Low-cost, pseudo-Halbach dipole magnets for NMR

Supporting information

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S.1 Safety

With surface fields that can exceed 0.5 tesla, rare earth magnets require careful handling to avoid damage or personal injury. The photograph below in Figure 1 shows an example of poor practice encountered when constructing our magnet array. A magnet block was being inserted into the array without proper confinement of the other magnet blocks, causing one of these to fly out at high speed, collide with a wall and shatter:

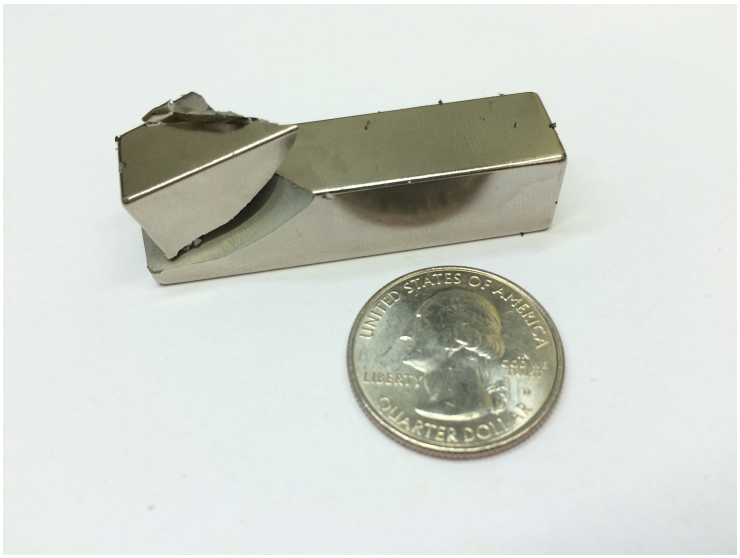


Figure 1: It is easy to break NdFeB magnet blocks if one lacks care.

Fortunately in this case there was no injury, except for a square dent left in the wall. Practice was altered to ensure safe assembly of the magnet arrays. We recommend that the instructions we have provided are followed carefully. However, to do so is still at the reader's own risk and we accept no liability for accidents, damage or loss incurred.

S.2 Fabricated parts

On the next few pages we show drawings that were used to make the parts required for the magnet array casings. The parts were produced by light machining of 6061 aluminum mill stock, which could be purchased in standard sizes from a materials supplier. All dimensions are in inches (1 inch equals 25.4 mm exactly).

Each magnet casing was made from seven machined parts:

- (1) a cylindrical bore insert, which formed the central part of the array structure.
- Four side panels: (2) left, (3) right, (4) front, (5) back. Pairs of left/right and front/back panels are identical. This part of the structure bears greatest force. To ensure sufficient strength and robustness while keeping weight and bulk low, a material thickness of 0.75 inches was chosen. The faces that would be in contact with the magnet blocks were fly-cut to a smooth finish to provide a low coefficient of friction.
- (6) Top and (7) bottom covers were made from 0.5 inch thick aluminum.

To form the casing, pieces (2)-(7) are joined together using 10-32 national-fine hex-head screws. In addition to the above, some extra parts are machined to assist with the assembly of the 24-block magnet:

- (8) Dummy magnet blocks made from aluminum, 0.002 inches oversize in the depth and width. A minimum of 12 were required for the 24-block magnet array.
- (9) "Jigs" made from 0.25 inch thick aluminum.

S.3 Magnet material

Magnet blocks were purchased from CMS Magnetics at the highest commercially available grades at the time: N48SH and N52. Hysteresis curves (at 20 °C) are shown with permission of the supplier in Figure 2:

S.4 Assembly instructions

The 24-block magnet array was assembled as outlined the sequence detailed below. We reference the photographs shown in Figure 2 of the main article and Figure 3 of this document.

1. All parts were machined to size and the dimensions were checked before further progress. Sharp edges and corners were filed smooth. Parts were cleaned after machining to remove oil and water.

2. The first magnet blocks to be placed were those lying across the 0.3 inch bore gap.

3. The left/right/front/back pieces were screwed together to forming the four side walls of the casing.

4. The part from step (2) was positioned inside that from step (3).

5. The array was filled with dummy blocks and the magnet blocks that attract to the central core from step (2), leaving no empty spaces between the walls.

6. Assembly jigs were screwed on to the top and bottom of the casing walls. The purpose of the jig is to prevent unsafe movement of the magnet blocks by allowing only one position in the array to be accessed at a time.

7. In our experience, the remaining magnet blocks could easily be inserted into the array by a healthy adult person without exhaustive effort. The casing was clamped across two of the side walls in a vise. The safety jig was attached to leave one dummy block accessible through the one of the square hole and was "tapped out" of the array by about 1/8 of an inch using a mallet and a piece of scrap aluminum rod. The magnet block intended to occupy that position in the array was then pushed into the space left by the dummy block (after checking that it was correctly oriented for the final magnet). Moderate force was applied to push the block fully into the array and displace the dummy block out of the other side. The jig was then positioned to make accessible another dummy block, and the process was repeated until all magnets were inserted. To minimize the work required, we found it easiest to first insert the magnet blocks closest to the center of the array (bore) and then proceed towards the edge. We did not use glue to secure the magnet blocks.

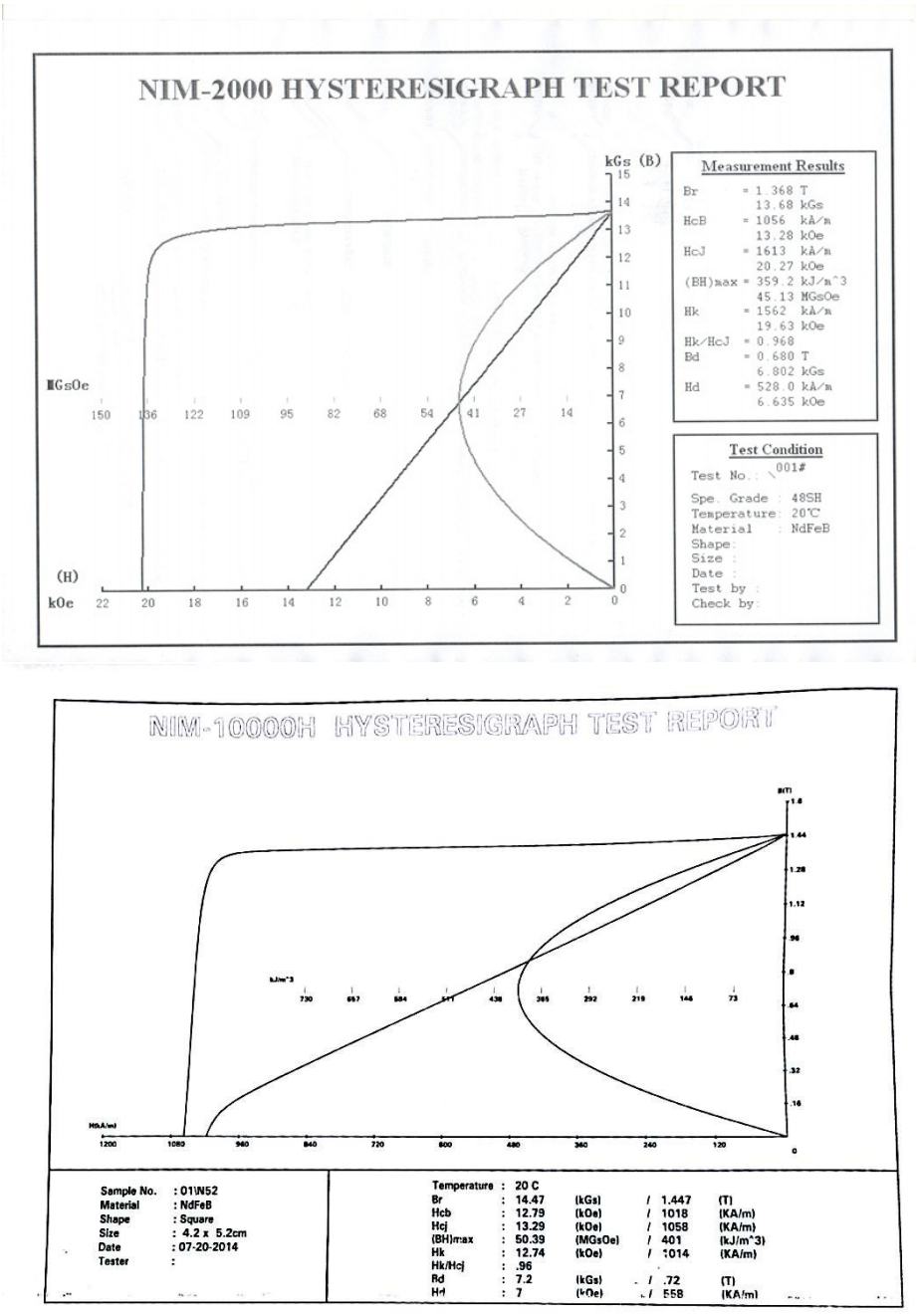


Figure 2: Hysteresis curves and material data for N48SH and N52 magnet blocks.

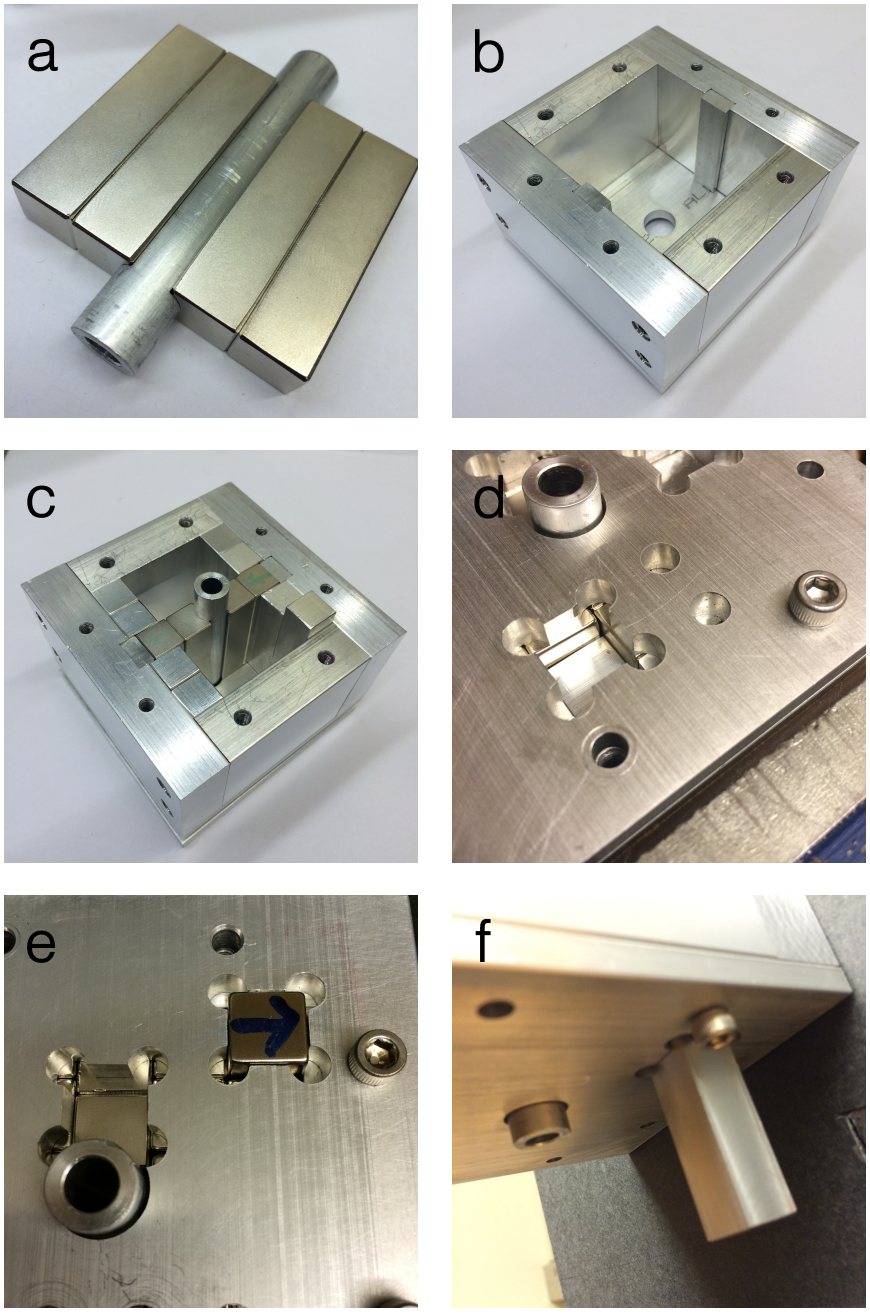
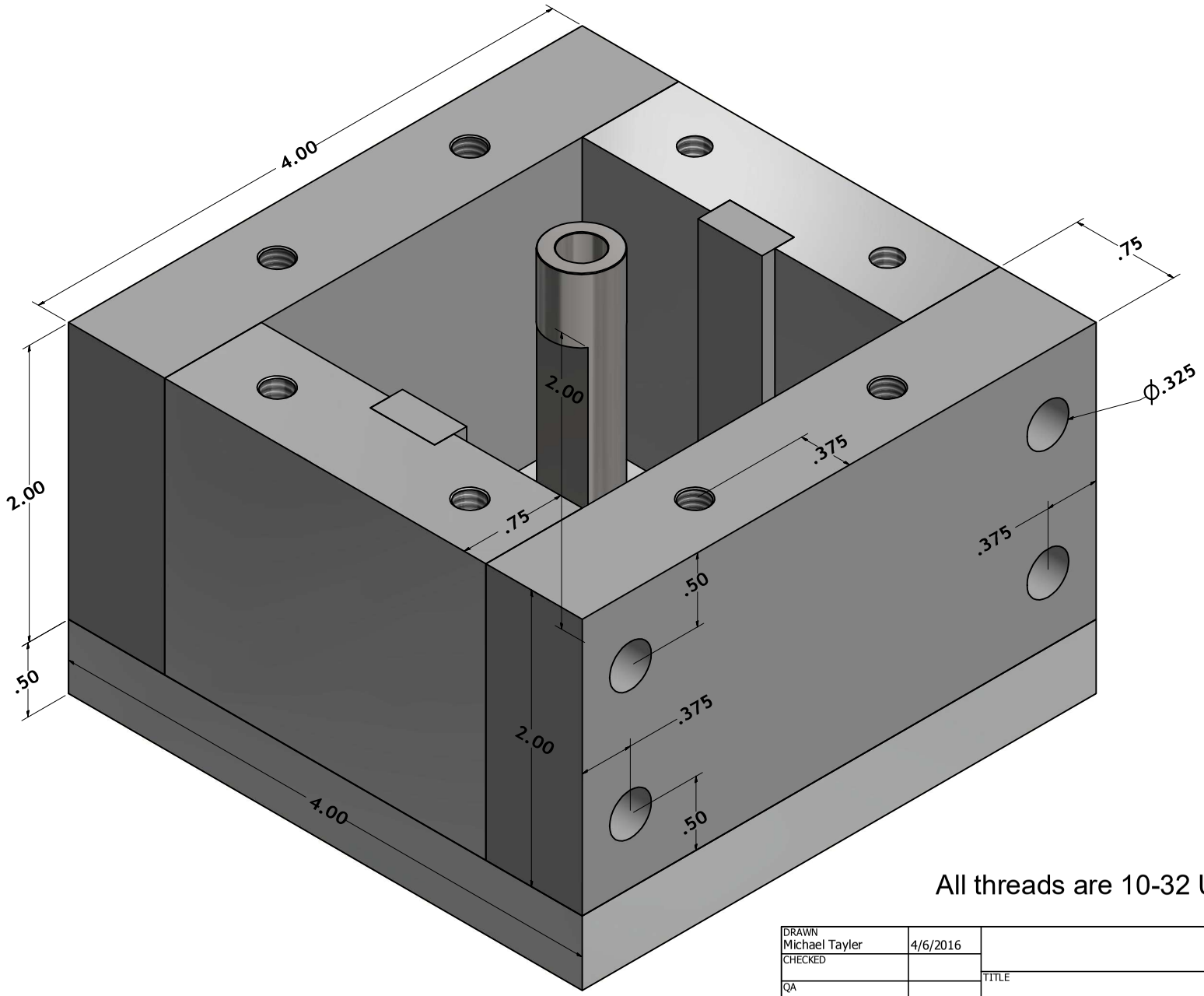


Figure 3: Assembly steps for the 24-block magnet arrays: (a) blocks magnetized along the axis of the magnet dipole are placed around the central bore; (b) side walls of the magnet casing are screwed together; (c) parts are placed inside one another; (d) with the retaining jigs screwed on to the top and bottom, one dummy block is partially "tapped out"; (e) a correctly oriented magnet block is pushed into the hole left by the "tapping out", displacing the dummy block out of the other side as shown in (f).



All threads are 10-32 UN fine

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MFG			
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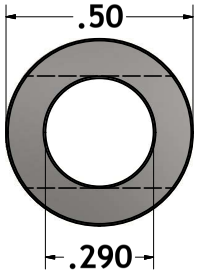

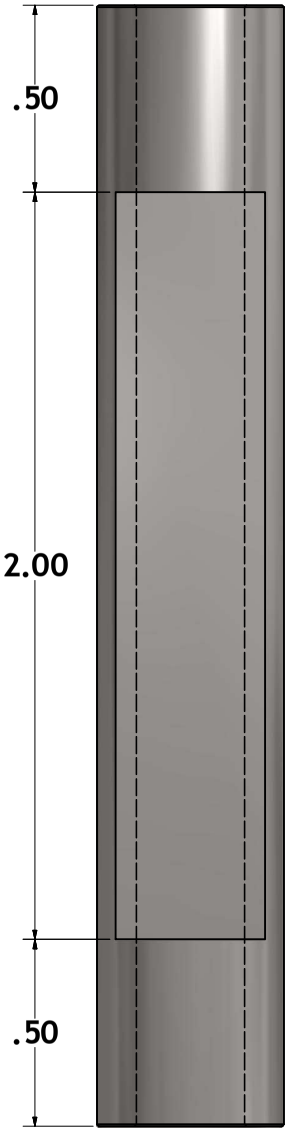

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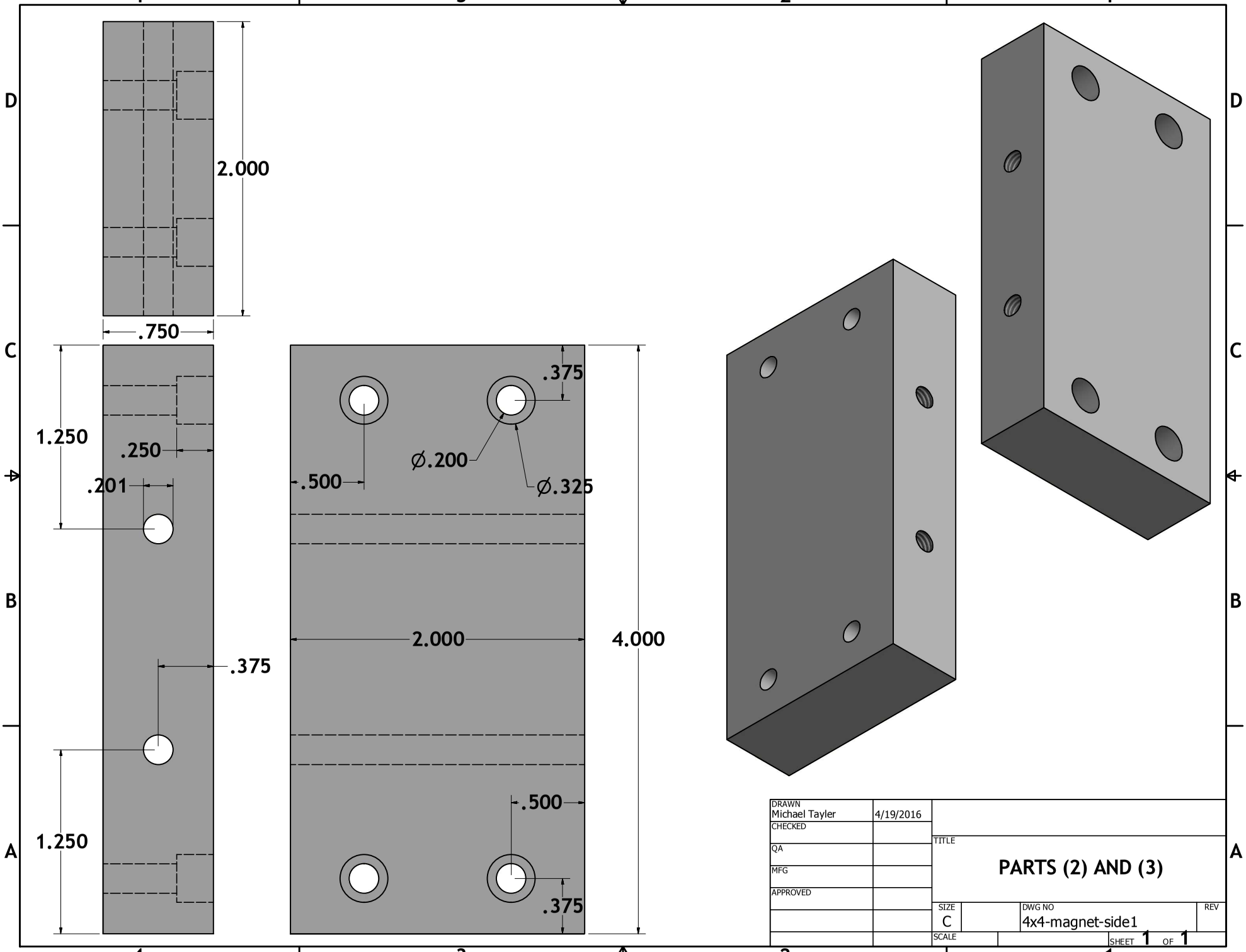
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Michael Tayler
4/19/2016
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PARTS (2) AND (3)
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4x4-magnet-side1
REV
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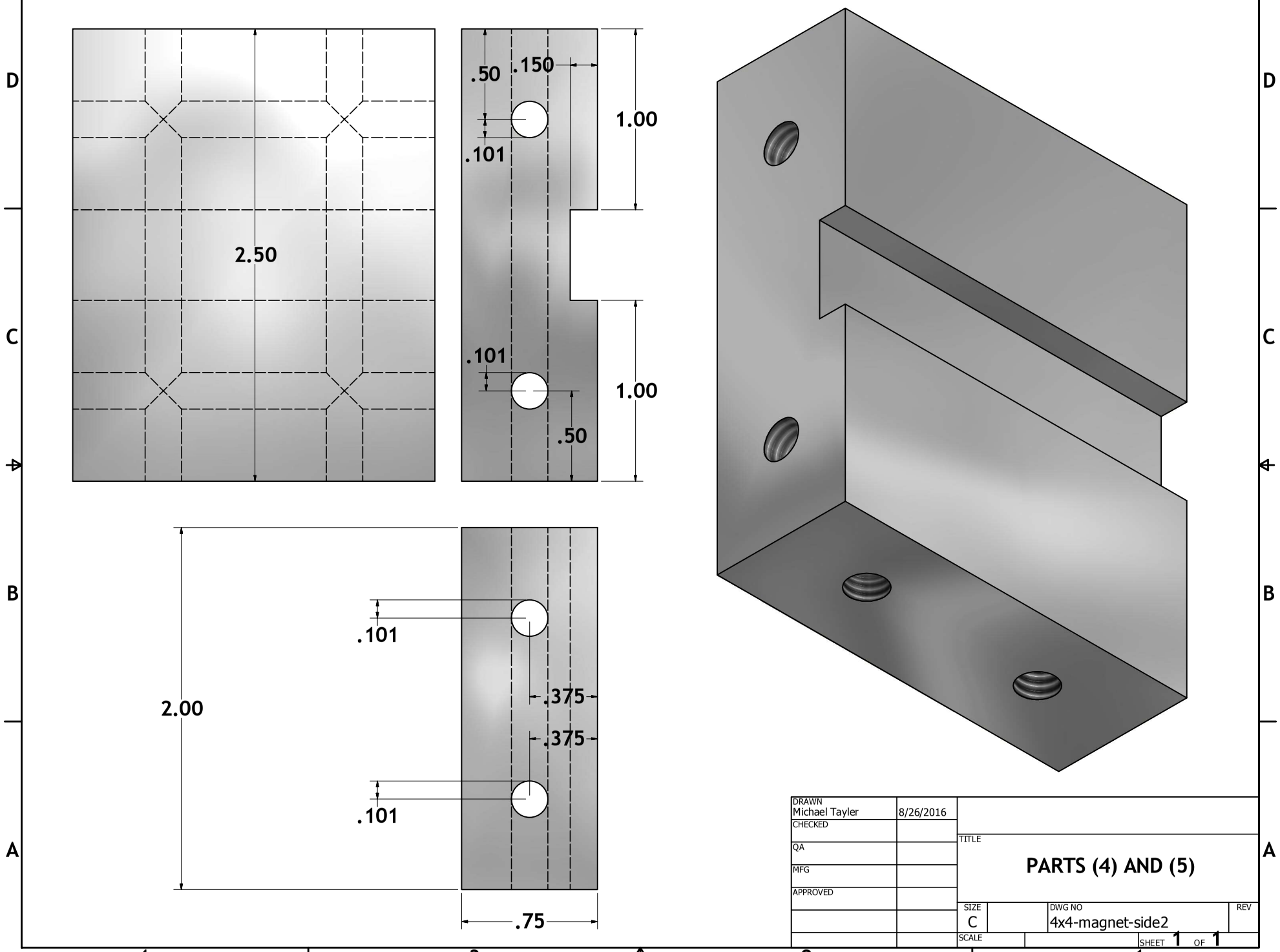
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Michael Tayler
8/26/2016
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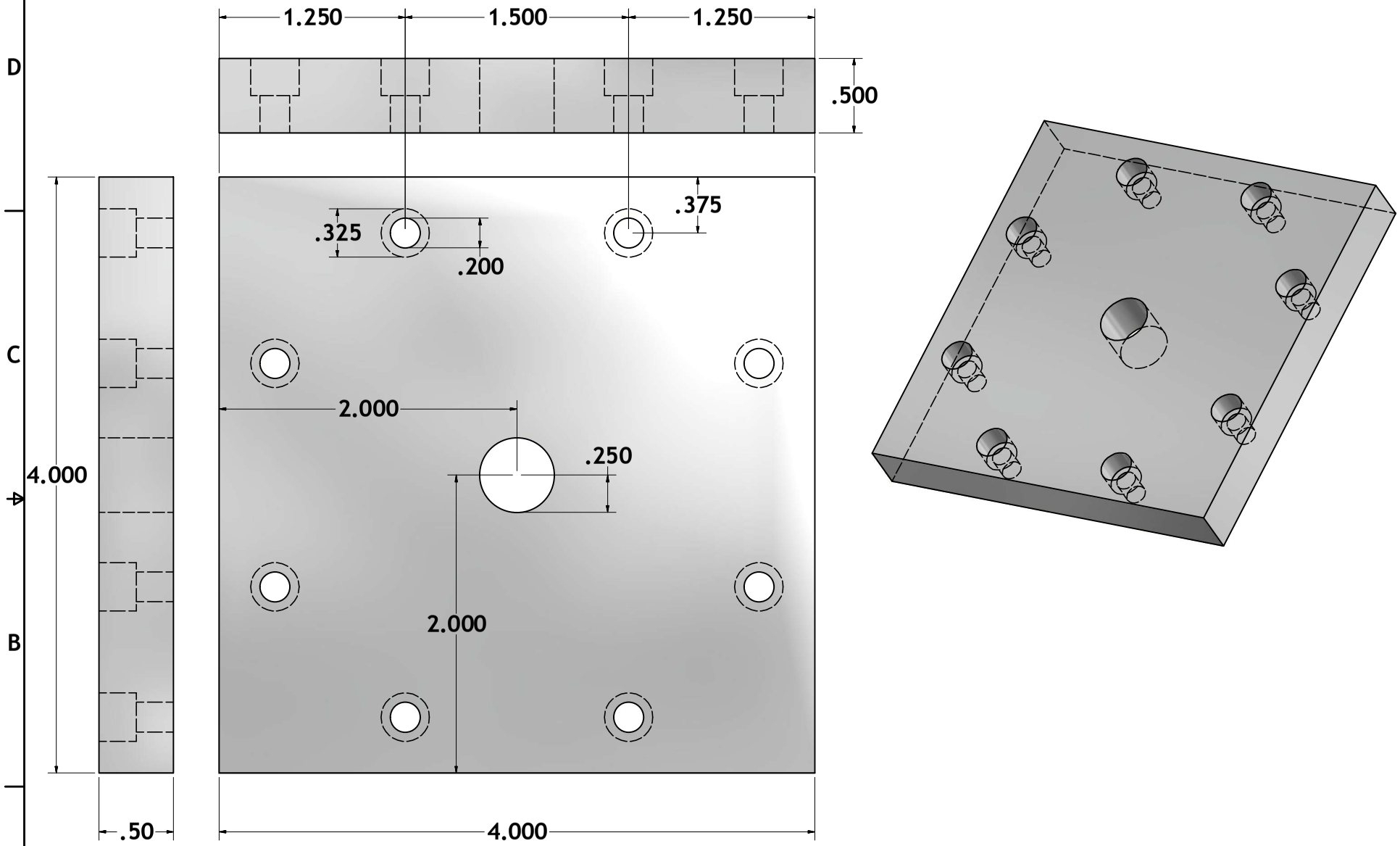

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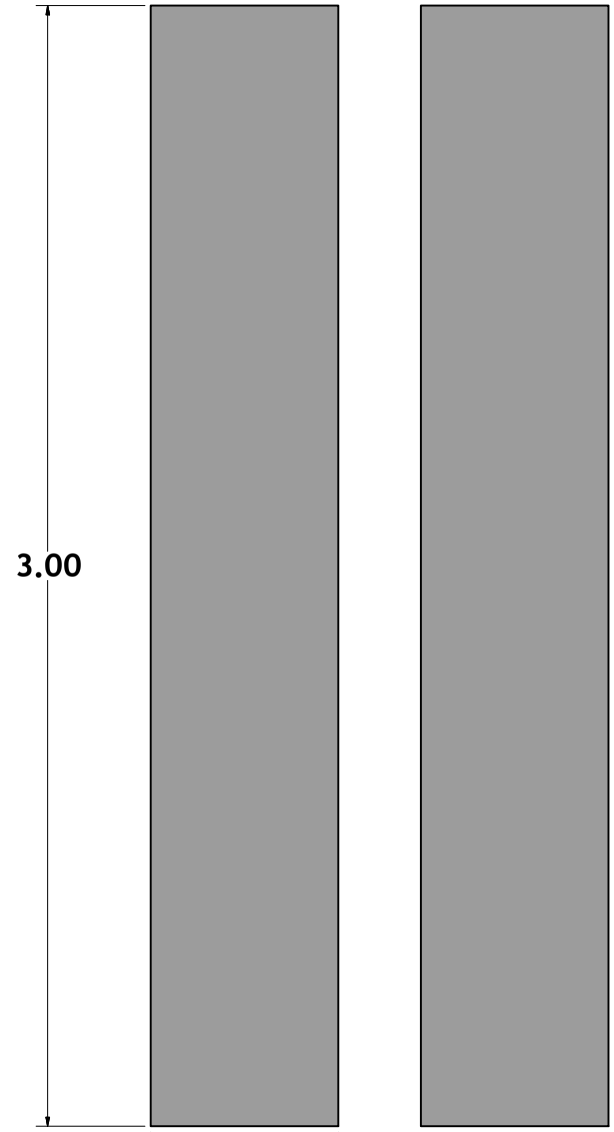

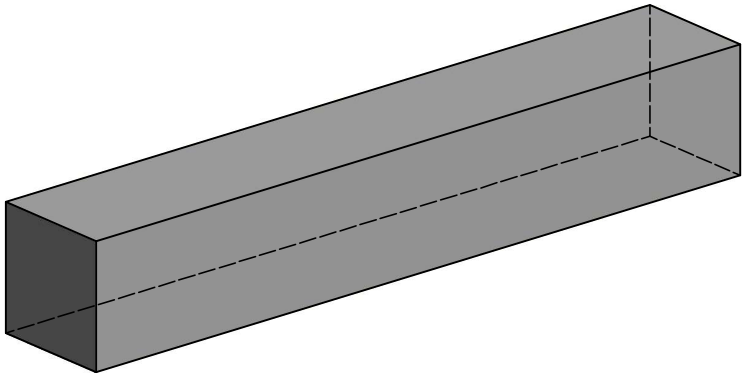

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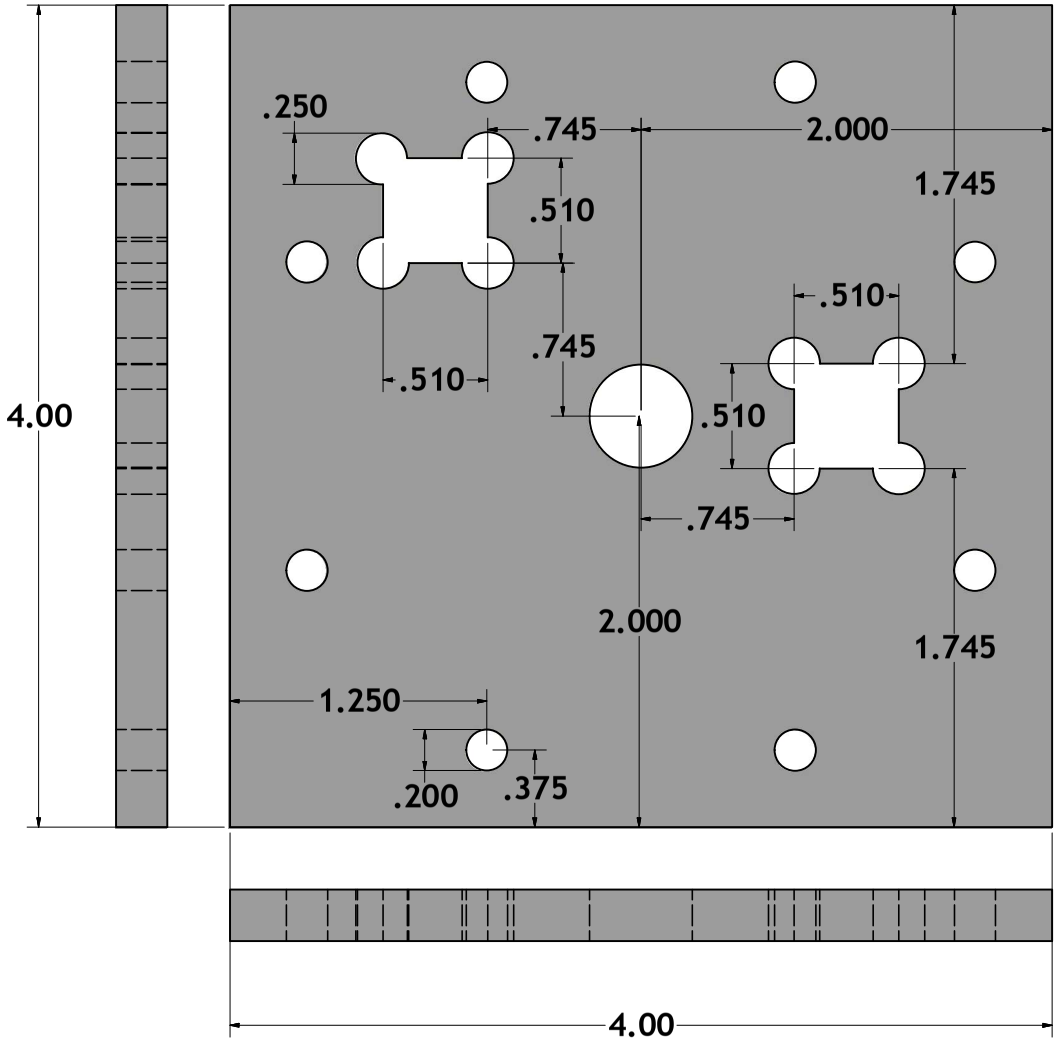

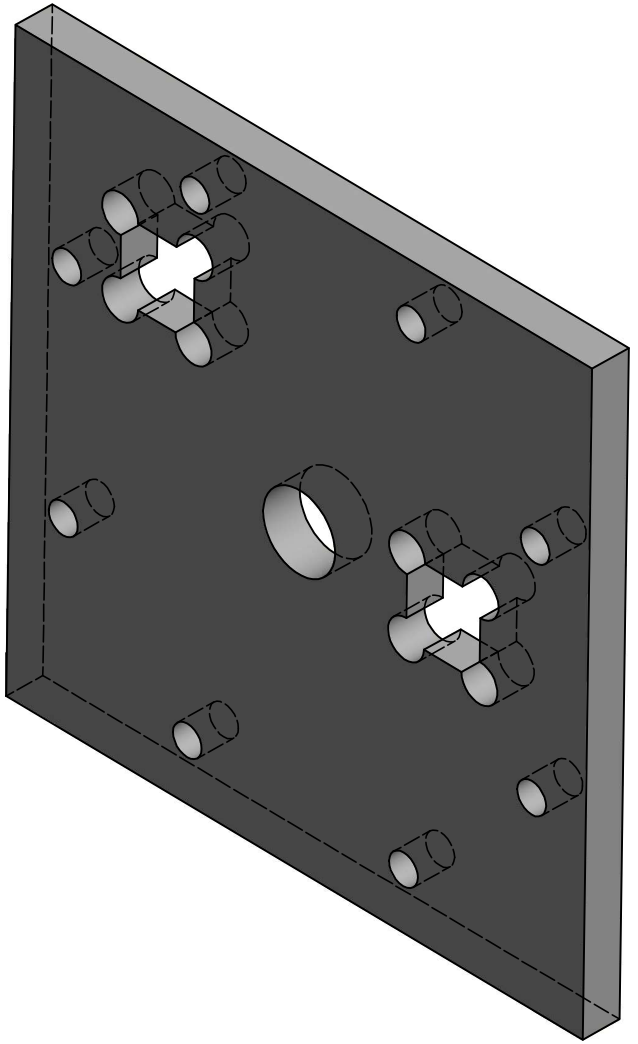

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