4.0 Streams

Streams represent the flow of bulk material or discrete entities from one unit procedure (process step) to the next. They are displayed as polylines on the computer screen. Section 4.1 of this chapter describes the various types of streams. Section 4.2 provides information on viewing and editing stream properties. Section 4.3 explains how streams should be drawn. Section 4.4 describes the editing of stream elbows. Section 4.5 explains how stream tags (labels) can be edited. Section 4.6 provides information on editing the style of a stream. Finally, Section 4.7 describes the classification of input and output streams for costing, economic evaluation, and environmental impact assessment purposes.

4.1 Types of Streams

Depending on the nature of the material flow in a stream, Pro-Designer distinguishes between two types of streams:

a. Bulk Streams, and

b. Discrete Streams,

Bulk streams carry material measured by the usual flowrate units (kg/h, or kg/batch). The material can be in liquid, gaseous or solid phase but it is assumed to be uniform. The flow of discrete streams, on the other hand, is measured in Entities/h or Entities/batch. Each discrete stream carries one and only one type of entity (e.g., a 2-L Plastic Bottle). Bulk streams can only be attached to bulk-stream ports (of process steps) and discrete streams can only be attached to discrete-stream ports. If you start a stream by clicking on an output port, Pro-Designer automatically creates the correct stream type (bulk or discrete) depending on the type of the port that you started. When creating an input stream, Pro-Designer will decide the nature of the stream only after you have clicked on the port of the destination process step. Pro-Designer will not allow you to hook-up a discrete stream to a bulk port and vice versa.

From a simulation point of view, there are three kinds of process streams:

a. Input streams,

b. Intermediate streams, and

c. Output streams.

The properties of input streams (e.g., temperature, pressure, composition, flowrate, etc.) are specified by the user. The properties of intermediate and output streams (except density-related data) are calculated as the result of the simulation and cannot be edited.

When reporting the composition of bulk output or intermediate streams on the screen, components with zero flowrates are not reported. Input streams, on the other hand, display all registered ingredients (pure components and stock mixtures).

From a costing and economic evaluation standpoint, a stream can be classified as:

a. Raw Material Stream

b. Revenue Stream

c. Waste Stream (Solid Waste, Organic Waste, Aqueous Waste, or Emission)

Even though the distinction between bulk/discrete and input/output/intermediate streams is done automatically by the system, Pro-Designer relies on you to designate which streams take any one of the above characterizations (raw material/revenue/solid waste/liquid waste/emission).

4.2 Viewing and Editing Stream Properties

4.2.1 Bulk Streams

Most variables of bulk input streams are editable whereas for output and intermediate streams only density-related variables are editable.

Composition Tab (Figure 4.1) - To bring up this dialog, either pick **Simulation Data...** from the stream's right-click menu or simply double click on the desired stream line. It displays the current state of the stream (the temperature, pressure, activity, total flow for the whole stream, and the mass flow, weight percent, concentration and extracellular fraction for each ingredient currently registered in the stream). When a stream property is not editable (e.g., the activity property), it is displayed in a grayed rectangle frame. Notice that by clicking with the mouse inside such grayed frames, you cannot get into edit-mode and type new values in those fields. These properties are updated automatically as conditions that affect them change.

The user-modifiable stream properties include:

- the stream temperature, pressure and either the mass or volumetric flowrate if the option "Ingredient %" is selected and
- for each component:
  - the flowrate if the "Ingredient Flows" option is selected,
  - the weight percentage if the "Ingredient %" option is selected,
  - the extracellular percentage
- the density parameters (through the Density tab)

To specify the temperature and pressure, simply move the mouse over the temperature or pressure filed, click and type the new value. To specify each component's extracellular fraction, click on the corresponding cell in the composition table, and type in the new value. The stream i/o dialog allows the specification of the stream's composition to be made in two modes:

- **Flowrate Mode** (Ingredient Flows option selected)
  User specifies the flowrate of each ingredient individually (system calculates automatically the total mass and volumetric flow and the weight percent of each ingredient), or
- **Mass/Molar Percent Mode** (Ingredient % option selected)
  User specifies the total stream mass or volumetric flowrate and the mass/molar percentage of each ingredient. The system automatically updates the flowrate of

each ingredient. In this mode, it is up to the user to make sure that all mass/molar percentages add up to 100.

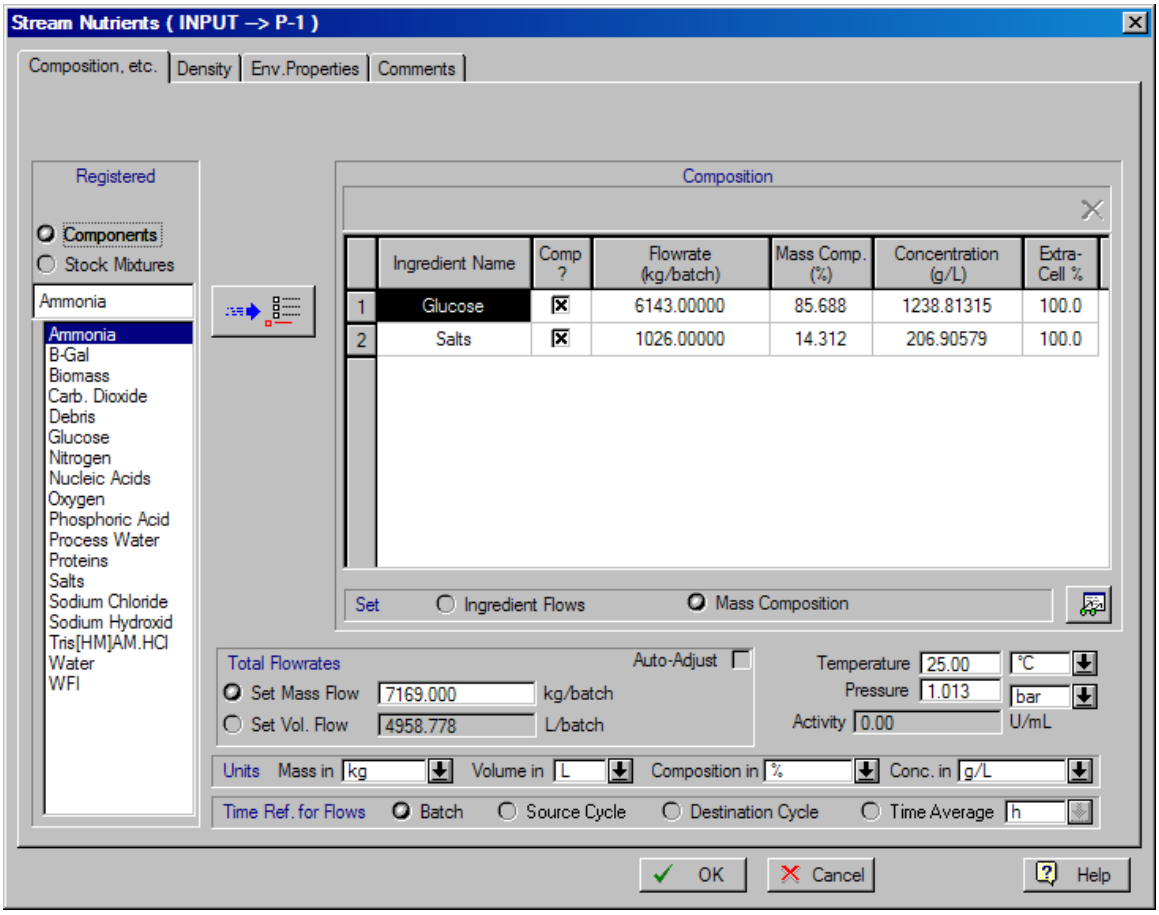

Figure 4.1: Bulk input stream dialog – Composition Tab.

Density Tab (Figure 4.2) - Through this tab, the user can specify either the *Density* of the stream or the *Volumetric Contribution Coefficients* (VCC) of the various components. The VCCs of a stream are used in calculating its volumetric flowrate and density according to the following equations:

$$V_{tot} = \sum \lambda_i \frac{m_i}{\rho_i}$$

and

$$\rho_{tot} = \frac{m_{tot}}{V_{tot}}$$

Where λ_i, m_i, and ρ_i are the VCC, mass flowrate, and density of component "i", respectively. V_{tot}, m_{tot}, ρ_{tot} are the stream's volumetric flowrate, mass flowrate, and density, respectively. The default VCC value for any component in any stream is equal to unity. This corresponds to volume additivity in the calculation of stream densities and volumetric flowrates. In general, the assumption of volume additivity leads to lower estimated densities and higher volumetric flowrates. This, in turn, leads to

oversizing of process equipment. You may use the following guidelines for specifying values of VCCs:

1) Assume a VCC of zero for addition into a solvent of a solid that dissolves.
2) Assume a VCC of 0.2-0.3 for addition of a solid that forms slurry with the solvent.

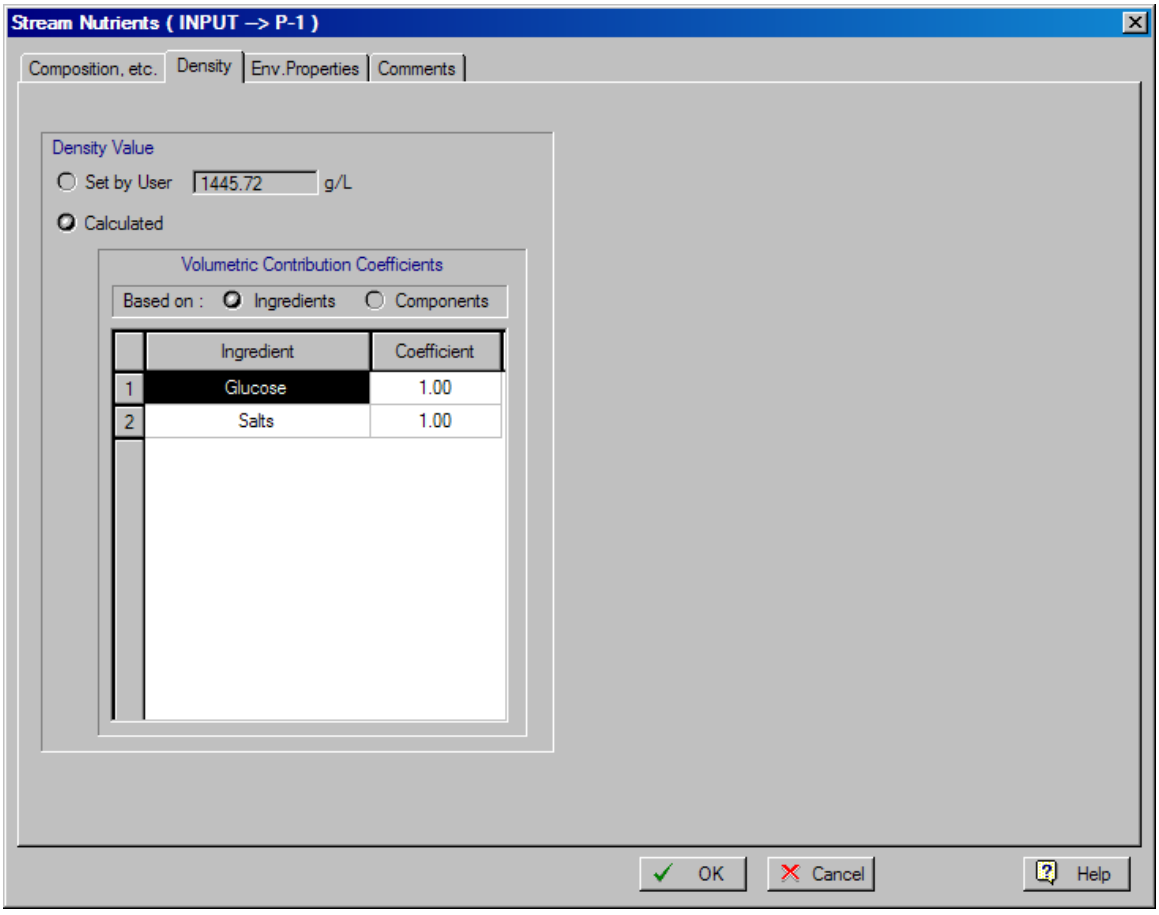

Figure 4.2: Bulk input stream dialog – Density Tab.

Env. Properties Tab (Figure 4.3) – This tab displays a set of collective environmental properties of the stream. Note that all the properties in this dialog are always non-editable (even for input streams). They are calculated based on the composition of the stream and the environmental contribution factors of the components that are present in the stream (see Chapter 3 for information on component environmental properties). The dialog displays the concentrations (in mg/L) and daily throughputs (kg/day) of the following environmental properties:

- Total Organic Carbon (TOC)
- Total Phosphorous (TP)
- Total Kjeldahl Nitrogen (TKN)
- Ammonia Nitrogen (NH3)
- Calcium Carbonate (CaCO3)
- Nitrate/Nitrite Nitrogen (NO3-NO2)

- Chemical Oxygen Demand (COD)
- Theoretical Oxygen Demand(ThOD)
- Ultimate Biochemical Oxygen Demand(BODu)
- 5-Day Biochemical Oxygen Demand (BOD5)
- Total Solids (TS)
- Total Suspended Solids (TSS)
- Volatile Suspended Solids (VSS)
- Degradable Volatile Suspended Solids (DVSS)
- Total Dissolved Solids (TDS)
- Volatile Dissolved Solids (VDS)
- Degradable Volatile Dissolved Solids (DVDS)

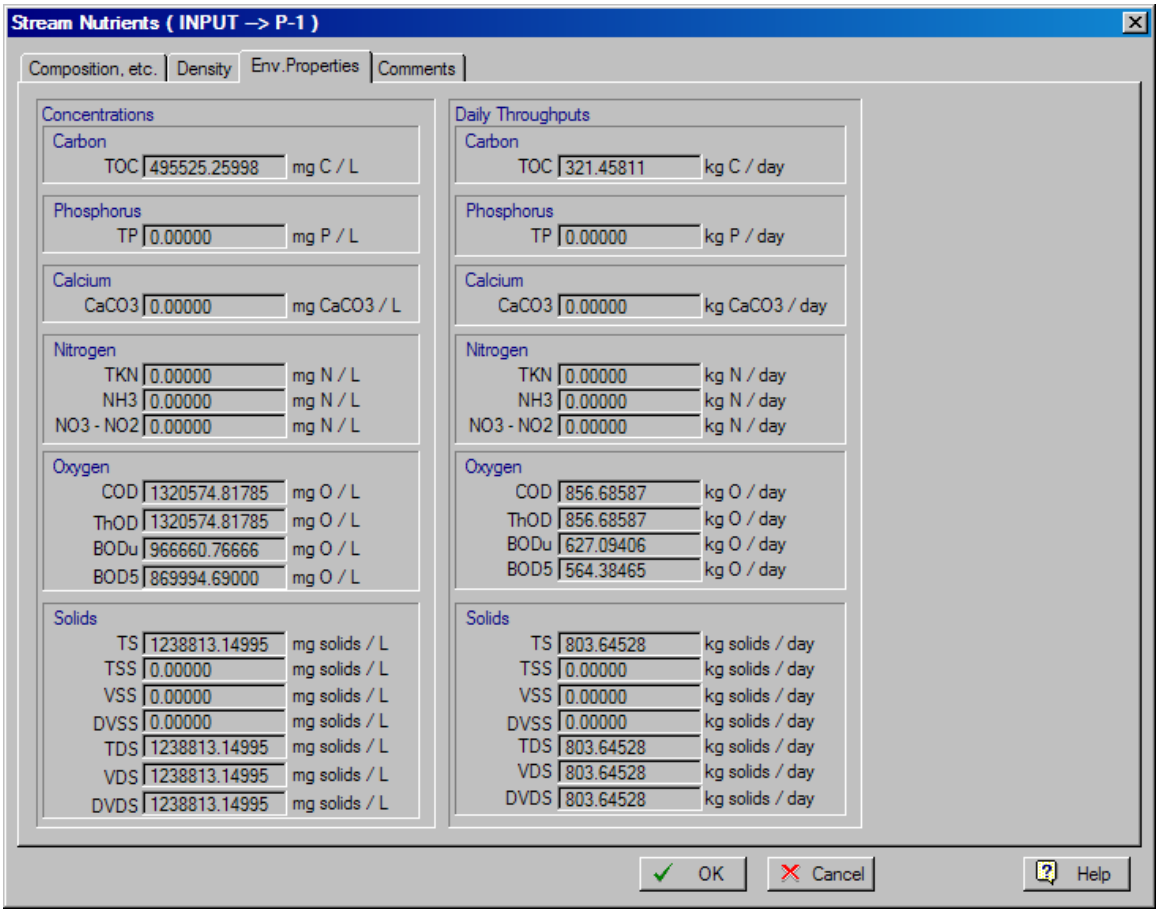

Figure 4.3: Bulk Input Stream dialog – Environmental Properties Tab.

NOTES: **a.** The stream and ingredient flowrates can be either in kg/(time basis) or kmol/(time basis). The first time the i/o dialog comes up for a given stream, the setting follows the Flowsheet settings of the physical units (as specified in the dialog that appears when you select **Edit/Flowsheet Options/Preferences/Physical Units**... from the main menu). However, the choice can be locally modified for viewing that particular

stream by the option buttons displayed on the stream i/o dialog under the heading View (see Figure 4.1). Note that your choice in this dialog for mass units does not affect the mass units in the stream report. The mass units for all streams in the stream report depend on the setting of the **Edit / Flowsheet Options / Preferences / Physical Units**... dialog.

b. The displayed composition for each ingredient is either mass percentage or molar percentage. The choice (mass or molar) follows the choice for mass units (see Note (a) above).

c. All flowrates for continuous flowsheets are displayed per hour. For batch flowsheets, three options are available: per Batch, per Source Cycle (the cycle of the source process steps), or per Destination Cycle.

4.2.2 Discrete Streams

The dialog of discrete input streams allows the user to view and edit the discrete entity flow in that stream. To bring up this dialog, either pick **Simulation Data...** from the stream's right-click menu or simply double click on the desired stream line.

Entity Tab (Figure 4.4) – Through this tab the user specifies the flow and properties of the discrete entity. The list of properties includes:

- The "Name" of the discrete entity.
- The "Bulk Amount Per Unit" in g/Entity or ml/Entity.
- The "Purchasing Price" in $/Entity.
- The "Selling Price" in $/Entity.

Composition Tab – This tab is identical to the composition tab of bulk streams (see Figure 4.1). Through this tab the user specifies the material composition (e.g., 100% glass for a Vial) or the flowrates of bulk ingredients that compose the discrete entity flow. By specifying the material (bulk) composition of discrete entities, Pro-Designer is in a position to close the material balances (based on bulk material flow) and readily convert discrete to bulk flow and vice versa.

Density Tab – This tab is identical to the density tab of bulk streams (see Figure 4.2).

NOTES: **a**. All dialog variables of intermediate discrete streams are non-editable. The selling price of the discrete entity is the only editable variable in the dialog of output discrete streams.

b. Different discrete entities can have the same name. For instance, an empty vial as well as a filled vial can both be called "Insulin Vial".

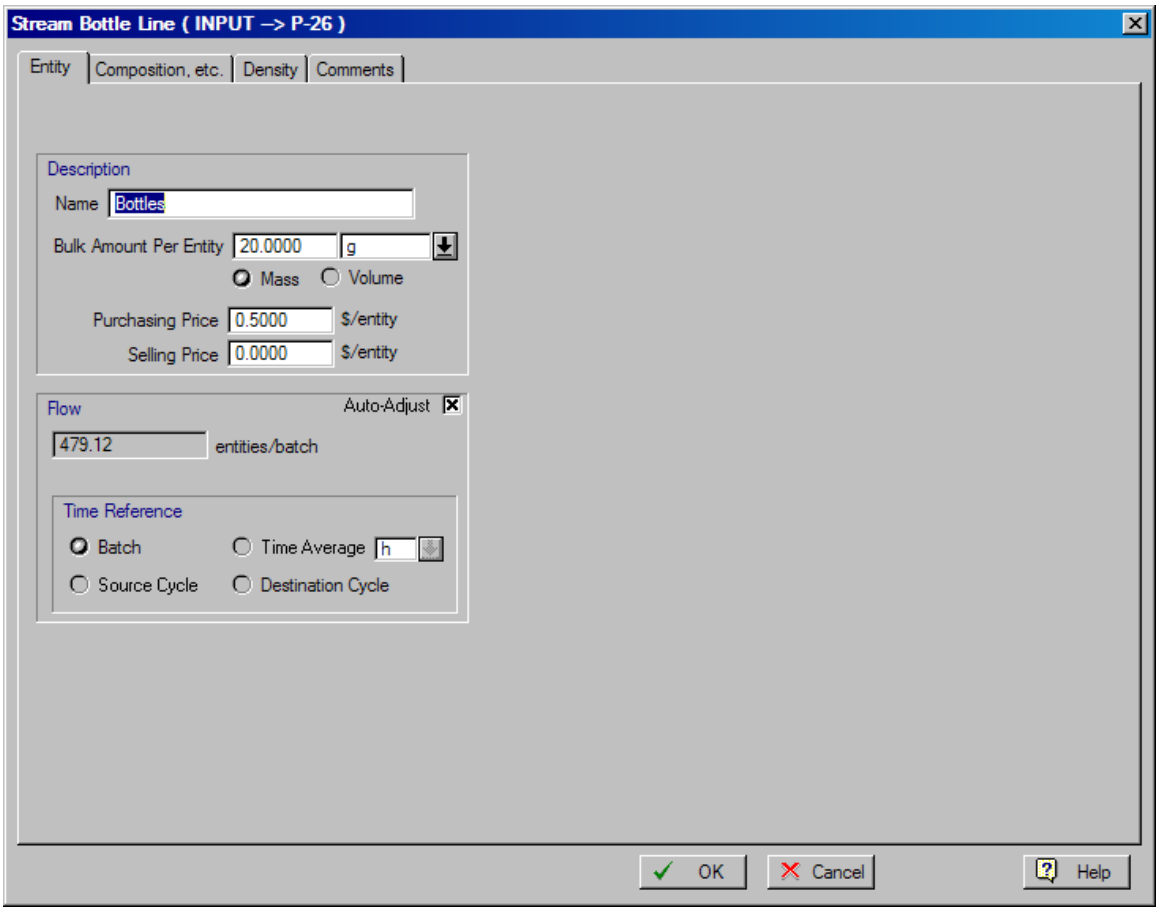

Figure 4.4: Discrete input stream dialog – Entity Tab.

4.3 Stream Drawing

Drawing several streams, one after another, is easier when you operate in **connect mode**. To enter the connect mode, click on the connect button displayed under the main menu. Notice that the cursor changes, reminding you that you are in connect mode.

The connect mode button: 

The connect mode cursor: 

To draw an input, output or intermediate stream follow the step-by-step instructions presented below. The system remains in connect mode after a stream has been created. Sometimes, if you want to simply draw one stream and then immediately go back to select mode, it is cumbersome to go into connect mode (by clicking on the connect button of the menu palette), draw the streams and then go back into select mode (by clicking on the arrow button at the menu palette.) Drawing just one stream can be done by entering the **temporary connect mode**. While in select mode, you can enter the temporary connect mode by holding down the **Ctrl** key and double-clicking with the mouse over an output port (to start an intermediate or output stream) or over an empty area (to start an input stream.) Immediately after the stream is created, the system will

revert back to select mode. To return to the normal mode (**selection mode**) of the program click on the select mode button.

The select mode button: 

The select mode cursor: 

➔ To Draw an Intermediate Stream...

1. Go over an output port (cursor changes to double direction arrow) and click.

2. Move the mouse to draw either a vertical or a horizontal segment for the stream (notice that you don't have to be exact in horizontal or vertical motion with the mouse as the system always draws either horizontal or vertical segments).

3. A single mouse click (of the left button) ends the current segment and starts another one (that changes the segment direction from horizontal to vertical or vice versa and introduces an elbow for the stream).

4. Repeat steps (2) and (3) to give the desired shape of the stream.

5. End the stream by a single click on an unoccupied input port. Note that an intermediate stream cannot end with a vertical segment.

➔ To Draw an Input Stream...

1. Click on an empty area; this initiates the drawing of the stream.

2. Move the mouse to draw either a vertical or a horizontal segment for the stream (notice that it is not necessary to be exact in horizontal or vertical motion with the mouse as the system always draws either horizontal or vertical segments).

3. A single mouse (left) mouse click ends the current segment and starts another one (that changes the segment direction from horizontal to vertical or vice versa and introduces an elbow for the stream).

4. Repeat steps 2 and 3 to give the desired shape of the stream.

5. End the stream by a single click on an unoccupied input port. Note that an input stream cannot end with a vertical segment.

➔ To Draw an Output Stream...

1. Click on an output port; this initiates the drawing of the stream.

2. Move the mouse to draw either a vertical or a horizontal segment for the stream (notice that it is not necessary to be exact in horizontal or vertical motion with the mouse as the system always draws either horizontal or vertical segments).

3. A single mouse (left) mouse click ends the current segment and starts another one (that changes the segment direction from horizontal to vertical or vice versa and introduces an elbow for the stream).

4. Repeat steps 2 and 3 to give the desired shape of the stream.

5. End the stream by double clicking on an empty area.

NOTES:

a. The first segment of an intermediate stream or an output stream must be a horizontal segment.

b. An input or an intermediate stream cannot end on a vertical segment (i.e., last segment must also be a horizontal segment).

c. An output port can only be the source of a single stream (intermediate or output).

d. An input port can only be the destination of a single stream (intermediate or input).

e. If the location of elbows on a stream or the length of its segments is not particularly important, it is possible to initiate the stream drawing as in step (a) above and then directly go to step (e). The system will generate a stream and place it in a location that most times will be satisfactory. It is not guaranteed that the all stream segments will not overlap with other segments or that the stream will not intersect other units. Therefore, the shortcut stream drawing option should be used with caution.

f. During drawing of any stream, while left click introduces a new elbow, a right click removes the currently last elbow of the stream.

g. During drawing of any stream, hitting **Esc** aborts the whole procedure.

h. After a stream has been drawn, the location of its elbows can be edited (see below).

4.4 Stream Elbow Editing

Sometimes, after having drawn a stream connection, you may decide to change the location of the stream's corners (elbows). Also, after the move of a unit, the system automatically adjusts the location of the last elbow to maintain strictly horizontal or vertical segments. If the new location of the stream's elbows is not satisfactory, you can edit it. The following is a procedure to accomplish this.

➔ **To Edit Stream Elbows...**

1. Go over the stream whose elbows you wish to edit and bring up the right click menu (be certain to be in select mode). Select the **Edit Elbows** option. Notice the appearance of small black rectangles (we call them *elbow handles*) right on the current location of the stream's elbows.
2. Move the mouse over the handle of the elbow that is to be moved. Notice how the cursor changes shape into a double arrow that shows the directions along which you can move the handle. Notice that some elbows can only move Up-Down, and some can only move Left-Right.
3. Drag the elbow handle to the new location.
4. Repeat with any other handle.
5. End the elbow editing session by clicking somewhere other than on an elbow handle.

4.5 Stream Tags

As soon as a new stream in inserted in the flowsheet, the program automatically decides upon its tag name: it is always composed of the prefix "S-" and a number that

starts at 101 and then it is incremented by one. The actual number picked is the first number available higher than 101 that is not already used by any stream currently in the flowsheet. You may change the name tag of the stream at any time by invoking the right-click (context) menu of that stream, and selecting **Edit Tag Name...** Then the following dialog appears:

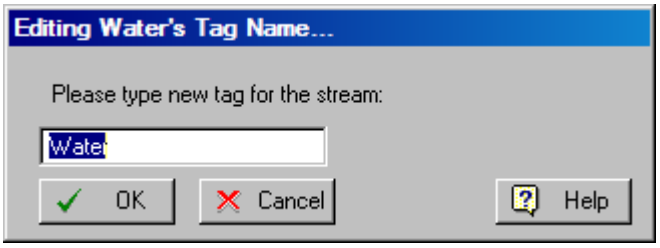

Figure 4.5: Editing the name tag of a stream.

The tag name of any stream should not exceed 15 characters in length and should be unique within a design case.

The system uses a default font for printing the tag names of all newly created streams. The tag name font along with other style attributes can be modified by selecting **Style/Edit Style…** from the right-click (context) menu of the specific stream (see Section 4.6 for more detailed information on the subject).

In addition to the name tag, you can specify additional information, such as the stream's pressure or temperature, to be displayed next to the stream using the info tag, which is by default not displayed. Select **Style/Edit Style…** from the right-click (context) menu of the specific stream and then choose one of the following tabs: **Info Tag: Text, Info Tag: Frame, Info Tag: Location** to define the type of information tag you want to display for the stream (if any).

4.6 Stream Style

When a new stream is created, the system draws the tag and lines of the stream using a default style. For instance, the default color of discrete stream lines is blue. The style attributes include the following: the thickness and color of the stream line; the font, text background, and visibility of the name and info tags; the thickness and color of the name and info tag frame, the location of the name and info tags. The default style of streams can be modified by selecting the **Edit/Flowsheet Options/Preferences/Default Styles/Bulk (or Discrete) Streams...** option from the main menu. Sometimes, however, it is desired to set the style of a particular stream to be something other than the default. This is accomplished by selecting the **Style/Edit Style...** option from the right-click (context) menu of that stream. That brings up the dialog of Figure 4.6. If later it is no longer desirable to have the stream's style be an exception, you can instruct the program to revert to the default style by selecting the **Style/Use Default** option from the context menu of that stream. The style of a stream can be copied by selecting the **Style/Pickup Style** option from the context menu of that stream and applied to other selected streams by selecting the **Style/Apply Style** option from the context menu of one of the selected streams.

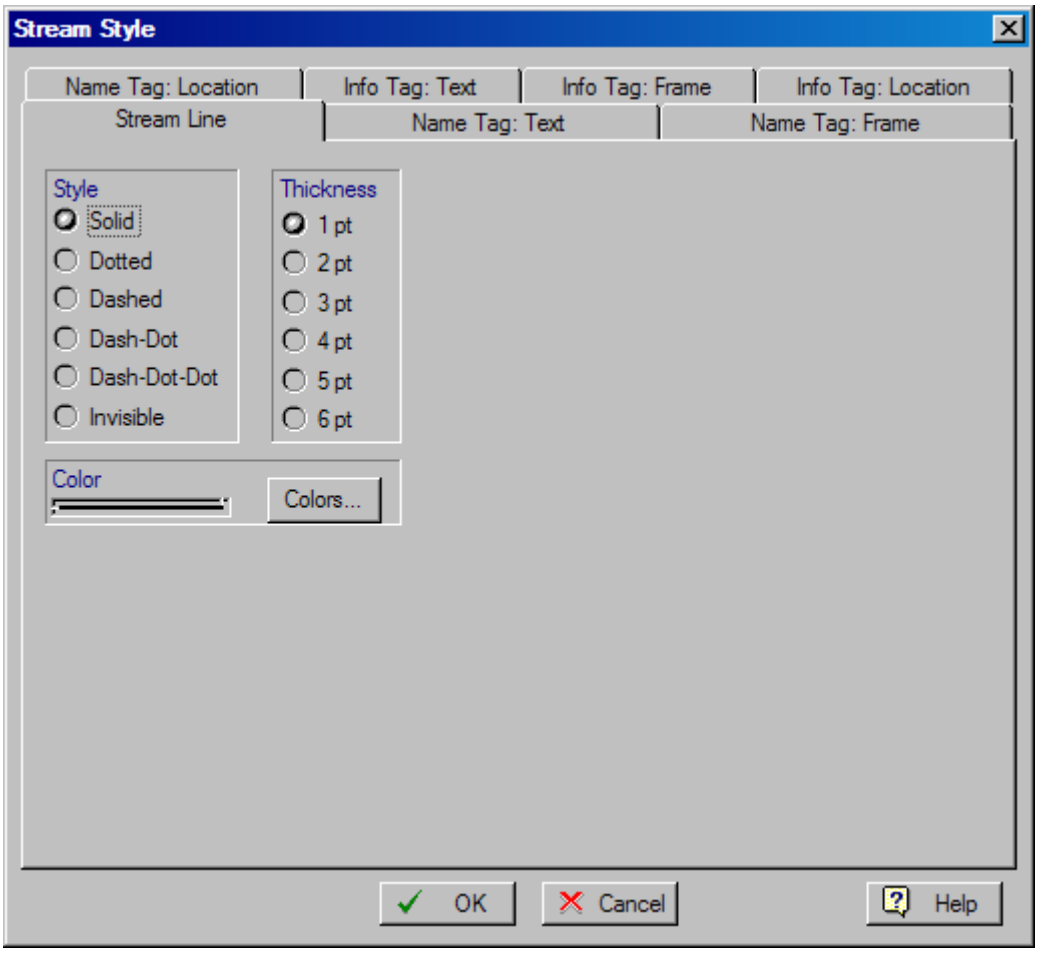

Figure 4.6: Dialog for specifying the style of a stream.

4.7 Classification of Input and Output Streams for Costing, Economic Evaluation, and Environmental Impact Assessment Purposes

The classification of input and output streams as Raw Material, Revenue, and Waste Streams affects the costing and economic evaluation calculations as well as the environmental impact report. It is done via the dialog that is presented when the **Tasks \ Stream Classification...** menu choice is selected from the menu (Figure 4.7)

4.7.1 Raw Material and Revenue Streams

All input streams are by default classified as Raw Material streams. The price of a bulk raw material stream (in $/kg) is estimated by the program based on the purchasing prices of the various ingredients (components and stock mixtures) that compose that stream. The prices of components and ingredients are set through the component

registration dialogs (see Chapter 3). The price of a discrete raw material stream (in $/entity) is set through the stream's simulation data dialog (see Figure 4.4). The unit cost (prices) of raw material streams along with the results of the material balances determine the raw materials costs that appear in the Itemized Cost and Economic Evaluation reports (see Chapters 7 and 8).

Both input and output streams can be classified as Revenue streams. A revenue stream is any stream that generates income. Typically, a revenue stream is an output stream that can be sold. This is what we call a **product stream**. Any number of product streams can be associated with a manufacturing facility. The revenues of waste treatment and disposal facilities, however, are usually based on the flowrates of their input streams. This is the reason for allowing input streams to be classified as revenue streams. To classify an input stream as revenue stream, click on the appropriate cell of the classification column and select "Revenue" from the displayed drop-down menu. The selling price of bulk product streams is either estimated by the system based on the selling prices of each of the components and stock mixtures that make up the stream weighed by their mass fractions, or it is set by the user (on a $/kg-stream flow-basis). To set the selling price of a stream, simply click on the **Set by User** box at the row that corresponds to that stream and then click on the Selling Price cell and type in the desired value. The selling price of discrete product streams is set through the stream's dialog (you simply specify the selling price of the discrete entity in $/entity). The processing fee (in $/kg) of input revenue streams (for waste treatment and disposal facilities) is set through the dialog of Figure 4.7 by first clicking on the appropriate **Set by User** box and then typing in the desired value.

NOTES: **a.** Starting with version 3.0, the unit cost (price) of raw material streams cannot be set through the dialog of Figure 4.7. It only can be set through the ingredient registration dialogs (for bulk streams) or through the stream dialog (for discrete streams). Consequently, the "Set by User" column is active for revenue input streams only.

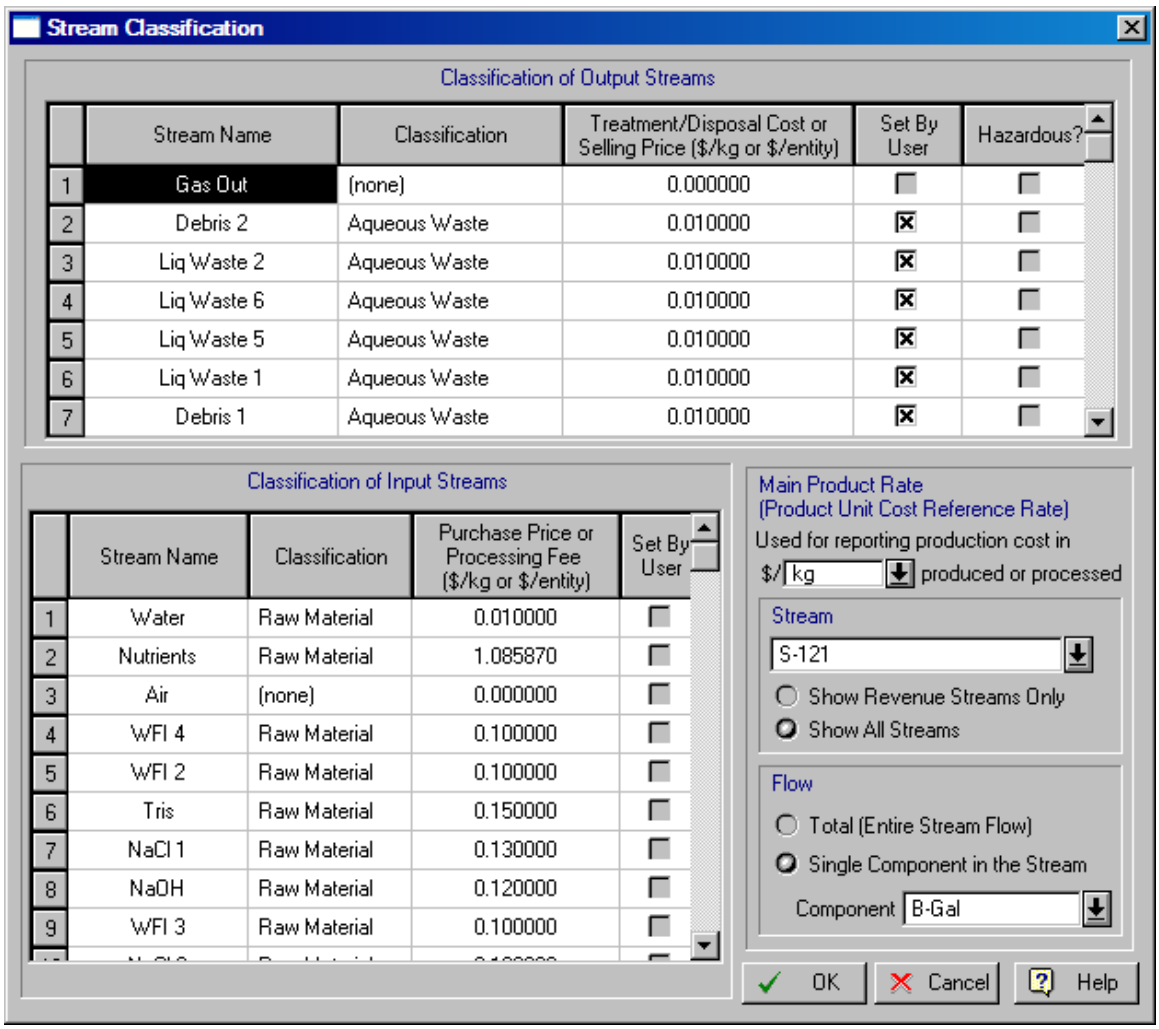

Figure 4.7: The stream classification dialog.

4.7.2 Main Product Rate Stream

The flowrate of the main product rate stream is used as the basis for reporting the unit production cost or the unit-processing fee of a manufacturing or waste processing facility, respectively. The main product stream is selected through the “Main Product Rate” box (lower-right corner) of the dialog of Figure 4.7. It can be selected from the list of Revenue Streams (default option) or from the list of All Streams. Thus, one may also use an intermediate stream as Main Product Rate stream. If the main product stream is a bulk stream, its flowrate (for reporting production or processing unit cost) can be based either on the total stream flow or the flow of a particular component in that stream. For discrete streams, the first option only (total discrete flow) is available.

4.7.3 Waste Streams

The cost associated with waste treatment and disposal has skyrocketed in recent years due to increasingly stricter environmental regulations. Further, new regulations require

the tracking of the fate of certain chemicals in every process as well as the reporting of releases of such chemicals into the environment. Pro-Designer aids the engineer to focus on such issues by explicitly forcing him/her to designate which output streams will have to be treated as wastes and which as emissions. Waste, in this context, is considered any stream that has a deleterious effect on the environment and possibly carries a price tag for treatment or disposal. Emission, on the other hand, is considered any release that is going to the atmosphere and may potentially include hazardous and/or regulated chemicals.

As mentioned above, any stream designated as a waste (through the dialog of Figure 4.7) may carry a waste treatment/disposal cost associated with it. This cost is reported in the Itemized Cost and Economic Evaluation reports (see Chapters 7 and 8) and is based on the unit cost of treatment/disposal (in $/kg). This unit cost is estimated by the system based on the waste treatment/disposal cost of each component that is present in the stream. You can overwrite the default estimate by clicking on the **Set by User** check box and typing in a new value.

The designation of streams as one of the four possible waste categories (solid waste, organic waste, aqueous waste, or emissions) does not affect the economics of the plant. The only thing it affects is the reporting (and bookkeeping) of all the chemicals released into the environment (see Chapter 11 for information on the Environmental Impact Report).

4.7.4 Hazardous Streams

Some components can be tagged by the user as hazardous (see Chapter 3). If such components are present in an output stream at a concentration level higher than their hazardous threshold (another environmental component property) they automatically tag the stream as hazardous. Furthermore, you may decide to explicitly tag output streams as hazardous. This can be done through the dialog shown in Figure 4.7. Any streams classified as hazardous will be listed in the hazardous stream section of the environmental impact report. Tagging a stream as hazardous incurs no further penalty on the economics of the project.

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