Specifications for Matrix-Array Ceramic Color Transfer Standards

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SUMMARY: In this document the author describes and presents detailed specifications for 2 matrix array designs. A contents page, which lists the individual drawings, precedes each series.

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Recommended Viewing Procedures

This document is formatted for viewing with Adobe Acrobat Reader® (v. 7.0.9 or newer). Do not attempt to use other viewers, including Apple Preview®.

Although the charts may be viewed using any screen resolution, the detail is improved for XGA (1,024 x 768) or better. If possible, use a resolution of 1,600 x 1,000, 1,280 x 960, or higher.

Additional detail may be achieved with the aid of the Zoom tool in Acrobat Reader®. From the keyboard execute command–+ (Macintosh) to zoom in, command–- to zoom out, or command–0 to restore the full-screen display size. Depending on the magnification level, you may notice occasional problems with line positioning and line weights. These artifacts result from the less-than-perfect conversion of MicroSpot MacDraft® drawings to the .pdf format.

Use the Full Screen presentation tool in Acrobat Reader® to view the entire document. Open it and then execute Full Screen View from the Window sub–menu, or command–L (Macintosh) from the keyboard. With this viewing method use the left and right mouse buttons to step through the charts in forward or reverse sequence. The arrow keys, the Home and End keys, and the zoom tool are active as well. Execute a second command–L to exit Full Screen View.

In Acrobat Reader® access individual drawings for viewing or printing using the Contents pages and the Bookmarks tool. In the hierarchical bookmarks menu, the charts in each series are nested below the introductory Contents page.

The colors displayed in the layouts of the Basic Colors, Special Colors, and Grey and Pastel Colors tile sets are rough approximations, which are included for information purposes only. (This document is not color managed.)

Introduction

Individually mounted 2-inch ceramic transfer standards have long been used to characterize and validate bench-top, reference quality spectrophotometers. Matrix arrays consisting of smaller ceramic tiles are more suitable for use with portable instruments. In this document the author describes and presents detailed specifications for 2 matrix array designs.

During 2007 Mt. Baker Research L.L.C. and Avian Technologies L.L.C. introduced ceramic tile sets for use by color scientists and color metrologists. This document describes two designs for matrix arrays of color transfer standards fabricated using these new tiles.

During the past decade color metrologists have preferred the BCRA Series II ceramic tiles, which are produced by Ceram Technology Ltd. The standard set of 12 BCRA Series II colors is often augmented with the addition of white and black tiles.

Among graphic artists the GretagMacbeth ColorChecker Chart (“GMCC”) is popular for use with portable spectrophotometers. However, because its 24 color plaques consist of coated paper, the GMCC easily becomes soiled, worn, or damaged. (Each square plaque measures 1.6 x 1.6 inches.) Unlike ceramic color standards, which are exceptionally durable and stable, the GMCC cannot be cleaned.

Our new collection of tiles includes 48 unique colors packaged in 3 sets with 16 tiles per set. The color distribution significantly extends the gamut of colors that is available with BCRA Series II tiles. This more complete coverage of color space should yield improved results for applications such as device profiling and instrument characterization and validation.

The public version of this document does not include the machine drawings, which contain proprietary information.

Compact Array Design

The compact array consists of a 4 x 4 matrix of 1.5-inch circular tiles permanently mounted in a holder machined from black Delrin. As shown in the accompanying drawings, the external dimensions of this array are 7.25 x 7.25 x 0.50 inches.

The sample stage of the Konica-Minolta CM-2500c spectrophotometer uses a cylindrical platform that measures 1.35 inches in diameter. The diameter of the sample port aperture is 0.43 inches, so this instrument may be used with 1-inch color standards. However, with 1-inch tiles consistent sample placement would be difficult to achieve.

Sample flatness (planarity) presents another potential problem. To facilitate the achievement of effective optical contact between the sample and the sample stage the Konica-Minolta CM-2500c instrument uses 4 small feet positioned along its bottom surface. This technique of alignment only works for samples that are perfectly flat.

During metrological measurements it is convenient to invert the CM-2500c instrument with the sample stage pointing up. Each sample is then centered on the sample stage and a weight is used to maintain effective optical contact.

Using this method satisfactory optical contact is readily achieved with small samples or with large samples that are perfectly flat. However, with large samples that deviate even slightly from planarity, physical contact of the sample with the first pair of positioning feet on the CM-2500c instrument may impair optical contact and reduce the photometric accuracy. This problem can occur with square samples larger than 4.25 inches along one side, or with circular samples having a diameter greater than 4.6 inches.

The GretagMacbeth Eye-One Pro spectrophotometer is another popular handheld instrument that is widely used in the graphic arts. The Eye-One Pro uses 2 positioning feet instead of 4, and they are placed further away from the sample stage. With this instrument square samples that are not flat cannot exceed 8.0 inches along one side, and round samples cannot exceed 8.2 inches in diameter.

With these 2 instruments (or similar handheld devices) the individual tiles in a mosaic array must be absolutely flat with co-planar optical surfaces. These requirements constrain the design of the array and the method of assembly. For example, the required co-planarity requires rigidity and the use of two-piece construction for the Delrin holder in which the tiles are mounted.

Layout Drawings — Compact Array Design

1. Basic Colors Dimensions

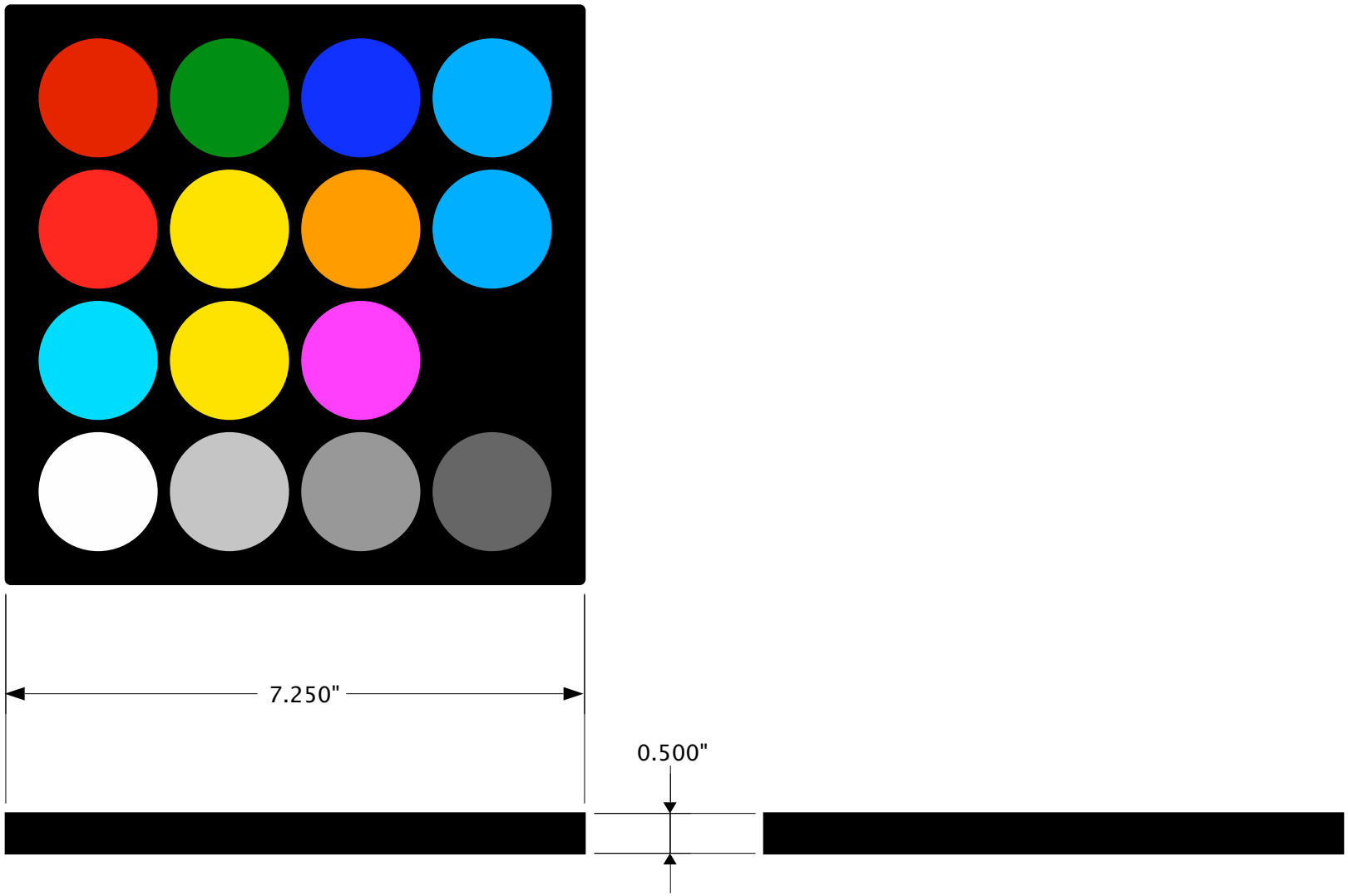
2. Basic Colors Layout

3. Special Colors Layout

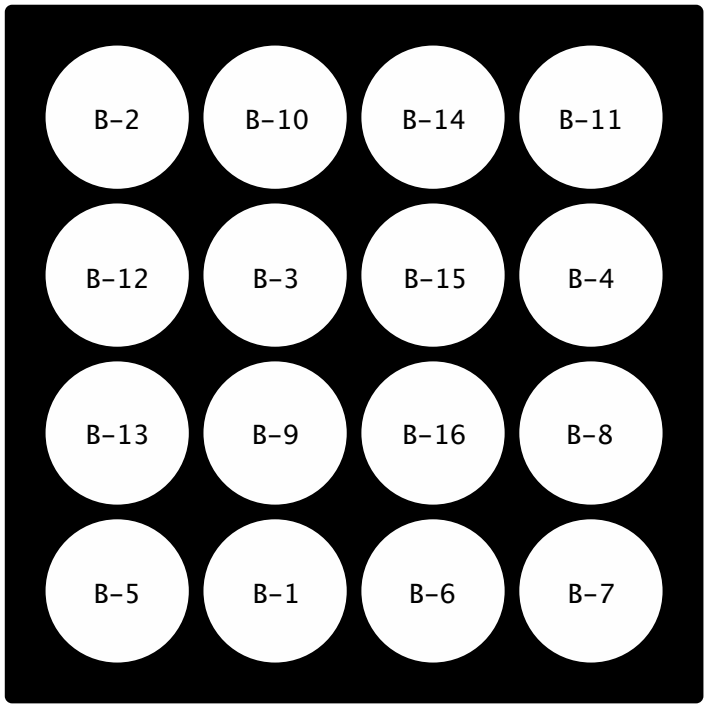
4. Grey & Pastel Colors Layout

5. Accessory Table (positioning block)

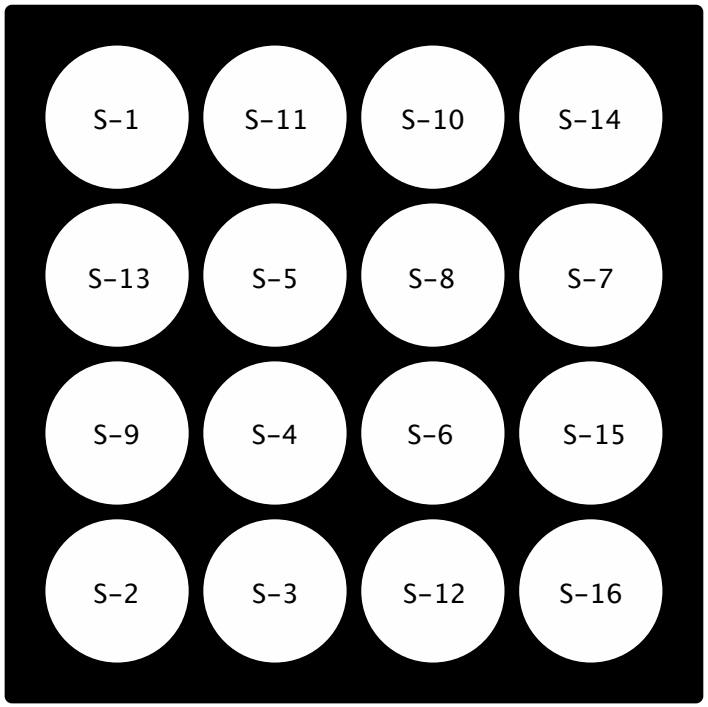
Basic Colors Dimensions

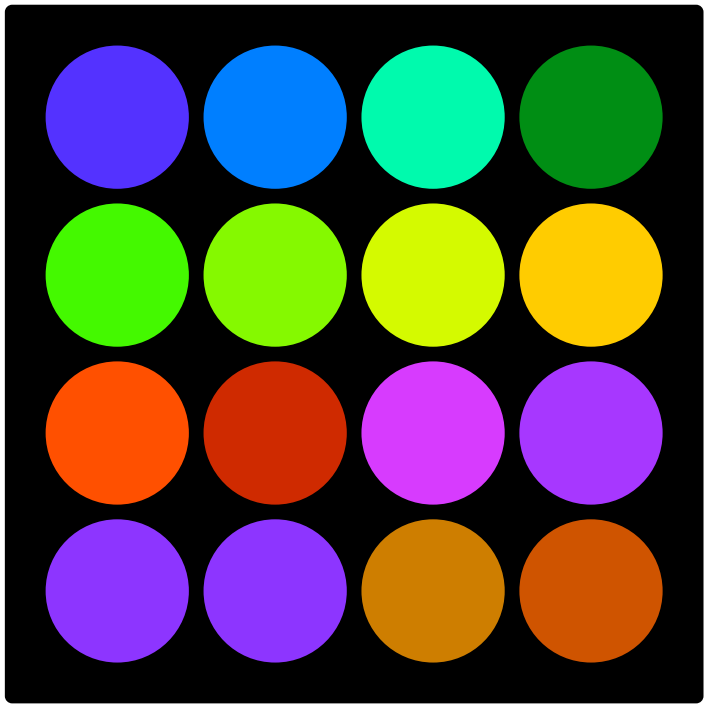


Basic Colors Layout



Special Colors Layout





Pastel Colors Layout

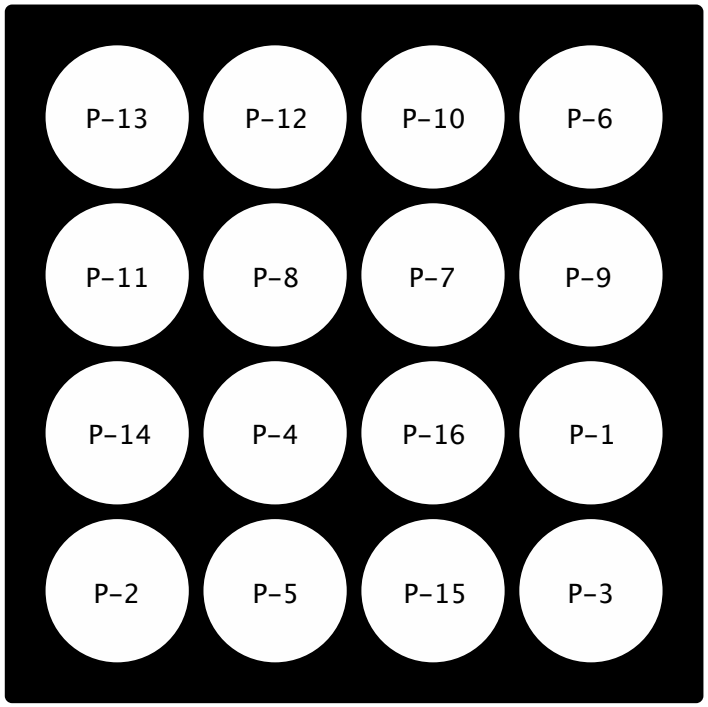
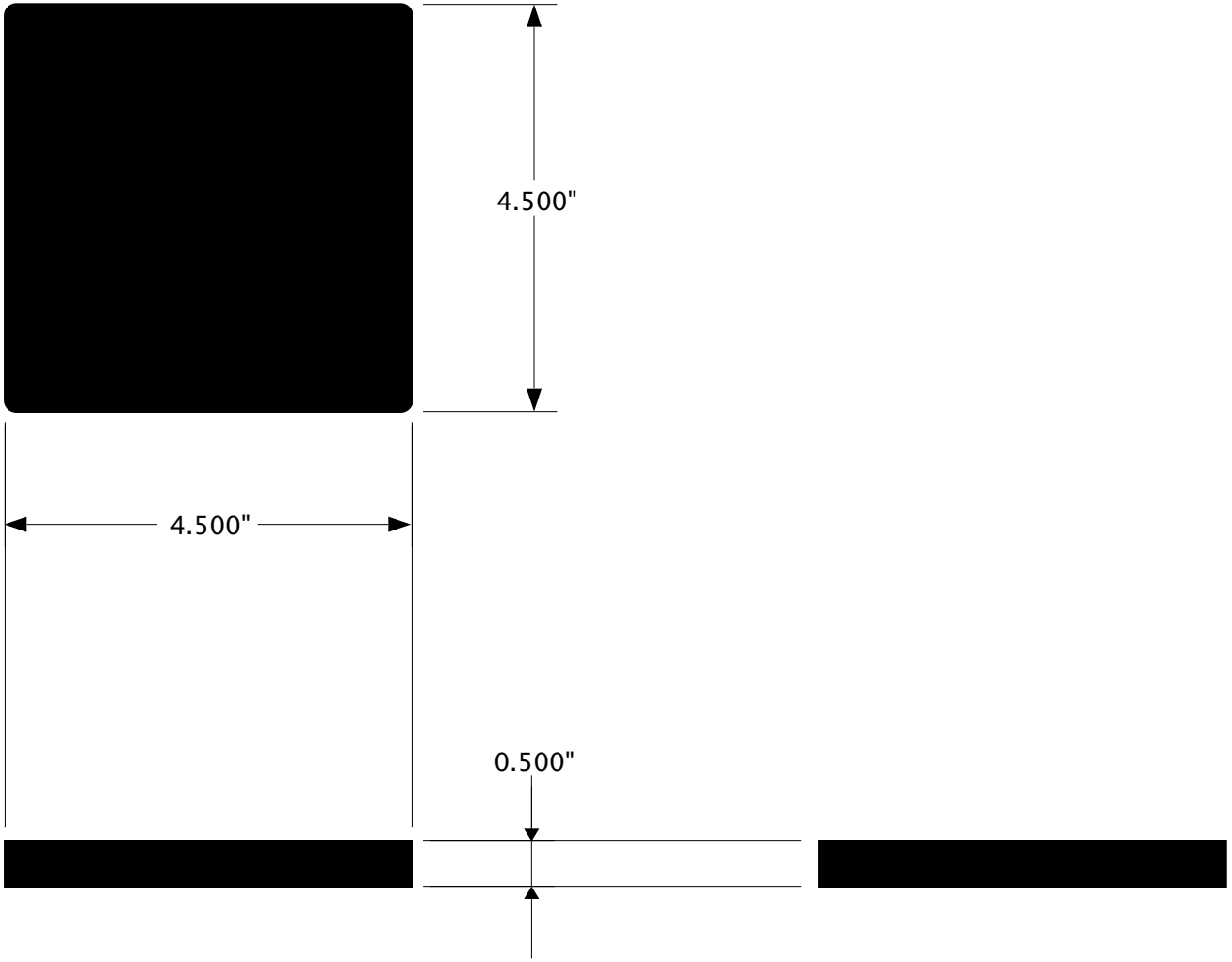


Table Accessory Dimensions



Achieving Optical Contact

In general, there are 2 ways to achieve effective optical contact between the sample and the sample stage of a handheld instrument. The instrument may be operated in the inverted position with the sample stage pointing up, or in the normal upright position. The following discussion is based on the Konica-Minolta CM-2500c instrument as the working example.

Method A — Inverted Operation

Step A: To accommodate the size of the sample stage of the CM-2500c instrument (see above), construct the compact array using circular tiles with a diameter of 1.50 inches. Mount the tiles in a square Delrin holder with a 0.13-inch spacing between them and a 0.40-inch margin along the outside edges.

Step B: Use a weight to maintain effective optical contact between the sample stage and the tile that is being measured. With this method visual sample placement may lead to positioning errors. To eliminate this problem create an accessory mask tailored to the sample stage of each supported instrument.

Step C: With the compact array that is described here, there is no difficulty achieving effective optical contact with the 12 tiles that are located along the perimeter of the array. However, the 4 interior tiles present more of a challenge.

The shortest distance from the outside edge of the array to the center of one of the interior tiles is 2.8 inches. When measuring one of these tiles, the closest pair of positioning feet on the CM-2500c instrument will rest on the surface of the adjoining tile located in the perimeter of the array. Provided that the array is perfectly flat, effective optical contact can be achieved.

Method B — Upright Operation

Step D: Assume the same setup as described above (see Step A).

Step E: To achieve effective optical contact during upright operation, place the CM-2500c instrument on an accessory block, or stand, having exactly the same thickness as the compact array. Provided that the bench top is perfectly flat and the upper and lower surfaces of the accessory block are co-planar, this insures that all 4 positioning feet on the instrument are in proper contact with the work surface.

A convenient size for the accessory block is 4.5 inches square with a uniform thickness of 0.50 inches. No external weight is needed, but positioning is visual and subject to errors unless an accessory mask is used (see Step B).

Step F: The same conclusions are applicable as noted above (see Step C). Effective optical contact will be achieved for the 4 interior tiles provided that: (1) The working surfaces of the matrix array and the accessory block are co-planar. (Both must be perfectly flat and the same thickness.) (2) The work surface must be clean and perfectly flat.

Large Array Design

As shown in the layout drawing, the large array consists of a 5 x 5 matrix of the same tiles permanently mounted along the perimeter of a square Delrin holder. The number of tiles is again 16 with 5 tiles mounted along each edge.

The accompanying drawings also show the external dimensions of the large array. For circular tiles with a diameter of 1.50 inches, an inter-tile spacing of 0.13 inches, and an edge margin of 0.33 inches, the array measures 8.75 x 8.75 x 0.50 inches.

The vacant area in the center of the large array contains no tiles. During upright operation of the CM-2500c instrument, this part of the surface performs the function of the accessory block that is used with the compact array in order to achieve effective optical contact between the sample and the sample stage.

For the large array constructed as described above, the central area measures 5.06 inches square, which easily accommodates the 4 positioning feet on the CM-2500c instrument.

With the large array the quality of the optical contact depends on the flatness of the array itself rather than that of the workbench. There are no other requirements for co-planarity.

Layout Drawings — Large Array Design

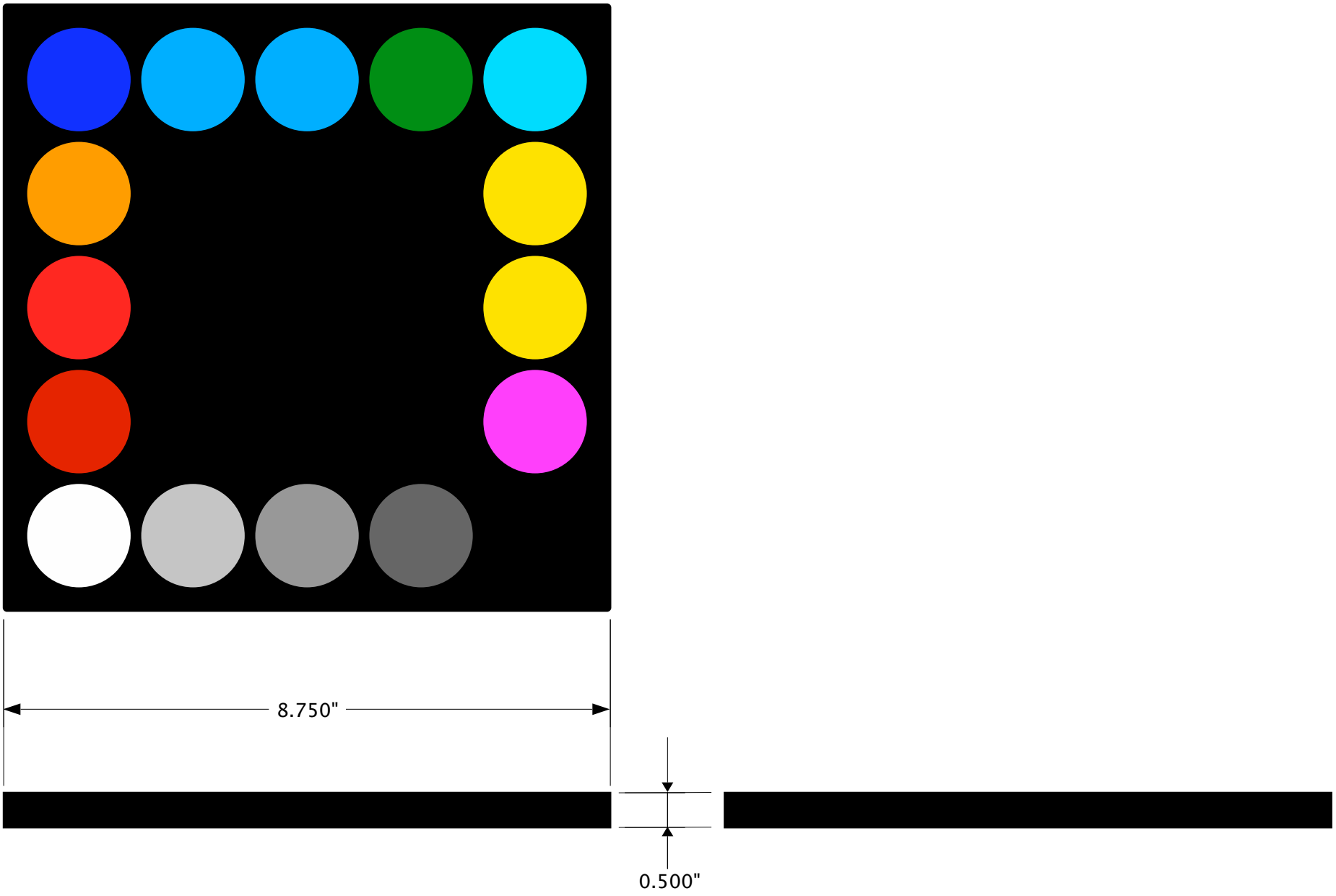
1. Basic Colors Dimensions

2. Basic Colors Layout

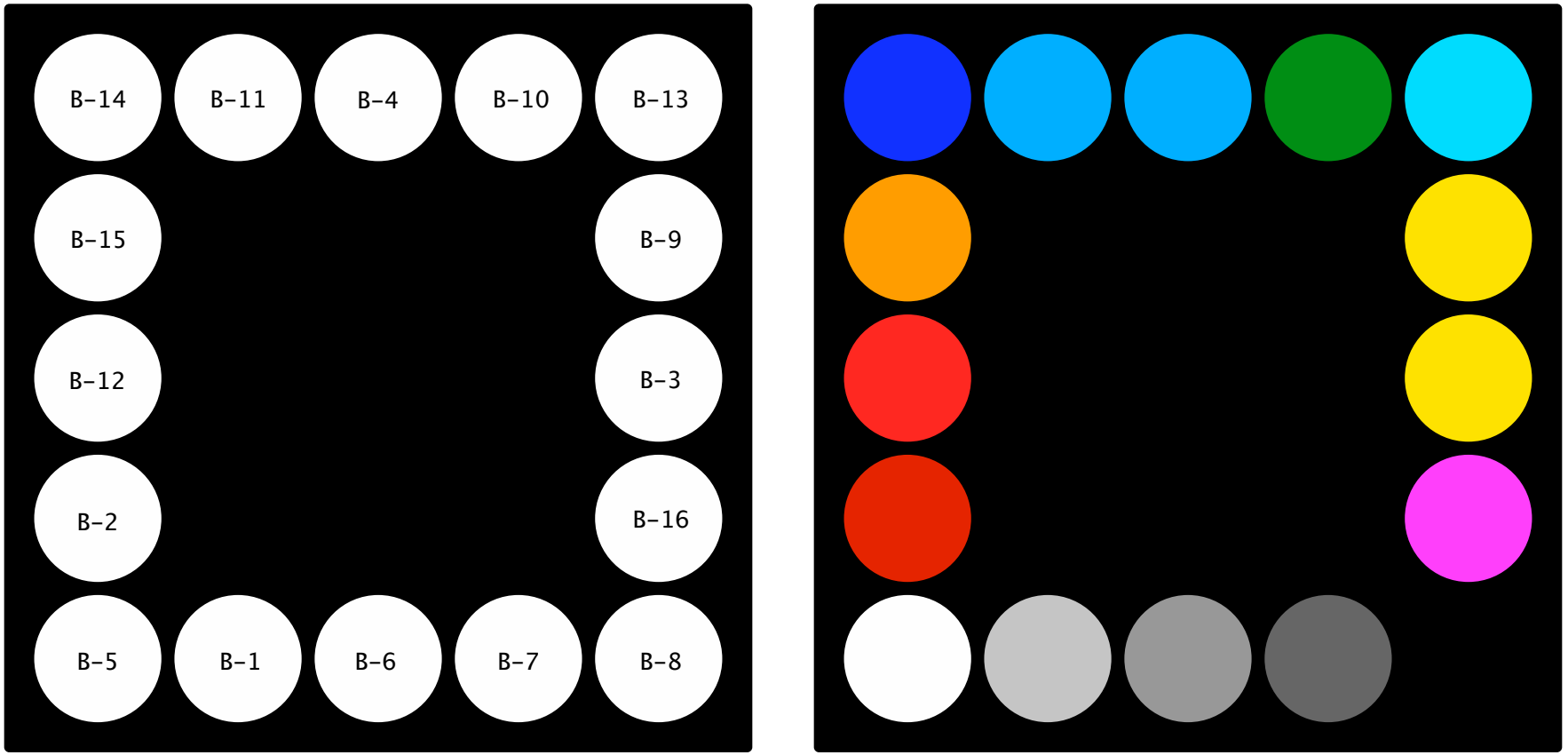
3. Special Colors Layout

4. Grey & Pastel Colors Layout

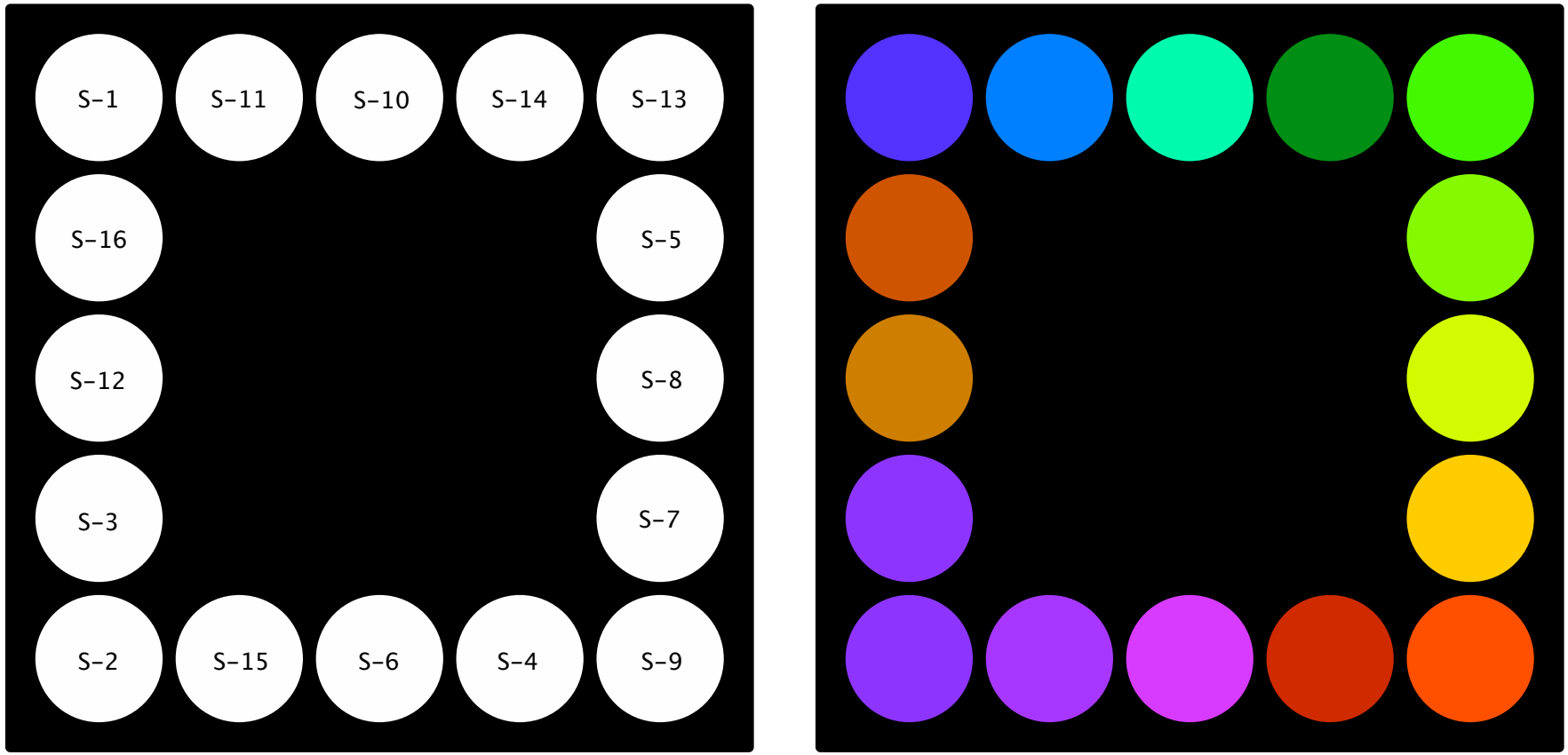
Basic Colors Dimensions



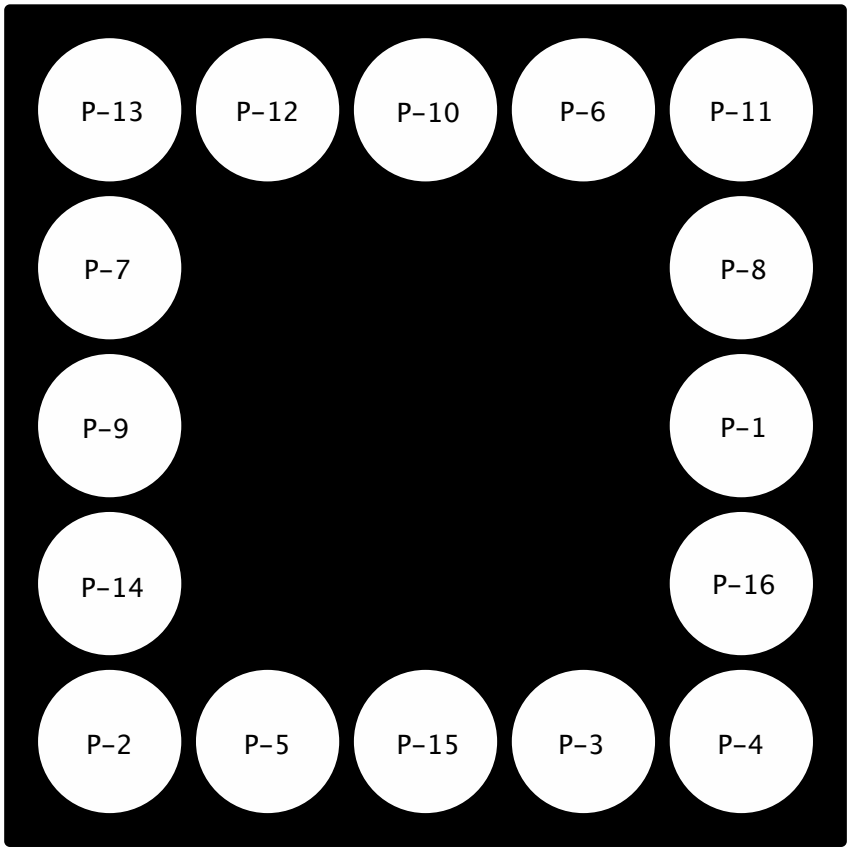
Basic Colors Layout

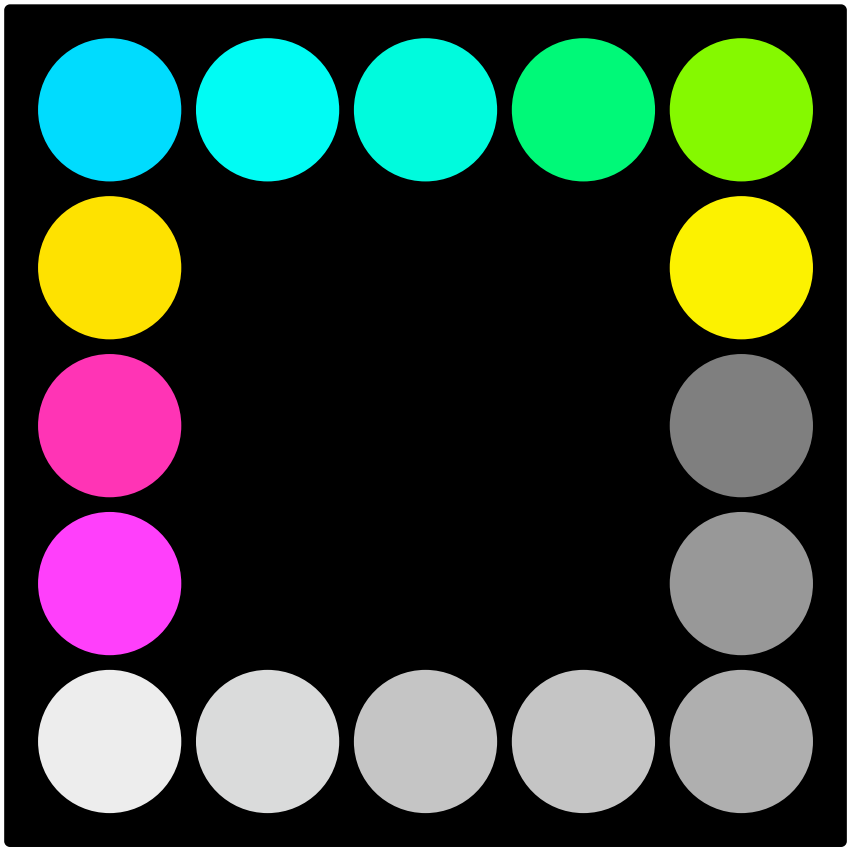


Special Colors Layout



Pastel Colors Layout





Summary & Conclusions

This document describes 2 designs for matrix arrays of color standards, as follows: (1) A compact square array that consists of 4 x 4 circular tiles with an inter-tile separation of 0.13 inches. (2) A larger square matrix of 5 x 5 circular tiles with a vacant center and an inter-tile separation of 0.13 inches. The external dimensions of the compact array are 7.25 x 7.25 x 0.50 inches. The large array measures 8.75 x 8.75 x 0.50 inches.

The reduced size of the compact array is advantageous for inverted operation of the spectrophotometer. However, during upright operation an accessory block is required that closely matches the thickness of the compact array, and the workbench must be clean and perfectly flat. As described above, the requirements for co-planarity are critically important.

During upright operation of the spectrophotometer the large matrix array permits easier attainment of effective optical contact between the sample and the sample stage. The vacant surface at the center of this array insures the quality of the optical contact.

Caveats & Other Design Options

Either array design may be implemented with square tiles or with circular tiles as shown in the accompanying drawings. However, with either approach potentially troublesome problems may occur.

At present, Mt. Baker Research L.L.C. outsources the cutting of ceramic color standards to a supplier that employs a precision CNC waterjet. We outsource the manufacture of Delrin holders to machine shops that use precision CNC, 3-axis milling machines.

Square tiles with sharp corners are much easier to manufacture than quasi-square tiles with rounded corners. However, the reverse situation applies to the wells that are machined in the Delrin holders to accommodate the individual tiles. It is not possible to machine these square wells with inside corners that are perfectly sharp (discontinuous).

The final radius of these inside corners is determined by the size of the small end mill that is used during the finishing procedure on a 3-axis milling machine. Therefore, with square tiles the wells in the holder must be designed properly in order to accommodate the sharp, pointed corners of the tiles.

With circular tiles there are no corners to match, so this problem does not arise. Provided that the circular tiles are not too small, the precision CNC waterjet is capable of producing them with acceptable circularity and edge quality. Within the workable size range the dimensional tolerance of the circular tiles is matched vis-à-vis the corresponding tolerance of the circular wells machined in the Delrin holder.

Caveat: When a precision waterjet is used to manufacture small circular tiles, the circularity and the edge quality are both reduced. As a result there is a working minimum size limit that underlies the manufacture of these circular tiles.

Careful testing is needed to establish this limiting size. The author has seen circular tiles of adequate quality with a diameter of 2.0 inches. However, the present matrix array layouts cannot be adapted to circular tiles with a 1.0-inch diameter.

Machine Drawings — Compact Array Design

1. Assembly Top View
2. Assembly Front View
3. Assembly Right Side View
4. Holder Top View
5. Holder Front View
6. Holder Right Side View
7. Base Plate Tope View
8. Base Plate Front View
9. Base Plate Right Side View
10. Table Accessory

Proprietary machine drawings are not included in this public document.

Machine Drawings — Large Array Design

1. Assembly Top View

2. Assembly Front View

3. Assembly Right Side View

4. Holder Top View

5. Holder Front View

6. Holder Right Side View

7. Base Plate Tope View

8. Base Plate Front View

9. Base Plate Right Side View

Proprietary machine drawings are not included in this public document.

Machine Drawings — Standards & Uncut Tiles

1. Standard #130R

2. Tile #130

3. Tile #130 WaterJet Cutting Template

4. Standard #131R

5. Tile #131

6. Tile #131 WaterJet Cutting Template

Proprietary machine drawings are not included in this public document.