Kiln Building: Methods, Tips and how I built das Uber Kiln

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Reasons to make your own kiln

• Lower cost
• Better components
  – Commercial kiln manufacturers must make a number of tradeoffs in their designs, not all of which (shipping) are to the benefit of the optimal kiln design for glass fusing.
• Designed to fit your needs exactly
• Fun!
What kind of glass work will you be doing?

- Casting
- High Fire fusing
- Glass fusing
- Annealing

- The important questions here are what are your peak operating temperatures and how long will you be holding these temperatures?
What are your particular working environment needs?

• Placement
  – Basement
  – Garage
  – House
  – Studio

• Available power
  – 110/220 at what amperage
What is your budget and your resources?

- **Cost**
  - For my kiln there was an even split 1/3 for structure, electrical and insulation

- **Access to steel working**

- **Handy?**

- **Tools?**
What is a kiln?

• Simply a box or container in which you dump heat into.
  – All the heat you put into a kiln must come out of the kiln.
    • A perfect insulator will never cool and likewise in the absence of an insulator, the kiln will never heat.
    • A good kiln design is a balance between heating and insulation to meet the needs of your particular design.
Types of kilns – Top Feed

• Clamshell/Top feed
  – Easy access inside
  – Simple design (Square)
Types of Kiln – Front Loader

• Front Loader
  – Nice for looking inside
  – Can be simple loading (needs to be at right height)
  – Good for combing
Types of Kiln - Bell

- Easy access around work surface
- High capacity – Large working surface
- More complicated lifting system
- Moderate expense
There are 3 basic systems in the design of a kiln

– **Structure**
  • What holds everything together, usually a steel box of some type

– **Insulation**
  • What holds the heat in. Materials range from fiber blanket, insulation board to brick

– **Electrical**
  • What you use to heat the kiln and how you distribute it to the kiln and how you control it. (Gas can be used but I will not discuss it)
Get a good plan

- Decide on your major components ahead of time
- Draw up your design
- Figure out major features of each system
  - Structure
    - What kind of steel? (angle iron, box steel, expanded metal or sheet sides)
    - How heavy?
    - How to support any lifting elements?
  - Insulation
    - What type?
    - How heavy?
    - How will you hang/support the insulation?
  - Electrical
    - How much heat required?
    - What type of elements?
      - Nichrome or Kanthal
    - How will you hang/support the elements?
    - How will you distribute power to elements?
    - What will your controller design look like?
    - What kind of controller?
Safety

• **Structure**
  – ONLY use rated materials on load bearing assemblies
    • Grade 5 or grade 8 bolts
    • Known tension strength cable, chain, etc.
    • Quality welds (TIG or MIG) on welded load elements
    • For the few parts that will hold the load spending a few more dollars for that rated bolt is better than having hundreds of pounds of insulation and steel coming crashing down later.
  – If you are concerned about a design, consult an engineer….post on the board, there are LOTS of very capable technical assistance.

• **Insulation**
  – Use foil on the outer layer to reduce dust
  – Use refrasial (lavacloth) to reduce dust on seal
  – ALWAYS wear respirator during assembly and maintenance

• **Electrical**
  – Know your local code and make sure you wire to code standards
  – Size your cable, relays, switches etc. accordingly
  – If you can afford it, put in a backup overtemp shutoff
  – Ditto on the above, if you have a question, post on the board.
Example Plans - 1

Bottom Plate  
1/8" x 4' x 4' 11.5"

3/8" Gap all around bottom metal plate an inside of angle iron border.

5'3" Dimension is inside dimension of angle iron border.

2 - Bottom Plates  
1/8" x 11.5" x 2' - 5.75"

10 1"x2"x2" 5 5/8" box steel
4 1"x2"x5' 5 1/4" box steel
1 1"x2"x5' 3" box steel
4 1/8"x1.5" x5' 3 1/4" angle iron

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Example Plans -2

98 Bricks
1.86lbs/brick = 183lbs in brick

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Example Plans - 4

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**Design – Electrical**

Power = Volts x Amps  
26.6 KW = 26.6 x 1000 Watts = 26,600 Watts  
26.6 KW = 240Volts x 111Amps

<table>
<thead>
<tr>
<th>Kiln Size</th>
<th>Length (in)</th>
<th>Width (in)</th>
<th>Height (in)</th>
<th>Total Vol (in³)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>17</td>
<td>52</td>
<td>52</td>
<td>45968</td>
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Power Required

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<tr>
<th>Total Power (KW)</th>
<th>1.25KW/ft³</th>
<th>1.00KW/ft³</th>
<th>0.85KW/ft³</th>
<th>0.5KW/ft³</th>
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<tr>
<td>33.25</td>
<td>26.60</td>
<td>22.61</td>
<td>13.30</td>
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</table>

Amps @ 220V

<table>
<thead>
<tr>
<th>Amps @ 220V</th>
<th>151</th>
<th>121</th>
<th>103</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amps @ 240V</td>
<td>139</td>
<td>111</td>
<td>94</td>
<td>55</td>
</tr>
</tbody>
</table>

Number of 60A Relays

<table>
<thead>
<tr>
<th>Amps @ 220V</th>
<th>3.02</th>
<th>2.42</th>
<th>2.06</th>
<th>1.21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amps @ 240V</td>
<td>2.77</td>
<td>2.22</td>
<td>1.88</td>
<td>1.11</td>
</tr>
</tbody>
</table>

Number of 14A Elements

| Amps @ 220V | 10.80 | 8.64 | 7.34 | 4.32 |

Power = Volts x Amps

26.6 KW = 26.6 x 1000 Watts = 26,600 Watts

26.6 KW = 240Volts x 111Amps
Design – Electrical Components

• From previous page we need 8 – 14Amp elements and at least 3 - 60Amp breakers
• Cost of 4 – 35Amp breakers was cheaper than 3 - 60 Amp breakers
  – 2 circuits for the sides (top and bottom)
  – 2 circuits for the top (front and back)
• Decided on Duralite elements for top (quartz tube hanging system)
• Decided on Joppa Glassworks system for the side (mullite rod hanging system)
Design – Simple Electrical Schematic
Design – Complex Electrical Schematic
Design – Insulation: Heat

• Heat is transported (moved) by 3 methods:
  – Radiation
    • An example is the sun’s rays.
  – Convection
    • Requires a moving material. Your home forced air system heats by convection.
  – Conduction
    • Your stove in your home heats by conduction. The stove elements get hot and by conduction heat your frying pan which cooks your morning eggs.
• In a kiln ALL 3 types of heat transport play an important part in how a kiln works
• Not all methods of heat transport work equally in all areas of a kiln
  – Inside
    • Radiation is the primary method of heat transport
    • Conduction of air is VERY poor so contribution inside is low
    • Convection is minimal
  – Kiln Walls
    • Radiation is nil
    • Conduction is the primary method of heat transport
    • Convection is nil
  – Outside face/walls of kiln
    • Radiation is significant if not primary method of heat transport
    • Conduction is nil (air an excellent insulator)
    • Convection may be significant, especially if you have fans
Heat Conduction

• The calculation of heat movement by conduction is VERY complicated
  – The rate heat moves is dependent upon the material and the current temperature that material is currently at
    • Makes for a problem that essentially can only be solved by a computer analysis

• Here, experience is probably better for an approximate solution
Types of Insulators

- **IFB – Insulating Firebrick (K23)**
  - Very good insulator
  - Heavy (31.7 lbs/cuft)
  - Tends to flake with time. Bad material to use for a top, best for bottom and sides (for high temp kiln)

- **Blanket – Typically 1” or 2” 8#** (refers to the density 8lbs/cuft)
  - Works well
  - Light
  - Requires some system/method of support for sides and top
  - Initial use it needs to be burned out. May flake for a while (might want to rigidize)

- **Board – Thermo 12, Duraboard (LD or HD)**
  - Nice for sides as provides rigid material for element support
  - Heavy (Thermo 12 = 14.5lbs/cuft)
  - Requires some system/method of support
  - Like blanket, initial use requires burning out. May want to rigidize.

- **Refrasial – Sometimes called lavacloth**
  - Makes a good gasket/sealing material around doors and seams
  - Shrinks significantly on first use (15%-20%) so either buy preshrunk or shrink it before you fasten it permanently
Insulation Design

- Design for your peak temp and maximum hold temperatures
  - In a high fire or casting kiln your peaks can reach 1800F with significant hold temps
  - In a glass fusing kiln your peaks will typically be around 1500F with minor hold times (15 – 30 min) and anneals at 1000F with hour long holds
  - In a tack fuse or anneal kiln your peak may only be around 1400F or as low as 1000F

- Rule of thumbs
  - For a casting kiln
    - Use K23 IFB for the bottom with 4-1/2 inch dimension being your bottom thickness
    - Use 6” of blanket or board insulation in walls and top
  - For a fusing kiln
    - Use K23 IFB for the bottom with 2-1/2 inch dimension being your bottom thickness
    - Use 4” of blanket or board insulation in walls and top
  - For annealing kiln
    - Use K23 IFB for bottom with 2-1/3 inch dimension being your bottom thickness
    - Use 2” – 3” of blanket or board insulation in walls and top
Construction - Steel
Construction - Steel
Construction - Steel
Construction - Steel
Construction - Steel
Construction - Steel

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Construction - Steel
Construction - Insulation

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Construction - Insulation
Construction - Insulation

2 layers of 1” insulation to stagger the seams
Note thermocouple wires

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Construction - Insulation
Construction - Insulation
Construction - Insulation
Construction - Electrical
Construction - Electrical
Cold box and Hot box
Construction - Electrical
Construction - Electrical

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Construction - Electrical
Finished!
First Glass

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How does it perform?

Uberkiln Characterization Curves

- **System Input**
- **Main2 Inside**
- **Fiber Lside**
- **Board Lside**
- **Board Top**
- **Outside Kiln Top**
- **Outside Brick Bottom**
- **Outside Kiln Side**
Example of Overshoot
Example of Controller Learning

Internal temp on a 400DPH ramp to 1500°F

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Lessons Learned/Tips

• Thing’s I might do different
  – Not use SS bowties on top. (Check for low carbon SS ahead of time. Do practice fires to check for flaking)
  – Get a more traditional limit switch for overtemp (such as a Watlow overtemp limit controller)
  – Probably use SSR’s instead of Merc Disp relays
  – Plan element’s better before top/steel layout
• You will spend a LOT more on hardware and special tools than you think so just plan on it
• Don’t forget your accessory costs (shelves, kilnwash, spare parts, etc.)
• Don’t forget to use anti-seize on bolts/nuts
• If you use an hour meter use the analog type not the digital type
Useful Links

- Elements
  - http://www.joppaglass.com/
  - http://www.duralite.com/

- General Hardware & Electrical Supplies
  - http://www.mcmaster.com/
  - http://www.mscdirect.com/
  - http://www.northerntool.com/
  - http://www.harborfreight.com/
  - http://www.grainger.com/
  - http://www.use-enco.com/

- Custom Machine Shop
  - http://www.emachineshop.com/

- Controllers
  - http://www.ortonceramic.com/
  - http://www.bartinst.com/
  - http://www.digitry.com/

- Temperature measuring equipment and thermocouples
  - http://www.omega.com/
  - http://www.iscsmartconnection.com/
Useful Links (cont)

- Insulation and refractories
  - http://www.unifrax.com/
  - http://a-1catalog.com/55un1.html/
  - http://www.tamparubber.com/
  - http://www.lavacloth.com/

- General Glass Equipment suppliers
  - http://www.crlaurence.com/
  - http://www.crlooo.com/
  - http://www.aaproducts.com/
  - http://www.fusionheadquarters.com/
  - http://www.sunshineglass.com/

- Abrasive tools and equipment
  - http://www.hisglassworks.com/
  - http://www.kingsleynorth.com/
  - http://www.granitecitytool.com/