LFOM Scale and Template, Calibration Column Scale, and CDC Label

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Part I
Problem Definition

Labels and templates for several components of the AguaClara plant, including the Linear Flow Orifice Meter (LFOM), Calibration Column, and the Chemical Dose Controller (CDC), are needed to facilitate fabrication processes and operator usage. The process of generating these templates and labels must be automated, as it is possible that they may be made available with the plant design specifications upon user request. The LFOM scale and template are a function of the plant flow rate and head loss in the LFOM, and therefore vary depending on plant design. The design of the Calibration Column scale and CDC label, while not yet dependent on variations in plant design, will also be automated to facilitate any subsequent modifications (range, font size, scale length, etc.) that need to be made. All labels and templates will be rendered in AutoCAD and be available on the AguaClara website with the other design tool outputs when finalized.

The LFOM template is a 2-dimensional rendering of the orifice pattern drilled into the appropriately sized PVC pipe during the fabrication of the LFOM. The orifices are drilled to replicate a weir that establishes a linear relationship between the height of the water in the entrance tank and overall plant flow rate. An algorithm was created to take the 3D pattern of orifices already present in the design code and render a 2D drawing with the appropriate parameters (number of orifices, spacing, height, etc.). The 2D drawing includes the correct orifice pattern with hole centers and diameters clearly marked. It is also delineated into 8.5" x 11" sheets, each of which are labeled to be easily pieced together on-site during LFOM fabrication. The template will be printed out and wrapped around the appropriate pipe to drill the orifices. Template design decisions were made with the collaboration of the Design and Fabrication teams.

To create appropriate scales for the LFOM (dependent on the plant flow rate), Calibration Column, and CDC, a general algorithm must be created in

Mathcad. The scale function takes in parameters such as range, font size, and orientation and produces a drawing of the scale in AutoCAD. In addition to rendering an AutoCAD drawing, the function will also be used to engrave the LFOM scale on a thin plaque to be attached to the outside of the LFOM with brackets. This option is preferred to creating a waterproof label to be placed directly on the LFOM and is to be included in the overall plant drawing. Both the Calibration Column and CDC scales will be printed as transparent waterproof labels to be placed on plant components.

Introduction

The first task was to create the LFOM template to be used on-site in drilling the orifice holes into the PVC pipe. The Mathcad code used to create the LFOM template in AutoCAD has been written and is nearly complete; however, code to properly calculate and mark the borders between the separate layouts must be perfected. These layouts are necessary in order to print the template on adjoining sheets to piece together during fabrication. The LFOM design was recently modified to include designs for a head loss of up to 40 cm for flow rates above 39 L/s to allow for a smaller, more practical nominal diameter for the LFOM. Due to this change, some errors have been detected in the template code when rendering layouts for high flow rates (60 L/s and above). See "Design Details" and "Future Work" below for more information. The current output renders the correct number of orifices, spacing, delineation and labeling of 8.5" x 11" sheets, and dimensioning for flow rates below 60 L/s. The orifice centers are marked with cross hairs and a smaller diameter circle to facilitate precise drilling. The template was tested in the AguaClara lab for its usefulness, and the Fabrication team noted that while it does facilitate the drilling process, modifications may still be made to improve the output (see "Design Details" for more information). See the current LFOM template below (1).
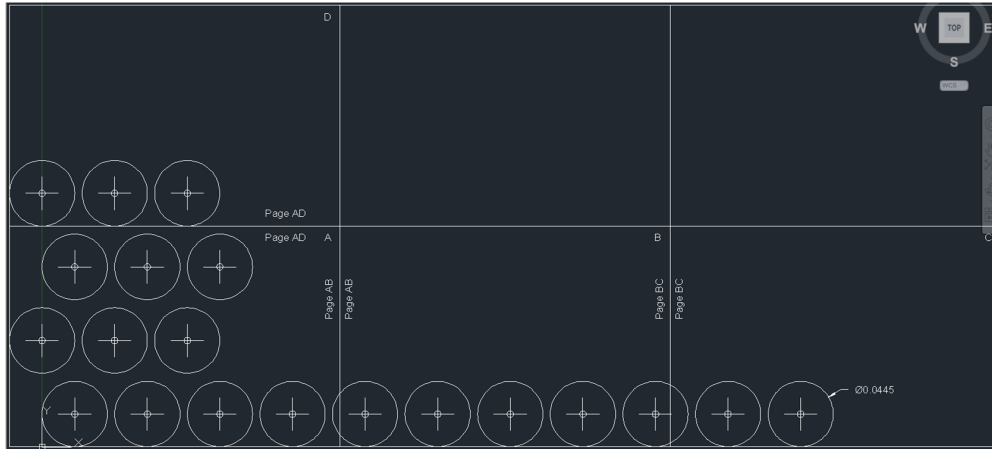
Figure 1: Current output for LFOM Template designed for a flow rate of 30 L/s.

Design Details

LFOM Orifice Template

For the LFOM template, the Mathcad code used to generate 3D LFOM models was modified to produce an output in 2D space rather than 3D. The code contains most of the previously designed variables, but the CylinderF function was replaced with a CircleF function, also found in MtoATranslatorsWrapped, and the array pattern was changed from a circular pattern to a straight line. In addition, cross hairs are drawn with smaller diameter circles to mark the orifice centers. The last orifice in the bottom row was dimensioned using the function LfomDiameterDim, and borders were drawn to mark 8.5" x 11" sheets of paper. If a different paper size is necessary, one must merely change the values of L.Paper and W.Paper in the "Variables" section of the template code. After discussing the available resources in Honduras with an AguaClara Engineer, it was decided that the delineation of 8.5" x 11" sheets would be a necessary part of the design, as there is not a plotter available for on-site use; the template must be distributed among sufficient 8.5" x 11" sheets to be joined together in fabrication. In order to distribute the drawing among several sheets, separate layouts in AutoCAD's Paper Space were created. The output is a zoomed-in viewport of each section of the template. In addition, each layout border is labeled appropriately to facilitate piecing the sheets together on-site. See figures below (2).
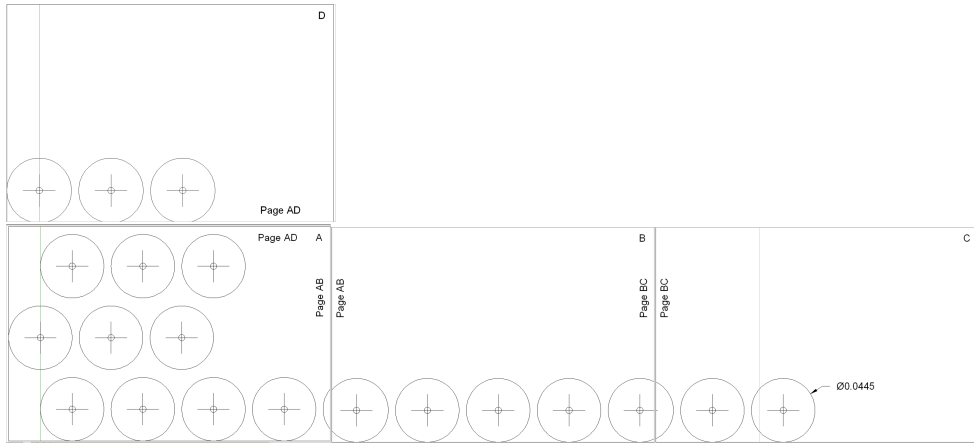
Figure 2: Output for LFOM Template layouts in Paper Space with a flow rate of 30 L/s.

The code generates the correct labeling and layouts for flow rates up to 60 L/s, however, it does not account for an LFOM head loss greater than 20 cm. Due to recent modifications to the LFOM design mentioned in the "Introduction," the template code must be adjusted to account for a larger head loss in the LFOM. See the output for 70 L/s below (3) and see the "Future Work" section for more information on necessary modifications to the template code.
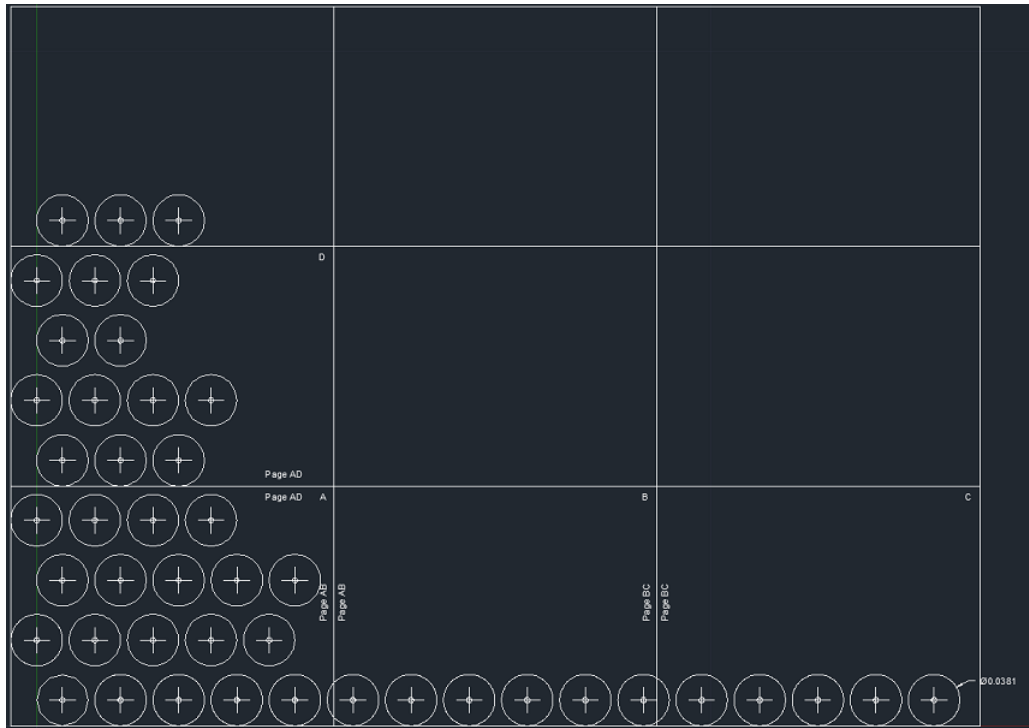
Figure 3: Current output for given a 70 L/s flow rate. Notice the incorrect labeling on the top left layout.

During the experimentation process, the Fabrication team had difficulty determining the exact placement of the template, as when it is placed on the LFOM, the template covers up the mark for the bottom row of orifices to be drilled. The Fabrication team suggested that it would be helpful to determine a way to measure from some fixed point (either from the floor of the entrance tank or from the overflow weir) to the LFOM. According to that height, a measurement should be placed on the template to annotate the distance to the bottom edge of the sheet of paper. A method by which to solve this problem has not yet been implemented, but should be formulated with the collaboration of the Fabrication and Design teams. See "Future Work" for more details.

The constraints on the template design include those of the LFOM orifices pattern design code. For example, the space between the orifices and orifice diameter is calculated so as not to negatively impact the integrity of the pipe. The hole center markings on the template were made as cross hairs to facilitate drilling precision for the fabricator. In addition, available resources in Honduras were taken into account: the templates needed to be placed on 8.5" x 11" layouts due to the lack of a plotter on-site, and the borders of each layout were labeled to facilitate piecing the sheets together accurately.

LFOM Scale, Calibration Column Label, and CDC Label

The scale code is in the preliminary stages: the parameters to design for have been determined and the first output has been rendered. The parameters include the maximum and minimum scale values, tick length, scale length, scale orientation, and font size. Not all parameters have been accounted for in the code, but will need to be in order to produce the desired output. The current code accounts for maximum and minimum values, tick length, scale length, and scale orientation. The current rendering is not the desired result, however, as it is only practical for small ranges (see "Future Work" for more information). Furthermore, font must be added to each step of the scale to denote tick values. See figure below (4). The algorithm should be generalized so as to be used to generate any type of scale, including that for the Calibration Column and Chemical Dose Controller.
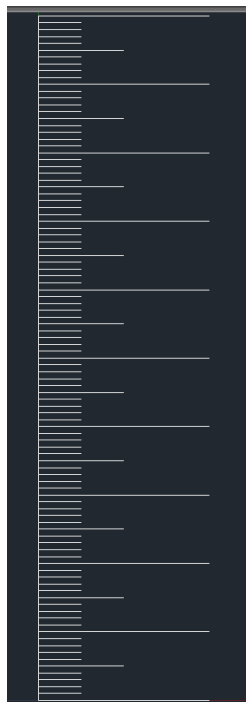

Figure 4: Current output for LFOM Scale at a flow rate of 10L/s.

Part II
Future Work

The LFOM Orifice Template will need to be modified in order to account for the changes to the LFOM design mentioned previously. There are two specific places where changes must be made, and both are clearly marked in the code. First, the method by which to generate the separate layouts in Paper Space must be adjusted. The functions used to generate these layouts can be found in the section entitled "Create Layouts." (They are called SetUpHLayouts, SetUpTLayouts, and SetUpVLayouts.) For flow rates of 70 L/s and above, SetUpVLayouts generates the vertical layouts incorrectly, as it does not properly account for the three rows of layouts necessary for an LFOM with a 40 cm head loss. As noted in the code, it might be helpful to combine the functions SetUpHLayouts, SetUpTLayouts, and SetUpVLayouts to set up all the layouts within one function. (Perhaps, this could be accomplished with nested for-loops, as if one were traversing a matrix.) After the layouts are properly generated, the function LabelT, found in the "Drawing Functions" section, must be modified to account for the third row of layouts. Currently, the function accounts for the labeling in the second row of layouts, while the labeling of the first row is accounted for in DelineateLMultiple.

Furthermore, a meeting should be set up between the Fabrication and Design teams to discuss a solution to the difficulty of properly placing the template on the LFOM during fabrication. As mentioned in the "Design Details" section, the Fabrication team had this concern during the summer, and perhaps it can be resolved during the upcoming semester.

Once the template is complete, significant work must be done on the LFOM Scale, Calibration Column Label, and CDC Label. As mentioned earlier, the parameters to design for were determined, but an output given all the necessary parameters (including font size) has yet to be rendered. In addition to failing to account for the necessary parameters, the output is not optimal because it generates far too many ticks for large ranges. The way the code is currently written, the tick spacing is the length of the scale divided by ten times the range (to output ticks for say, every .1 L/s for the LFOM scale). This should be modified to instead generate a nice number of ticks given the range (i.e. the number of ticks could be a certain fraction of the range). The pseudo-code found online (noted in the Design Challenges) may be helpful in generating these labels. See the current code below (5).

$Line(StartPt, EndPt) := concat("\_line ", \textbf{point}(StartPt), sp, point(EndPt), sp)$

$$ScaleF(Max, Min, L_{Tick}, L_{Scale}, Orientation) := \begin{array}{|l} MainArm \leftarrow \begin{bmatrix} \begin{pmatrix} 0 \\ 0 \end{pmatrix} m \\ \begin{pmatrix} 0 \\ L_{Scale} \end{pmatrix} m \end{bmatrix} \\ Local \leftarrow stack(\textbf{Line}(MainArm_0, MainArm_1)) \\ S_{Tick} \leftarrow \left\lfloor \dfrac{L_{Scale}}{(Max - Min) \cdot 10} \right\rfloor \\ YStartPoint \leftarrow 0 \\ NumTick \leftarrow 0 \\ while \;\; NumTick \leq (Max - Min) \cdot 10 \\ \quad \begin{array}{|l} StartPt \leftarrow \begin{pmatrix} 0 \\ YStartPoint \end{pmatrix} m \\ EndPt \leftarrow \begin{pmatrix} L_{Tick} \\ YStartPoint \end{pmatrix} m \;\; if \;\; mod(NumTick, 10) = 0 \\ EndPt \leftarrow \begin{pmatrix} \dfrac{L_{Tick}}{2} \\ YStartPoint \end{pmatrix} m \;\; if \;\; (mod(NumTick, 10) \neq 0 \wedge mod(NumTick, 5) = 0) \\ EndPt \leftarrow \begin{pmatrix} \dfrac{L_{Tick}}{4} \\ YStartPoint \end{pmatrix} m \;\; otherwise \\ Local \leftarrow stack(Local, Line(StartPt, EndPt)) \\ YStartPoint \leftarrow YStartPoint + S_{Tick} \\ NumTick \leftarrow NumTick + 1 \end{array} \\ Local \leftarrow stack\left(Local, Union_{All}, Rotate_{All}\left(MainArm_0, \dfrac{-\pi}{2}\right), ZoomExtents\right) \;\; if \;\; Orientation = 0 \\ Local \leftarrow stack(Local, Union_{All}, ZoomExtents) \;\; if \;\; Orientation = 1 \\ return \;\; Local \end{array}$$

Figure 5: Algorithm used to generate the scale in AutoCAD.

Before going into the while loop, the origin and end point of the main arm of the scale are used to create a line. Then, while the number of ticks is less than ten times the range (this will have to be changed), the start and end points of the ticks are changed based on if the tick is the 10th, 5th, or a value in between in the sequence. The starting y-value is then changed based on the tick spacing, the number of ticks already drawn is incremented, and the loop begins again. Before the output is returned, the scale is rotated, if needed. For the orientation values, the code is written with a value of 1 for vertical and 0 for horizontal.