**WBS Number: 64**
**WBS Title: Bakeout Systems**
**Job Number: 6401**
**Job Title: Bakeout Systems**
**Job Manager: Mike Kalish**

**Estimate Backup**

6401 HEAT TORCH Bakeout System REV3.xls    5/21/2007

| Size | | Labor Manhours | Material Cost ($) | Total Labor (Mhours) | M&S ($) (in 2002 $) |
|---|---|---|---|---|---|
| **304 SS** | | | | | |
| **Sch10 with Clevis hangers** | Linear Feet | | | | |
| 1" | | 0.160 | $8 | 0 | $0 |
| 1-1/4" | | 0.176 | $10 | 0 | $0 |
| 1-1/2" | | 0.193 | $11 | 0 | $0 |
| 2" | 200 | 0.239 | $14 | 48 | $2,700 |
| 2-1/2" | | 0.314 | $17 | 0 | $0 |
| 3" | 500 | 0.348 | $21 | 174 | $10,250 |
| **Sch 5 and 10** | NO. JOINTS | | | | |
| 1" | | 1.000 | | 0 | $0 |
| **ELBOWS** | Quantity | | | | |
| 1-1/2" | | 1.230 | $14 | 0 | $0 |
| 2" | 30 | 1.450 | $19 | 44 | $555 |
| 2-1/2" | | 2.000 | $40 | 0 | $0 |
| 3" | 10 | 2.670 | $48 | 27 | $475 |
| 4" | | 4.000 | $78 | 0 | $0 |
| **TEES** | Quantity | | | | |
| 2" | 10 | 2.290 | $37 | 23 | $370 |
| 1-1/2" | | 3.200 | $116 | 0 | $0 |
| 3" | 5 | 4.000 | $81 | 20 | $405 |
| 4" | | 8.000 | $101 | 0 | $0 |
| Adders | | | | | |
| Elevated Installation | 15% | 72.735 | | 73 | |
| amic Breaks (Fab and Install) | 6 | 8.000 | $2,000 | 48 | $12,000 |
| Insulation | 10% | 48.490 | $1,476 | 48 | $1,476 |

| Size | | Labor Manhours | Material Cost ($) | Total Labor (Mhours) | M&S ($) (in 2002 $) |
|---|---|---|---|---|---|
| **304 SS** | | | | | |
| VALVES | | | | | |
| **3" Backpressure control valve** | 1 | 8.000 | $8,000 | 8 | $8,000 |
| 2" Ballancing Valvs | 6 | 8.000 | $800 | 48 | $4,800 |
| 16" | | 16.000 | $800 | 0 | $0 |
| 3" Ceramic Breaks | 24 | 6.000 | $1,200 | 144 | $28,800 |
| 3" Bellows | 24 | 6.000 | $135 | 144 | $3,240 |
| **Gast Blower** | 1 | 32.000 | **$4,000** | 32 | $4,000 |
| **Instll Htr** | 1 | 40.000 | $6,000 | 40 | $6,000 |
| **Install Instru** | | 16.000 | $200 | 0 | $0 |
| **Install Pwr** | 1 | 120.000 | $5,000 | 120 | $5,000 |
| **Install Tank** | | 96.000 | $5,000 | 0 | $0 |
| Piping Support Towers | 4 | 160.000 | $3,000 | 640 | $12,000 |
| | | **Totals** | | | |
| **Subtotal (2002$)** | | | | 2470 | $112,071 |
| **Escalation from 2002$ to 2007$ for 304SS** | | | | | 1.40 |
| **Approximate Cost of M&S in 2007$** | | | | | **$157,185** |

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**Calculations**

Michael Kalish 7/2/2004

**THE FOLLOWING CALCULATIONS DETERMINE THE MASS FLOW RATE THROUGH THE INTERNAL PFC TUBING GIVEN THE PRESSURE DROP AND air PROPERTIES**
**For air, once through**

**Calculate the pressure drop through the PFC tubing.**

Adjust k and $\mu_h$ for Temperature

$k := .015 \cdot \frac{BTU}{hr \cdot ft \cdot R} \cdot \frac{273 + T_{inlet}}{273 + 20}$  $c_p := .241 \cdot \frac{BTU}{(lb \cdot R)}$  $\mu_h := 39.16 \cdot 10^{-8} \cdot lbf \cdot \frac{sec}{ft^2}$

viscosity from CRC handbook or (Marks pg 3-36) changes with temp. but not pressure  $\mu_h = 39.2 \, 10^{-8} \cdot \frac{lbf \cdot sec}{ft^2}$  $\mu_h = 0.0187$ centipoise

$\rho_{h\_at\_std} := .076 \cdot \frac{lb}{ft^3}$

$p = 1.5\,psi$  $P_{avg} := P_{sys} - \frac{\frac{p}{psi}}{2}$  $P_{avg} = 14.25$  $T_{avg\_sys} := \left(\frac{T_{inlet} - T_{outlet}}{2} + T_{outlet} + 273\right)$

$\rho_h := \rho_{h\_at\_std} \cdot \left(\frac{P_{avg} + 14.7}{14.7}\right) \cdot \left(\frac{293}{T_{avg\_sys}}\right)$  $\rho_h = 0.098 \frac{lb}{ft^3}$  $T_{avg\_sys} - 273 = 175$  $T_{inlet} = 200.0$  $T_{outlet} = 150.0$

$\varepsilon_{cu} := 10 \cdot 10^{-6} \cdot ft$ for drawn copper tube  $\varepsilon_{pipe} := 150 \cdot 10^{-6} \cdot ft$ for steel pipe (ref. 3-56 Marks)

$d_p = 0.257\,in$  $d_p = 0.653\,cm$  inner diameter of cooling passage for a round cross-section

$L = 216.535\,in$  hydraulic length of opening under evaluation  $\rho_h = 1.568 \times 10^{-3} \frac{gm}{cm^3}$

$\mu := \mu_h$  $\rho := \rho_h$  $\varepsilon := \varepsilon_{pipe}$  Input Values  $\nu := \frac{\mu}{\rho}$  $P_{avg} = 14.25$

Calculate the Reynolds # using the velocity and diameter. Use the hydraulic diameter if it is not a round cross-section  $T_{avg\_sys} - 273 = 175$

For a round pipe  $d_p = 0.257\,in$  $Area_p := \left(\frac{d_p}{2}\right)^2 \cdot \pi$

$D := d_p$  $A := Area_p$  Input Hydraulic Diameter and Area  $A = 0.052\,in^2$

Now calculate the flow through a pipe when only the head loss through the pipe and pipe size is known

$D = 0.257\,in$  $\rho = 5.665 \times 10^{-5} \frac{lb}{in^3}$  $p = 1.5\,psi$  $\varepsilon = 1.5 \times 10^{-4}\,ft$  $\mu = 3.916 \times 10^{-7} \frac{lbf \cdot sec}{ft^2}$

$h_f := \frac{p}{\rho \cdot g}$

$$f := \left[-2 \cdot \log\left[\frac{\frac{\varepsilon}{D}}{3.7} + \frac{2.51}{\rho \cdot \frac{D}{\mu} \cdot \left(2 \cdot g \cdot h_f \cdot \frac{D}{L}\right)^{.5}}\right]\right]^{-2}$$

This equation solves for f (friction factor) when the flow rate is unknown but the head loss is known, check for laminar flow

$f = 0.04$  $\frac{\varepsilon}{D} = 7.004 \times 10^{-3}$

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Now solve for the Reynolds # in terms of the friction factor.

$Re_t := \frac{9.287}{\sqrt{f}} \cdot \left(3.7 \cdot \exp\left(\frac{-1.15129}{\sqrt{f}}\right) - \frac{\varepsilon}{D}\right)^{-1}$  $Re_t = 1.086 \times 10^4$  for turbulent flow

$Re_l := \frac{64}{f}$  $Re_l = 1.619 \times 10^3$  for laminar flow

Check that Re is turbulent if not use Re=64/f

Reference pg. 3-55 Marks to determine if flow is laminar or turbulent Generally turbulance begins at Re>2000

$Re := if(Re_t < 2000, Re_l, Re_t)$  $Re = 1.086 \times 10^4$  $f = 0.04$

$v := \frac{\mu \cdot Re}{D \cdot \rho}$  $v = 65.295 \frac{ft}{sec}$  The velocity of the fluid

$Q := v \cdot A$  $Q = 1.411 \frac{ft^3}{min}$  $mf := Q \cdot \rho$  $mf = 2.303 \times 10^{-3} \frac{lb}{sec}$  $mf = 1.044 \frac{gm}{sec}$

$H_f := \frac{v^2}{2 \cdot g}$  $H_f = 66.257\,ft$  $H_f \cdot \rho \cdot g = 0.045\,psi$  $A = 0.052\,in^2$

To find f.t for turbulent flow calculate the relative roughness, e/d, and use along with the Re # to look up f on the graph (pg. 3-55 Marks or pg. A-24 of the Crane tech. manual)

$mf \cdot N = 1.592 \times 10^3 \frac{lb}{hr}$  $dt_{allow} = 50\,K$

$P_{cool} := mf \cdot c_p \cdot dt_{allow}$  $P_{cool} \cdot N = 10.117\,kW$  $mf = 1.044 \times 10^{-3} \frac{kg}{sec}$

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# NCSX June 2007 ETC
# TABLE V - Basis of Estimate

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$v := \frac{\mu \cdot Re}{D \cdot \rho}$ $v = 65.295 \frac{ft}{sec}$ The velocity of the fluid

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**INPUTS** $N = 96 \cdot 2$ number parrallel paths

$T_{surface} = 150$ $T_{inlet} = 200$ In deg C

$T_{blower\_in} = 20$ $T_{outlet} = T_{surface} + .0004$ $T_{outlet} = 150$

$P_{sys} = 15$ psi avg pressure in NCSX

$\rho_h = 0.098 \frac{lb}{ft^3}$ $\rho_h = 1.568 \frac{kg}{m^3}$ $T_{inlet} \cdot \frac{9}{5} + 32 = 392$ $T_{outlet} \cdot \frac{9}{5} + 32 = 302.001$

$dt_{allow} = (T_{inlet} - T_{outlet}) \cdot K$ $dt_{allow} = 89.999\, R$ $dt_{allow} = 50\, K$ Temp. drop of helium across vessel

$L = 5.5 \cdot m$ Total length of tubing

$d_p = (.313 - 2 \cdot .028) \cdot in$ Diameter of hole in tubing $d_p = 0.257\, in$ $d_p = 0.653\, cm$

$p = 1.5 \cdot psi$ dp across tubes

**OUTPUTS**

$v = 65 \frac{ft}{sec}$ Velocity of Helium $P_{avg} = 14$ psi $v = 19.902 \frac{m}{sec}$

$Q \cdot N = 271 \frac{ft^3}{min}$ Volume flowrate of helium through vessel $Q_{total\_Blower} = 349 \frac{ft^3}{min}$ Flow at inlet to Blower

$Q \cdot \rho \cdot N = 1.592 \times 10^3 \frac{lb}{hr}$ Mass Flow $\rho = 0.098\, lb\, ft^{-3}$

$P_{conv} \cdot N = 10\, kW$ From hAdt Convection heat transfer must equal energy balance

$P_{cool} \cdot N = 10\, kW$ From $mc_p dt$

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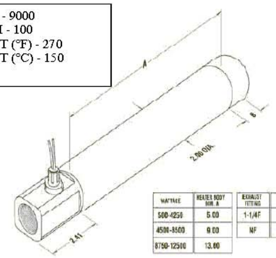
**NCSX June 2007 ETC**
**TABLE V - Basis of Estimate**

**Heat Torch Data**

Watts - 9000
SCFM - 100
Delta T (°F) - 270
Delta T (°C) - 150




| WATTAGE | HEATER BODY DIM. A |
|---|---|
| 500-4250 | 5.00 |
| 4500-8500 | 9.00 |
| 8750-12500 | 13.00 |

| EXHAUST FITTING | DIM. B |
|---|---|
| 1-1/4F | 1.13 |
| NF | 0.10 |

**Specifications**
Max. wattage: 12500
Max. exhaust air temp: 1300°F
Max. inlet air temp: 250°F
Max. SCFM: 100
Pressure rating: 120 PSIG
Horizontal mounting
Leads: 12 gauge, 12" long

**Construction**
Heater body: stainless steel
Inlet fitting: nickel plated steel
Exhaust fitting: stainless steel

Calculate the wattage, flow rate or temperature requirement as follows:

Watts = SCFM x $\Delta T/3$

SCFM = airflow in standard cubic feet per minute

$\Delta T$ = temperature rise in degrees F from the inlet to the exhaust

| Wattage | Minimum SCFM required |
|---|---|
| 1000 | 9.6 |
| 4000 | 9.6 |
| 5000 | 12.4 |
| 6000 | 14.8 |
| 7000 | 17.0 |
| 8000 | 19.3 |
| 9000 | 21.4 |
| 10000 | 23.5 |
| 11000 | 25.5 |
| 12500 | 28.4 |

| Airflow (SCFM) | 500W-4250W Pressure Drop (PSIG) | 4500W-8500W Pressure Drop (PSIG) | 8750W-12500W Pressure Drop (PSIG) |
|---|---|---|---|
| 10 | .36 | .72 | 1.1 |
| 20 | .75 | 1.5 | 2.3 |
| 30 | 1.7 | 3.4 | 5.1 |
| 40 | 3.0 | 6.0 | 9.0 |
| 50 | 4.7 | 9.4 | 14 |
| 60 | 6.8 | 14 | 20 |
| 70 | 9.2 | 18 | 28 |
| 80 | 12 | 24 | 36 |
| 90 | 15 | 30 | 45 |
| 100 | 19 | 38 | 57 |