PAPERMACHINE BUILDING VENTILATION SURVEY
FOR PAPERMACHINES #1 AND #2
BUILDING #2

A. Building Dimensions

1. Operating Floor Length: 203'-4 1/2"
2. Basement Floor Length: 87'-0"
3. Operating Floor Width: 76'-10"
4. Basement Floor Width: 76'-10"
5. Operating Floor to Roof Height: 50'-6 11/16"
6. Basement to Operating Floor Height: 8'-9"

B. Building Volume

1. Operating Floor:

   203'-4 1/2" (1) x 76'-10"(w) x 50'-6 11/16" (h) = 790,007 ft^3

2. Basement:

   87'-10" (1) x 76'-10" (w) x 8'-9" (h) = 58,489 ft^3

3. Total Building Volume 848,496 ft^3

C. Building Air Volume

1. Operating Floor: 790,007 ft^3 x 0.85 = 671,506 ft^3
2. Basement: 58,489 ft^3 x 0.70 = 40,942 ft^3
3. Total Building Air Volume = 712,448 ft^3

D. Building Exhaust

1.	#1 PM Yankee Hood Exhaust	35,408.26 SCFM	155,499.50 lb dry air/hr
2.	#1 PM Open Hood Exhaust	19,596.34 SCFM	83,291.539 lb dry air/hr
3.	#1 PM Open Hood Exhaust	19,596.34 SCFM	83,291.539 lb dry air/hr
4.	#2 PM W.E. Open Hood Exh.	22,437.70 SCFM	96,783.719 lb dry air/hr
5.	#2 PM Center Open Hood Exh.	26,635.50 SCFM	113,756.453 lb dry air/hr
6.	#1 PM D.E. Open Hood Exh.	24,416.49 SCFM	105,745.352 lb dry air/hr
7.	Sub Total- P.M. Hood Exh.	148,090.63 SCFM	638,368.102 lb dry air/hr
8.	#1 PM Dorr Oliver Roof Exh.	20,040.00 SCFM	88,276.438 lb dry air/hr
9.	#1 PM Dorr Oliver Roof Exh.	20,040.00 SCFM	88,276.438 lb dry air/hr
10.	D.E. Wall Exhaust Fan	21,284.70 SCFM	93,759.961 lb dry air/hr
11.	D.E. Wall Exhaust Fan	9,430.53 SCFM	41,541.855 lb dry air/hr
12.	Basement Wall Exh. Fan	27,302.32 SCFM	120,267.82 lb dry air/hr
13.	Basement Tubeaxial Exh. Fan	15,296.32 SCFM	67,380.883 lb dry air/hr
14.	Total Building Exhaust	261,484.50 SCFM	1,137,871.497 lb dry air/hr

15. Building Exhaust Air Change Rate

$$\frac{\text{Air Changes}}{\text{Hr}} = \frac{261{,}484.50 \text{ SCFM} \times 60 \text{ min/hr}}{712{,}448 \text{ ft}^3}$$

= 22.02 Exhaust Air Changes/hr

E. Building Supply Air

1.	#1 PM Yankee Hood Supply	15,645.00 SCFM	70,337.43 lb dry air/hr
2.	#1 PM Open Hood Supply	26,305.74 SCFM	117,974.695 lb dry air/hr
3.	#2 PM Open Hood Supply	17,630.60 SCFM	79,068.852 lb dry air/hr
4.	Total Building Supply	59,581.34 SCFM	267,377.977 lb dry air/hr

F. Building Infiltration

To determine the amount of building air infiltration it is necessary to add the building exhaust and supply, and then subtract one from the other. This process cannot be done with ACFM air flows since each air flow has a different air density. Therefore the ACFM air flows are converted to mass air flows (lbs dry air/hr). Subtracting the supply air dry air mass flow from the exhaust air does identify the true building air infiltration. Some consultants convert the ACFM air flows to SCFM which is air at a common density of 0.075 lb/ft^3. This method is fairly accurate but it does result in some error due to the addition of water vapor as the air travels thru the machine room. Usually this results in a SCFM air infiltration rate that is 4% too high.

1. Building Air Infiltration Rate

$$\text{Infiltration} = \text{Exhaust } m \left(\frac{\text{lb dry air}}{\text{hr}} \right) - \text{Supply } m \left(\frac{\text{lb dry air}}{\text{hr}} \right)$$

$$= 1,137,871.497 \frac{\text{lb d.a.}}{\text{hr}} - 267,377.977 \frac{\text{lb d.a.}}{\text{hr}}$$

$$= 870,493.52 \frac{\text{lb d.a.}}{\text{hr}}$$

2. Building Air Infiltration Rate - Expressed in ACFM & SCFM

a. t outside air = 47°F
b. Relative Humidity = 50%
c. Mass Infiltration Rate = 870,493.52 lb d.a./hr
d. Air Infiltration ACFM = 187,023
e. Air Infiltration SCFM = 194,100

3. Approximate Infiltration Rate - Expressed in SCFM

Infiltration = Exhaust (SCFM) - Supply (SCFM)
= 261,484.50 - 59,581.34 = 201,903.16 SCFM

G. Annual Cost for Building Infiltration Or Building Make-Up Air

Building infiltration into the papermachine building is a common occurrence in the papermill industry. The reason it occurs is because the building exhaust is greater than the building supply, therefore the excess exhaust rate results in infiltration of air from other buildings or infiltration directly from outside. In either case if a pound of dry air is exhausted to outside, a pound must infiltrate from outside otherwise the buildings would collapse. The further the air must travel to get to the papermachine building the more negative the air pressure becomes in the papermachine building. If the papermachine building has more exhaust than is needed, and can be shut off, it saves in air heating costs and electrical cost to pull the air thru the adjacent buildings.

1. Annual Cost to Heat Air Infiltration or Building Make-Up Air

$$\frac{\text{Air heating cost}}{\text{yr}} = \text{SCFM} \times 1.08 \times \text{degree days} \times 24\ \frac{\text{hr}}{\text{day}} \times \left(\frac{\text{tsa-toa}}{\text{65-toa}}\right) \times \frac{\text{cost}}{10^6\ \text{BTU}}$$

$$= \text{SCFM} \times 1.08 \times 6297 \times 24\ \frac{\text{Hr}}{\text{Day}} \times \frac{(70-35.2)}{(65-35.2)} \times \frac{\$7.167}{10^6\text{BTU}}$$

$$\text{Air Heating Cost} = \frac{\$1.368 \times \text{SCFM}}{\text{year}}$$

a. SCFM - Air flow quantity converted to standard air density($0.075 lb/ft^3$)

b. Degree Days - This is the number of heating degree days for this region. For this case you do not use the full season degree days because air is not heated during the summer months.

c. tsa - Supply air temperature to the building (^oF)

d. toa - Average outside air for the winter air heating season.

e. $\frac{\text{Cost}}{10^6\ \text{BTU}}$ - This is the energy cost for heating the air

f. (tsa - toa) - This ratio is used to convert heating degree days. Heating degree days assume the air is heated to 65^oF, however in the paper industry we heat the air to higher temperatures.

2. Annual Electrical Cost t Exhaust Air or Supply Air to the Building

$$\frac{\text{Electrical Cost}}{\text{year}} = \text{SCFM} \times 0.00068187\ \frac{\text{kw}}{\text{scfm}} \times \frac{\text{operating hours}}{\text{yr}} \times \frac{\text{cost}}{\text{kwh}}$$

$$= \text{SCFM} \times 0.00068187\ \frac{\text{kw}}{\text{scfm}} \times 8400\ \frac{\text{hr}}{\text{yr}} \times \frac{\$0.0648}{\text{kwh}}$$

$$\text{Electrical Cost} = \frac{\$0.371 \times \text{SCFM}}{\text{year}}$$

Note: Most exhaust air systems and supply air systems operate all year long which for the paper industry is 350 days/year or 8,400 hours/yr

3. Total Annual Cost for Exhausting Building Air or Supplying Make-up Air

$$\frac{\text{Air Cost}}{\text{year}} = \frac{\text{Air Heating Cost}}{\text{year}} \times \frac{\text{Electrical Cost}}{\text{year}}$$

$$= \frac{(\$1.368 \times \text{SCFM}) \times (\$0.371 \times \text{SCFM})}{\text{year}}$$

$$= \frac{\$1.739 \times \text{SCFM}}{\text{year}}$$

H. Energy Savings Associated With the Reduction of Building Exhaust

This building has an exhaust air change rate of 22 air changes/hr which is high for a papermachine building. The papermachine hood exhaust is 56% of the building exhaust (12.47 air changes/hr) and the remaining 44% is building exhaust.

1.	Hood Exhaust	148,090.63 SCFM	638,368.102 lb D.A./hr	(56.10%)
2.	Building Exhaust	113,393.87 SCFM	499,503.395 lb D.A./hr	(43.90%)
3.	Total Bldg. Exh	261,484.50 SCFM	1,137,871.497 lb D.A./hr	(100%)

The purpose of the building exhaust is two fold, to remove water vapor which causes building condensation and to remove sensible heat in an effort to make the employee comfortable. Based on my observations and discussions with mill personnel the building exhaust could be dropped by 40,000 SCFM which equates to $69,560/year of energy savings. This reduction would drop the building air change rate down to 18.65 air changes/hr. Some machine rooms in James River operate at 12 to 13 air changes/hr but this machine cannot for 2 reasons. One is papermachine open hoods require a lot more exhaust air than the other types of hoods, and the machine room basement is very small which indirectly affects the calculation or air change rate.

CLIMATOLOGICAL DATA FOR SYRACUSE NEW YORK

	Month	No. of Days	Heating Degree Days	Average Outside Air Temperature
1.	January	31 Days	1271	24.0°F
2.	February	28 Days	1140	24.3°F
3.	March	31 Days	1004	32.6°F
4.	April	30 Days	570	46.0°F
5.	May	31 Days	248	57.0°F
6.	June	30 Days	45	63.5°F
7.	July	31 Days	6	64.8°F
8.	August	31 Days	28	64.1°F
9.	September	30 Days	132	60.6°F
10.	October	31 Days	415	51.6°F
11.	November	30 Days	744	40.2°F
12.	December	31 Days	1153	27.8°F
13.	Totals	365 Days	6756	46.49°F (≃ 47.0°F)

Notes:

1. Average Outside Air Temperature
   Σ DD = 1271 = (65 - t avg. O.A.) x 31 Days
   t avg. O.A. = 24.0°F

2. Winter Make-Up Air Heating Season
   a. Months: Jan, Feb, Mar, April, Oct, Nov, Dec.
   b. t avg. O.A. = 35.2°F
   c. Days = 212 (5088 hrs/yr)
   d. Degree Days = 6297

c. Estimated flows using information freom fan catalogs.

(12)
t_{DB} = 190°F
t_{WB} = 104°F
W = 0.02817 lbwv/lbDA
ACFM= 22,000
SCFM= 17,551:24
$\dot{m}$ lbDA/hr = 76,816.75
$\dot{m}$ lbwv/hr = 2,163.8401
Q_S = 2,928,791 BTU/HR
Q_L = 2,470,901 BTU/HR
Q_T = 5,399,692 BTU/HR

(11)
t_{DB}
t_{WB}
W
ACF
SCF
$\dot{m}$
$\dot{m}$
Q_S
Q_L
Q_T

(14)
t_{DB} = 125.6°F
t_{WB} = 111.6°F
W = 0.05873 lbwv/lbDA
ACFM= 22,500
SCFM= 19,596.34
$\dot{m}$ lbDA/hr = 83,291.5390
$\dot{m}$ lbwv/hr = 4891.9824
Q_S = 1,876,755 BTU/HR
Q_L = 5,458,853 BTU/HR
Q_T = 7,335,608 BTU/HR

(13)
t_{DB}
t_{WB}
W
ACF
SCI
$\dot{m}$
$\dot{m}$
Q_S
Q_L
Q_T

(19)
t_{DB} = 92°F
t_{WB} = 82.06°F
W = 0.02156 lbwv/lbDA
ACFM= 21,250
SCFM= 20,040
$\dot{m}$ lbDA/hr = 88,276.4380
$\dot{m}$ lbwv/hr = 1,902.9955
Q_S = 1,272,982 BTU/HR
Q_L = 2,096,452 BTU/HR
Q_T = 3,369,433 BTU/HR

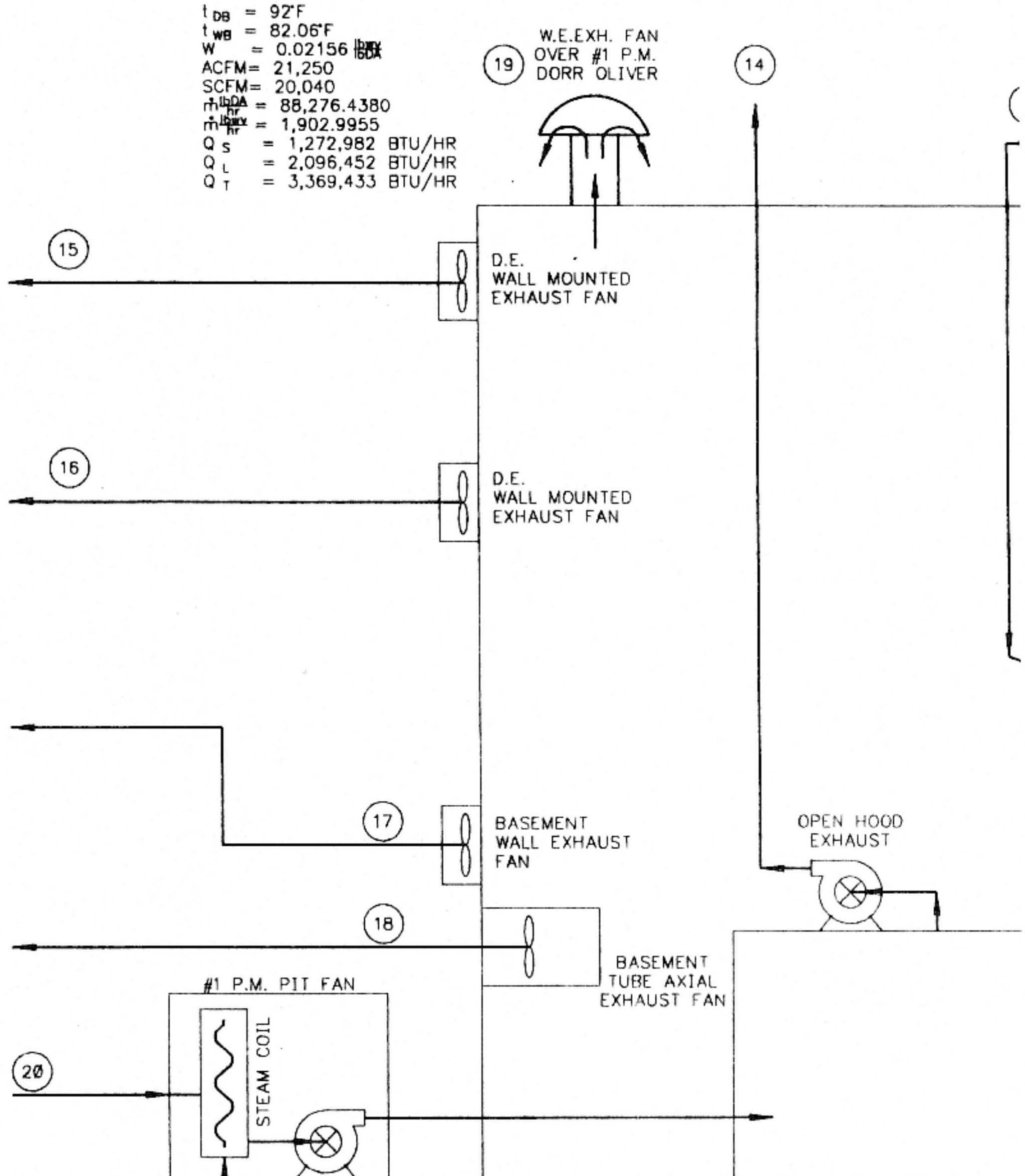
(15)
t_{DB} = 92°F
t_{WB} = 82.06°F
W = 0.02156 lbwv/lbDA
ACFM= 22,570
SCFM= 21,284.70
$\dot{m}$ lbDA/hr = 93,759.961
$\dot{m}$ lbwv/hr = 2,021.2051
Q_S = 1,352,056 BTU/HR
Q_L = 2,226,678 BTU/HR
Q_T = 3,578,735 BTU/HR

(16)
t_{DB} = 92°F
t_{WB} = 82.06°F
W = 0.02156 lbwv/lbDA
ACFM= 10,000
SCFM= 9430.53
m lbDA/hr = 41,541.8550
m lbwv/hr = 895.5273
Q_S = 599,050 BTU/HR
Q_L = 986,566 BTU/HR
Q_T = 1,585,616 BTU/HR

(17)
t_{DB} = 92°F
t_{WB} = 82.06°F
W = 0.02156 lbwv/lbDA
ACFM= 28,951
SCFM= 27,302.32
$\dot{m}$ lbDA/hr = 120,267.82
$\dot{m}$ lbwv/hr = 2,592.6411
Q_S = 1,734,310 BTU/HR
Q_L = 2,856,206 BTU/HR
Q_T = 4,590,516 BTU/HR

(18)
t_{DB} = 92°F
t_{WB} = 82.06°F
W = 0.02156 lbwv/lbDA
ACFM= 16,220
SCFM= 15,296.32
$\dot{m}$ lbDA/hr = 67,380.8830
$\dot{m}$ lbwv/hr = 1,452.5452
Q_S = 971,659 BTU/HR
Q_L = 1,600,209 BTU/HR
Q_T = 2,571,869 BTU/HR

(20)
t_{DB} = 47°F
t_{WB} = 39.44°F
RH = 50%
W = 0.00340014
ACFM= 25,346.57
SCFM= 26,305.74
$\dot{m}$ lbDA/hr = 117,974.6950
$\dot{m}$ lbwv/hr = 401.1390
Q_S = 424,992 BTU/HR
Q_L = 434,110 BTU/HR
Q_T = 859,102 BTU/HR

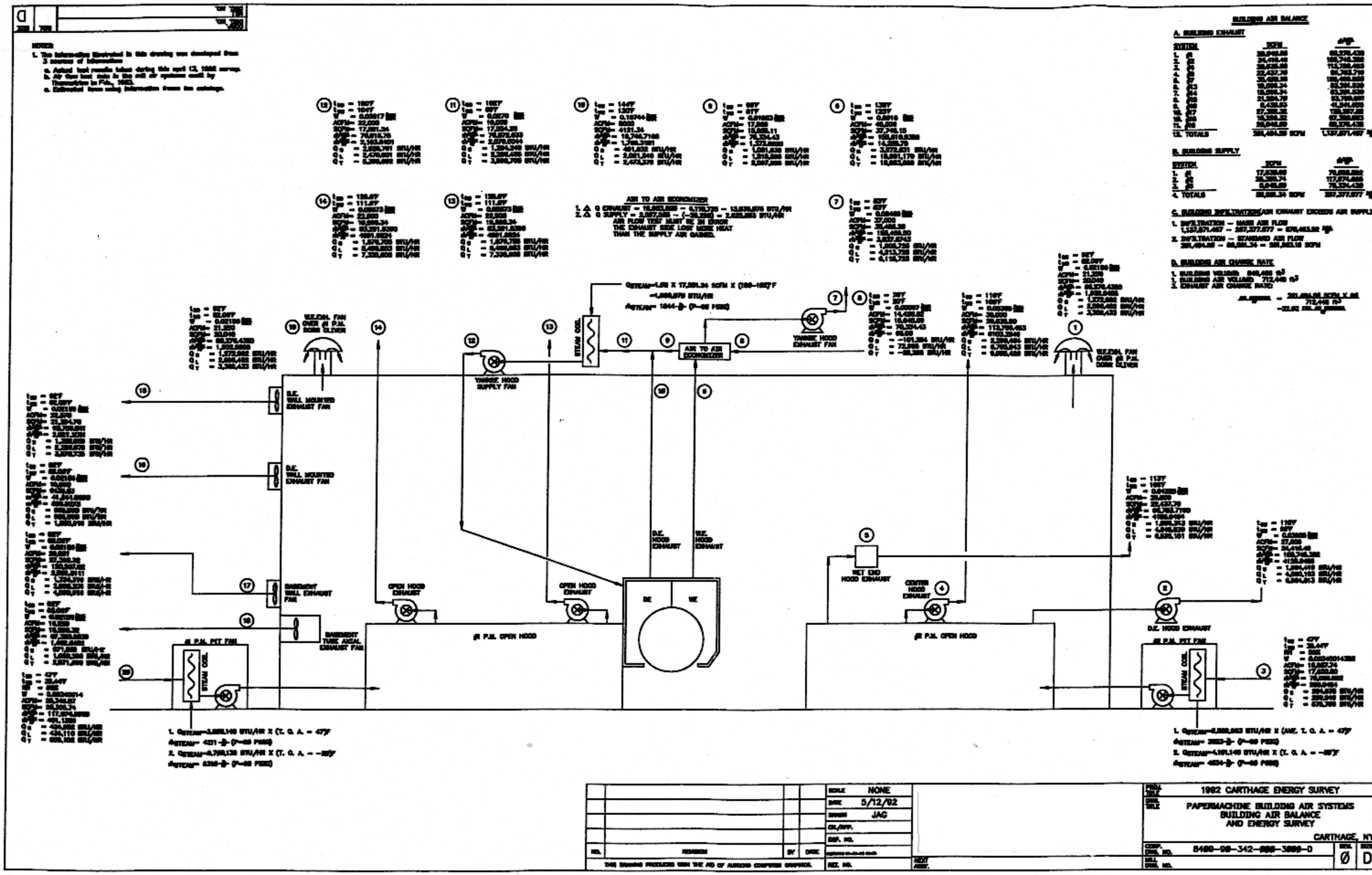


1. Q_{STEAM}=3,809,149 BTU/HR X (T. O. A. = 47)F

$\dot{m}_{STEAM}$= 4211 lb/hr (P=60 PSIG)

2. Q_{STEAM}=5,708,139 BTU/HR X (T. O. A. = −20)F

$\dot{m}_{STEAM}$= 6310 lb/hr (P=60 PSIG)



BUILDING AIR BALANCE
AIR TO AIR ECONOMIZER
STEAM COIL
YANKEE HOOD EXHAUST FAN
YANKEE HOOD SUPPLY FAN
W.E.IDM. FAN OVER #1 P.M. DOME DLIVER
D.E. WALL MOUNTED EXHAUST FAN
BASEMENT WALL EXHAUST FAN
BASEMENT TUBE AXIAL EXHAUST FAN
#1 P.M. PIT FAN
OPEN HOOD EXHAUST
#1 P.M. OPEN HOOD
D.E. HOOD EXHAUST
W.E. HOOD EXHAUST
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WET END HOOD EXHAUST
CENTER HOOD EXHAUST
#2 P.M. OPEN HOOD
D.E. HOOD EXHAUST
#2 P.M. PIT FAN
SCALE NONE
DATE 5/12/92
DRAWN JAG
1992 CARTHAGE ENERGY SURVEY
PAPERMACHINE BUILDING AIR SYSTEMS
BUILDING AIR BALANCE
AND ENERGY SURVEY
CARTHAGE, NY
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