

Units

$\text{inH}_2\text{O} := 0.0360911906567 \cdot \text{psi}$ Low pressures are often expressed in terms of inches of H₂O.

[Link](#) [Link](#) [Link](#)

$\text{kBTU} := 1000 \cdot \text{BTU}$ Working in terms of 1000 BTU/hr makes the numbers smaller.

Gas Flow Through an Orifice

I don't know how accurate this formula is, but it seems to be used on many sites that deal with burners.

$$H(h, SG, C_D, A, HC) := \frac{1658.5 \frac{A}{\text{in}^2} \cdot C_D}{\sqrt{\frac{SG}{\frac{h}{\text{inH}_2\text{O}}}}} \cdot \frac{HC}{\frac{\text{BTU}}{\text{ft}^3}} \cdot \frac{\text{BTU}}{\text{hr}}$$

Gas flow equation through an orifice of area A square inches.

Drill Bit Sizes

In North America, we have an archaic system for calling out hole sizes based on drill bit sizes. The following table gives me the correspondence between the common drill bit name, hole diameter, and hole area.

dName	dArea
80	0.0135
79	0.0145
1/64	0.0156
78	0.016
77	0.018
76	0.02
75	0.021
74	0.0225
73	0.024

These are the standard drill bit sizes used in North America.

Optimization Function

The following function selects the hole size that gives me the minimum absolute percentage error from the desired heat output.

$$f(\text{obj}, p, SG, HC) := \left| \begin{array}{l} \zeta \leftarrow \frac{H(p, SG, 0.82, dArea \cdot \text{in}^2, HC) - \text{obj}}{\text{obj}} \\ \sigma \leftarrow \text{match}(\min(\zeta), \zeta)_0 \\ \text{dName}_{\sigma} \end{array} \right|$$

Computation Setup

Desired Heat Generation Levels

These are some common BTU output values for barbeques.

$$\mathbf{B} := (10 \ 12 \ 14 \ 16 \ 18 \ 20 \ 25 \ 30 \ 35 \ 40)^T \cdot \frac{\text{kBTU}}{\text{hr}} \quad \begin{array}{l} \text{Range of Heat Flows For} \\ \text{Which I Require Orifice} \\ \text{Sizes} \end{array}$$

Natural Gas Orifice Sizes

$$\mathbf{p} := \begin{pmatrix} 3 & 0.65 & 1120 \\ 3.5 & 0.65 & 1120 \\ 4 & 0.65 & 1120 \\ 4.5 & 0.65 & 1120 \\ 7 & 0.65 & 1120 \\ 11 & 1.55 & 2500 \end{pmatrix}$$

These are the natural gas pressures, densities, and heats of combustion which I will use to compute the required orifice sizes.

$$\alpha := [\mathbf{p}^{(0)} \cdot (1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1)]^T \quad \gamma := [(\mathbf{p})^{(2)} \cdot (1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1)]^T$$

$$\beta := [\mathbf{p}^{(1)} \cdot (1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1)]^T \quad \theta := \mathbf{B} \cdot (1 \ 1 \ 1 \ 1 \ 1 \ 1)$$

$$\eta := f\left(\theta, \alpha \cdot \text{inH}_2\text{O}, \beta, \gamma \cdot \frac{\text{BTU}}{\text{ft}^3}\right) \quad \begin{array}{l} \text{Compute an array of} \\ \text{natural gas orifice sizes.} \end{array}$$

Results

Drill Size	Pressure (in of H ₂ O)					
	NG	NG	NG	NG	NG	LNG
kBTU/hr	3.0"	3.5"	4.0"	4.5"	7.0"	11.0"
10	1/16	53	53	54	55	63
12	50	51	52	1/16	54	59
14	48	50	50	51	53	57
16	47	48	49	50	52	3/64
18	45	46	5/64	48	51	55
20	43	44	45	47	50	54
25	40	41	42	43	47	53
30	36	37	39	40	44	52
35	32	33	7/64	37	42	50
40	1/8	31	32	33	38	48

$$\left(\eta \ p^{(0)T} \ \frac{\mathbf{B}}{\text{kBTU}} \ \frac{\text{hr}}{\text{ft}^3} \right)$$

Cross-Check My Results

Using the orifice sizes computed above, compute the exact value of heat flow generated.

$\text{area}(x) := \text{dArea}_{\text{match}(x, \text{dName})_0}$

Let's define a function that will lookup the hole area based on the common name of the drill size.

$\omega := \overrightarrow{\text{area}(\eta)}$ matrix of all the drill hole areas

$$\eta_1 := \frac{H \left(\alpha \cdot \text{inH2O}, \beta, 0.82, \omega \cdot \text{in}^2, \gamma \cdot \frac{\text{BTU}}{\text{ft}^3} \right)}{\frac{\text{kBTU}}{\text{hr}}} \quad \text{Compute the heat flows for the drill sizes listed above.}$$

Heat Gen	Pressure (in of H2O)					
	NG	NG	NG	NG	NG	LNG
kBTU/hr	3.0"	3.5"	4.0"	4.5"	7.0"	11.0"
10	10.1	9.9	10.6	9.2	10.5	9.8
12	12.4	12.4	12.1	12.4	11.5	12.0
14	14.1	13.4	14.4	14.0	14.0	13.1
16	16.0	15.2	15.9	15.2	16.0	15.7
18	17.3	18.0	18.1	17.2	17.5	19.0
20	20.3	20.5	20.0	19.6	19.0	20.8
25	24.5	25.4	26.1	24.8	24.5	25.4
30	29.5	30.0	29.5	30.1	29.0	29.0
35	34.7	35.3	35.5	34.1	34.5	34.4
40	40.2	39.9	40.1	40.1	40.5	38.9

Error %	Pressure (in of H2O)					
	NG	NG	NG	NG	NG	LNG
kBTU/hr	3.0"	3.5"	4.0"	4.5"	7.0"	11.0"
10	1.4%	-1.0%	5.8%	-7.8%	5.0%	-2.2%
12	3.6%	3.1%	0.8%	3.5%	-4.2%	-0.4%
14	0.5%	-4.1%	2.6%	0.2%	0.0%	-6.2%
16	0.2%	-5.0%	-0.8%	-4.8%	0.0%	-2.1%
18	-3.6%	0.1%	0.8%	-4.3%	-2.8%	5.7%
20	1.4%	2.5%	0.1%	-1.8%	-5.0%	4.2%
25	-1.8%	1.8%	4.3%	-0.6%	-2.0%	1.4%
30	-1.8%	0.1%	-1.8%	0.2%	-3.4%	-3.4%
35	-0.9%	1.0%	1.5%	-2.7%	-1.5%	-1.7%
40	0.6%	-0.2%	0.1%	0.2%	1.2%	-2.6%

$$\eta_1 = \frac{B \cdot (1 \ 1 \ 1 \ 1 \ 1 \ 1)}{\frac{\text{kBTU}}{\text{hr}}} \quad p^{(0)^T} \quad \frac{B}{\frac{\text{kBTU}}{\text{hr}}}$$

Link

Drill Sizes
75
70
65
60
3/64
55
50
45

$$\mathbf{dN} := \begin{pmatrix} 4 \\ 7 \\ 11 \end{pmatrix} \cdot \mathbf{inH2O} \quad \mathbf{HC} := \begin{pmatrix} 1050 \\ 1050 \\ 2500 \end{pmatrix} \cdot \frac{\mathbf{BTU}}{\mathbf{ft}^3} \quad \mathbf{sg} := \begin{pmatrix} 0.65 \\ 0.65 \\ 1.55 \end{pmatrix}$$

area(name) := dArea **match**(name, dName)₀

v :=
$$\left| \begin{array}{l} \text{for } i \in 0.. \text{length}(\mathbf{dN}) - 1 \\ \text{for } j \in 0.. 2 \\ \phi_i, j \leftarrow H(p_j, sg_j, 0.82, \text{area}(\mathbf{dN}_i) \cdot \mathbf{in}^2, HC_j) \end{array} \right| \phi$$

Heat Flow Versus Gas , Orifice, Pressure			
kBTU/hr	Pressure (inH2O)		
Drill Sz	4.0 (NG)	7.0 (NG)	11.0 (Pro)
75	1.2	1.6	3.2
70	2.2	2.9	5.6
65	3.4	4.5	8.7
60	4.5	5.9	11.4
3/64	6.1	8.1	15.7
55	7.4	9.8	19.0
50	13.5	17.8	34.4
45	18.8	24.8	48.0
3/32	24.4	32.3	62.5
40	26.6	35.1	67.9
7/64	33.3	44.0	85.1
35	33.7	44.5	86.0
1/8	43.6	57.6	111.4
30	46.1	60.9	117.7
9/64	55.3	73.1	141.3
25	62.0	82.0	158.5
5/32	68.0	90.0	173.9
20	71.9	95.1	183.9
11/64	82.2	108.7	210.1
15	90.0	119.0	230.1
3/16	97.8	129.3	250.0
10	104.1	137.8	266.3
13/64	114.8	151.8	293.5
5	117.6	155.6	300.7
7/32	133.2	176.2	340.6
1	144.9	191.7	370.4

$$\left(\frac{v}{\frac{kBTU}{hr}} \quad \mathbf{dN} \quad \frac{\mathbf{p}^T}{\mathbf{inH2O}} \right)$$

BTU and Orifice Size Guide						
BTU Input	Natural Gas Pressure Inches W.C.					L/P Gas Pressure Inches W.C
	3.0"	3.5"	4.0"	4.5"	7.0"	
10,000	51	52	1/16	53	54	62
12,000	50	50	51	51	53	59
14,000	48	49	50	50	52	57
16,000	46	5/64	48	49	51	56
18,000	45	46	47	48	50	55
20,000	44	44	45	46	49	54
25,000	3\32	42	43	44	46	53
30,000	38	40	41	42	44	52
35,000	35	36	38	39	42	50
40,000	31	33	35	36	41	48
Drill Sizes						
K Factor .82	Calculation Based on: Natural-1050 BTU Gas -0.65 Spec. Gr. L/P-2500 BTU Gas - 1.55 Spec Gr. Approximate sizes based on average data for all orifice types.					