HEAVENT

Step-by-Step Example Problem

Step-by-Step Example Problem

 Steven E. Guffey, PhD, CIH

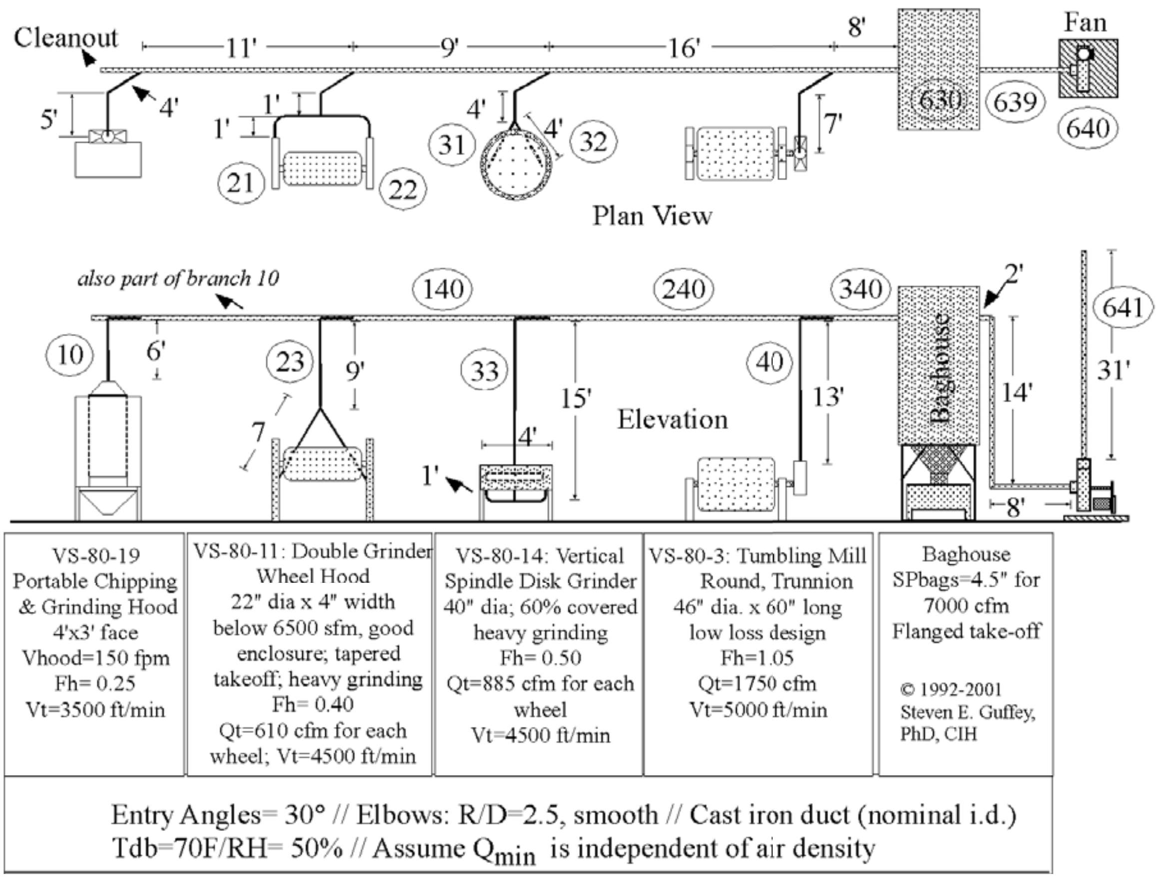


Figure 1: The Example Problem Statement

LEARN BY DOING

It is said that the best way to learn is by doing. With that thought in mind, this section is one long tutorial centered on computing pressures and flows for one example problem (see Figure 1). Do not be concerned if the numbers on these pages do not match yours exactly. While putting the screen shots together I was making concurrently changing the problem and changing some of the program's displays.

OVERVIEW OF HEAVENT AND DESIGN

Heavent can be used to design a new system, redesign an existing system, or troubleshoot an existing system. For all three, you should (1) gather information before using Heavent, (2) start Heavent and choose or create a file to save your data to, (3) lay out the ductwork in the schematic view, (4) input information about each branch, submain, main, and air-cleaning device, and (5) make design or other decisions based on the results.

In each case, it is necessary to do certain steps, which are described next.

STEPS PRIOR TO USING HEAVENT

To use Heavent efficiently, there are some things you should do prior to creating a file and inputing information.

1. For hoods, determine airflow and velocity goals as well as temperature and humidity conditions for each hood. Determine the target velocity for each duct.
2. Lay out the path of the duct system connecting the hoods to the fan and air-cleaning devices.
3. Label all ducts (e.g., branches and submains) and air-cleaning devices
4. Determine centerline-to-centerline distances for duct lengths.
5. Make choices about fittings to use (e.g., radius of curvature of elbow, type of hood take-off, etc.

To reliable control airborne contaminants, hoods must be (i) designed appropriately, (ii) employed under favorable conditions, including use of good work practices, and (iii) supplied sufficient exhaust air based on the hood design, work conditions, and work practices. Thus, a minimum airflow (Q_{min}) must be specified for each hood.

For the hoods to work *reliably*, it is imperative that particulates fly through the ducts and not settle inside them, where they would then impede or even block the flow. One avoids settling by selecting “duct sizes” (i.e., duct cross-sectional areas) that are small enough that the minimum duct velocity (V_{min}) is high enough to transport the particulates. On the other hand, duct abrasion and pressure increase with velocity squared, so it is prudent to select the largest duct that produces a velocity lower than the V_{min}.

Even if there are no particulates in the ducts so that settling is not a consideration, it is convenient to size ducts based on a target velocity. In that case, the goal is not avoidance of settling but minimization of total system costs. Larger ducts require lower pressures, but cost more and are more difficult to install in crowded or tight spaces.

Note that Heavent initially assigns a default value for both V_{min} and Q_{min} for each duct. You can change the default value from the Main: Default Menu.

STEPS TO COMPUTING PRESURES AND FLOWS FOR A NEW SYSTEM

Create a new file or open an existing file (see Main Menu: Files), then:

I. Set defaults

II. Set toggles (especially whether or dampers will be used)

III. Lay out the system (i.e., link duct together)

IV. Set minimum airflow, duct velocity, duct temperature, etc.

V. Input duct lengths, number of elbows, and other descriptors for the system

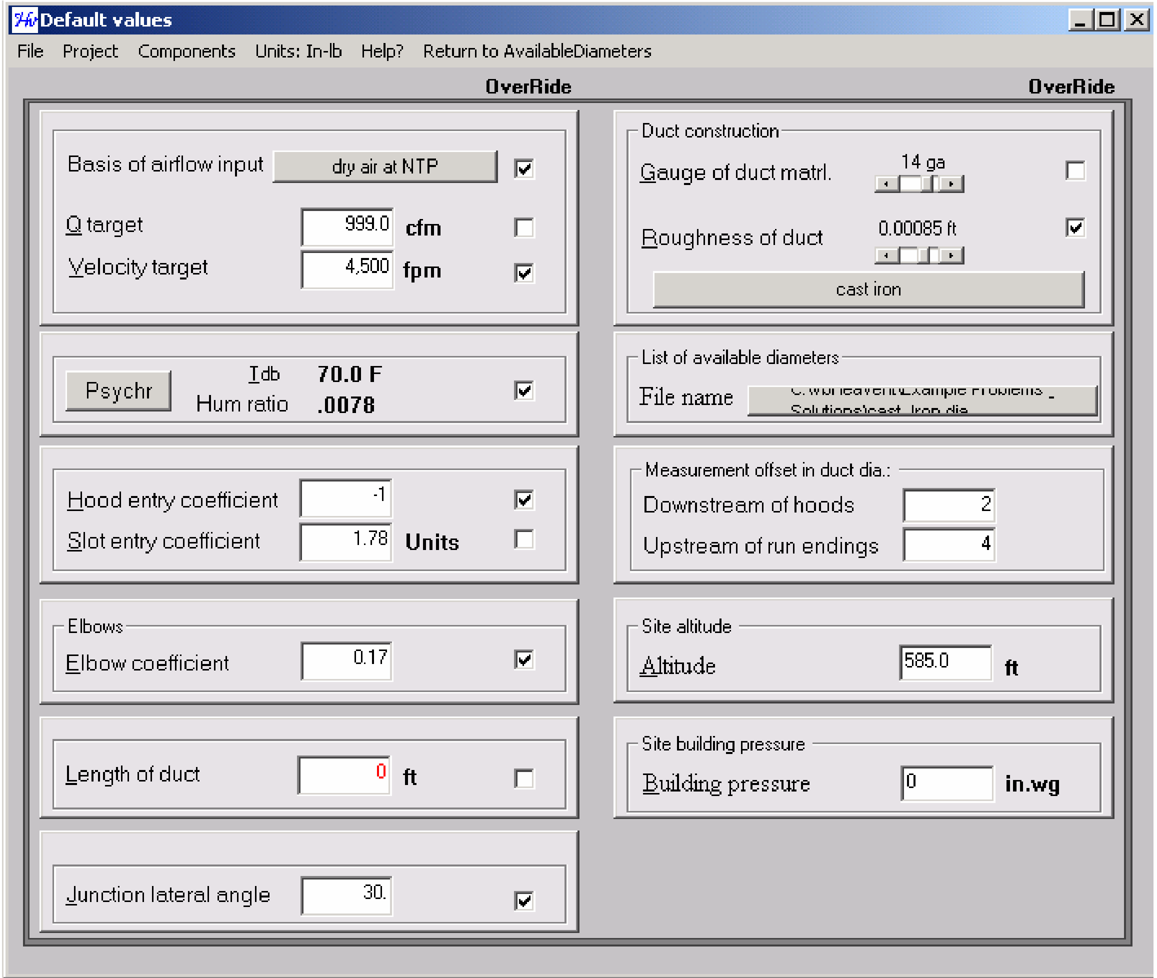
VI. Optimize airflow distribution if dampers are not used

I. SET DEFAULTS

Setting defaults saves you from repetitive inputs when the same values appear on many ducts. Heavent automatically assigns the default values to any new duct you create. If you set the default values before creating the system, you reduce the number of inputs dramatically. For example, if the loss coefficient for elbows on most ducts will have a value of 0.12 and you have a default value of 0.19, then you will have to input a value of 0.12 for each of those ducts. On the other hand, if you set the default value to be 0.12, then you must change the value only for those ducts whose Fel value is NOT 0.12. It saves you time.

In this example, you are given on Figure 1 the following values for all ducts:

Entry angles for laterals = 30 degrees
Elbows are smooth and have a radius of curvature of 2.5 (i.e., R/D = 2.5)
Ducts are cast iron
Tdb = 70F and relative humidity = 50%. Altitude is 585 ft
Q_{min} should be inputted based on Qstd. It is not a consistent value from hood to hood
Measurements will be taken later 2D downstream of hood connections and 4D upstream from junction fittings

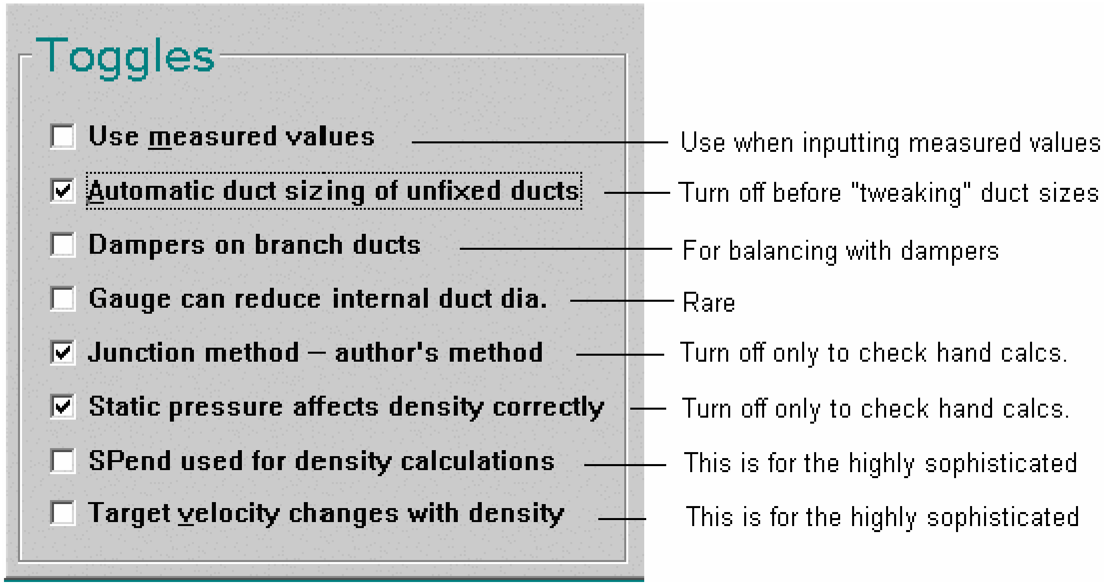


Note that we clicked on the checkbox to the right of each input to "Over ride" previous inputs, making all values equal to our default values for each of those variables. Because of the Over Ride feature, we can change our minds or choose to set default values whenever we choose. The main limitation to keep in mind is that there is no "undo" to put individual values back to previous inputted values.

II. SET TOGGLES

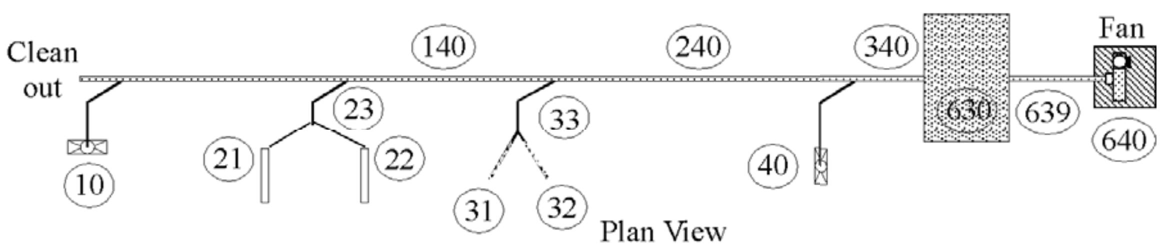
Let us assume that we do not wish to use dampers for this particular system. How do we tell the program that? The answer is the Toggles Screen, which lets us tell the program how we want it to work.

As shown on the figure below, we would choose to have only a few thing clicked on for a new system design



LAYING OUT THE NEW SYSTEM

You "layout" or link a system together in the Schematics screen. You can start with the single-branch default system and build on to it, or you can generate a multiple branch system and modify it to match the desired system. A straight-line system is one without any subsystems. Put another way, if two submains are connected at a junction fitting, each upstream section is a subsystem. The example problem has two subsystems: submain 23 with branches 21 and 22, and submain 33 with branches 31 and 32.

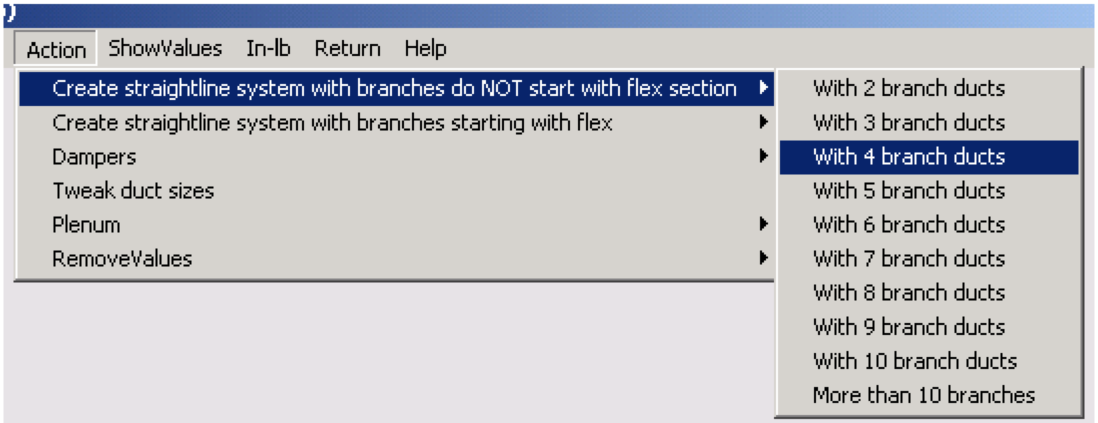


Laying Out the system, starting with a multiple-branch straight-line system

For this example problem, we will start with a straight line system, which we will generate in the Schematic screen:

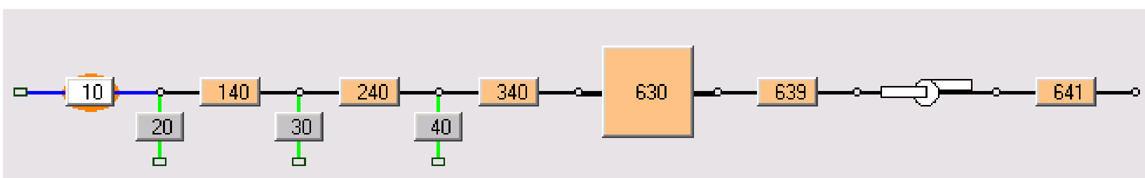
A. From the bar menu across the top of any menu, select Project/Schematic

B. Click "Action" on the menu bar button and choose to create a 4-branch, straightline system with branches that do not start with flexible sections. We chose 4 "branches" since there are only 4 junctions off the main system.



Note that the horizontal portion of Branch 10 is not given a separate ID number since all of the airflow through the hood flows through the horizontal section without mixing with airflow from another duct.

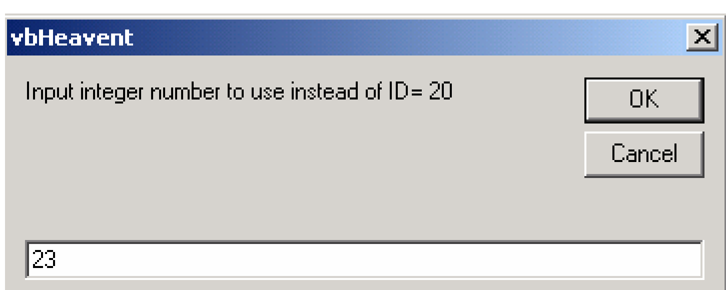
So we click on the right arrow of the scroll bar until "4 branches" appears.



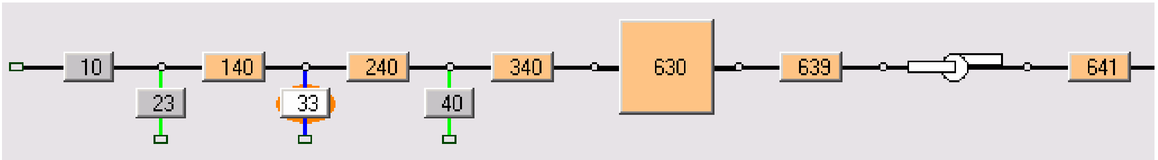
Adding the Subsystems at the Layout Screen

As expected, all of the branch ducts come off to one side and there are no subsystems. It looks a lot like the system we want, except that some of the ID numbers assigned by the program are not the ones we wanted, and we need to add branches 21, 22, 31 and 33. To modify the layout to match what we need, we click on the "branch" ducts that should be submains and add branches upstream of them.

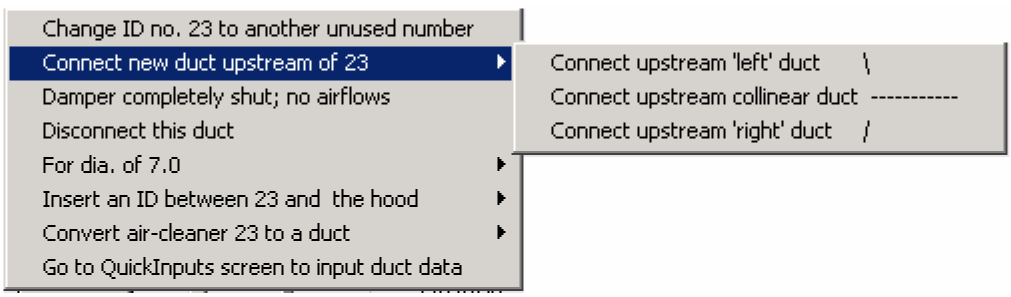
First we click on duct 20 and choose to "Change Id no. 20 to another unused number."



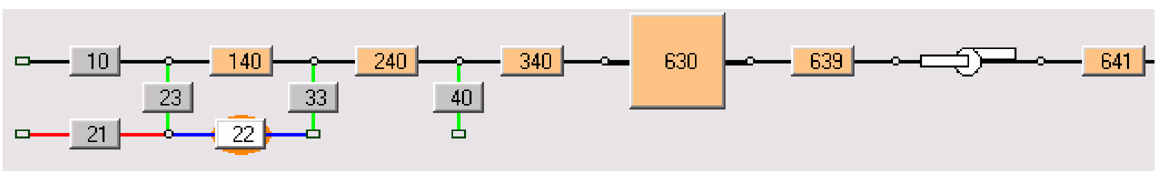
We do the same for duct 30, changing its ID to 31, which gives us the following:



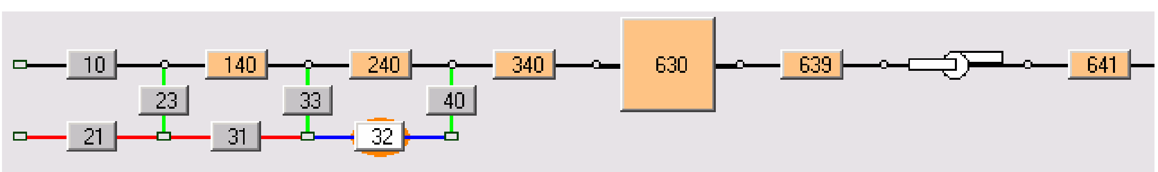
Now we will “Connect” branches 21 and 22 to duct 23 by clicking on duct 23 and selecting “Connect “. Note that “connect” is used to add a duct id upstream of the current location and to do so only when there is presently no duct in that position. The available positions are ‘left’, ‘collinear’, and ‘right’. The left and right are based on a view looking down towards the fan. For example, duct 40 is the right of 340.



Branch 21 should be added by selecting “Connect upstream ‘left’ duct \”, then branch 22 should be added by selecting “Connecting upstream ‘right’ duct /”. The result of both connections are shown below.



Similarly, Branches 31 and 33 should be connected upstream of duct 33, giving the results shown below. Note that Branch 31 now obscures Branch 22.



INPUTTING DUCT INFORMATION

Heavent will automatically assign the default values for parameters that have defaults, and it will select a tentative duct size from the list of available round duct diameters. Your task is to change those items that should differ from the default value.

For round ducts, Heavent immediately determines an initial duct diameter, so we will not concern ourselves about it until we are ready to “optimize” duct sizes. In the meantime, we must describe the ducts to Heavent and our goals for them to Heavent. Our goals are to have a minimum airflow through hoods (Qmin) and a minimum velocity through each duct (Vmin). For each duct we must input the length, roughness, and gauge (or allow the values to remain at the default values), as well as the number of elbows and their loss coefficient.

Only branch ducts begin with hoods, so we will input hood entry coefficients, minimum airflows, temperature, and humidity only for branch ducts. A branch is any duct into which air flows from the ambient atmosphere (e.g., the factory room).

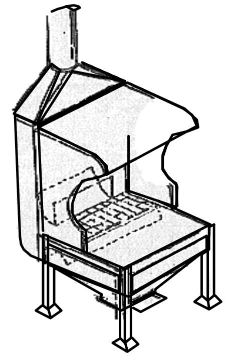
We can input these data either in the QuickInputs Screen or in specialized screens, such as screens for inputting hood entry coefficients, duct roughness, length and gauge, number of elbows, etc. In most cases, it is your choice which you employ. The exceptions are temperatures and humidities, which can be inputted only in “Airflow and Psychrometrics Screen”. Also, the QuickInputs Screen is more restrictive in what it allows you to input in some cases.

For this example problem, we will start inputs using the QuickInputs Screen. Note that many inputs are already taken care of by defaults.

ID	Type	Shape	Init.Dia.	Fix Dia	Dia	Width	Q basis	min.Q	min.Vd	Fhood	SPfilter	Length	Rough	Gau
10	Branch	Round	3.79		3.0	n/a	dry air at NTF	350	4500	0.25	0	0	0.0008	16
23	Branch	Round	3.78		3.0	n/a	dry air at NTF	350	4500	0.25	0	0	0.0008	16
33	Branch	Round	3.78		3.0	n/a	dry air at NTF	350	4500	0.25	0	0	0.0008	16
40	Branch	Round	3.79		3.0	n/a	dry air at NTF	350	4500	0.25	0	0	0.0008	16
140	Submain	Round	5.45		5.0	n/a		----	4500	----	----	0	0.0008	16
240	Submain	Round	6.65		6.0	n/a		----	4500	----	----	0	0.0008	16
340	Submain	Round	7.67		7.0	n/a		----	4500	----	----	0	0.0008	16
639	FanInlet	Round	8.79		8.0	n/a		----	3600	0	----	0	0.0008	16
641	FanExhaust	Round	8.79		8.0	n/a		----	3600	----	----	0	0.0008	16

☐ Show slot data ☐ Show temp./hum. ☐ Show roughness and gauge ☐ Show specified take off data ☐ Show %min

To reduce the visual clutter, Heavent allows you to hide columns of data that are not relevant to a particular system. In this case, we should select the checkbox only for "Show slot data."



Temperature, humidity, roughness and gauge are all at default values, and airflow for these branches is not based on specified take-off diameters and velocities or minimum hood static pressures.

Branch 10

Let us enter the required inputs for Branch 10, doing them in the order they appear on the table to make it easier to follow. We start with the required airflow from the problem statement:

$$Q = V_{face} \times A_{face} = 150 \text{ fpm} \times (4 \text{ ft} \times 3 \text{ ft}) = 1800 \text{ cfm}$$

We input 1800 cfm under the column for "min.Q" by clicking on the cell for Branch 10 (see above). Note that the program assigned an initial diameter of 8 inches. We will not question that choice at the moment, but we will re-visit it during "optimization" after all data has been inputted.

Init.Dia.	Fix Dia	Dia	Width	Q basis	min.Q
8.6		8.0	n/a	dry air at NTF	1800
3.79		3.5	n/a	dry air at NTF	350
3.79		3.5	n/a	dry air at NTF	350

Hood pressure losses: Air entering a duct from a hood can have experienced three types of losses: slot-expansion, filter, and duct-entry. In this case there is no filter, but there is a slot with a desired minimum velocity of 1000 ft/min. Heavent will display the input columns for slot losses if you click the checkbox on the bottom of the QuickInputs screen.

☑ Show slot data ☐ Show temp./hum. ☐ Show roughness and gauge ☐ Show specified take off data ☐ Show %min

Note that for slot-expansion losses, Heavent will compute the pressure and one unknown for you: either slot height or slot velocity. Thus the first input must be to choose which you will have Heavent compute for you. In this case it is slot height.

ID	Type	Fhood	SPfilter	Slot basis	Nslot	Lslot	Hslot	Vslot	SPslot
10	Branch	0.25	0	no slot	1.0	30.0	5.56	0	0
21	Branch	0.4	0				6	0	0
22	Branch	0.4	0				6	0	0
23	Submain	----	----					----	----

Slot basis drop-down list:
- no slots - 0
- Lslot computed by Heavent - 1
- Hslot computed by Heavent - 2
- Vslot computed by Heavent - 3

Giving the result below:

ID	Type	Fhood	SPfilter	Slot basis	Nslot	Lslot	Hslot	Vslot	SPslot
10	Branch	0.25	0	Hslot	1.0	30.0	5.76	1500	0.245

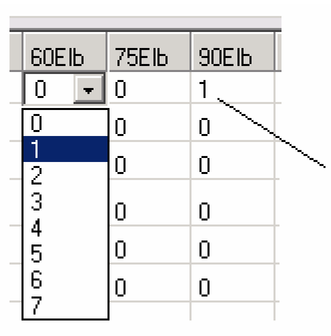
Note that SPslot sill vary as other changes are made to the system because the actual airflow (as opposed to the minimum airflow) will vary with relative resistances to flow.

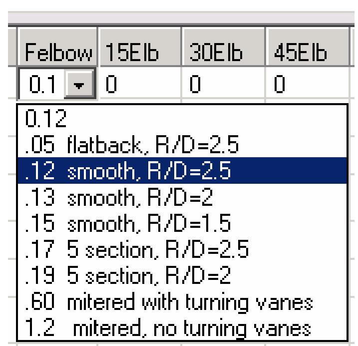
Duct velocity: the default duct velocity was 4500 ft/min, but according to Figure 1, this branch requires only 3500 ft/min. As shown below, we click on the cell in the row for Branch 10 under the "min.Vd" column, and input the value of 3500.

Init.Dia.	Fix Dia	Dia	Width	Q basis	min.Q	%minQ	min.Vd	%minVd
9.75		9.0	n/a	dry air at NTF	1800	156%	3500	181%
3.79		3.5	n/a	dry air at NTF	350	103%	4500	120%
3.79		3.5	n/a	dry air at NTF	350	109%	4500	126%

Heavent adjusted the duct diameter from 8" to 9" for the lower velocity. [Note that %minQ and %minVd are very high. Don't worry about those columns until it is time to optimize.]

Elbows: From inspection of the figure, we can see one 90-degree turn and one 60-degree turn. [The junction fitting that includes the blanked off cleanout is not an elbow.] We input those on the QuickInputs table, as shown below. Although it is not necessary since the value for this duct is the same as the default value, we can input the elbow loss coefficient (Felbow), as shown below.





Duct length, gauge, and roughness: In similar fashion, we can input these parameter values. Note that Branch 10 extends all the way to Submain 140 since the cleanout "junction" has no airflow.

Length	Rough	Gauge
26.0	0.0008	16
0	0.0008	16
0	0.0008	16

Length	Rough	Gauge	Felbow	15Elb	30Elb	45Elb	60Elb	75Elb	90Elb	No
26.0	0.0	16	0.17	0	0	0	1	0	1	1.7

0.00085	default value
0.00001	drawn tubing
0.00015	uncoated clean carbon steel / PVC / Aluminum
0.0003	galv steel: 4' joints longit. or most spiral (e.g.,1,2, or 3 ribs (12'Joints)
0.0004	asphalted cast iron / used galvanized with 4' joints
0.0005	galvanized longitudinal steel with joints every 2.5'
0.00085	cast iron
0.003	wood stave / rigid fibrous glass / fiberglass smooth lining
0.005	fully extended metallic or fabric flexible
0.01	riveted steel / spray-coated fiberglass lining / loose wire & fabric flexible
0.1	fabric over wire flex duct in bad shape

Fmisc: Branch 10 extends all the way to Submain 140 since the cleanout "junction" has no airflow. However, it really is connected to itself with a junction fitting, which is now acting as an elbow. We could input another elbow, but it is perhaps clearer to input an additional loss for the junction as Fmisc. In this case, we inputted 0.20 – a typical value for elbows. It is quite possible that a far higher value should be used.

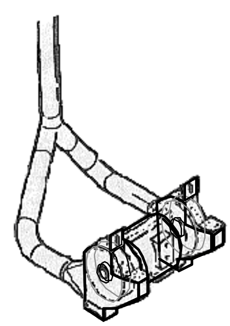
NoEq90	Fmisc	LatAngle
1.7	0.2	0
1.0	0	30
1.0	0	30

Lateral angle: Note that if we try to input a lateral angle for Branch 10, Heavent will return the value to an angle of zero. It does that because we have specified that this duct goes straight into the downstream submain. Therefore, the angle must be zero.

Fmisc	LatAngle	Comments and warnings
0.2	0	
0	30	

Note in the figure above that there is nothing included under 'Comments and warnings' for this duct. If a warning is given, it should be investigated thoroughly.

<u>Branches 21 and 22</u>



Let us go through Branch 21, but do so much more expeditiously. In Figure 1, we are given that each grinding wheel hood should receive at least 610 cfm, the minimum duct velocity is 4500 ft/min, and Fh = 0.40. There are no slot-expansion losses or filter losses. From inspection of the line drawing, the duct length is 8 ft and there is one 90-degree elbow. This angle of entry into Submain 23 should be 45-degrees. Branch 22 is identical.

After entering the values in the same manner as we did for Branch 10 for Branches 21 and 22, we should see the following on the QuickInputs screen.

ID	Type	Shape	Init.Dia.	Fix Dia	Dia	Width	Q basis	min.Q	min.Vd	Fhood	SPfilter	Slot basis
10	Branch	Round	9.77		9.0	n/a	dry air at NTF	1800	3500	0.25	0	no slot
21	Branch	Round	5.03		5.0	n/a	dry air at NTF	610	4500	0.4	0	no slot
22	Branch	Round	5.02		5.0	n/a	dry air at NTF	610	4500	0.4	0	no slot

If we scroll to the right, we see the elbow, Fmisc and lateral angle inputs (see below).

Length	Rough	Gauge	Felbow	15Elb	30Elb	45Elb	60Elb	75Elb	90Elb	NoEq90	Fmisc	LatAngle	Comme
26.0	0.0008	18	0.12	0	0	0	1	0	1	1.7	0.2	0	
8.0	0.0008	16	0.12	0	0	0	0	0	1	1.0	0	30	
8.0	0.0008	14	0.12	0	0	0	0	0	1	1.0	0	30	

Under 'Comments and warnings' Heavent notes that airflow is nearly 170% of Qmin for Branch 10. That excess is temporary and we will not worry about it until all branch and submain data entry is complete.

<u>Submain 23</u>

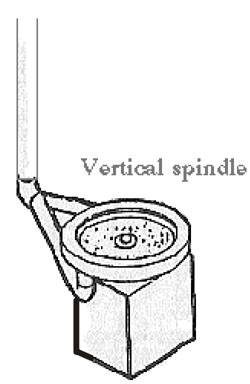
The inputs for Submain 23 are similar to the branch duct inputs, except that there is no minimum airflow to input, or is there an Fh value to input. We just input the duct length (14 ft) and the number of elbows (1-90 degree and 1-60 degree).

ID	Type	Length	Rough	Gauge	Felbow	15Elb	30Elb	45Elb	60Elb	75Elb	90Elb	NoEq90	Fmisc	LatAngle	Comme
10	Branch	26.0	0.0008	18	0.12	0	0	0	1	0	1	1.7	0.2	0	
21	Branch	8.0	0.0008	16	0.12	0	0	0	0	0	1	1.0	0	30	
22	Branch	8.0	0.0008	14	0.12	0	0	0	0	0	1	1.0	0	30	
23	Submain	14.0	0.0008	16	0.12	0	0	0	1	0	1	1.7	0	30	

Note that the lateral angle for Branches 21 and 22 and for Submain 23 is 30-degrees.

<u>Branches 31 and 32 and Submain 33</u>

This is very much the same as the 21-22-23 duct subsystem. In Figure 1, we are given that each vertical spindle disk grinder hood should receive at least 885 cfm, the minimum duct velocity is 4500 ft/min, and Fh = 0.50. Branch 32 is identical to 31. There is a slot-expansion loss for each take-off, but no filter losses. The slot is 40 inches long and 1 inch in width for each hood. Unlike the slot for Branch 10, the entry coefficient for this slot (F_{slot})is 1.0, not the default value. From inspection of the line drawing for both branches, the duct length for each is 5 ft and there is one 90-degree elbow for each. The angle of entry into Submain 33 should be 45-degrees. We can't alter the slot coefficient in the QuickInputs screen, but we will come back to it shortly.

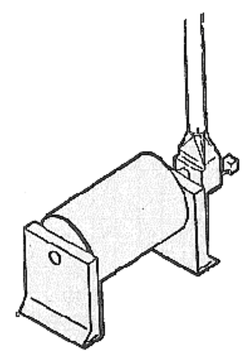


After entering the other values in the same manner as we did for Branches 21 and 22, we should see the following on the QuickInputs screen.

ID	Type	Shape	Init.Dia.	Fix Dia	Dia	Width	Q basis	min.Q	min.Vd	Fhood	SPfilter	Slot basis	Nslot
10	Branch	Round	9.77		9.0	n/a	dry air at NTF	1800	3500	0.25	0	Vslot	1.0
21	Branch	Round	5.03		5.0	n/a	dry air at NTF	610	4500	0.4	0	no slot	----
22	Branch	Round	5.02		5.0	n/a	dry air at NTF	610	4500	0.4	0	no slot	----
23	Submain	Round	7.11		7.0	n/a		----	4500	----	----	----	----
31	Branch	Round	6.04		6.0	n/a	dry air at NTF	885	4500	0.5	0	Vslot	1.0
32	Branch	Round	6.04		6.0	n/a	dry air at NTF	885	4500	0.5	0	Vslot	1.0
33	Submain	Round	8.55		8.0	n/a		----	4500	----	----	----	----

Lslot	Hslot	Vslot	SPslot	Fslot	Length	Felbow	15Elb	30Elb	45Elb	60Elb	75Elb	90Elb
30.0	5.44	1588	0.274	1.78	26.0	0.12	0	0	0	1	0	1
----	----	----	----	----	8.0	0.12	0	0	0	0	0	1
----	----	----	----	----	8.0	0.12	0	0	0	0	0	1
----	----	----	----	----	14.0	0.12	0	0	0	1	0	1
60.0	1.06	2042	0.255	1.0	5.0	0.12	0	0	0	0	0	1
60.0	1.06	2042	0.255	1.0	5.0	0.12	0	0	0	0	0	1
----	----	----	----	----	23.0	0.12	0	0	0	1	0	2

You can input Fslot on the QuickInputs screen or from the Hood Losses screen under the menu bar (Components/Hood losses). For this example, we will input it from QuickInputs.



Branches 40

In Figure 1, we are given that the Tumbling Mill hood should receive at least 1750 cfm, the minimum duct velocity is 5000 ft/min (not the default, 4500 ft/min), and Fh = 1.05. There is no slot-expansion, so there is no slot loss. We input these values as shown below.

ID	Type	Dia	Width	Q basis	min.Q	min.Vd	Fhood	SPfilter	Length	Felbow	15Elb	30Elb	45Elb
10	Branch	9.0	n/a	dry air at NTF	1800	3500	0.25	0	26.0	0.12	0	0	0
21	Branch	5.0	n/a	dry air at NTF	610	4500	0.4	0	8.0	0.12	0	0	0
22	Branch	5.0	n/a	dry air at NTF	610	4500	0.4	0	8.0	0.12	0	0	0
23	Submain	7.0	n/a		----	4500	----	----	14.0	0.12	0	0	0
31	Branch	6.0	n/a	dry air at NTF	885	4500	0.5	0	5.0	0.12	0	0	0
32	Branch	6.0	n/a	dry air at NTF	885	4500	0.5	0	5.0	0.12	0	0	0
33	Submain	8.0	n/a		----	4500	----	----	23.0	0.12	0	0	0
40	Branch	8.0	n/a	dry air at NTF	1750	5000	1.05	0	24.0	0.12	0	0	0

The rest of the scrolling table is shown to below.

45Elb	60Elb	75Elb	90Elb	NoEq90	Fmisc	LatAngle	Comments and warnings
0	1	0	1	1.7	0.2	0	
0	0	0	1	1.0	0	30	
0	0	0	1	1.0	0	30	
0	1	0	1	1.7	0	30	
0	0	0	1	1.0	0	30	
0	0	0	1	1.0	0	30	
0	1	0	2	2.7	0	30	
0	1	0	1	1.7	0	30	

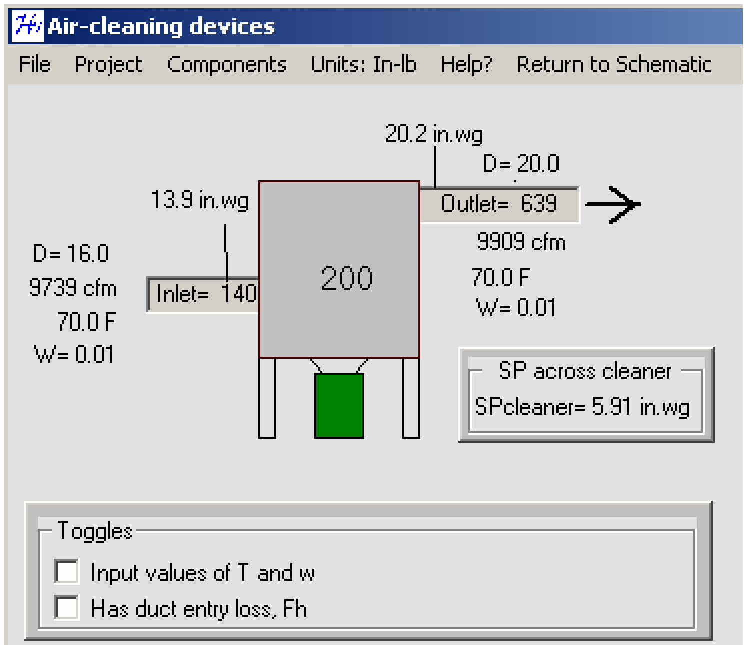
Submains 120, 130 and140 Main 340

Submains and mains are easily completed since there are fewer input variables involved. Indeed the only variables not taken care of by defaults are duct length and number of elbows. The results of those inputs are shown below.

ID	Type	Length	Felbow	15Elb	30Elb	45Elb	60Elb	75Elb	90Elb	NoEq90	Fmisc	LatAngle
22	Branch	8.0	0.12	0	0	0	0	0	1	1.0	0	30
23	Submain	14.0	0.12	0	0	0	1	0	1	1.7	0	30
31	Branch	5.0	0.12	0	0	0	0	0	1	1.0	0	30
32	Branch	5.0	0.12	0	0	0	0	0	1	1.0	0	30
33	Submain	23.0	0.12	0	0	0	1	0	2	2.7	0	30
40	Branch	24.0	0.19	0	0	0	1	0	1	1.7	0	30
120	Submain	9.0	0.12	0	0	0	0	0	0	0	0	0
130	Submain	16.0	0.12	0	0	0	0	0	0	0	0	0
140	Submain	8.0	0.12	0	0	0	0	0	0	0	0	0

AIR-CLEANER

The next step is to input parameter variables for the air-cleaner serving this system.



The air-cleaning device for this system is a baghouse with a flanged takeoff. This cannot be inputted in the QuickInputs screen. To access the appropriate input screen we go to the bar menu to "Components>>Air-Cleaning Devices." Alternatively, we can click on the Air-Cleaning Device block on the Schematic of the system and choose "go to air-cleaning devices to input data." The Air-Cleaning Devices screen (see portion above) is designed to assist you input information on the pressure characteristics of the air-cleaning device.

Filter losses for the baghouse: The program expects you to input values it can substitute in the following equation:

$$SP_{pred} = SP_{pred}\left(\frac{Q_{pred}}{Q_{given}}\right)^{x}\left(\frac{\rho_{pred}}{\rho_{given}}\right)$$

where: "pred" is predicted

"x" refers to an exponent between 1.0 and 2.0 (typically, x = 1.0 for filters and x = 2.0 for non-filters)

"ρ" refers to density

For this system, we are given that:

Q_{given} = 7000 cfm when SP_{given} = 4.5 inches w.g. at density = 1.0.
It has a flanged takeoff.

At the bottom of the screen a scrolling table shows typical values for air-cleaning devices. Baghouses would be covered under "Industrial Filters." We see that pressures are typically around 4 inches w.g. and that the "exponent" has a value of 1.

Typical values

Type	Device	SPreq,in.wg	Exponent
Industrial filters	Cloth bag or envelope	>4	1
High voltage precip.	Single stage (plate or pipe)	<1	2
Dry inertial coll.	Settling chamber	<0.1	2

We input this information so that the table below the air-cleaning figure shows:

ID	Qinlet	Tinlet	Texit	Winlet	Wexit	SPfixed	SPknown	Qknown	DFknown	Exponent	SPdevice	Fhood
630	4398	70.0	70.0	0.008	0.008	0	0	4189	1.0	0	0	0.25

Note that "Fixed SP" is reserved for pre-filters, which are treated here as having a constant pressure requirement.

Flanged takeoff: The air-entering the flanged takeoff from the plenum at the top of the baghouse must speed up from nearly zero to thousands of feet per minute. To the air, the entry into the duct looks just like the entry into a duct from an enclosing hood, and it incurs a hood-entry loss (F_{hood}) just like a duct entry from a hood.

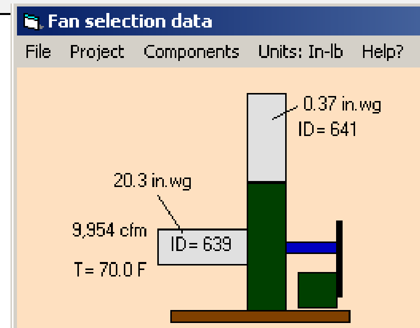
Toggles

- ☐ Input values of T and w
- ☑ Has duct entry loss, Fh   Duct entry coef, Fh = 0.25

The value for a flanged hood is 0.5, which is inputted in the table below the air-cleaner schematic. Note that it is possible to input the exit temperature and humidity (w) expected for the air-cleaner. This is appropriate for scrubbers, but not baghouses.

Note that the duct size that can be connected to the air-cleaner is fixed by the outlet port. If so, input that diameter for Main 639 and set it to "fixed" so that Heavent will not change the value.

Fan

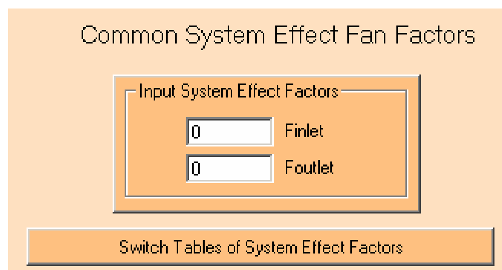


Inlet and outlet diameters: The ducts connected to the inlet and outlet must match them in area and shape. However, we can't select the most appropriate fan until we have finished designing the system. For that reason, we should simply stick with Heavent's choice for inlet and outlet diameter until after we have selected the fan and the actual values are known. At that point, we can come back and input the correct values. That change will affect the fan pressure, so we would need to select the fan rotation rate after making all final corrections to the system.

Heavent computes fan pressures using estimated system flows and pressures. In addition, it computes the values one would look up in fan tables when actually selecting the fan.

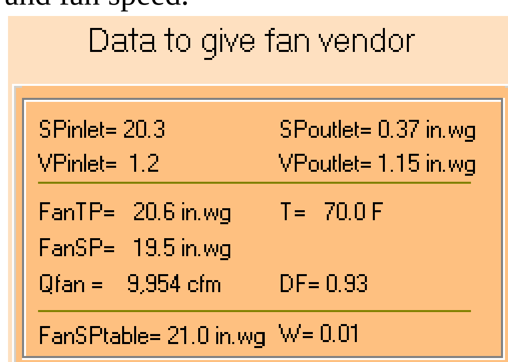
To see fan selection data, select Components>>Fan from the bar menu at the top of any screen.

System effects: Non-ideal inlet and outlet conditions can reduce fan performance, forcing selection of a higher rotation rate and a larger motor. For Heavent to account for these so-called "system effects" we must enter coefficients from the Fan Selection screen, as shown to the right. The most common system effect coefficient values are shown in a table below the inputs. For this system the system effect coefficients are both zero since there is at least 4 diameters length of straight duct up and downstream of the fan and there are no expansions or contractions immediately upstream of the fan.



Note that system effect factors do not affect pressures in the system at all. They are kludges computed to help in selecting a larger motor and fan speed.

Fan Pressure: Heavent uses the fan data it has computed and the system effect factors you have computed to compute the actual fan pressure and the equivalent "FanSPtable" value (see the last row on "Data to give fan vendor"). FanSPtable is a "work-around" to allow appropriate selection from vendor catalogues.



1. actual fan static pressure:

$$\text{Fan SP} = \text{Fan TP} - VP_{outlet} = SP_{outlet} - SP_{inlet} - VP_{inlet}$$

b. equivalent table value (a work-around to correct for the limitations of fan tables):

$$\text{Table Pressure} = \frac{\text{Fan Pressure} - SP_{bldg} + F_{inlet}VP_{inlet} + F_{outlet}VP_{outlet}}{df}$$

Table Q = actual Q

Note: Q should be the actual, not “standard” airflow.

After Inputting All Data and Design Choices: Optimizing A New system’s Duct Sizes

In duct design, an optimized system is one which is laid out to minimize interference with the process and will perform reliably at the least cost. The least cost system uses the most economic combination of fan pressure, fan airflow, and choice of duct sizes. Larger ducts cost more, but require lower fan pressures than a set of smaller ducts. However, minimizing fan airflow is crucial since excessive airflows require greater energy costs and greater initial costs due to the necessity for selecting larger submains, mains, fan and air-cleaner device.

Heavent makes it relatively easy to minimize airflow requirements. For a system that is laid out well, it becomes an exercise in tweaking duct size selections. The optimum system is the one whose combination of duct sizes produces the lowest fan airflow and pressure while achieving at least the target airflow in every branch.

The best design strategy is to leave the automatic duct-sizing (Project>>Toggles) on until you have inputed all information about all branches and other ducts. When that is done, “fix” any duct sizes that must be set at a particular value, then turn off automatic duct sizing and “tweak” other duct sizes to obtain the optimal flows in the system. Of course, tweaking is not necessary if the system will be balanced with dampers (Project>>Toggles).

To assist in optimizing, the Schematic screen allows you to show the percent of target airflow (%minQ) going to each branch or the percent of target velocity for each duct. The most important value is %minQ at the fan. The best possible value is 100%, and values less than 120% may be the best you can achieve. By trial and error you can achieve an optimal or near optimal (i.e.,system.

At least one duct will have exactly %minQ=100. That duct is the most “starved” for air, and the attempt to supply it may be driving up airflows throughout the system. If one or two branches have high %minQ values, it is worthwhile to reduce their diameters and see what happens. If you like the result (%minQ at the fan gets closer to 100%), good; if not, change it back to the previous duct diameter. If all or nearly all branches except one or two have high %minQ values, it may be better to increase their diameters, particularly if their “%minV” values are excessive.

Input Information and Comments

The “Information On Project” screen (Files>>InformationOnProject) allows you to input information that will appear as the first page of the printed report. Similarly, you can input a comment about each duct at Components>>Comments.

Printing Reports

You reach the report section at File>>Print. Heavent displays the currently selected printer on the bar menu to the far right. The line below the bar menu shows the viewing printing options. The ones to the left let you view specific pages of the report before printing. The magnifying glass icon lets you zoom in or out, and the printer icon lets you print. The printout for this example problem is the file "foundry_smallChipGrind", which was included with the Heavent package.