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Panel: GLASS STUDIO AS ENERGY SOURCE

Moderator: Eddie Bernard

Panelists: Charlie Correll, Doug Ohm, and Jim Gosnell

This panel is part of an ongoing series of GAS Conference discussions that have covered the previous topics of "Fueling the Habit" (2006), "BioGlass: How to Create More Efficient Studios that Utilize Renewable Energy Sources" (aka "Alternative Energy" 2007), "The Glass is Greener" (aka "Energy Usage" 2008), and "Energy and Atmosphere" (2009).

While there are countless approaches to reducing the environmental impact of studio operations, this panel focuses on the massive amount of energy emitted from hot glassmaking equipment. After one reduces the amount of energy used in a heating appliance by better insulating, using better habits, dampering flues, etc. – even using alternative fuels such as vegetable oil, and recuperating return heat from the exhaust stream back to the air supply stream – there is still much that can be done with the rejected heat.

For example, let's compare 70°F combustion air to 800°F combustion air. With an exhaust temperature of 2200°F using 70°F combustion air at 10% excess air, the available heat is 37%. Now taking 800°F combustion air at 10% excess air, it increases the available heat to 53%. This is a 16% increase in available heat, which translates to 30% fuel savings (as shown in the equation below).

1 - 37 = 1 - 0.70 = 0.30 = *30% fuel savings*

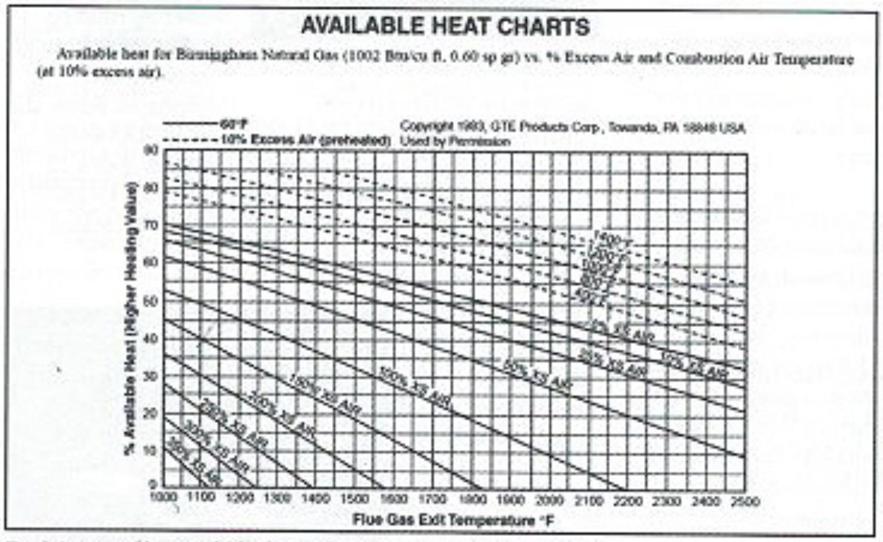

Fig. 1 Amount of heat available after combustion air robs heat from a flame

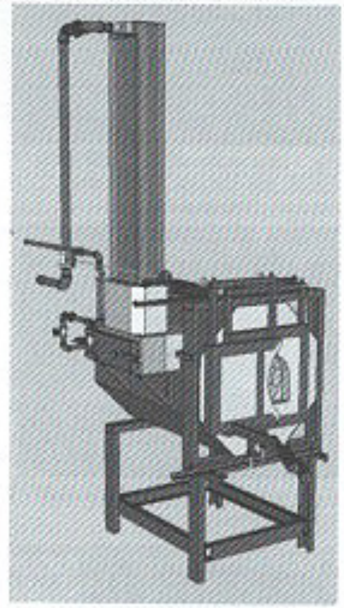

Fig 2 A recuperator on a glory hole, rendering by Charlie Correll

Fig. 3 Gas fired kiln-forming oven with recuperator by Ohm Equipment

Fig. 4 Double-ended recuperated glory hole with integral hood by Wet Dog Glass, LLC

The chart outlines how much heat is available after combustion air robs heat from a flame. (Fig. 1) The dotted lines reveal that as combustion air is preheated, available heat rises. As an example, follow the vertical line up from 2200°F until you hit the diagonal 800°F dotted line. Where they intersect, follow the horizontal line to the left to find the percentage of available heat you have.

The formula for determining fuel consumption reduction with a given air preheat temperature is as follows:

$$1 - \frac{\%\ \text{available a}}{\%\ \text{available b}}$$

Using a recuperator on a glory hole makes sense if the designer sees the need for a flue. (Fig. 2 - 4) The flue helps create a flame path as well as reduce the blast of heat exiting from the front doors. The flue should be dampered so that it cannot create a draft that pulls cold air into the glory hole through

Fig. 5 Heat reclamation by exhausting directly into the pipe warmer that exhausts into a small garage

Fig. 6 James Clark's use of his furnace exhaust to heat cullet

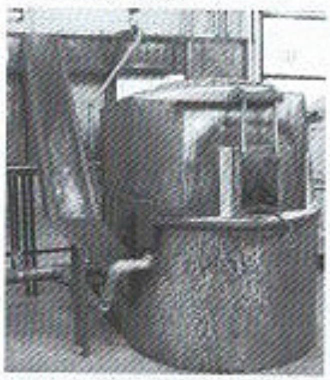

Fig. 7 Christian Thornton uses the exhaust heat to heat annealing ovens

Fig. 8 Pablo Soto's secondary air-to-liquid heat exchanger reclaims heat after his recuperator to heat the adjacent studio space via a radiant floor

the doors. Recuperating allows for closing off all doors completely. This works best either with an electronic temperature control or a vigilant operator to maintain the output settings.

A really obvious idea for heat reclamation and reuse is to exhaust directly and immediately, as with a pipe warmer that exhausts into a small garage. (Fig 5) James Clark, a Canadian glassblower, uses his furnace exhaust to heat cullet to the softening point prior to charging. (Fig. 6) This enables him to charge every 40 minutes as opposed to every 60 or 75 minutes. It also reduces shock to the furnace crucible or liner.

Christian Thornton at XaQuixe Glass Studio in Oaxaca, Mexico, uses the exhaust heat to heat annealing ovens. (Fig. 7) A recent modification shows a stainless drum that is a heat exchanger, which reclaims heat for furnace combustion air from the annealer's exhaust, and finally flows around a water tank to heat water for a neighbor. An exhaust fan helps maintain airflow through the system.

Pablo Soto in Penland, North Carolina, reclaims heat in water, and pumps it through the radiant floor of the adjoining studio space. (Fig 8) After his recuperator, which preheats his combustion air, the exhaust is still roughly 900°F. A diverter either sends the heat directly out the roof or underneath the water tank depending on how much heat is needed.

A recent modification (not pictured) lets the water circulate from the tank, out to and inside a heat exchanger above the flue and back to the tank. One of the most basic principles of a heat exchanger, whether it's an air-to-air, air-to-liquid, or liquid-to-liquid, is to establish a large surface area for greater heat transfer.

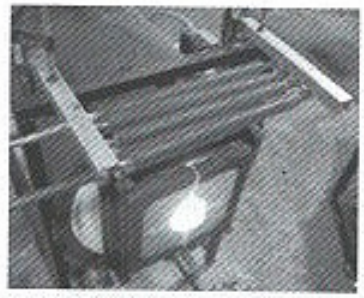

Fig. 9 STARworks Glass Lab's glory hole waste heat exchanger heats 40 gallons of water from 78F to 122F in one hour

Brent Young of Benchmark Glass in Cleveland, Ohio, used 100' of ¾" soft copper tubing over his furnace flue and he claims he heats his entire studio in the winter by running the hot water through a radiator, and blowing air across the radiator into the room. In an experiment at STARworks Glass Lab in Star, North Carolina, this system over a 12" glory hole heated 40 gallons of water from 78°F to 180°F in 3 hours. (Fig. 9) Note the finned tubes for increased surface area.

Water is not compressible. As it heats, it expands, so it's important to use an expansion tank to hold air, which is compressible to absorb the expansion and contraction of heated water. The diagram (Fig. 10) of a more complex system shows a liquid-to-liquid heat exchanger in the water tank. This method is used in cases where the liquid

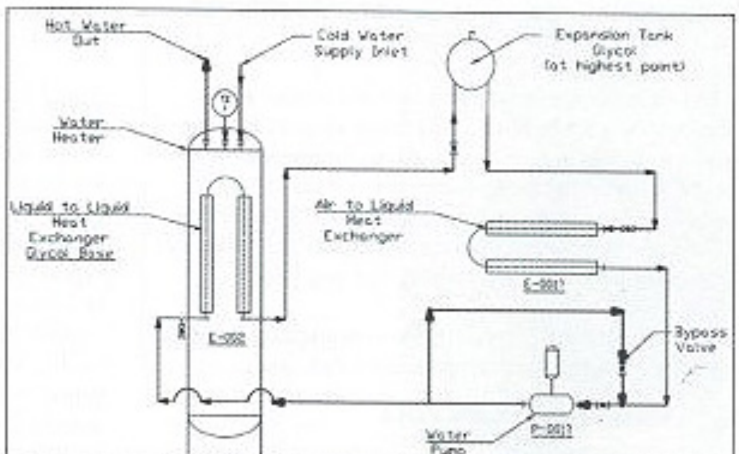

Fig. 10 Liquid-to-liquid heat exchanger is used to heat domestic hot water

might pass outside and freeze, or where it is not desirable to run potable drinking water through the circulation loop. This may include radiant floor tubing and other materials not rated for food-safe applications. (Note the expansion tank at its highest point.) Water can be pushed through a backup water heater for supplementary heating, if the heat collector is not sufficient to generate all the required heat.

As more components come into play, such as collectors, pumps, storage tanks, controllers, special valves, and expansion tanks, it becomes increasingly expensive and complex. It is important to determine beforehand how the reclaimed heat will be used. If there is little need, then money is wasted. However, everyone needs heat, even your neighbors. Consider distributing heat as a commodity to neighboring homes and businesses.

A typical hot liquid pump uses much less energy to circulate liquid, compared to the energy required to heat water. The nameplate on the pump rates it at 92 watts. Compare that to 5,500 watts for a 40 gallon water heater, or to 11,000 watts for an 80 gallon water heater. At 10¢ per kWh, the result is a savings of over $1.00 per hour, if there's a continual need for hot water.

A 3-D model of the setup at STARworks Glass Lab shows a furnace with a recuperator to preheat its own combustion air, then a diverter to send the 1100°F exhaust to either a batch preheater or an air-to-liquid heat exchanger that takes the exhaust down below the dew point. (Fig. 11) The liquid used is glycol because it has a greater ability to transfer heat. There is a 500 gallon glycol storage tank with pumps that also circulate hot glycol out to waste veggie oil tanks in a biodiesel refinery. In this process, most exhaust heat is removed from the glass studio, and 5-10 gallons of water are captured per day from the cooled exhaust. Jim Gosnell of Industrial Integration was instrumental in this design.

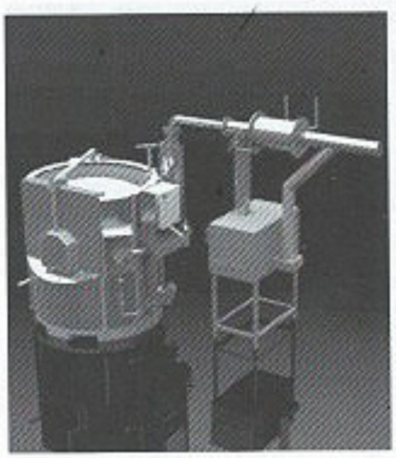

Fig. 11 Model of the setup at STARworks Glass Lab shows a furnace with a recuperator

The generic heat flow diagram (Fig. 12) illustrates how heat dissipates dramatically within the first few inches of a cold face. This suggests that to avoid robbing heat from a heating appliance, one must avoid actual contact with

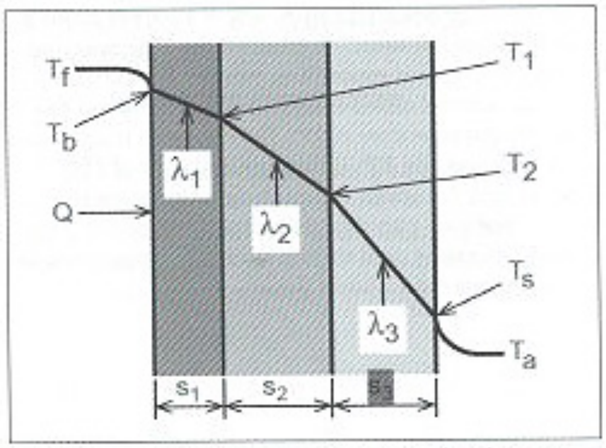

Fig. 12 The generic heat flow diagram illustrates how heat dissipates dramatically within the first few inches of a cold face

the cold face of the appliance. Air expands and contracts. When compared to air at 70°F, you can use this formula.

$$\frac{\text{Temperature} + 460}{530}$$

For example: 600°F + 460 = 1060. 1060 ÷ 530 = 2.
(600°F air is twice the volume of 70°F air.)

The implications of this fact are multifold. For one, piping must be sized to deliver larger air volume. For another, when heat is reclaimed from exhaust, the exhaust decreases in volume, and thereby requiring less energy to remove the exhaust from the building. Much heat is removed from the studio space via heat reclamation piping, or less heat is introduced to the space because it is being reused.

Considerations for Heat Collection, Storage, Delivery, and Reuse:

Remember, timing and distance are important factors in heat reclamation/reuse system design.

- *What heat is needed* *__when__* *heat is being exhausted? What heat is needed in the immediate vicinity of the waste heat source?* Heat returned to an application will typically travel less distance and not need storage for use later. The time to preheat batch or cullet coincides perfectly when the furnace exhausts more heat. An annealing oven is typically needed while a glory hole is expelling heat.

- *What heat is needed farther away?* Consider the medium (gas or liquid, for example) that you will use to convey the heat farther, and how you will insulate the ducting or piping for that heat transfer.

- *What heat is needed at a later time?* Thermal storage systems such as an insulated water tank allow heat to be stored for postponed use (such as for space heating or domestic hot water). A greater Delta T (temperature difference) means greater heat transfer. For example, if 120° water is mixed in equal parts of 70° water, the resulting temperature is 95°. The change in temperature for each part was 25°. If mixing equal parts of 150° water with 70° water, the resulting temperature is 110°, and each part changed temperature by 40°. This principle can be used to your advantage when trying to reclaim heat from a waste source.

- *What are your reasons for choosing an air-to-air system and the means (such as shorter conveyance distance, simpler system, etc.)?*
- *What are your reasons for choosing air-to-liquid system and methods?* Liquid can store more heat in a lower volume and therefore be conveyed by smaller piping than air.
- *What are your reasons for choosing to directly heat raw material such as batch? Is the timing in sync with the charging of the furnace and the distance typically short?*

Eddie Bernard earned a BFA in glass in 1996 from Rochester Institute of Technology. The same year, he founded Wet Dog Glass, LLC, a business that designs and manufactures high-end glass-processing equipment. He has instructed numerous hot glass sculpting workshops at Penland School of Crafts, Glass Furnace in Istanbul, and The Studio of the Corning Museum of Glass. He and his wife, Angela Bernard, founded the New Orleans Creative Glass Institute, a non-profit, community-access studio. He recently oversaw the creation of a second one, GlassLab in Star, NC. Bernard has served on the Board of Directors of the Glass Art Society since 2004.

Charles Correll began working with glass in 1971, when he took a part-time job blowing glass at the Jamestown Glasshouse of 1608. Today, he works in his studio in Conway, MA, blowing glass and building hotshop equipment for private studios and educational institutions worldwide. He designed and built his first recuperative glass furnace in 1981, resulting in better glass, more durable furnaces, and a 60% reduction in fuel consumption.

Jim Gosnell is a mechanical engineer with 15 years of experience in combustion control systems and heat recovery optimization. He has worked with Lean Six Sigma Methodologies and Supply Chain Management, optimizing manufacturing processes for small cap organizations to large corporations. His previous experiences in process pollution control and heat distribution, combined with his experiences in manufacturing oversight, provide alternative energy solutions to the smallest of operations.

Douglas Ohm began blowing glass in 1984 at San Francisco State University. He received his MFA from the University of Illinois at Champaign-Urbana. He has taught at Hartwick College, Rochester Institute of Technology, and Penland School, and conducted workshops specializing in advanced casting techniques and Fig.ure sculpting. Ohm was also on the staff of Pilchuck Glass School from 1991 to 1997. He also owns and operates Ohm Equipment, LLC, a premier glass equipment fabrication company. Ohm-Equipment specializes in hotshop equipment and scientific glass annealing lears.

From left to right, Charles Correll, Jim Gosnell, Douglas Ohm, and Eddie Bernard