A SunCam online continuing education course

Compressed Air Systems for Forest Products Facilities

by

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1.0 PURPOSE

The purpose of this course is to provide selection and sizing criteria for compressed air systems for forest products plants. The principles in this guide would also likely be applicable to other facilities that are primarily materials handling in nature.

Photo 1: Typical compressed air system.

2.0 ABSTRACT

2.1 Forest products plants, including sawmills, plywood mills, particleboard and OSB plants, typically require a large quantity of compressed air. This arises mainly from a large number of compressed air cylinders needed for discreet piece handling, gate switching, etc. Usually, this compressed air is supplied by a single air compression center, with compressed air being piped to various user locations.

2.2 The task of the Consulting Engineer is to adequately specify a compression system to be put out for bids.

2.3 The sub-tasks involved are:

2.3.1 Determine compressed air demand.
2.3.2 Determine equipment to be supplied in the Contract.
2.3.3 Write specifications for the equipment.

2.4 These tasks are discussed in detail below.

3.0 DETERMINE COMPRESSED AIR DEMAND

3.1 This step is best handled by setting up an excel spreadsheet. Go through the equipment list, Process Flow Diagram (PFD), or other documentation and determine all compressed air users. List them in the left-hand column. Add utility stations and any other miscellaneous users that might not be included on the documents.

3.2 Add a column for inlet pressure cubic feet per minute (ICFM). This is the volumetric flow rate as would be measured at the compressor inlet, sometimes referred to as "free air". Note that compressors are normally specified on an ICFM basis. This takes out variations in barometric pressure and altitude that would otherwise affect the rating. Equipment users should therefore also be specified in ICFM, allowing a direct comparison of demand to compression capacity. The values in this column may requires separate calculations, as will be demonstrated below.

3.3 There will usually be two types of equipment:

3.2.1 For some vendor-supplied equipment, the compressed air usage may be available from the vendor. Sometimes vendors supply usage rate as measured at delivery pressure. Very often, their documentation does not specify the reference pressure. Be sure that you know what their pressure basis is and get it in writing. A misunderstanding here can result in a large error. Also, be sure that the usage is based on the expected maximum processing rate for the plant.

3.2.2 Often, equipment is supplied with a number of compressed air cylinders, and it becomes the engineer's task to estimate compressed air usage. Two categories of cylinders must be recognized, two stroke, in which compressed air is supplied on both extension and retraction stroke, and one-stroke, in which compressed air is supplied only in one direction (usually extension). In this case, retraction force is usually supplied by gravity, but may be spring-return.

For each cylinder type (characterized by diameter, stroke and rod diameter), calculate cylinder volume:

Two Stroke

V = Extension Volume + Retraction Volume

$$V = \pi D_c^2 L/4/1728 + \pi(D_c^2 - D_r^2)L/4/1728$$

One Stroke

V = Extension Volume

$$V = \pi D_c^2 L/4/1728$$

Where:

V = volume of cylinder in cubic feet
D_c = diameter of cylinder, inches
D_r = rod diameter, inches
L = stroke length, inches

Note that air bags have a number of applications in forest products, usually as jump conveyors, allowing selective transfer to alternate conveyors. Within the accuracy required, these can be treated as single-stroke cylinders with an equivalent diameter.

Once the volume is known, the compressed air consumption is estimated as follows:

$Q = NVR(P_c + P_a)/P_a$

Where:

N = Number of cylinders involved
R = Cycle Rate, cycles/minute
P_c = Pressure to the cylinder, psig
P_a = Atmospheric Pressure, psia
Q = Compressed air consumption, ICFM.

The stroke rate is based on an estimated piece count through the machine center, often one stroke per piece.

Usually, there will be a pressure regulator upstream of the cylinder, which may have a recommended setting below plant air pressure. This pressure is Pc. For conservatism, plant air pressure may be used, as operators will often set the regulators wide open, believing this will improve throughput.

P_a varies with elevation. For southern plants, it can be assumed to be 14.7 psia. However, for higher elevations, actual average barometric pressure must be used. For example, atmospheric pressure in Denver, CO is 12.1 psia.

A formula for calculating atmospheric pressure is (1):

$$Pa = 14.7 \times ((1-6.73\times10^{-6}) \times Z)^{5.258}$$

Where:

Z = elevation above sea level in feet

(1) Taken from <u>Industrial Ventilation, A Manual of Recommended Practice</u>, Chapter 1)

In some types of plants, such as pellet plants, pulse jet bag filters are a major source of compressed air usage, as it is used for periodic filter cleaning. Typically, they will use 10-15 ICFM for each filter unit. The vendor should be consulted to determine the expected usage.

Below is an example spreadsheet for a sawmill. Note that the column titled “CFM” is the actual flow at pressure and is strictly dependent on the displacement volume of the cylinders. The formula contains an “If, Then, Else” formula so that the calculation depends on whether “1” or “2” is placed in the “STROKE” column. The column titled “ICFM” is flow corrected to atmospheric pressure.

ATMOSPHERIC PRESSURE									14.7	PSIG	
DESCRIPTION	**STROKE**	**CYL. BORE**	**CYL. STK.**	**QTY**	**CYCLE RATE**	**ROD DIA**	**CYL VOL**	**CFM**	**PRESS**	**ICFM**	**TOTALS**
		in	**in**		**1/min**	**in**	**cf**		**psi**		
DEBARKER				1	9		2.300	20.70	80	133.4	133
PRIMARY BREAKDOWN											
LOG TURNER	2	6	6	2	20	1.75	0.188	7.52	60	38.2	
INFEED PRESS-ROLLS	2	5	9	12	20	1.5	0.195	46.88	65	254.2	
CENTERING ROLLS	2	4	5	4	20	1.5	0.068	5.41	60	27.5	
SPIKE ROLLS	2	4	4	4	20	1.5	0.054	4.33	80	27.9	
THUMPER	2	5	9	1	20	1.5	0.195	3.91	80	25.2	
SHIFTING OUTFEED	2	4	8	1	20	1.5	0.108	2.16	60	11.0	
SEPARATOR	2	4	8	1	20	1.5	0.108	2.16	40	8.1	
CANT TURNER	2	6	12	1	20	1.75	0.376	7.52	80	48.4	
SUBTOTAL											440
EDGER FEED TABLE											
LIFT CYLINDER	2	2.5	8	4	10	1	0.042	1.67	80	10.8	
CHAIN TAKE-UP	2	4	12	1	0	1	0.169	0.00	80	0.0	
PAN AIR BAGS	1	5.7	2	5	20	0	0.030	2.95	80	19.0	
PRESS ROLLS	2	3.25	4	4	20	1	0.037	2.93	80	18.9	
FAR SIDE PUSHER	2	3.25	16	4	10	1.375	0.140	5.60	80	36.0	
CHAIN OILER	2									5.0	
SUBTOTAL											85
EDGER											
PRESS ROLLS	2	4	4	4	20	1.375	0.055	4.38	80	28.2	
SAW LUBRICATION										4.0	
OUTFEED ROLLS	2	4	4	4	20	1.375	0.055	4.38	80	28.2	
SUBTOTAL											60
TRIMMER SYSTEM											
PINSTOPS	2	2	1.5	1	20	1	0.005	0.10	80	0.6	
BOARDFEEDER HOOK	2	3.25	1	1	20	1	0.009	0.18	80	1.2	
SAW LIFT	2	3.25	8	2	20	1.375	0.070	2.80	80	18.0	
DOOR LIFT (I/F SIDE)	2	4	24	2	0	1.375	0.328	0.00	80	0.0	
DOOR LIFT (O/G SIDE)	2	5	24	2	0	1.375	0.525	0.00	80	0.0	
TIPPLE CYLINDER	2	3.25	3	3	20	1	0.027	1.65	80	10.6	
SUBTOTAL											30
SORTER											
TIPPLE	2	2.5	2	1	20	1	0.010	0.21	80	1.3	
DUMP ARM	2	5	12	43	0	1.25	0.264	0.00	80	0.0	
											1
TOTAL SAWMILL											**751**
* 1--SINGLE-STROKE CYLINDER, 2--DOUBLE-STROKE CYLINDER.											

4.0 DETERMINE EQUIPMENT REQUIREMENTS

4.1 Typically, a compressed-air system will be comprised of:

4.1.1 One or more compressors.

4.1.2 Aftercoolers

4.1.3 Compressed air dryer.

4.1.4 Receiver.

4.1.5 Oil/water separator.

4.2 Air Compressors: The primary parameters for selecting air compressors are pressure, volumetric capacity and number of compressors required.

4.2.1 Pressure: Most forest products plants use nominal 100 psig air, with the assumption that 80 psig will be available at the equipment boundaries. Most compressors for use in Forest Products are single-stage units, rated at 100-125 psig. If multiple compressors are used, 100 psig compressor rating may not be adequate, since the compressors are staged to come on line sequentially at progressively lower pressures.

4.2.2 Design Flow Capacity: The plant volume requirements are calculated as described in Section 3. Typically, this is increased by factors to determine the design capacity:

a. Vapor condensation factor, D_a: This accounts for volume of water removed by the dryer. A factor of 1.05 accounts for the worst case temperature/humidity case.

b. Dryer air usage factor, D_b:
Use 1.0 for refrigerated dryer.

Use 1.0-1.08 for blower-purge dryer. Varies depending on cooling method.
Use 1.18 for heatless desiccant dryer.
Use 1.08 for internally heated desiccant dryer.
Some caution is advised in using these dryer factors, as purge requirements are based on the rated capacity of the dryer, not on compressor capacity.

c. Error of omission factor, D_c: Use 1.1-1.2 to account for possible equipment that may have been left off of the list.
d. Future expansion factor, D_d: Use 1.0-1.2 to allow for future plant upgrades.
e. Leakage factor: 1.1 is customary.
f. Error factor for compressor testing accuracy:
1.05 for 50-500 CFMI
1.04 for over 500 CFMI
(Per CAGI Pneuprop PN2CPTC2 test accuracy requirements)

This may be expressed:

$Q_d = Q \times D_a \times D_b \times D_c \times D_d \times D_e \times D_f$

Where:

Q_d is the design compressor capacity, ICFM.

For a plant with calculated capacity of 1,000 ICFM, using blower purge desiccant dryer, the design capacity might be:

$Q_d = 1{,}000 \times 1.05 \times 1.0 \times 1.1 \times 1.2 \times 1.1 \times 1.05 = 1{,}600$ ICFM

4.2.3 Number of compressors. Typically, the most economical solution is a single compressor. This solution has a number of disadvantages.

a. One is that the motor size may be larger than the plant maximum for 460V motors (usually the break point is 250 to 400 HP, beyond which a 4160V motor is required). Plant personel would usually prefer to keep the motors at 460V where possible.

b. If the one compressor is down, the entire plant is down. With multiple compressors, if one compressor shuts down, the plant can continue to run, albeit at a reduced rate, until the compressor is repaired. Many plants prefer a three-compressor installation.

c. A very common solution is to drop "D_d" from the design capacity calculation. Select a compressor size such that two compressors will produce equal or better than design capacity, then add a third equal sized compressor as an installed spare and to accommodate future expansion.

In this case, the flow requirement for the system above would be 1,334 ICFM with three (3) compressors, each rated at 667 ICFM.

4.2.4 The compressors may be reciprocating or rotary screw type. Most modern forest products plants are opting for rotary screw compressors due to low vibration and low maintenance. They are also more efficient than reciprocating compressors. This is because the oil that is injected into the inlet air cools the air as it is compressed, resulting in a near-isothermal characteristic. Typically, reciprocating compressors discharge air at about 450F, while rotary screw compressors discharge at about 220F.

4.2.5 Rotary screw compressors, may in turn be "Oil Flooded" or "Oil Free". Oil Flooded systems utilize oil injected at the inlet to lubricate the compression screws and bearings. Oil Free compressors are only used in applications where it is necessary to prevent oil contact with downstream processes. They do not provide for "near isothermal" characteristics as described above. They are not normally use in forest products applications.

4.2.6 Terminology: The compression screws and housing are usually referred to as the "air end", and sometimes as the "element".

4.2.7 Compressors should be provided with an inlet air filter to protect the compressor parts from dust.

4.3 Aftercooler:

4.3.1 As the air is compressed, it heats considerably, even in rotary screw compressors. Hot compressed air reduces overall system efficiency, may damage operating equipment and is a safety hazard. The aftercooler is a heat exchanger through which the discharge air flows to reduce its temperature. Aftercoolers may be water-cooled or air-cooled. Water-cooled after-coolers are more economical, but the savings is usually more than lost with the requirement of a cooling tower. Most forest products facilities use air-cooled aftercoolers, requiring a fan. Air-cooled aftercoolers should be specified to maintain compressed air at a 20F, or less, approach to ambient.

4.3.2 A considerable amount of water will be condensed in the aftercooler. It should be provided with an automatic drain valve.

4.3.3 An air-cooled aftercooler should be provided with an inlet ambient-air filter.

4.3.4 Intercoolers are used for multiple-stage compressors to cool air between stages. This not only prevents equipment damage, but improves energy-efficiency of the compressor. Compressors rated at 100-125 psig, as used in forest products applications are single-stage units and do not require intercoolers.

4.4 Compressed Air Dryer

4.4.1 The compressed air leaving the aftercooler will usually be saturated, at least for Southeastern U.S. installations. This is because the water vapor molecules have been forced closer together, raising the dew point. If the plant is at a lower temperature than the compressed air, then water will condense in the pipe and equipment, which may damage the equipment over time. Worse still, if the equipment is shut down overnight in freezing weather, valves may freeze, making it difficult to start the plant in the morning, resulting in lost production. The solution is to dry the compressed air.

4.4.2 There are two principal types of dryers in use in forest products plants: refrigerant and desiccant.

a. Refrigerant dryers cool the compressed air down to about 38F to condense water then re-heat it with exhaust air from the refrigeration unit. They cannot further cool the air because it will freeze on the cooling coils. These are the most economical choice. However, being limited to a dew point of 38F, they are not very helpful for freeze protection, especially for outdoor equipment.

b. Desiccant dryers use a desiccant to reduce the dew point to -40F. These are most favored in forest products plants. The most common arrangement would be twin-tower, auto-regeneration, so that while one tower is regenerating, the other is in use. There are three regeneration methods commonly used:

<u>Blower purge heated</u>—ambient air is heated by an electric heater and passed through the regenerating tower. This is the most expensive of the three, however, it uses the least compressed air. The desiccant must be cooled after regeneration, to be effective, as the dew point of the hot desiccant will be higher. This is sometimes done with ambient air, which puts some moisture back into the desiccant. Alternatively, it may be done with dry, depressurized compressed air. Although, the average consumption is typically 2% of the rated dryer capacity, the instantaneous flow is typically about 4 times this, or 8%. The compressor station must be sized to handle this flow, by application of an appropriate design factor.

<u>Heatless</u>—a portion of the dried, compressed air is decompressed and passed through the regenerating tower. This requires about 15% of the rated dryer flow, and must

be accounted for in sizing the compressor station. This is the least expensive of the three. The savings may be offset by a higher compressor cost however.

Externally heated—a portion of the dried, compressed air is decompressed then heated and passed through the regenerating tower. This requires about 7.5% of the rated dryer flow, and must be accounted for in sizing the compressor station.

The author of this course knows of no trend in client preference regarding the three options.

The dryer should be provided with an inlet coalescing oil filter to keep oil out of the desiccant and a discharge particle filter to keep particulate out of the compressed air.

Bypass pipe and valves should be supplied so that the plant can continue to operate if the dryer is down.

Dryer selection tables are usually based on air at 100F and 100 psig. Correction factors must be applied for other temperatures and pressures. Compressed air leaving an air-cooled aftercooler in summer will likely be 120F. One supplier gives a flow rating correction factor of 0.56 for 120F. The correction factors are based on capacity of air for water vapor. However, consideration should also be given to:

> Fluidization velocity: 60 feet/minute based on empty cross sectional area of desiccant tube.
>
> Residence time: 3 seconds minimum.

It is usually left to the equipment supplier to size the dryer, however, all bidders may not propose the same dryer size.

Understanding the sizing criteria will aid the engineer in bid-tabbing and selecting the best proposal.

Authors Opinion: Of the three methods of regenerating, the blower purge carries the least annual operating cost. For the heatless and externally heated dryers, the purge flow is based on a percentage of rated flow of the dryer, providing a strong disincentive to over-sizing the dryer, since the compressor must be sized to provide this flow. Considering the blower-purge heated regeneration, it is probably overkill to use dry compressed air for cooling. The problem of dewpoint spikes resulting from adsorption of ambient air moisture will be worst on hot, humid days. On cold days, when protection is most needed, the problem will be minimal, as there will be less water vapor in the cooling air. For most forest products applications, some dewpoint spikes should be acceptable. Furthermore, use of compressed air for cooling must be accounted for in sizing the compressors and in the operating cost. Therefore, the author favors use of heated blower purge with ambient air cooling.

If automatic dewpoint control is not supplied, then the dryer will cycle through time-scheduled purge rotations even if no compressed air is being produced. This is especially a problem with dryers that use dry compressed air for purging, as the compressor will have to cycle on just to maintain the purge cycles. Therefore, the author favors use of automatic dewpoint control.

Photo 2: Particulate filter at dryer discharge.

4.5 Air Receivers

4.5.1 An air receiver acts as a buffer and a storage medium between the compressor and the consumption system. There are typically two different types of air receivers in a compressed air system:

- Primary Receiver - located near the compressor, after the after-cooler.
- Secondary Receivers - located close to points of larger intermittent air consumptions. This type of receiver is not always used in compressed air system design. Check with the project design criteria or confirm a user can be as much as 20% of the compressor output before recommending a secondary receiver.

The air consumption varies due to the processes supported. In shorter periods the demand for compressed air may even exceed the maximum capacity of the compressor(s). In fact, it is common in well designed systems not to design the compressor for the maximum peek loads.

Air receivers in compressed air systems serves the important purposes of:

- equalizing the pressure variation from the start/stop and modulating sequence of the compressor
- storage of air volume equalizing the variation in consumption and demand from the system.

- collecting condensate and water in the air after the compressor

Photo 3: Compressed air receiver.

4.5.2 Sizing the Air Receiver

The air receiver must in general be sized according to:

- the variation in the consumption demand
- the compressor size and the modulation strategy

In general it is possible to calculate the maximum consumption in the system by summarizing the demand of each consumer.

For calculating the receiver volume, note that it is necessary to assume a pressure band for the receiver to be effective. If the consumption process requires *100 psig* and the compressor is set to *100 psig*, there is no storage and no buffer. Any increased demand causes the pressure to drop below *100 psig* until the compressor controls respond by increasing the volume compressed.

If the compressors operate at *110 psig* the difference between *110 psig* and *100 psig* accounts for the air stored in the receiver. If the demand increases, the pressure can drop *10 psig* before the minimum requirement is met. Note that in a compressed air system the pipe system also serves the purpose of a buffered volume.

The receiver volume may be calculated with the formula

$$V = t\ Q\ P_a / (P_1 - P_2)$$

Where:

V = volume of the receiver tank, CF

t = time for the receiver to go from upper to lower pressure limits (minutes).

Q = free air needed, ICFM

P_a = atmosphere pressure, psia

P_1 = maximum tank pressure, psia

P_2 = minimum tank pressure (psia)

In forest products plants, "t" and "Q" may be difficult to define in terms of the Primary Receiver. This formula may be best applied to sizing Secondary Receivers being applied to specific machines.

Some common rules of thumb to sizing receivers are:

- 1 gallon for each ACFM (Actual Cubic Feet per Minute), or
- 4 gallons per compressor hp (horse power)

4.5.3 Locating the Primary Air Receiver.

In general, the primary air receiver may be located either upstream or downstream of the dryer. Locating upstream of the dryer provides the advantage of removing some condensed water prior to the dryer, thus reducing the load imposed on the dryer. However, the dryer will feel the full effect of load swings and may at times be overwhelmed by the load spikes, resulting in moist air getting through. This can be improved by locating the receiver downstream of the dryer. One solution is to divide the required volume into two receivers, locating one upstream and one downstream of the dryer.

4.5 Oil/Water Separator

4.5.1 In Rotary Screw Compressors, oil is injected into the air stream ahead of the compression zone to lubricate the compression surfaces and bearings and to act as an air coolant. Most of the oil is separated from the compressed-air stream by an impingement-type separator, integral to the compressor, and returned to the oil reservoir. A small amount of the oil however, remains in air stream as carryover. Most of this oil will drop out at the aftercooler and receiver and become port of the condensate stream. According to Compressed Air and Gas Handbook, the carryover concentration will normally vary from 0.002 to 0.005 oz per 1,000 CF of free air and may reach 0.02 before the separating element requires changing. The carryover concentration should be obtained from the compressor supplier as part of the bid information. Sometimes, the concentration may be expressed as parts per million (PPM). The conversion of 1 PPM oil in air would be:

(1 #oil/10^6 #air) x (16 oz/#) x (0.075 #air/CF free air) x (1,000 CF/MCF)

=0.0012 oz/MCF free air.

4.5.2 The condensate may be piped to an oil/water separator to reduce the concentration prior to discharge. However, the issue arises as to whether an oil/water separator is required. There is no clear-cut answer to this question, however, there are two discharge cases that may be addressed:

a. The condensate is to be discharged to a surface water outfall. Plant outfalls are identifiable streams that cross the property line, often an open ditch or culvert. These are monitored for various pollutants, including oil and grease. EPA requires that the oil and grease level be below 15 mg/liter, and the permitting process will require this to be demonstrated. The concentration of untreated condensate will often be above this as will be shown in the calculation below; however, as the plant will be considering the overall outfall concentration, the relatively small volume of flow from the compressors may not require separate treatment. In addition, many plants use a single centralized treatment facility to treat all water discharge prior to the outfall(s). Often, the process is to monitor the outfall, and if the concentration goes beyond 15 mg/liter, then address individual sources, such as the air compressors.

Note that numerically, 1 mg/liter, water = 1 ppm (parts per million).

b. The condensate may alternatively be discharged to a publicly operated treatment work (POTW), or sanitary sewer system. If this is the case, then the POTW should be contacted and provided with appropriate flow and oil condensation data. The POTW may or may not require pre-treatment of the discharge.

Photo 4: Oil/Water Separator for air compressor system.

c. A calculation procedure to estimate condensate flow and oil concentration follows:

Given:

Compressor Flow: 1,000 CFM free air.

Discharge Pressure: 100 psig

Ambient Temperature: 100F

Aftercooler Discharge Temperature: 115F

Barometric Pressure: 14.0 psia

Relative Humidity: 80 percent

Oil carryover: 0.002 oz/1,000 CF free air

Density of Dry Air at Standard Conditions (70F, 14.7 psia): 0.075 #/cf.

Solution:

From steam tables

P_v, sat at 100F = 0.949 psia

P_v, sat at 115F = 1.471 psia

Calculate partial pressure of water vapor entering compressor:

At 80% RH, 100F,

$P_v = 0.80 \times 0.949 = 0.759$ psia

The humidity ratio is calculated as follows See typical thermodynamics text for a discussion of non-reactive ideal gas mixtures):

$W = 0.622\, P_v / (P - P_v)$

Where:

W = humidity ratio, pounds water per pound dry air

P_v = vapor pressure, psia

P = system pressure, psia

Calculate humidity ratio entering compressor:

$W_1 = 0.622 \times (0.759/(14.0 - 0.759)) = 0.0356$ #vap/#dry air.

Calculate humidity ratio leaving aftercooler (assume 100%RH):

$W_2 = .622 \times 1.471/(114.0-1.471) = 0.0081$ #vap/#dry air

Calculate density of dry air entering the compressor:

$D_1 = 0.075 \times (460+70)/(460+100) \times (14.0/14.7) = .0676$ #/cf

Calculate flow rate of dry air to compressor:

$Q_{a1} = 1{,}000(14.0-.759)/14.0 = 946$ CFM dry free air

Calculate mass flow rate of dry air to compressor:

M_{a1} = 946 CF/min x .0676 #/cf = 63.9 #dry air/min

Calculate mass flow rate of water vapor to compressor:

M_{v1} = 63.9 #dry air/min x .0356 #vap/#dry air = 2.27 #vap/min

Calculate mass flow rate of water vapor leaving aftercooler:

M_{v2} = 63.9 #dry air/min x 0.0081#vap/#dry air = 0.520 #vap/min

Calculate rate of water condensed:

$M_{c2} = M_{v1} – M_{v2}$ = 2.27-0.52 = 1.75 #/min

Calculate volumetric flow of condensed water:

Q_c = 1.75 #/min /8.33 #/gal = 0.21 gal/min

Q_c = 0.21 gal/min x 3.72 liter/gal = <u>0.781 liter/min</u>

Note that most of this flow will be discharged from the water separator downstream of the aftercooler. A portion of the condensate may be carried over and discharge at the wet receiver and at the coalescing filter upstream of the dryer. All of these discharges should be piped to the oil/water separator if one is provided.

Calculate oil mass discharge rate:

M_o = 1,000 CF/min x 0.002 oz/1000 CF / 16 oz/lb / 2.2 #/kg x $1x10^6$ mg/kg = 56.8 mg/min

Calculate oil concentration in condensate:

56.8 mg oil/min / 0.781 liter condensate/min = 72.7 mg oil/liter condensate

Conclusion:

The aftercooler will discharge 0.781 liter/min condensate with an oil concentration of 66.1 mg/liter.

This information will be provided to the plant Environmental Professional to determine whether an oil/water separator is required.

Note that if a refrigerated dryer is utilized, additional water will condense in the dryer. The calculations would reflect a discharge temperature of 38F and a saturation vapor pressure, Pv sat = 0.112 psia.

5.0 PREPARE THE SPECIFICATIONS: The format of equipment specifications varies among consulting firms and clients. Usually, functional specifications are adequate, if they are provided to reputable firms with proven equipment designs. This means that the Engineer need only provide the requirements of the system, leaving the design of the equipment to the Supplier. A partial checklist of items to include in the specifications is provided below.

5.1 Information to provide the bidder:

5.1.1 Geographical location of the equipment installation.
5.1.2 Elevation above sea level.
5.1.3 Conditions of operation (outdoors, dusty, etc.).
5.1.4 Power available (3-phase, 460V, 60 Hz in the U.S.).
5.1.5 Expected temperature range of operation.
5.1.6 Scope of supply by Vendor, typically includes:

a. Compressor(s).
b. Aftercooler(s).
c. Receiver(s).
d. Dryer.

e. Oil/Water separator.
f. Freight to site.
g. Installation supervision.
h. Startup assistance.
i. Training.

5.1.7 Scope of supply by Owner, typically includes:
a. Unloading at site.
b. Storage until installation.
c. Foundation design and installation.
d. Mechanical installation.
e. Power wiring.

5.1.8 Type of compressor required (reciprocating, rotary screw, etc.).

5.1.9 Instrumentation and control requirements. Note that a detailed discussion of instruments and controls is beyond the scope of this course.

5.1.10 Number of air compressors required.

5.1.11 Minimum required pressure.

5.1.12 Design flow, calculated as described in Section 4.

5.1.13 Type of aftercooler (water-cooled or air-cooled).

5.1.14 Required aftercooler approach to ambient (typically 20F).

5.1.15 Volume of air receivers.

5.1.16 Number and arrangement of air receivers.

5.1.17 Type of drain valves (automatic or manual).

5.1.18 Type of dryer
a. Refrigerant.
b. Desiccant, heated blower purge.
c. Desiccant, heatless.
d. Desiccant, externally heated.

5.1.19 Dryer detailed requirements.
a. Sizing requirements.
b. Compressed air consumption of dryer.
c. Bypass piping and valves.
d. Automatic dewpoint control if desired.
e. Number of towers for desiccant dryers.

f. Auto-drain for refrigerant dryers.
g. Skid-mounting of equipment.

5.1.20 Minimum requirements for oil/water separator (usually 15 mg/liter oil concentration in water discharge).

5.1.21 Motor frame requirement (TEFC, ODP, etc.).

5.2 Information to be provided by the bidders:

5.2.1 Price to provide scope of work including breakdown for individual items.

5.2.2 Flow and pressure ratings of equipment.

5.2.3 Dryer flow rating at aftercooler discharge temperature and pressure.

5.2.4 Assumptions for pricing installation, startup assistance and training (man-hours, expenses, etc.).

5.2.5 Description of controls and operations data presentation.

5.2.6 Motor list.

6.0 SUMMARY AND CONCLUSIONS:

A compressed air system for a manufacturing plant such as a forest products facility should be sized for the expected plant load plus design factors including water vapor removal, dryer usage, possible equipment omissions, future expansion, leakage and testing accuracy. The result of these factors may be that the design flow is as much as 60 percent higher than the expected plant load. When the load consists of compressed air cylinders, then the engineer will need to predict the flow based on the design processing rate of the plant. Otherwise, the equipment vendors will usually be responsible for providing the load. The loads must always be standardized to inlet air pressure, that is, the average barometric pressure of the facility.

A dryer is usually required. Dryers may be desiccant or refrigerant-type. Desiccant-type dryers are usually preferred if the ambient temperature is expected to get below freezing.

A receiver system is required to improve compressor control, reduce pulsation and reduce the effect of demand spikes on the compressor and dryer.

An oil/water separator may be required for oil-flooded rotary screw compressors to meet environmental requirements for water discharge purity.

Once the requirements of the system have been determined, the specifications can be written so that the system can be put out for bids.

