARIOUS PUMP SIZES

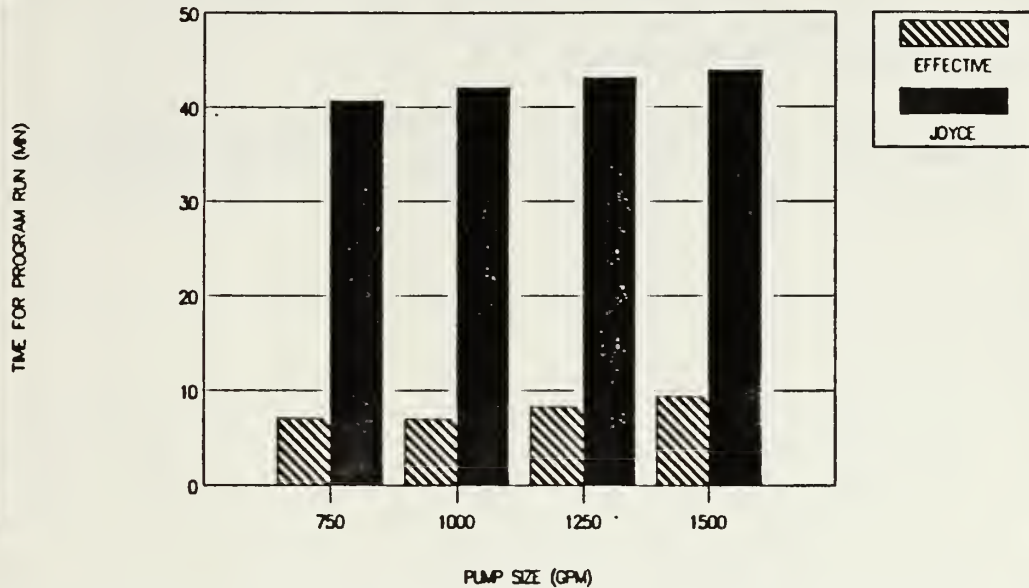


Figure 9. Time Savings at Various Pump Sizes.

The results of this project are very encouraging. For a general trend and a first time run through finding the optimum design this revised effectiveness model fits the bill. The reduction in computational time will allow an engineer flexibility in investigating various systems reaching an optimum design in a shorter time frame.

## BIBLIOGRAPHY

- Braun, J. E. 1988. "Methodologies for the Design and Control of Central Cooling Plants." Ph.D. Thesis. University of Wisconsin-Madison.
- Joyce, C. T. 1990. "Optimized Design of a Commercial Building Chiller/Cooling Tower System." Master's Thesis. Georgia Institute of Technology.
- Weber, E. D. 1988. "Modelling and Generalized Optimization of Commercial Building Chiller/Cooling Tower Systems." Master's Thesis. Georgia Institute of Technology.

**APPENDIX A**  
**EFFECTIVENESS COMPUTER PROGRAM**

# EFFECTIVENESS PROGRAM MODEL

15 OCT 91

THIS PROGRAM CALCULATES THE ANNUAL ENERGY COST, AND THE CAPITAL CONSTRUCTION COST OF THE CONDENSER SIDE OF A CENTRIFUGAL CHILLER PLANT. VARIES THE CONDENSER GPM TO MAINTAIN OPT GPM FOR A PARTICULAR TEMP. BIN ASSUMING 1071 GPM MAX. USED TO COMPARE FIXED SPEED DESIGN WITH VARIABLE SPEED.

## INPUT PARAMETERS:

- 1) THE CITY (ATLANTA=1, L.A.=2, N.Y.=3)
- 2) THE COOLING TOWER NO. CORRESPONDING TO ONE OF THE COOLING TOWERS IN THE DOCUMENTATION.
- 3) THE CONDENSER WATER PIPE SIZE IN INCHES.
- 4) THE COOLING TOWER CFM.
- 5) THE NO. OF CONDENSER PASSES IN THE CHILLER.
- 6) THE MAXIMUM FLOWRATE (GPM) FOR VARIABLE SPEED PUMP.

\*\*\*\* THIS PROGRAM IS A MODIFICATION OF THE PROGRAM ANUALFIX WRITTEN BY ERIC WEBER IN CONJUNCTION WITH HIS MASTERS THESIS ENTITLED "MODELING AND GENERALIZED OPTIMIZATION OF COMMERCIAL BUILDING CHILLER/COOLING TOWER SYSTEMS"

## UPDATES

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LAST UPDATE TO ANUALFIX BY EDW ON 23 OCT 1988  
MOD TO PREVENT RECALC OF PUMP HP BY CTJ ON 3 SEPT 89  
MOD TO PREVENT RECALC OF FAN HP BY CTJ ON 5 SEPT 89  
MOD TO TWR CALC. FOR COOLING WITH FAN OFF BY CTJ ON 15 SEP 89  
MOD1 TO BISECTION USE OLD CW TEMP FOR BRACKETS BY CTJ ON 29 SEP 89  
MOD2 TO BISECTION TO CHECK SIGNS ON BRACKETS BY CTJ ON 30 SEP 89  
MOD3 TO BISECTION WARN IF SIGNS ARE SAME BY CTJ ON 1 OCT 89  
MOD: STD WTHR DATA NOT COMPR. WTHR DATA BY CTJ ON 15 OCT 89  
MOD TO ADD WTHR DATA FOR N.Y. AND L.A. BY CTJ ON 20 OCT 89  
MOD TO ADD ENERGY BILL CALC. FOR 3 CITIES BY CTJ ON 23 OCT 89  
MOD TO ADD CAPITAL COST FOR 3 CITIES BY CTJ ON 25 NOCT 89  
MOD TO USE BRENT METHOD VICE OF BISECTION BY CTJ ON 27 OCT 89  
MOD TO ASSIGN TC1 70 IF PREVIOUS HIGHER TDB ASSIGNED TC1 TO 70, AND CHECK FOR INCREASE IN DELTATCOND BY CTJ ON 29 OCT 89  
MOD TO ADD VARIABLE SPEED PUMP BY CTJ ON 29 OCT 89  
UPDATE TO INCLUDE THE EFFECTIVENESS MODEL TO CALCULATE THE OUTPUT TEMP OF THE COOLING TOWER ON 15 OCT 91 BY JDR

DECLARE SUB EFFECTIVE (NTU!, TWIN!, MDOTW!, MDOTA!, TWB!, TDB!, EXPTWO!, TWOUT!)

```

DECLARE SUB BRENT (TWIN1!, TWIN2!, DIFF1!, DIFF2!, TWOUT1!,
TWOUT2!, NTU!, fda!, MDOTW!, MDOTA!, TDB!, TWB!, DELTATCOND1!,
CTR2%, TC1!, TC2!, CITY!)
DECLARE SUB SYSCOST (PMPHP!, FANHP!, TWRCOST!, diameter!, CITY!,
CAPCST!)
DECLARE SUB ENRGYCST (KWPK!(), KWHTOT!(), BILLDEM!(), BILL!(),
YRBILL!, PMPKWH!(), FANKWH!(), CMPKWH!(), CITY!)
DECLARE SUB Hairm (T2!, T1!, W2!, OMEGMIXTURE!, HAIRMIX!)
DECLARE SUB Hairs (TF!, WS!, HSAT!)
DECLARE SUB FLOW (GPM!, CFM!, TDB!, MDOTW!, MDOTA!)
DIM HRSDAT(20), KWPK(20), KWHTOT(20), BILLDEM(20), BILL(20),
TWBR(20), TDBR(20), PMPKWH(20), FANKWH(20), CMPKWH(20)

```

```

'*****

```

```

' USER INPUT

```

```

'*****

```

```

INPUT "INPUT CITY NUMBER (1-3) ", CITY
INPUT "INPUT TOWER NUMBER (1-19) ", i
INPUT "INPUT DESIRED CONDENSER WATER PIPE SIZE IN INCHES ",
diameter
INPUT "INPUT DESIRED TOWER CFM ", CFM
INPUT "INPUT NUMBER OF CONDENSER PASSES ", PASSES
INPUT "INPUT THE MAXIMUM GPM FOR A VARIABLE SPEED PUMP ", MAXGPM

```

```

'*****

```

```

' STORE THE START TIME FOR THE ITERATIONS

```

```

'*****

```

```

STARTIME$ = TIME$

```

```

'*****

```

```

' GET THE TOWER CONSTANT AND THE EXPONENT FROM DATA FILE

```

```

'*****

```

```

KWHSUM = 0!

```

```

TWR = i

```

```

OPEN "b:tower.dat" FOR INPUT AS #1

```

```

DO WHILE i > 0

```

```

    INPUT #1, TNUM, EXPONENT, CONSTANT, GPML, GPMH, XXX, FHPCA,
    FHPCB, TWRCST

```

```

    i = i - 1!

```

```

LOOP

```

```

CLOSE #1

```

```

'*****

```

```

' THIS SECTION SETS UP THE DRY BULB TEMPERATURE BINS

```

```

'*****

```

```

FOR k = 1 TO 10
  TDBR(k) = 102 - ((k - 1) * 5)
NEXT k
/
/*****
/ THIS SECTION GETS THE WEATHER DATA FOR THE DRY BULB TEMP. BINS /
/ FOR EACH MONTH -- JAN(i=1) thru Dec(i=12)
/*****
/
FOR i = 1 TO 12
/
/*****
/ INITIALIZE MONTHLY KWH AND PEAKKW
/*****
  KWHTOT(i) = 0!           'MONTHLY KWH
  KWPK(i) = 0!           'MAX MONTHLY KW FOR AT LEAST 15% OF HRS
                          ' IN MONTH

  PMPKWH(i) = 0!
  FANKWH(i) = 0!
  CMPKWH(i) = 0!
  CWSTEMPCHK = 0           'CHECK VALUE TO INSURE CWS TEMP DOESNT
                          ' RISE WITH DECREASING TDB, AND LOAD
  CTR% = 0                 'TRACKS # OF TEMP BINS WITH NON-0 TWB
                          ' PER MONTH

  HRSMNTH = 0!
  SELECT CASE CITY
    CASE 1
      OPEN "b:atlwth.dat" FOR INPUT AS #3
    CASE 2
      OPEN "b:lawth.dat" FOR INPUT AS #3
    CASE 3
      OPEN "b:nywth.dat" FOR INPUT AS #3
  END SELECT
  k = i
  DO WHILE k > 0!
    FOR m = 1 TO 10
      INPUT #3, HRSDAT(m), HOURSSUM, TWBR(m)
    NEXT m
    k = k - 1
  LOOP
  CLOSE #3
/
/*****
/SELECT THE WEATHER DATA BIN
/*****
/
FOR j = 1 TO 10
  TWB = TWBR(j)           'WET BULB TEMP
  EXPTWO = TWB           'EXPECTED TEMP WATER FROM TOWER
                          ' FOR EFF MODEL

```

```

TDB = TDBR(j)                                ' DRY BULB TEMP
HOURS = HRSDAT(j)                            ' MONTHLY HOURS AT TDB & TWB FROM
                                                ' 6AM TO 6PM

IF TWB = 0 THEN GOTO GETNEXTWEATHER
CTR% = CTR% + 1
CTR1% = 0                                     ' TRACKS # OF ITERATIONS THRU
                                                ' RESTARTA
CTR2% = 0                                     ' TRACKS # OF ITERATIONS THRU
                                                ' BRENT MTHD
CTR3% = 0                                     ' TRACKS # OF ITERATIONS THRU
                                                ' TRYAGAIN
CTR4% = 0                                     ' TRACKS # OF ITERATIONS THRU
                                                ' CYCLEFAN
/
/ *****
/ CALCULATION OF THE EVAPORATING TEMP.
/ *****
/
EVAPGPM = 1200                                ' FLOWRATE THRU EVAPORATOR
TE2 = 44                                     ' FIXED CHILLED WATER SUPPLY
                                                ' TEMP.
/
/ *****
/ EVAP LOAD ALGORITHM
/ *****
/
GPM = -1242 + (93.90529 * TDB) - (1.45875 * TDB ^ 2) + (.007462
* TDB ^ 3)
IF GPM <= 775 THEN GPM = 750
tons = -531.578 + 10.526 * TDB
IF tons > 500 THEN
  tons = 500
END IF
IF tons < 100 THEN
  tons = 100
END IF
QDOTEVAP = tons * 12000
DELTATEVAP = QDOTEVAP / (EVAPGPM * 499.27)
UAEVAP = 1000 * (134.11603# + 1284.3418# * (tons / 500) -
640.54974# * ((tons / 500) ^ 2))
LMTDevap = QDOTEVAP / UAEVAP
TE = (-TE2 - DELTATEVAP + TE2 * EXP(DELTATEVAP / LMTDevap)) /
(EXP(DELTATEVAP / LMTDevap) - 1!)
/
/ *****
/ ESTIMATE OF THE KW FOR COMPRESSOR
/ *****
/
KW = 30 + .61 * (tons)

```

```

TWIN1 = 50.5
TWIN2 = 110
/
/*****
' CALCULATE THE HEAT BURDEN FOR THE CHILLER CONDENSER
'*****
/
RESTARTA:
  QDOTCOND = QDOTEVAP + (KW * 3413)
  DELTATCOND1 = QDOTCOND / (GPM * 499.27)
  CALL FLOW(GPM, CFM, TDB, MDOTW, MDOTA)
  fda = MDOTW * CONSTANT * ((MDOTW / MDOTA) ^ EXPONENT)
  NTU = CONSTANT * ((MDOTW / MDOTA) ^ (EXPONENT + 1))
/
/*****
' BRACKETING FOR BRENT METHOD
'*****
/
  CALL EFFECTIVE(NTU, TWIN1, MDOTW, MDOTA, TWB, TDB, EXPTWO,
TWOUT1)
  DELTA1 = TWIN1 - TWOUT1
  DIFF1 = DELTATCOND1 - DELTA1
  CALL EFFECTIVE(NTU, TWIN2, MDOTW, MDOTA, TWB, TDB, EXPTWO,
TWOUT2)
  DELTA2 = TWIN2 - TWOUT2
  DIFF2 = DELTATCOND1 - DELTA2
  IF SGN(DIFF1) = SGN(DIFF2) THEN
    TWIN1 = TWIN1 - 5
    TWIN2 = TWIN2 + 5
    SELECT CASE CITY
      CASE 1
        OPEN "B:ATLEFF.DAT" FOR APPEND AS #4
      CASE 2
        OPEN "B:LAEFF.DAT" FOR APPEND AS #4
      CASE 3
        OPEN "B:NYEFF.DAT" FOR APPEND AS #4
    END SELECT
    PRINT #4, "ROOT NOT BRACKETED FOR BRENT. PROG ASSIGNING NEW
BRACKETS"
    PRINT #4, "MONTH= "; i, "BIN ="; TDB
    CLOSE #4
    PRINT "ROOT NOT BRACKETED FOR BRENT. PROG ASSIGNING NEW
BRACKETS"
    PRINT "MONTH= "; i, "BIN ="; TDB
    GOTO RESTARTA:
  END IF
  CTR1% = CTR1% + 1
  CALL BRENT(TWIN1, TWIN2, DIFF1, DIFF2, TWOUT1, TWOUT2, NTU, fda,
MDOTW, MDOTA, TDB, TWB, DELTATCOND1, CTR2%, TC1, TC2, CITY)
  DELTA3 = TWIN2 - TWOUT2

```



```

/
/ *****
/ DETERMINATION OF CONDENSER PERFORMANCE (UA, Tc)
/ *****
/
GPMCOND = GPM
UAcond = 608.5483400000001# + 130.64856# * (tons / 500) -
192.20566# * ((tons / 500) ^ 2)
UAcond = UAcond + 1203.80505# * (GPM / (PASSES * 1500)) -
557.4549# * ((GPM / (PASSES * 1500)) ^ 2)
UAcond = UAcond * 1000
LMTDCOND = QDOTCOND / UAcond
TC = (TC1 - (TC1 + (TC2 - TC1)) * EXP((TC2 - TC1) / LMTDCOND)) /
(1! - EXP((TC2 - TC1) / LMTDCOND))
/
/ *****
/ DETERMINE MODEL KW USING THE CARNOT KW/TON AND TWO EFFICIENCIES
/ *****
/
KWCARNOT = (((TC + 460) / (TE + 460)) - 1!) * 3.517
NfTON = 4.5869 * (tons / 500) - 8.16536 * ((tons / 500) ^ 2) +
6.65014 * ((tons / 500) ^ 3) - 2.07167 * ((tons / 500) ^ 4)
NfISENT = .516061 + .31889 * ((KWCARNOT - .3) / .2) - .14911# *
(((KWCARNOT - .3) / .2) ^ 2)
KWTONMODEL = KWCARNOT / (NfISENT * NfTON)
KWTONGUESS = KW / tons
/
/ *****
/ COMPARE MODEL KW/TON TO THE GUESSED KW/TON
/ *****
/
IF ABS(KWTONMODEL - KWTONGUESS) > .0001 THEN
    KW = KWTONMODEL * tons
    GOTO RESTARTA
END IF
TC1A = TC1
TC2A = TC2
/
/ *****
/ IF THE ENTERING COND. WATER TEMP. IS BELOW 80 THEN FIX IT AT 80
/ AND CYCLE THE COOLING TOWER FAN.
/ *****
/
IF TC1 < 80 THEN
    GOTO CYCLEFAN
END IF
IF CTR% > 1 THEN
    GOTO CALCTOTALKW
END IF
FANHP = EXP(FHPCA + ((LOG(CFM) - 10.5) / 2!) * FHPCB)
FanKW = ((FANHP * .7457) / .85)
GOTO CALCTOTALKW

```

```

/
/*****
/
/
/ THIS SECTION WILL HOLD CONDENSER WATER INPUT TEMPERATURE TO
/ 80 F AND CYCLE THE TOWER FAN USING THE TOWER TEMPERATURE DROP
/ VERSUS THE CONDENSER TEMPERATURE DROP
/
/*****
/
CYCLEFAN:
TRYAGAIN:
  CTR3% = CTR3% + 1
  QDOTCOND = QDOTEVAP + (KW * 3413)
  DELTATCOND = QDOTCOND / (GPM * 499.27)
  CALL FLOW(GPM, CFM, TDB, MDOTW, MDOTA)
  fda = MDOTW * CONSTANT * ((MDOTW / MDOTA) ^ EXPONENT)
  NTU = CONSTANT * ((MDOTW / MDOTA) ^ (EXPONENT + 1))
  TC1 = 80
  TC2 = TC1 + DELTATCOND
  CALL EFFECTIVE(NTU, TC2, MDOTW, MDOTA, TWB, TDB, EXPTWO, TWOUT1)
  DELTATTOWER = TC2 - TWOUT1
  UAcond = 608.5483400000001# + 130.64856# * (tons / 500) -
192.20566# * ((tons / 500) ^ 2)
  UAcond = UAcond + 1203.80505# * (GPM / (PASSES * 1500)) -
557.4549# * ((GPM / (PASSES * 1500)) ^ 2)
  UAcond = UAcond * 1000
  LMTDCOND = QDOTCOND / UAcond
  TC = (TC1 - (TC1 + (TC2 - TC1)) * EXP((TC2 - TC1) / LMTDCOND)) /
(1! - EXP((TC2 - TC1) / LMTDCOND))
  KWCARNOT = ((TC + 460) / (TE + 460)) - 1! * 3.517
  NfTON = 4.5869 * (tons / 500) - 8.16536 * ((tons / 500) ^ 2) +
6.65014 * ((tons / 500) ^ 3) - 2.07167 * ((tons / 500) ^ 4)
  NfISENT = .516061 + .31889 * ((KWCARNOT - .3) / .2) - .14911# *
((KWCARNOT - .3) / .2) ^ 2)
  KWTONMODEL = KWCARNOT / (NfISENT * NfTON)
  KWTONGUESS = KW / tons
  IF ABS(KWTONMODEL - KWTONGUESS) > .0001 THEN
    KW = KWTONMODEL * tons
    GOTO TRYAGAIN
  END IF
  FANHP = EXP(FHPCA + ((LOG(CFM) - 10.5) / 2!) * FHPCB)
  TOWERDUTY = (DELTATCOND - (.1 * DELTATTOWER)) / (DELTATTOWER *
.9)
  FanKW = ((FANHP * .7457) / .85) * TOWERDUTY
  CTR4% = CTR4% + 1
/
/*****
/ CALCULATION OF THE POWER REQUIRED BY THE CONDENSER WATER PUMP
/*****
/

```

CALCTOTALKW:

PipeD = diameter / 12

Condenservelocity = (GPM \* .002228) \* (PASSES / 1.15241)

Pipevelocity = (GPM \* .002228) / ((3.1416 \* (PipeD ^ 2)) / 4)

REd = (Pipevelocity \* PipeD) / 8.64E-06

IF RED < 2300 THEN

    pipefrict = 64 / RED

ELSE

 / \*\*\*\*\*

 / FROM EQU. 6.64a IN FLUID MECHANICS BY WHITE

 / \*\*\*\*\*

    AA = (6.9 / RED) + ((.00015 / (PipeD \* 3.7)) ^ 1.11)

    BB = LOG(AA) / LOG(10!)

    pipefrict = (1! / (-1.8 \* BB)) ^ 2

END IF

PHTower = 11

SELECT CASE PASSES

  CASE 1

    PHcond = EXP(-13.95945 + 20.21629 \* (LOG(GPM) / 10))

  CASE 2

    PHcond = EXP(-10.96759 + 19.02989 \* (LOG(GPM) / 10))

  CASE 3

    PHcond = EXP(-8.96627 + 17.76877 \* (LOG(GPM) / 10))

  CASE 4

    PHcond = EXP(-8.76329 + 18.62906 \* (LOG(GPM) / 10!))

END SELECT

PipeL = 200

PipefL = 450 \* PipeD

PipestrainL = 250 \* PipeD

Ltotal = PipeL + PipefL + PipestrainL

PHpipe = ((Pipevelocity ^ 2) / 64.4) \* ((pipefrict \* Ltotal) /  
PipeD)

PHTOTAL = PHcond + PHTower + PHpipe

PERGPM = (GPM / MAXGPM) \* 100

PMPEFF = 10.57993 + (2.436639 \* PERGPM) - (.01966 \* (PERGPM ^ 2))

VFDEFF = 4.983855 + (1.846339 \* PERGPM) - (.01029 \* (PERGPM ^ 2))

PMPHP = (GPM \* PHTOTAL) / (3960 \* PMPEFF / 100)

PumpKW = (PMPHP \* .7457) / (VFDEFF / 100)

,

 / \*\*\*\*\*

 / CALCULATION OF THE TOTAL POWER REQUIRED BY THE SYSTEM

 / \*\*\*\*\*

,

TOTALKW = PumpKW + FanKW + KW

 ' TOTAL SYSTEM KW

KWHBIN = TOTALKW \* HOURS

 ' ENERGY CONSUMPTION OF BIN

KWHTOT(i) = KWHTOT(i) + KWHBIN

 ' ENERGY CONSUMPTION OF MONTH

KWHSUM = KWHSUM + KWHBIN

 ' ENERGY CONSUMPTION OVER YEAR

PKHOURS = .15 \* HOURSSUM

IF (HOURS >= PKHOURS) AND (TOTALKW > KWPK(i)) THEN KWPK(i) =  
TOTALKW

```

HRSMNTH = HRSMNTH + HOURS
PMPKWH(i) = PMPKWH(i) + (PumpKW * HOURS)
FANKWH(i) = FANKWH(i) + (FanKW * HOURS)
CMPKWH(i) = CMPKWH(i) + (KW * HOURS)
,
'*****
'STORE THE END TIME FOR ITERATIONS
'*****
,
  ENDTIME$ = TIME$
,
'*****
' PRINTING OF THE RESULTS
'*****
,
SELECT CASE CITY
  CASE 1
    OPEN "B:ATLEFF.DAT" FOR APPEND AS #4
  CASE 2
    OPEN "B:LAEFF.DAT" FOR APPEND AS #4
  CASE 3
    OPEN "B:NYEFF.DAT" FOR APPEND AS #4
END SELECT
PRINT #4, "TIME START = "; STARTIME$; "TIME END = ", ENDTIME$
PRINT #4, "ctr1="; CTR1%, "ctr2 = "; CTR2%, " ctr3 = "; CTR3%; ""
PRINT #4, "I="; i, "J="; j
PRINT #4, "TDB(DEG F)          TWB(DEG F)    HOURS          TOWER "
PRINT #4, ; TDB, TWB, HOURS, TWR
PRINT #4, "GPM                %GPM          CFM              TONS"
PRINT #4, ; GPM, PERGPM, CFM, tons
IF TC1 > 80 THEN
PRINT #4, "CWS(DEG F)          CWR(DEG F)    DELTATCOND    DELTATTOWER"
PRINT #4, ; TC1A, TC2A, DELTATCOND1, DELTA3
ELSE
PRINT #4, "CWS(DEG F)          CWR(DEG F)    DELTATCOND    DELTATTOWER
  TOWERDUTY"
PRINT #4, ; TC1, TC2, DELTATCOND, DELTATTOWER, TOWERDUTY
END IF
PRINT #4, "PIPE D(FT)    Pipevelocity(FT/SEC)  RED              pipe
frict            "
PRINT #4, ; PipeD, Pipevelocity, RED, pipefrict
PRINT #4, "pipeL total    PHpipe          PHcond          Phtower
  PHTotal(FT Water)"
PRINT #4, ; Lttotal, PHpipe, PHcond, Phtower, PHTOTAL
PRINT #4, "PASSES          Condenservelocity"
PRINT #4, ; PASSES, Condenservelocity
,
PRINT #4, "UACOND          LMTDCOND          NfISENT          NFTON
  COND.TEMP"
PRINT #4, ; UAcond, LMTDCOND, NfISENT, NfTON, TC
PRINT #4, "KWTONGUESS    KWTONMODEL          KWHBIN          KWHTOT"

```

```

PRINT #4, ; KWTONGUESS, KWTONMODEL, KWHBIN, KWHTOT(i)
PRINT #4, "HOURS          HOURSSUM"
PRINT #4, ; HOURS, HOURSSUM
PRINT #4, "CHILLERKW          PUMPKW          FANKW          TOTALKW  "
PRINT #4, ; KW, PumpKW, FanKW, TOTALKW
PRINT #4, ""
PRINT #4, ""
PRINT #4, ""
PRINT #4, ""
CLOSE #4
OVER:
GETNEXTWEATHER:
/*****
'GET THE NEXT WEATHER DATA BIN
'*****
NEXT j
/*****
'START CALC FOR THE NEXT MONTH
'*****
NEXT i
,
CALL ENRGYCST(KWPK(), KWHTOT(), BILLDEM(), BILL(), YRBILL,
PMPKWH(), FANKWH(), CMPKWH(), CITY)
CALL SYSCOST(PMPHP, FANHP, TWRCSST, diameter, CITY, CAPCST)
,
END

```

```

SUB BRENT (TWIN1, TWIN2, DIFF1, DIFF2, TWOUT1, TWOUT2, NTU, fda,
MDOTW, MDOTA, TDB, TWB, DELTATCOND1, CTR2%, TC1, TC2, CITY)
ITMAX = 50
TOL = .0001
EPS = 1 * 10 ^ -7
DIFF3 = DIFF2
TWOUT3 = TWOUT2
FOR ITER = 1 TO ITMAX
  CTR2% = CTR2% + 1
  IF (DIFF2 * DIFF3) > 0 THEN
    TWIN3 = TWIN1
    DIFF3 = DIFF1
    TWOUT3 = TWOUT1
    TWIN4 = TWIN2 - TWIN1
    TWIN5 = TWIN4
  END IF
  IF ABS(DIFF3) < ABS(DIFF2) THEN
    TWIN1 = TWIN2
    TWIN2 = TWIN3
    TWIN3 = TWIN1
    DIFF1 = DIFF2

```

```

TWOUT1 = TWOUT2
DIFF2 = DIFF3
TWOUT2 = TWOUT3
DIFF3 = DIFF1
TWOUT3 = TWOUT1
END IF
TOL1 = (2 * EPS * ABS(TWIN2)) + (.5 * TOL)
XM = .5 * (TWIN3 - TWIN2)
IF (ABS(XM) <= TOL1) OR (DIFF2 = 0) THEN
    TC2 = TWIN2
    TC1 = TWOUT2
    EXIT SUB
END IF
IF (ABS(TWIN5) >= TOL1) AND (ABS(DIFF1) > ABS(DIFF2)) THEN
    S = DIFF2 / DIFF1
    IF TWIN1 = TWIN3 THEN
        P = 2 * XM * S
        Q = 1 - S
    ELSE
        Q = DIFF1 / DIFF3
        R = DIFF2 / DIFF3
        P = S * (2 * XM * Q * (Q - R) - (B - A) * (R - 1))
        Q = (Q - 1) * (R - 1) * (S - 1)
    END IF
    IF P > 0 THEN Q = -Q
    P = ABS(P)
    MIN1 = 3 * XM * Q - ABS(TOL1 * Q)
    MIN2 = ABS(TWIN5 * Q)
    IF MIN1 < MIN2 THEN
        MIN = MIN1
    ELSE
        MIN = MIN2
    END IF
    IF (2 * P) < MIN THEN
        TWIN5 = TWIN4
        TWIN4 = P / Q
    ELSE
        TWIN4 = XM
        TWIN5 = TWIN4
    END IF
ELSE
    TWIN4 = XM
    TWIN5 = TWIN4
END IF
TWIN1 = TWIN2
DIFF1 = DIFF2
TWOUT1 = TWOUT2
IF (ABS(TWIN4) > TOL1) THEN
    TWIN2 = TWIN2 + TWIN4
ELSE
    SELECT CASE XM

```

```

CASE IS > 0
  SIGN = 1
CASE 0
  SIGN = 1
CASE IS < 0
  SIGN = -1
END SELECT
TOL2 = TOL1 * SIGN
TWIN2 = TWIN2 + TOL2
END IF
CALL EFFECTIVE(NTU, TWIN2, MDOTW, MDOTA, TWB, TDB, TWB, TWOUT2)
DELTA2 = TWIN2 - TWOUT2
DIFF2 = DELTATCOND1 - DELTA2
NEXT ITER
SELECT CASE CITY
CASE 1
  OPEN "B:ATLEFF.DAT" FOR APPEND AS #1
CASE 2
  OPEN "B:LAEFF.DAT" FOR APPEND AS #1
CASE 3
  OPEN "B:NYEFF.DAT" FOR APPEND AS #1
END SELECT
PRINT #1, "BRENT METHOD EXCEEDED MAX ITERATIONS"
TC2 = TWIN2
TC1 = TWOUT2
CLOSE #1
PRINT "BRENT METHOD EXCEEDED MAX ITERATIONS"
PRINT "MONTH ="; i, "BIN ="; TDB
END SUB

```

```

SUB EFFECTIVE (NTU, TWIN, MDOTW, MDOTA, TWB, TDB, EXPTWO, TW2)
DELTA3 = 10
Ttemp = EXPTWO
DO WHILE ABS(DELTA3) > .0001
,
'Calculate the inlet and outlet saturation enthalpy of the
'saturated air.
,
CALL Hairs(Ttemp, WSAT1, hsw)
CALL Hairs(TWIN, WSAT1, hswi)
,
'Calculate the saturation specific heat and the m* parameter as
'defined by Braun.
,
Cs = (hswi - hsw) / (TWIN - Ttemp)
m = MDOTA / (MDOTW * (1 / Cs))
eff = (1 - EXP(-NTU * (1 - m))) / (1 - m * EXP(-NTU * (1 - m)))
,
'Calculate the humidity ratio of the air-vapor mixture.

```

```

CALL Hairs(TWB, WSAT, H)
CALL Hairm(TWB, TDB, WSAT, OMEG1, hai)
hao = hai + eff * (hswi - hai)
Tref = 32
TW2 = ((MDOTW * (TWIN - Tref) - MDOTA * (hao - hai)) / (MDOTW * 1))
+ Tref
DELTA3 = TW2 - Ttemp
Ttemp = TW2
LOOP
END SUB

```

```

SUB ENRGYCST (KWPK(), KWHTOT(), BILLDEM(), BILL(), YRBILL,
PMPKWH(), FANKWH(), CMPKWH(), CITY)

```

```

    TOTKWH = 0
    FOR l = 1 TO 12
    TOTKWH = TOTKWH + KWHTOT(l)
    KWHTOT(l) = KWHTOT(l) + 360585
    KWPK(l) = KWPK(l) + 946
    NEXT l
    SELECT CASE CITY
    CASE 1
    GOTO ATLANTA
    CASE 2
    GOTO LOSANGELES
    CASE 3
    GOTO NEWYORK
    END SELECT

```

```

ATLANTA:

```

```

'*****
'          CALCULATION OF MONTHLY ENERGY COST IN ATLANTA
'          Georgia Power schedule PL_8_GS
'          General Commercial Service
'          Current as of June 1989
'

```

```

KWDEM = 5
FOR i = 6 TO 9
    KWSMDEM = .95 * KWPK(i)
    IF KWSMDEM > KWDEM THEN KWDEM = KWSMDEM
NEXT i
FOR i = 1 TO 12
    IF (i > 5) AND (i < 10) THEN GOTO ATLNOTWNTR
    KWWNTR = .6 * KWPK(i)
    IF KWWNTR > KWDEM THEN KWDEM = KWWNTR
ATLNOTWNTR:
NEXT i
FOR i = 6 TO 9
    IF KWPK(i) > KWDEM THEN
    BILLDEM(i) = KWPK(i)
    ELSE

```



```

    BILLDEM(i) = KWDEM
    END IF
NEXT i
FOR i = 1 TO 5
    BILLDEM(i) = KWDEM
NEXT i
FOR i = 10 TO 12
    BILLDEM(i) = KWDEM
NEXT i
/*****
/ CALCULATION OF THE MONTHLY ENERGY BILL FOR ATLANTA
/*****
YRBILL = 0
PMPENGY = 0
FANENGY = 0
CMPENGY = 0
FOR i = 1 TO 12
BLOKHRS = KWHTOT(i) / BILLDEM(i)
    IF (BLOKHRS <= 200) THEN
        GOTO BASEI
    ELSEIF (BLOKHRS <= 400) THEN
        GOTO BASEII
    ELSEIF (BLOKHRS <= 600) THEN
        GOTO BASEIII
    ELSE
        GOTO BASEIV
    END IF
/
BASEI:
    IF KWHTOT(i) <= 3000 THEN
        COST1 = (.10185 * KWHTOT(i)) + 13.5
    ELSEIF KWHTOT(i) <= 10000 THEN
        COST1 = (.09282 * KWHTOT(i)) + 40.59
    ELSEIF KWHTOT(i) <= 200000 THEN
        COST1 = (.07918 * KWHTOT(i)) + 176.99
    ELSE
        COST1 = (.05972 * KWHTOT(i)) + 4068.99
    END IF
    GOTO ATLSUMBILL
/
BASEII:
    IF (BILLDEM(i) >= 5) AND (BILLDEM(i) <= 15) THEN
        COST1 = (18.314 * BILLDEM(i)) + (.01028 * KWHTOT(i)) + 13.5
    ELSEIF (BILLDEM(i) <= 50) THEN
        COST1 = (16.508 * BILLDEM(i)) + (.01028 * KWHTOT(i)) + 40.59
    ELSEIF (BILLDEM(i) <= 1000) THEN
        COST1 = (13.78 * BILLDEM(i)) + (.01028 * KWHTOT(i)) + 176.99
    ELSE
        COST1 = (9.888 * BILLDEM(i)) + (.01028 * KWHTOT(i)) + 4068.99
    END IF
    GOTO ATLSUMBILL

```

```

BASEIII:
  IF (BILLDEM(i) >= 5) AND (BILLDEM(i) <= 15) THEN
    COST1 = (19.938 * BILLDEM(i)) + (.00622 * KWHTOT(i)) + 13.5
  ELSEIF BILLDEM(i) <= 50 THEN
    COST1 = (18.132 * BILLDEM(i)) + (.00622 * KWHTOT(i)) + 40.59
  ELSEIF BILLDEM(i) <= 1000 THEN
    COST1 = (15.404 * BILLDEM(i)) + (.00622 * KWHTOT(i)) + 176.99
  ELSE
    COST1 = (11.512 * BILLDEM(i)) + (.00622 * KWHTOT(i)) + 4068.99
  END IF
  GOTO ATLSUMBILL

```

```

BASEIV:
  IF (BILLDEM(i) >= 5) AND (BILLDEM(i) <= 15) THEN
    COST1 = (20.46 * BILLDEM(i)) + (.00535 * KWHTOT(i)) + 13.5
  ELSEIF BILLDEM(i) <= 50 THEN
    COST1 = (18.654 * BILLDEM(i)) + (.00535 * KWHTOT(i)) + 40.59
  ELSEIF BILLDEM(i) <= 1000 THEN
    COST1 = (15.926 * BILLDEM(i)) + (.00535 * KWHTOT(i)) + 176.99
  ELSE
    COST1 = (12.034 * BILLDEM(i)) + (.00535 * KWHTOT(i)) + 4068.99
  END IF

```

```

'***** CALC. OF THE TOTAL BILL *****

```

```

ATLSUMBILL:

```

```

  FCADJ = .016896 * KWHTOT(i)
  TAX = .05 * (COST1 + FCADJ)
  BILL(i) = COST1 + FCADJ + TAX
'*****CHECK FOR MIN. BILL*****
  CHKKW = BILLDEM(i) - 30
  IF CHKKW > 0 THEN
    MINBILL = (13.5 + (7.5 * CHKKW) + FCADJ) * 1.05
  ELSE
    MINBILL = (13.5 + FCADJ) * 1.05
  END IF
  IF MINBILL >= BILL(i) THEN BILL(i) = MINBILL
  YRBILL = YRBILL + BILL(i)
  PMPENGY = PMPENGY + PMPKWH(i)
  FANENGY = FANENGY + FANKWH(i)
  CMPENGY = CMPENGY + CMPKWH(i)

```

```

NEXT i

```

```

FOR j = 1 TO 12
  OPEN "B:ATLEFF.DAT" FOR APPEND AS #4
  PRINT #4, "THE MAX MONTHLY KW =", KWPK(j)
  PRINT #4, "THE BILLING DEMAND =", BILLDEM(j)
  PRINT #4, "THE MONTHLY KWH      =", KWHTOT(j)
  PRINT #4, "THE MONTHLY BILL      = ", BILL(j)
  PRINT #4, ""
  PRINT #4, ""
  IF j = 12 THEN

```

```

PRINT #4, "THE YEARLY TOTAL ($) =", YRBILL
PRINT #4, "THE PUMP ENERGY (KWH) =", PMPENGY
PRINT #4, "THE FAN ENERGY (KWH) =", FANENGY
PRINT #4, "THE CHILLER ENERGY (KWH) =", CMPENGY
PRINT #4, "THE TOTALSYSTEM ENERGY (KWH) =", TOTKWH
PRINT #4, ""
PRINT #4, ""
END IF
CLOSE #4
NEXT j
EXIT SUB
/
LOSANGELES:
/*****
/*****
/      CALCULATION OF MONTHLY ENERGY COSTS IN LOS ANGELES
/      Souther California Edison Schedule GS-2
/      General Commercial - Large
/      Eff. Date 1 June 1988
/      Current as of June 1989
/
/  ** IN LA THE MONTHLY DEMAND IS STRICTLY DET. BY THE CURRENT
/  MONTH'S PERFORMANCE. THEREFORE THE DEMAND COST IS AS FOLLOWS:
/*****
/*****
YRBILL = 0
PMPENGY = 0
FANENGY = 0
CMPENGY = 0
FOR i = 1 TO 12
  BILLDEM(i) = KWPK(i)
  DEMCOST = 0
  IF (i > 5) AND (i < 10) GOTO LASUMMER
  MIN = 31.1
  DEMCOST = 2.7 * BILLDEM(i)
  IF KWHTOT(i) <= 180000 THEN
    ENGCOST = .07197 * KWHTOT(i)
  ELSEIF KWHTOT(i) > 180000 THEN
    ENGCOST = 12954.6 + ((KWHTOT(i) - 180000) * .04973)
  ELSE
  END IF
  GOTO LASUMBILL
LASUMMER:
  MIN = 31.1
  DEMCOST = 8.6 * BILLDEM(i)
  IF KWHTOT(i) <= 180000 THEN
    ENGCOST = .07833 * KWHTOT(i)
  ELSEIF KWHTOT(i) > 180000 THEN
    ENGCOST = 14099.4 + ((KWHTOT(i) - 180000) * .05247)
  ELSE
  END IF
/

```

LASUMBILL:

```
COST1 = MIN + DEMCOST + ENGCOST
SURCOST = .05 * COST1
BILL(i) = COST1 + SURCOST
YRBILL = YRBILL + BILL(i)
PMPENGY = PMPENGY + PMPKWH(i)
FANENGY = FANENGY + FANKWH(i)
CMPENGY = CMPENGY + CMPKWH(i)
NEXT i
```

```
FOR j = 1 TO 12
OPEN "B:LAEFF.DAT" FOR APPEND AS #4
PRINT #4, "THE MAX MONTHLY KW IS =", KWPK(j)
PRINT #4, "THE BILLING DEMAND      =", BILLDEM(j)
PRINT #4, "THE MONTHLY KWH              =", KWHTOT(j)
PRINT #4, "THE MONTHLY BILL              =", BILL(j)
PRINT #4, ""
PRINT #4, ""
IF j = 12 THEN
PRINT #4, "THE YEARLY TOTAL ($) =", YRBILL
PRINT #4, "THE PUMP ENERGY (KWH) =", PMPENGY
PRINT #4, "THE FAN ENERGY (KWH) =", FANENGY
PRINT #4, "THE CHILLER ENERGY (KWH) =", CMPENGY
PRINT #4, "THE TOTAL SYSTEM ENERGY (KWH) =", TOTKWH
PRINT #4, ""
PRINT #4, ""
END IF
CLOSE #4
NEXT j
EXIT SUB
```

NEWYORK:

```
*****
*****
/      CALCULATION OF MONTHLY ENERGY COSTS IN NEW YORK (CON. ED.)
/      Con Edison Rate Schedule No.9
/      General Commercial - Large
/      Eff. Date 1 Apr. 1987
/      Current as of July 1989
/      ** IN NY THE MONTHLY DEMAND IS STRICTLY DET. BY THE CURRENT
/      MONTHS PERFORMANCE. THEREFORE THE DEMAND COST IS AS FOLLOWS:
*****
YRBILL = 0
PMPENGY = 0
FANENGY = 0
CMPENGY = 0
FOR i = 1 TO 12
BILLDEM(i) = KWPK(i)
DEMCOST = 0
IF (i > 5) AND (i < 10) GOTO NYSUMMER
MIN = 74.18
```

```

IF (BILLDEM(i) > 5) AND (BILLDEM(i) <= 900) THEN
  DEMCOST = 15.86 * BILLDEM(i)
ELSEIF BILLDEM(i) > 900 THEN
  DEMCOST = 14274 + ((BILLDEM(i) - 900) * 13.68)
ELSE
  END IF
GOTO NYENGYCOST
NYSUMMER:
  MIN = 96.98
  IF (BILLDEM(i) > 5) AND (BILLDEM(i) <= 900) THEN
    DEMCOST = 20.36 * BILLDEM(i)
  ELSEIF BILLDEM(i) > 900 THEN
    DEMCOST = 18324 + ((BILLDEM(i) - 900) * 18.18)
  ELSE
    END IF
  /*****
  /  CALCULATION OF THE ENERGY CHARGES
  /*****
NYENGYCOST:
  IF KWHTOT(i) <= 15000 THEN
    ENGCOST = .0562 * KWHTOT(i)
  ELSEIF KWHTOT(i) > 15000 THEN
    ENGCOST = 843! + ((KWHTOT(i) - 15000) * .0523)
  ELSE
    END IF
  ,
  COST1 = MIN + DEMCOST + ENGCOST
  MAXBILL = .3207 * KWHTOT(i)
  IF COST1 > MAXBILL THEN COST1 = MAXBILL
  MINBILL = MIN
  IF COST1 < MINBILL THEN COST1 = MINBILL
  ,
  FCADJ = .004414 * KWHTOT(i)
  TAX = .0825 * COST1
  BILL(i) = COST1 + FCADJ + TAX
  YRBILL = YRBILL + BILL(i)
  PMPENGY = PMPENGY + PMPKWH(i)
  FANENGY = FANENGY + FANKWH(i)
  CMPENGY = CMPENGY + CMPKWH(i)
NEXT i
,
FOR j = 1 TO 12
  OPEN "B:NYEFF.DAT" FOR APPEND AS #4
  PRINT #4, "THE MAX MONTHLY KW IS =", KWPK(j)
  PRINT #4, "THE BILLING DEMAND      =", BILLDEM(j)
  PRINT #4, "THE MONTHLY KWH                 =", KWHTOT(j)
  PRINT #4, "THE MONTHLY BILL                 =", BILL(j)
  PRINT #4, ""
  PRINT #4, ""
  IF j = 12 THEN
    PRINT #4, "THE YEARLY TOTAL ($)           =", YRBILL

```

```

PRINT #4, "THE PUMP ENERGY (KWH) =", PMPENGY
PRINT #4, "THE FAN ENERGY (KWH) =", FANENGY
PRINT #4, "THE CHILLER ENERGY (KWH) =", CMPENGY
PRINT #4, "THE TOTALSYSTEM ENERGY (KWH) =", TOTKWH
PRINT #4, ""
PRINT #4, ""
END IF
CLOSE #4
NEXT j
,
END SUB

```

```

SUB FLOW (GPM, CFM, TDB, MDOTW, MDOTA)
MDOTW = GPM * 8.32124 * 60!
MDOTA = CFM * (28.97 / (.73 * (TDB + 459.67))) * 60!
END SUB

```

```

SUB Hairm (T2, T1, W2, OMEGMIXTURE, HAIRMIX)
HWB = 1061 + .444 * T2
HDB = 1061 + .444 * T1
HFLUID = T2 - 32
OMEGMIXTURE = ((.24 * (T2 - T1)) + (W2 * (HWB - HFLUID))) / (HDB - HFLUID)
HAIRMIX = (.24 * T1) + OMEGMIXTURE * (1061 + .444 * T1)
END SUB

```

```

SUB Hairs (TF, WS, HSAT)
TK = (TF - 32) * (5 / 9) + 273.15
LNPWS = -5800.2206# / TK + 1.3914993# - .04860239# * TK
LNPWS = LNPWS + .000041764768# * (TK ^ 2) - .000000014452093# * (TK ^ 3) + 6.5459673# * LOG(TK)
PWS = EXP(LNPWS)
WS = .62198 * (PWS / (101325 - PWS))
HSAT = .24 * TF + WS * (1061 + .444 * TF)
END SUB

```

```

SUB SYSCOST (PMPHP, FANHP, TWRCS, diameter, CITY, CAPCST)
'*****
' THIS SUB IS USED TO CALCULATE THE CAPITAL COST INVOLVED
' IN THE CONDENSER SIDE EQUIPMENT INSTALLATION FOR THOSE
' ITEMS WHICH HAVE A DIFFERENTIAL COST FOR THE SYSTEM MODS
' DETERMINE THE COST OF THE PUMP INCLUDING ELECT INSTALLATION
'*****

```

```
SELECT CASE PMPHP
  CASE 0 TO 5
    PMPCST = 2690
    VFDCST = 5183
  CASE IS <= 7.5
    PMPCST = 2740
    VFDCST = 5183
  CASE IS <= 10
    PMPCST = 3275
    VFDCST = 5183
  CASE IS <= 15
    PMPCST = 3765
    VFDCST = 6933
  CASE IS <= 20
    PMPCST = 4365
    VFDCST = 8618
  CASE IS <= 25
    PMPCST = 4440
    VFDCST = 10738
  CASE IS <= 30
    PMPCST = 5365
    VFDCST = 11938
  CASE IS <= 50
    PMPCST = 6795
    VFDCST = 13948
  CASE IS > 50
    PMPCST = 8720
    VFDCST = 18050
```

```
END SELECT
```

```
*****
' DETERMINE THE COST OF THE ELECT INSTALLATION FOR THE TOWER FAN
*****
```

```
SELECT CASE FANHP
  CASE 0 TO 5
    FANCST = 1315
  CASE IS <= 7.5
    FANCST = 1315
  CASE IS <= 10
    FANCST = 1450
  CASE IS <= 15
    FANCST = 1815
  CASE IS <= 20
    FANCST = 1965
  CASE IS <= 25
    FANCST = 1965
  CASE IS <= 30
    FANCST = 2500
  CASE IS <= 50
    FANCST = 2750
  CASE IS > 50
    FANCST = 4085
```

```
END SELECT
```

```

/ *****
/   DETERMINE THE CAPITAL COST OF THE PIPING, VALVING, FITTINGS
/ *****
SELECT CASE diameter
    CASE 5.05
        PIPECST = 19850
    CASE 6.07
        PIPECST = 23495
    CASE 8.07
        PIPECST = 33548
    CASE 10.02
        PIPECST = 52217
END SELECT
/ *****
/   DETERMINE THE TOTAL CAPITAL COST
/ *****
TOTCST = TWRCST + PMPCST + FANCST + PIPECST + VFDCST
OVRHD = .15 * TOTCST
SUB1 = TOTCST + OVRHD
PROF = .1 * SUB1
CAPCST = SUB1 + PROF
/ *****
/   INCLUDE THE 1989 MEANS CITY COST INDEXES
/ *****
SELECT CASE CITY
    CASE 1
        CTYINDX = .917
    CASE 2
        CTYINDX = 1.117
    CASE 3
        CTYINDX = 1.235
END SELECT
CAPCST = CAPCST * CTYINDX
SELECT CASE CITY
    CASE 1
        OPEN "B:ATLEFF.DAT" FOR APPEND AS #4
    CASE 2
        OPEN "B:LAEFF.DAT" FOR APPEND AS #4
    CASE 3
        OPEN "B:NYEFF.DAT" FOR APPEND AS #4
END SELECT
PRINT #4, "THE TOWER COST IS ", TWRCST
PRINT #4, "THE PUMP COST IS ", PMPCST
PRINT #4, "THE FAN ELECT COST", FANCST
PRINT #4, "THE PIPE SYS COST ", PIPECST
PRINT #4, "THE SUBTOTAL IS   ", TOTCST
PRINT #4, "THE OVERHEAD          ", OVRHD
PRINT #4, "THE PROFIT IS        ", PROF
PRINT #4, "THE CITY INDEX IS    ", CTYINDX
PRINT #4, "THE TOTAL COST IS   ", CAPCST
CLOSE #4
END SUB

```



## **APPENDIX B**

### **DATA GENERATED FROM WEBER MODEL COMPARISON**

OUTPUT OF DELTA TEMPERATURE FOR EFFECTIVENESS AND JOYCE METHOD

DELTA EFFECTIVENESS (DEG F)	DELTA WEBER (DEG F)	DELTA WEBER PLUS 15%	DELTA WEBER MINUS 15%
1.6	1.4	1.61	1.19
6.4	5.9	6.79	5.02
6.5	5.9	6.79	5.02
6.5	5.9	6.79	5.02
7.8	7.3	8.39	6.2
9.8	8.9	10.235	7.57
11	10	11.5	8.5
11	10	11.5	8.5
11.1	10.4	11.96	8.84
12.2	11.2	12.88	9.52
14.5	13	14.95	11.05
14.6	13	14.95	11.05
14.6	13	14.95	11.05
19.9	17.8	20.47	15.13
20	18.1	20.82	15.39
20.1	17.8	20.47	15.13
20.2	17.8	20.47	15.13
26.9	23.4	26.91	19.89
26.9	23.4	26.91	19.89
26.9	23.4	26.91	19.89
27	23.6	27.14	20.06
28.6	25	28.75	21.25
28.8	25	28.75	21.25
29	25	28.75	21.25

**APPENDIX C**

**DATA GENERATED FROM JOYCE MODEL COMPARISON**

AT750.DAT PUMP SIZE 750 GPM JOYCE METHOD

MONTH= 12	BIN = 57			
START TIME = 11:12:25	END TIME = 11:53:09	RUNTIME = 40:44		
ctrl= 7	ctr2 = 92	ctr3 = 3		
I= 12	J= 10			
TDB(DEG F)	TWB(DEG F)	HOURS	TOWER	
57	52	24.82143	3	
GPM	%GPM	CFM	TONS	
750	100	120000	100	
CWS(DEG F)	CWR(DEG F)	DELTATCOND	DELTATTOWER	TOWERDUTY
80	84.03179	4.031794	19.60413	.1174005
PIPE D(FT)	Pipevelocity(FT/SEC)	RED	pipe frict	
.6666667	4.787051	369371.3	1.592428E-02	
pipeL total	PHpipe	PHcond	PHTower	
PHTotal(FT Water)				
666.6667	5.666439	5.105591	11	21.77203
PASSES	Condenservelocity			
2	2.900009			
UACOND	LMTDCOND	NfISENT	NFTON	COND.TEMP
893100.2	1.690421	.5164742	.6406521	84.4407
KWTONGUESS	KWTONMODEL	KWHBIN	KWHTOT	
.9074575	.9074562	2526.094	6573.959	
HOURS	HOURSSUM			
24.82143	57.5			
CHILLERKW	PUMPKW	FANKW	TOTALKW	
90.74575	6.151319	4.87361	101.7707	

THE YEARLY TOTAL (\$)	=	334021.2	
THE PUMP ENERGY (KWH)	=	17345.86	
THE FAN ENERGY (KWH)	=	46195.46	
THE CHILLER ENERGY (KWH)	=	337459.7	
THE TOTALSYSTEM ENERGY (KWH)	=		401001

AT100.DAT PUMP SIZE 1000 GPM JOYCE METHOD

MONTH= 12 BIN = 57  
 START TIME = 11:55:00 END TIME = 12:37:03 RUNTIME = 42:03  
 ctrl= 7 ctr2 = 92 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 3  
 GPM %GPM CFM TONS  
 750 75 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 19.60413 .1174005  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond PHTower  
 PHtotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074575 .9074562 2481.199 6469.957  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74575 4.342596 4.87361 99.96196

THE YEARLY TOTAL (\$) = 333374  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 46195.46  
 THE CHILLER ENERGY (KWH) = 337459.7  
 THE TOTALSYSTEM ENERGY (KWH) = 393479.1

AT125.DAT PUMP SIZE 1250 GPM JOYCE METHOD

MONTH=	12	BIN =	57			
START TIME =	11:36:25	END TIME =	12:19:33	RUNTIME =	43:08	
ctrl=	7	ctr2 =	92	ctr3 =	3	
I=	12	J=	10			
TDB( DEG F)		TWB( DEG F)		HOURS	TOWER	
57		52		24.82143	3	
GPM		%GPM		CFM	TONS	
750		60		120000	100	
CWS( DEG F)		CWR( DEG F)		DELTATCOND	DELTATTOWER	TOWERDUTY
80		84.03179		4.031794	19.60413	.1174005
PIPE D( FT)		Pipevelocity( FT/SEC)		RED	pipe frict	
.6666667		4.787051		369371.3	1.592428E-02	
pipeL total		PHpipe		PHcond	PHTower	
PHTotal( FT Water)						
666.6667		5.666439		5.105591	11	21.77203
PASSES		Condenservelocity				
2		2.900009				
UA COND		LMTDCOND		NfISENT	NFTON	COND. TEMP
893100.2		1.690421		.5164742	.6406521	84.4407
KWTONGUESS		KWTONMODEL		KWHBIN	KWHTOT	
.9074575		.9074562		2486.145	6481.415	
HOURS		HOURSSUM				
24.82143		57.5				
CHILLERKW		PUMPKW		FANKW	TOTALKW	
90.74575		4.541853		4.87361	100.1612	

THE YEARLY TOTAL (\$)	=	333380.8
THE PUMP ENERGY (KWH)	=	10126.37
THE FAN ENERGY (KWH)	=	46195.46
THE CHILLER ENERGY (KWH)	=	337459.7
THE TOTALSYSTEM ENERGY (KWH)	=	393781.5

AT150.DAT PUMP SIZE 1500 GPM JOYCE METHOD

MONTH= 12 BIN = 57  
 START TIME = 12:25:32 END TIME = 13:09:23 RUNTIME = 43:51  
 ctr1= 7 ctr2 = 92 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 3  
 GPM %GPM CFM TONS  
 750 50 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 19.60413 .1174005  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond Phtower  
 PHtotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074575 .9074562 2501.478 6516.936  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74575 5.159607 4.87361 100.779

THE YEARLY TOTAL (\$) = 333485.1  
 THE PUMP ENERGY (KWH) = 11436.89  
 THE FAN ENERGY (KWH) = 46195.46  
 THE CHILLER ENERGY (KWH) = 337459.7  
 THE TOTALSYSTEM ENERGY (KWH) = 395092

ATEF750.DAT PUMP SIZE 750 GPM EFFECTIVENESS METHOD

```

MONTH= 12      BIN = 57
TIME START = 16:44:50  TIME END = 16:51:52  RUNTIME = 7:02
ctrl1= 7      ctr2 = 92      ctr3 = 3
I= 12        J= 10
TDB(DEG F)   TWB(DEG F)   HOURS           TOWER
 57          52          24.82143        3
GPM          %GPM        CFM             TONS
 750        100        120000         100
CWS(DEG F)   CWR(DEG F)   DELTATCOND     DELTATTOWER    TOWERDUTY
 80          84.03179    4.031794      21.74524
9.490044E-02
PIPE D(FT)   Pipevelocity(FT/SEC)  RED           pipe frict
.6666667    4.787051      369371.3     1.592428E-02
pipeL total  PHpipe        PHcond       PHTower
PHTotal(FT Water)
 666.6667   5.666439     5.105591    11          21.77203
PASSES      Condenservelocity
 2          2.900009
UACOND      LMTDCOND      NfISENT      NFTON        COND.TEMP
 893100.2   1.690421     .5164742    .6406521    84.4407
KWTONGUESS  KWTONMODEL    KWHBIN      KWHTOT
.9074576   .9074562     2502.91     6502.745
HOURS       HOURSSUM
 24.82143   57.5
CHILLERKW   PUMPKW        FANKW        TOTALKW
 90.74576   6.151319     3.939574    100.8366
    
```

```

THE YEARLY TOTAL ($) = 333296
THE PUMP ENERGY (KWH) = 17345.86
THE FAN ENERGY (KWH) = 40526.96
THE CHILLER ENERGY (KWH) = 337296.7
THE TOTALSYSTEM ENERGY (KWH) = 395169.5
    
```



ATEF100.DAT PUMP SIZE 1000 GPM EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 17:22:58 TIME END = 17:29:55 RUNTIME = 6:57  
 ctr1= 7 ctr2 = 92 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 3  
 GPM %GPM CFM TONS  
 750 75 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 21.74524  
 9.490044E-02  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond Phtower  
 Phtotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074576 .9074562 2458.015 6398.744  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74576 4.342596 3.939574 99.02793

THE YEARLY TOTAL (\$) = 332648.8  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 40526.96  
 THE CHILLER ENERGY (KWH) = 337296.7  
 THE TOTALSYSTEM ENERGY (KWH) = 387647.6

ATEF125.DAT PUMP SIZE 1250 GPM EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 17:32:44 TIME END = 17:40:57 RUNTIME = 8:13  
 ctr1= 7 ctr2 = 92 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 3  
 GPM %GPM CFM TONS  
 750 60 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 21.74524  
 9.490044E-02  
 PIPE D(FT) Pipevelocity(FT/SEC) REd pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond PHTower  
 PHTotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074576 .9074562 2462.961 6410.201  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74576 4.541853 3.939574 99.22719

THE YEARLY TOTAL (\$) = 332655.6  
 THE PUMP ENERGY (KWH) = 10126.37  
 THE FAN ENERGY (KWH) = 40526.96  
 THE CHILLER ENERGY (KWH) = 337296.7  
 THE TOTALSYSTEM ENERGY (KWH) = 387950

ATEF150.DAT PUMP SIZE 1500 GPM EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 17:42:20 TIME END = 17:51:43 RUNTIME = 9:23  
 ctr1= 7 ctr2 = 92 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 3  
 GPM %GPM CFM TONS  
 750 50 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 21.74524  
 9.490044E-02  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond Phtower  
 Phtotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074576 .9074562 2478.294 6445.722  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74576 5.159607 3.939574 99.84494

THE YEARLY TOTAL (\$) = 332759.9  
 THE PUMP ENERGY (KWH) = 11436.89  
 THE FAN ENERGY (KWH) = 40526.96  
 THE CHILLER ENERGY (KWH) = 337296.7  
 THE TOTALSYSTEM ENERGY (KWH) = 389260.5

ATTOW2.DAT TOWER # 2 JOYCE METHOD

MONTH= 12	BIN = 57			
START TIME = 10:02:55		END TIME = 10:43:28		RUNTIME = 40:33
ctrl= 7	ctr2 = 90	ctr3 = 3		
I= 12	J= 10			
TDB(DEG F)	TWB(DEG F)	HOURS	TOWER	
57	52	24.82143	2	
GPM	%GPM	CFM	TONS	
750	75	120000	100	
CWS(DEG F)	CWR(DEG F)	DELTATCOND	DELTATTOWER	TOWERDUTY
80	84.03179	4.031794	19.00449	.1246106
PIPE D(FT)	Pipevelocity(FT/SEC)	Red	pipe frict	
.6666667	4.787051	369371.3	1.592428E-02	
pipeL total	PHpipe	PHcond	PHTower	
PHTotal(FT Water)				
666.6667	5.666439	5.105591	11	21.77203
PASSES	Condenservelocity			
2	2.900009			
UACOND	LMTDCOND	NfISENT	NFTON	COND.TEMP
893100.2	1.690421	.5164742	.6406521	84.4407
KWTONGUESS	KWTONMODEL	KWHBIN	KWHTOT	
.9074574	.9074562	2541.575	6686.729	
HOURS	HOURSSUM			
24.82143	57.5			
CHILLERKW	PUMPKW	FANKW	TOTALKW	
90.74574	4.342596	7.306037	102.3944	

THE YEARLY TOTAL (\$)	=	336101.8	
THE PUMP ENERGY (KWH)	=	9823.913	
THE FAN ENERGY (KWH)	=	67227.36	
THE CHILLER ENERGY (KWH)	=	337547.8	
THE TOTALSYSTEM ENERGY (KWH)	=		414599.1

ATTOW5.DAT TOWER # 5 JOYCE METHOD

MONTH= 12	BIN = 57			
START TIME = 10:44:54		END TIME = 11:26:56		RUNTIME = 42:02
ctr1= 7	ctr2 = 92	ctr3 = 3		
I= 12	J= 10			
TDB(DEG F)	TWB(DEG F)	HOURS	TOWER	
57	52	24.82143	5	
GPM	%GPM	CFM	TONS	
750	75	120000	100	
CWS(DEG F)	CWR(DEG F)	DELTATCOND	DELTATTOWER	TOWERDUTY
80	84.03179	4.031794	19.60413	.1174005
PIPE D(FT)	Pipevelocity(FT/SEC)	RED	pipe frict	
.6666667	4.787051	369371.3	1.592428E-02	
pipeL total	PHpipe	PHcond	PHTower	
PHTotal(FT Water)				
666.6667	5.666439	5.105591	11	21.77203
PASSES	Condenservelocity			
2	2.900009			
UACOND	LMTDCOND	NfISENT	NFTON	COND.TEMP
893100.2	1.690421	.5164742	.6406521	84.4407
KWTONGUESS	KWTONMODEL	KWHBIN	KWHTOT	
.9074575	.9074562	2481.199	6469.957	
HOURS	HOURSSUM			
24.82143	57.5			
CHILLERKW	PUMPKW	FANKW	TOTALKW	
90.74575	4.342596	4.87361	99.96196	

THE YEARLY TOTAL (\$)	=	333374	
THE PUMP ENERGY (KWH)	=	9823.913	
THE FAN ENERGY (KWH)	=	46195.46	
THE CHILLER ENERGY (KWH)	=	337459.7	
THE TOTALSYSTEM ENERGY (KWH)	=		393479.1

ATTOW9.DAT      TOWER # 9      JOYCE METHOD

MONTH= 12	BIN = 57			
START TIME =	11:29:52	END TIME =	12:13:13	RUNTIME = 43:21
ctrl= 7	ctr2 = 91	ctr3 = 3		
I= 12	J= 10			
TDB(DEG F)	TWB(DEG F)	HOURS	TOWER	
57	52	24.82143	9	
GPM	%GPM	CFM	TONS	
750	75	120000	100	
CWS(DEG F)	CWR(DEG F)	DELTATCOND	DELTATTOWER	TOWERDUTY
80	84.03179	4.031794	19.93193	.1136424
PIPE D(FT)	Pipevelocity(FT/SEC)	Red	pipe frict	
.6666667	4.787051	369371.3	1.592428E-02	
pipeL total	PHpipe	PHcond	PHTower	
PHtotal(FT Water)				
666.6667	5.666439	5.105591	11	21.77203
PASSES	Condenservelocity			
2	2.900009			
UACOND	LMTDCOND	NfISENT	NFTON	COND.TEMP
893100.2	1.690421	.5164742	.6406521	84.4407
KWTONGUESS	KWTONMODEL	KWHBIN	KWHTOT	
.9074575	.9074562	2405.123	6187.521	
HOURS	HOURSSUM			
24.82143	57.5			
CHILLERKW	PUMPKW	FANKW	TOTALKW	
90.74575	4.342596	1.808699	96.89704	

THE YEARLY TOTAL (\$)	=	329604.7	
THE PUMP ENERGY (KWH)	=	9823.913	
THE FAN ENERGY (KWH)	=	17438.78	
THE CHILLER ENERGY (KWH)	=	337425.3	
THE TOTALSYSTEM ENERGY (KWH)	=		364687.9

ATTOW12.DAT      TOWER # 12      JOYCE METHOD

MONTH= 12	BIN = 57			
START TIME = 12:21:59		END TIME = 13:02:36		RUNTIME = 40:37
ctr1= 7	ctr2 = 91	ctr3 = 3		
I= 12	J= 10			
TDB(DEG F)	TWB(DEG F)	HOURS	TOWER	
57	52	24.82143	12	
GPM	%GPM	CFM	TONS	
750	75	120000	100	
CWS(DEG F)	CWR(DEG F)	DELTATCOND	DELTATTOWER	TOWERDUTY
80	84.03179	4.031794	19.7356	.1158782
PIPE D(FT)	Pipevelocity(FT/SEC)	RED	pipe frict	
.6666667	4.787051	369371.3	1.592428E-02	
pipeL total	PHpipe	PHcond	Phtower	
PHtotal(FT Water)				
666.6667	5.666439	5.105591	11	21.77203
PASSES	Condenservelocity			
2	2.900009			
UACOND	LMTDCOND	NfISENT	NFTON	COND.TEMP
893100.2	1.690421	.5164742	.6406521	84.4407
KWTONGUESS	KWTONMODEL	KWHBIN	KWHTOT	
.9074575	.9074562	2397.792	6159.366	
HOURS	HOURSSUM			
24.82143	57.5			
CHILLERKW	PUMPKW	FANKW	TOTALKW	
90.74575	4.342596	1.513313	96.60166	

THE YEARLY TOTAL (\$)	=	329208.7	
THE PUMP ENERGY (KWH)	=	9823.913	
THE FAN ENERGY (KWH)	=	14440.33	
THE CHILLER ENERGY (KWH)	=	337443.6	
THE TOTALSYSTEM ENERGY (KWH)	=		361707.9

ATTOW16.DAT TOWER # 16 JOYCE METHOD

MONTH= 12	BIN = 57			
START TIME =	13:04:09	END TIME =	13:46:03	RUNTIME = 41:54
ctr1= 7	ctr2 = 90	ctr3 = 3		
I= 12	J= 10			
TDB(DEG F)	TWB(DEG F)	HOURS	TOWER	
57	52	24.82143	16	
GPM	%GPM	CFM	TONS	
750	75	120000	100	
CWS(DEG F)	CWR(DEG F)	DELTATCOND	DELTATTOWER	TOWERDUTY
80	84.03179	4.031794	20.19933	.1106671
PIPE D(FT)	Pipevelocity(FT/SEC)	RED	pipe frict	
.6666667	4.787051	369371.3	1.592428E-02	
pipeL total	PHpipe	PHcond	PHTower	
PHTotal(FT Water)				
666.6667	5.666439	5.105591	11	21.77203
PASSES	Condenservelocity			
2	2.900009			
UACOND	LMTDCOND	NfISENT	NFTON	COND.TEMP
893100.2	1.690421	.5164742	.6406521	84.4407
KWTONGUESS	KWTONMODEL	KWHBIN	KWHTOT	
.9074575	.9074562	2385.629	6114.878	
HOURS	HOURSSUM			
24.82143	57.5			
CHILLERKW	PUMPKW	FANKW	TOTALKW	
90.74575	4.342596	1.023324	96.11167	

THE YEARLY TOTAL (\$)	=	328628.1	
THE PUMP ENERGY (KWH)	=	9823.913	
THE FAN ENERGY (KWH)	=	10003.45	
THE CHILLER ENERGY (KWH)	=	337395.2	
THE TOTALSYSTEM ENERGY (KWH)	=		357222.5



```

MONTH= 12      BIN = 57
START TIME = 14:35:43      END TIME = 15:19:20      RUNTIME = 43:37
ctr1= 7      ctr2 = 90      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      19
GPM      %GPM      CFM      TONS
750      75      120000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031794      20.77497      .104522
PIPE D(FT)      Pipevelocity(FT/SEC)      RED      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      Phtower
PHTotal(FT Water)     
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074577      .9074562      2385.587      6115.9
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.74577      4.342596      1.021625      96.10999

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THE YEARLY TOTAL ($) =      328658.3
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      10252.19
THE CHILLER ENERGY (KWH) =      337320.8
THE TOTALSYSTEM ENERGY (KWH) =      357396.9

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ATEF2.DAT TOWER # 2 EFFECTIVENESS METHOD

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MONTH= 12      BIN = 57
TIME START = 15:37:19      TIME END = 15:44:00      RUNTIME = 6:41
ctr1= 7        ctr2 = 91      ctr3 = 3
I= 12         J= 10
TDB(DEG F)      TWB(DEG F)      HOURS          TOWER
  57            52            24.82143       2
GPM             %GPM            CFM            TONS
  750          75            120000         100
CWS(DEG F)      CWR(DEG F)      DELTATCOND     DELTATTOWER     TOWERDUTY
  80            84.03179      4.031794      20.96244        .1025935
PIPE D(FT)      Pipevelocity(FT/SEC)  Red           pipe frict
  .6666667      4.787051      369371.3      1.592428E-02
pipeL total     PHpipe           PHcond         PHTower
PHTotal(FT Water)
  666.6667      5.666439      5.105591      11              21.77203
PASSES         Condenservelocity
  2             2.900009
UACOND         LMTDCOND         NfISENT        NFTON           COND.TEMP
  893100.2      1.690421      .5164742      .6406521        84.4407
KWTONGUESS     KWTONMODEL       KWHBIN         KWHTOT
  .9074575      .9074562      2509.533      6588.154
HOURS          HOURSSUM
  24.82143      57.5
CHILLERKW      PUMPKW           FANKW          TOTALKW
  90.74575      4.342596      6.015156      101.1035

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THE YEARLY TOTAL ($) = 335101.8
THE PUMP ENERGY (KWH) = 9823.913
THE FAN ENERGY (KWH) = 59464.87
THE CHILLER ENERGY (KWH) = 337298.5
THE TOTALSYSTEM ENERGY (KWH) = 406587.3

```

ATEF5.DAT TOWER # 5 EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 15:46:17 TIME END = 15:54:27 RUNTIME = 8:10  
 ctr1= 7 ctr2 = 92 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 5  
 GPM %GPM CFM TONS  
 750 75 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 21.74524  
 9.490044E-02  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond Phtower  
 Phtotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074576 .9074562 2458.015 6398.744  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74576 4.342596 3.939574 99.02793

THE YEARLY TOTAL (\$) = 332648.8  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 40526.96  
 THE CHILLER ENERGY (KWH) = 337296.7  
 THE TOTALSYSTEM ENERGY (KWH) = 387647.6

ATEF9.DAT TOWER # 9 EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 15:57:15 TIME END = 16:06:35 RUNTIME = 9:20  
 ctr1= 7 ctr2 = 92 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 9  
 GPM %GPM CFM TONS  
 750 75 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 22.17689  
 9.089065E-02  
 PIPE D(FT) Pipevelocity(FT/SEC) REd pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond PHTower  
 PHTotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074577 .9074562 2396.136 6159.948  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74577 4.342596 1.446589 96.53496

THE YEARLY TOTAL (\$) = 329324.2  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 15236.21  
 THE CHILLER ENERGY (KWH) = 337296.9  
 THE TOTALSYSTEM ENERGY (KWH) = 362357

ATEF12.DAT TOWER # 12 EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 16:28:21 TIME END = 16:35:14 RUNTIME = 6:53  
 ctr1= 7 ctr2 = 93 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 12  
 GPM %GPM CFM TONS  
 750 75 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 21.91807  
 9.327599E-02  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond Phtower  
 Phtotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074577 .9074562 2390.465 6136.881  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74577 4.342596 1.218139 96.30651  
  
 THE YEARLY TOTAL (\$) = 328978.1  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 12646.48  
 THE CHILLER ENERGY (KWH) = 337296.8  
 THE TOTALSYSTEM ENERGY (KWH) = 359767.2

ATEF16.DAT      TOWER # 16      EFFECTIVENESS METHOD

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MONTH= 12      BIN = 57
TIME START = 16:36:34      TIME END = 16:44:47      RUNTIME = 8:13
ctrl= 7      ctr2 = 91      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
 57      52      24.82143      16
GPM      %GPM      CFM      TONS
 750      75      120000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
 80      84.03179      4.031794      22.53072
8.771837E-02
PIPE D(FT)      Pipevelocity(FT/SEC)      Red      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)
 666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
 2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
 893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074577      .9074562      2380.363      6098.738
HOURS      HOURSSUM
 24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
 90.74577      4.342596      .8111207      95.89949

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THE YEARLY TOTAL ($) =      328464.3
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      8709.041
THE CHILLER ENERGY (KWH) =      337297.1
THE TOTALSYSTEM ENERGY (KWH) =      355830.1

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ATEF19.DAT TOWER # 19 EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 16:46:15 TIME END = 16:55:43 RUNTIME = 9:28  
 ctrl1= 8 ctr2 = 104 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 19  
 GPM %GPM CFM TONS  
 750 75 120000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 23.29736  
 8.117554E-02  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond PHTower  
 PHTotal(FT Water)  
 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074578 .9074562 2379.924 6098.561  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74578 4.342596 .7934307 95.88181

THE YEARLY TOTAL (\$) = 328486.1  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 8849.848  
 THE CHILLER ENERGY (KWH) = 337296.8  
 THE TOTALSYSTEM ENERGY (KWH) = 355970.5

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MONTH= 12      BIN = 57
START TIME = 14:10:57      END TIME = 14:51:45      RUNTIME = 40:48
ctr1= 6      ctr2 = 80      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      80000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031793      14.52383      .1973316
PIPE D(FT)      Pipevelocity(FT/SEC)      RED      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074569      .9074562      2386.287      6108.143
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.74569      4.342596      1.049877      96.13816

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THE YEARLY TOTAL ($) =      329347.2
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      7669.604
THE CHILLER ENERGY (KWH) =      341085.2
THE TOTALSYSTEM ENERGY (KWH) =      358578.7

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MONTH= 12      BIN = 57
START TIME = 15:34:44      END TIME = 16:17:07      RUNTIME = 42:23
ctr1= 6      ctr2 = 80      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      100000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031794      16.90012      .1539621
PIPE D(FT)      Pipevelocity(FT/SEC)      RED      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)     
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074571      .9074562      2401.928      6167.014
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.74571      4.342596      1.680003      96.76831

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THE YEARLY TOTAL ($) =      329446
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      13997.07
THE CHILLER ENERGY (KWH) =      338508.3
THE TOTALSYSTEM ENERGY (KWH) =      362329.2

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ATFM12.DAT      CFM 120,000      JOYCE METHOD

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MONTH= 12      BIN = 57
START TIME = 09:38:23      END TIME = 10:19:09      RUNTIME = 40:46
ctr1= 7      ctr2 = 91      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      120000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031794      18.92442      .1256079
PIPE D(FT)      Pipevelocity(FT/SEC)      REd      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074574      .9074562      2421.411      6244.041
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.74574      4.342596      2.464895      97.55323

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THE YEARLY TOTAL ($) =      330303.3
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      22643.94
THE CHILLER ENERGY (KWH) =      337620.4
THE TOTALSYSTEM ENERGY (KWH) =      370088.2

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MONTH= 12      BIN = 57
START TIME = 09:20:36      END TIME = 10:03:05      RUNTIME = 42:29
ctr1= 7      ctr2 = 90      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      140000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031794      20.65385      .1057865
PIPE D(FT)      Pipevelocity(FT/SEC)      Red      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)     
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND. TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074576      .9074562      2444.862      6341.728
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.74576      4.342596      3.409683      98.49804

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THE YEARLY TOTAL ($) =      331787.7
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      34027.18
THE CHILLER ENERGY (KWH) =      337324.1
THE TOTALSYSTEM ENERGY (KWH) =      381175.2

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MONTH= 12      BIN = 57
START TIME = 10:04:59      END TIME = 10:48:51      RUNTIME = 43:52
ctr1= 8      ctr2 = 100      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      160000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031794      22.13515
9.127153E-02
PIPE D(FT)      Pipevelocity(FT/SEC)      Red      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074579      .9074562      2472.463      6462.413
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.74579      4.342596      4.521638      99.61002

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THE YEARLY TOTAL ($) = 333746.1
THE PUMP ENERGY (KWH) = 9823.913
THE FAN ENERGY (KWH) = 48544.85
THE CHILLER ENERGY (KWH) = 337296.6
THE TOTALSYSTEM ENERGY (KWH) = 395665.4

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MONTH= 12      BIN = 57
START TIME = 13:28:34      END TIME = 14:09:48      RUNTIME = 41:14
ctr1= 8      ctr2 = 94      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      180000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031794      23.40676      .0802768
PIPE D(FT)      Pipevelocity(FT/SEC)      RED      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074581      .9074562      2504.454      6608.818
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.7458      4.342596      5.810467      100.8989

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THE YEARLY TOTAL ($) =      336225.5
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      66800.08
THE CHILLER ENERGY (KWH) =      337297.3
THE TOTALSYSTEM ENERGY (KWH) =      413921.3

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AFMEF08.DAT CFM 80,000 EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 14:16:25 TIME END = 14:24:02 RUNTIME = 7:37  
 ctr1= 6 ctr2 = 85 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 8  
 GPM %GPM CFM TONS  
 750 75 80000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 15.58475 .1763346  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond PHTower  
 PHTotal(FT Water) 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .907457 .9074562 2383.514 6099.48  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.7457 4.342596 .9381654 96.02646

THE YEARLY TOTAL (\$) = 328801.4  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 7206.588  
 THE CHILLER ENERGY (KWH) = 339184.5  
 THE TOTALSYSTEM ENERGY (KWH) = 356215

AFMEF10.DAT CFM 100,000 EFFECTIVENESS METHOD

MONTH= 12 BIN = 57  
 TIME START = 14:28:05 TIME END = 14:36:57 RUNTIME = 8:52  
 ctr1= 6 ctr2 = 81 ctr3 = 3  
 I= 12 J= 10  
 TDB(DEG F) TWB(DEG F) HOURS TOWER  
 57 52 24.82143 8  
 GPM %GPM CFM TONS  
 750 75 100000 100  
 CWS(DEG F) CWR(DEG F) DELTATCOND DELTATTOWER TOWERDUTY  
 80 84.03179 4.031794 18.4128 .1321855  
 PIPE D(FT) Pipevelocity(FT/SEC) RED pipe frict  
 .6666667 4.787051 369371.3 1.592428E-02  
 pipeL total PHpipe PHcond PHTower  
 PHTotal(FT Water) 666.6667 5.666439 5.105591 11 21.77203  
 PASSES Condenservelocity  
 2 2.900009  
 UACOND LMTDCOND NfISENT NFTON COND.TEMP  
 893100.2 1.690421 .5164742 .6406521 84.4407  
 KWTONGUESS KWTONMODEL KWHBIN KWHTOT  
 .9074572 .9074562 2396.03 6148.765  
 HOURS HOURSSUM  
 24.82143 57.5  
 CHILLERKW PUMPKW FANKW TOTALKW  
 90.74572 4.342596 1.442381 96.53069

THE YEARLY TOTAL (\$) = 329002.8  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 12707.91  
 THE CHILLER ENERGY (KWH) = 337642.3  
 THE TOTALSYSTEM ENERGY (KWH) = 360174.1

AFMEF12.DAT      CFM 120,000      EFFECTIVENESS METHOD

```

MONTH= 12      BIN = 57
TIME START = 12:46:37      TIME END = 12:53:25      RUNTIME = 6:48
ctr1= 7      ctr2 = 92      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      120000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031794      20.85859      .1036575
PIPE D(FT)      Pipevelocity(FT/SEC)      REd      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074575      .9074562      2410.719      6211.164
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.74575      4.342596      2.034147      97.12249

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THE YEARLY TOTAL ($) =      329947.8
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      20089.43
THE CHILLER ENERGY (KWH) =      337312.3
THE TOTALSYSTEM ENERGY (KWH) =      367225.7

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AFMEF14.DAT      CFM 140,000      EFFECTIVENESS METHOD

MONTH= 12      BIN = 57  
 TIME START = 12:54:56      TIME END = 13:03:20      RUNTIME = 8:24  
 ctr1= 8      ctr2 = 104      ctr3 = 3  
 I= 12      J= 10  
 TDB(DEG F)      TWB(DEG F)      HOURS      TOWER  
 57      52      24.82143      8  
 GPM      %GPM      CFM      TONS  
 750      75      140000      100  
 CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY  
 80      84.03179      4.031794      22.95394  
 8.405238E-02  
 PIPE D(FT)      Pipevelocity(FT/SEC)      RED      pipe frict  
 .6666667      4.787051      369371.3      1.592428E-02  
 pipeL total      PHpipe      PHcond      PHTower  
 PHTotal(FT Water)  
 666.6667      5.666439      5.105591      11      21.77203  
 PASSES      Condenservelocity  
 2      2.900009  
 UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP  
 893100.2      1.690421      .5164742      .6406521      84.4407  
 KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT  
 .9074579      .9074562      2427.475      6288.67  
 HOURS      HOURSSUM  
 24.82143      57.5  
 CHILLERKW      PUMPKW      FANKW      TOTALKW  
 90.74579      4.342596      2.709155      97.79754

THE YEARLY TOTAL (\$) = 331261.7  
 THE PUMP ENERGY (KWH) = 9823.913  
 THE FAN ENERGY (KWH) = 29775.94  
 THE CHILLER ENERGY (KWH) = 337297  
 THE TOTALSYSTEM ENERGY (KWH) = 376896.8

AFMEF16.DAT      CFM 160,000      EFFECTIVENESS METHOD

```

MONTH= 12      BIN = 57
TIME START = 11:06:16      TIME END = 11:13:18      RUNTIME = 7:02
ctr1= 8      ctr2 = 105      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      160000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031794      24.73064      .0700314
PIPE D(FT)      Pipevelocity(FT/SEC)      REd      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074581      .9074562      2446.345      6383.272
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.7458      4.342596      3.469392      98.55779

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THE YEARLY TOTAL ($) =      332982.5
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      42322.18
THE CHILLER ENERGY (KWH) =      337297.3
THE TOTALSYSTEM ENERGY (KWH) =      389443.3

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AFMEF18.DAT      CFM 180,000      EFFECTIVENESS METHOD

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MONTH= 12      BIN = 57
TIME START = 12:18:54      TIME END = 12:27:39      RUNTIME = 8:45
ctr1= 9      ctr2 = 116      ctr3 = 3
I= 12      J= 10
TDB(DEG F)      TWB(DEG F)      HOURS      TOWER
57      52      24.82143      8
GPM      %GPM      CFM      TONS
750      75      180000      100
CWS(DEG F)      CWR(DEG F)      DELTATCOND      DELTATTOWER      TOWERDUTY
80      84.03179      4.031795      26.22048
5.973898E-02
PIPE D(FT)      Pipevelocity(FT/SEC)      RED      pipe frict
.6666667      4.787051      369371.3      1.592428E-02
pipeL total      PHpipe      PHcond      PHTower
PHTotal(FT Water)
666.6667      5.666439      5.105591      11      21.77203
PASSES      Condenservelocity
2      2.900009
UACOND      LMTDCOND      NfISENT      NFTON      COND.TEMP
893100.2      1.690421      .5164742      .6406521      84.4407
KWTONGUESS      KWTONMODEL      KWHBIN      KWHTOT
.9074584      .9074562      2467.557      6497.896
HOURS      HOURSSUM
24.82143      57.5
CHILLERKW      PUMPKW      FANKW      TOTALKW
90.74583      4.342596      4.323931      99.41236

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THE YEARLY TOTAL ($) =      335188.1
THE PUMP ENERGY (KWH) =      9823.913
THE FAN ENERGY (KWH) =      58278.78
THE CHILLER ENERGY (KWH) =      337297.4
THE TOTALSYSTEM ENERGY (KWH) =      405400.2

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